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Exploration and Research on the Innovation of "Vehicle to Person" Contact Point Operation in Express Delivery Collection and Delivery Business

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Abstract: Under the conditions of digital life and production, the continuously expanding consumption scale, high-frequency consumption behaviors, and high timeliness requirements have brought huge delivery pressures to manufacturing enterprises, distribution and retail enterprises, and logistics enterprises. In this context, improving transportation and delivery efficiency is crucial. This paper focuses on the research on the innovation of the operation mode of express delivery collection and delivery business under the digital development of logistics enterprises, and deeply analyzes several key issues that enterprises can control under the "vehicle to person" contact point operation. It systematically expounds the development status, necessity of the innovation of express delivery collection and delivery business, and puts forward the innovation points of the "vehicle to person" contact point operation. Based on these analyses, research is carried out around the division of labor between people and vehicles, the path planning and scheduling of unmanned vehicles, information interaction, and cargo delivery. This not only provides new ideas for promoting the high-quality development of China's logistics industry in express delivery collection and delivery business but also contributes to the acceleration of the construction of a modern logistics system.

1. Development Status of the Innovation of "Vehicle to Person" Contact Point Operation in Express Delivery Collection and Delivery Business

1.1 The General Trend of National Policies and the Market Economy

The state has issued the "14th Five-Year Plan for the Development of Modern Logistics", which promotes the digital transformation of the logistics industry. The innovation of "vehicle to person" contact point operation is in line with the policy orientation. It is not only conducive to the standardized development of the industry and the improvement of the industry's status, but also enhances the status and role of the express delivery industry in the national economy [4]. The traditional collection and delivery mode is difficult to cope with the parcel volume during peak periods. The innovation of "vehicle to person" contact point operation, as the key to enhancing competitiveness, can help enterprises improve efficiency, reduce costs, enhance service quality, and attract more customers.

1.2 Low-carbon Economy under Green Development

The "vehicle to person" mode optimizes the supply chain, reduces the transportation mileage and the number of vehicles in use, thus reducing energy consumption and carbon emissions [3]. Relevant data shows that after adopting the "vehicle to person" mode, the carbon emissions per unit of transportation mileage of some logistics enterprises have been reduced by 20%. In the news report "JD ESG Report: Replace 100% with New Energy Logistics Vehicles by 2030_The Beijing News", JD Logistics has made breakthroughs in multiple links such as green warehousing, green transportation, green packaging, and green recycling through the launch of the "Qingliu Plan". It has used recyclable packaging boxes for more than 200 million times, and the utilization rate of transfer bags has reached 100%.

1.3 High Proportion of Labor Costs in Traditional Logistics

The logistics and express delivery industry is a typical labor-intensive industry, and labor costs account for a large proportion of the enterprise's operating costs. According to the "Research Report on China's On-demand Delivery Industry in 2024" released by iResearch, under the traditional express delivery operation mode, labor costs account for about 50%-60% of the total cost. Taking a large express delivery enterprise like JD as an example, before the introduction of unmanned delivery vehicles, its monthly labor cost expenditure in the developed eastern region was as high as 3 million yuan. After the introduction of unmanned delivery vehicles, the delivery efficiency has increased by about 3 times. From the perspective of the cost side, the labor cost in the pilot area has been reduced by about 30%. The original delivery team that required 30 people has seen the labor demand reduced to about 20 people after the introduction of unmanned delivery vehicles, saving about 1 million yuan in labor costs per month.

2. Analysis of the Drawbacks of the Traditional Operation Mode of Express Delivery Collection and Delivery Business

2.1 Excessive Proportion of the Functions of Couriers in the Traditional Express Delivery Collection and Delivery Business

Under the current labor-intensive production and operation mode, the functions of couriers account for an excessive proportion in the traditional express delivery collection and delivery business. Couriers need to undertake a series of activities such as order receiving, goods collection, delivery, and transportation. The express sorting, collection, and delivery process is highly dependent on human labor. With the vigorous development of the current express delivery industry and the rapid growth of business volume, the traditional express delivery collection and delivery mode is difficult to adapt to the current development situation. There is an urgent need for an innovative mode to adjust the division of functions in this link to improve quality and efficiency. At the same time, couriers are often affected by various factors such as weather conditions, dispute handling, and special requirements. The high labor intensity and large business pressure have a negative impact on personal safety, driving safety, and the safety of goods, and also limit the improvement of the overall service level of express delivery enterprises.

2.2 Inadequate Path Planning and Scheduling of Unmanned Vehicles in the Traditional Express Delivery Collection and Delivery Business

In the traditional collection and distribution model, unmanned vehicles, as a type of production tool subordinate to delivery personnel, are only used on fixed routes, for unmanned vehicle logistics with the nature of shuttle buses, or for unmanned vehicle passenger transport on customer-specified routes. However, with the sharp increase in express delivery volume and the growing complexity of delivery demands, due to the uneven distribution of delivery and collection times, unmanned vehicles in the traditional collection and distribution model are often underutilized and lack precise demand prediction and overall analysis, resulting in low utilization of their carrying capacity. With the development of big data analysis technology, logistics and transportation enterprises should apply big data analysis and processing technology, combined with cloud computing technology and AI artificial intelligence, to improve the path planning and scheduling of unmanned vehicles in the traditional collection and distribution business, which is particularly crucial[1].

2.3 In the traditional express delivery collection and distribution business, information exchange is lagging and goods delivery is chaotic

The traditional express delivery industry is a labor-intensive industry, with the main expenditure being human resources. However, with the rapid development of digitization and the sharp increase in consumer demand, in the delivery process of the traditional express delivery collection and distribution business, there are delays and deviations in information transmission. There is a lack of efficient collaboration among delivery personnel, business departments, and delivery vehicles, and the status of packages is not updated in a timely manner, making it difficult for customers to accurately and promptly obtain package information. The lag in logistics information updates often leads to the phenomenon where the information displayed to consumers does not match the actual situation when they check the logistics status[2]. Meanwhile, workers at different stages rely heavily on telephones and instant messaging tools, making it difficult to integrate information and achieve efficient information sharing. Additionally, in the goods delivery stage, manual judgment is often relied upon, and there is a lack of precise scanning and determination equipment, resulting in frequent issues such as wrong or missing package loading.

3. Research on the Innovation of "Vehicle-to-Person" Contact-Point Operation Path and Its Implementation Path for Express Delivery Collection and Delivery Business under the Digital Development of Logistics Enterprises

3.1 Innovations in the Contact-based Operational Path of "Vehicle-to-Person" in Express Pick-up and Delivery Services

With the development of digital transformation, the innovation of production and operation models in the logistics industry is the fundamental path to enhancing the comprehensive service capabilities of logistics enterprises and is also an inevitable requirement for promoting scenario-based technological innovation and efficiently connecting the consumer and production ends. This paper attempts to conduct an innovative research on the operation model of urban express delivery collection and distribution. The main idea is to apply unmanned vehicles and unmanned driving technologies in the urban business departments and community "contact points" of express delivery enterprises, transforming the traditional "person-to-goods-to-site" and "person-to-goods-to-door" operation models into a "vehicle-to-person" operation model. That is, to re-divide the functions of people and transportation tools, stripping the round-trip transportation tasks between the urban business department and the community "contact points" from the functions of delivery personnel and having unmanned vehicles undertake them independently. Delivery personnel will be stationed at the community "contact points" to exclusively handle the collection and delivery of items.

3.2 Research on the Implementation Path of the" Vehicle-to-Person" Contact Point Operation for Express Delivery Collection and Distribution

This paper studies the key issues of unmanned vehicle transportation in the urban business departments and community "contact points" of express delivery enterprises to build a new model of efficient, safe, and intelligent express delivery terminal distribution, improve the operational efficiency and service quality of express delivery enterprises, enhance their competitiveness, and provide a reference example for the intelligent development of the logistics industry. The specific goals include: optimizing the division of labor between people and vehicles to enhance the efficiency of human resources; achieving precise planning and reasonable scheduling of unmanned vehicle routes to reduce transportation costs; ensuring smooth information interaction and efficient goods delivery to increase customer satisfaction;

3.2.1 The functional division of labor between man and car

Under the traditional express collection and delivery operation model, Couriers are responsible for the entire process including order acceptance, parcel collection, distribution, and transportation. In this model, vehicles serve as production tools that are fully controlled by the Couriers.

Under the "Contact Point" operational model, unmanned vehicles autonomously handle round-trip transportation between city branches and community service grids. These vehicles are centrally managed by upper-level organizational units , like regional headquarters, business divisions, or corporate entities, that employ dynamic route optimization algorithms based on real-time parcel volume, weight, and dimensions within community grids. Couriers now focus exclusively on terminal operations: executing last-mile delivery after automated parcel handover with unmanned vehicles, or loading parcels onto vehicles following system instructions while completing digital documentation upon vehicle arrival, as shown in Table 1.

Table 1: Functional Division of Labor Between Couriers and Unmanned Vehicles Under the "Contact Point" Integrated Collection and Delivery Model.

Functional Entity / Operation Phase	Courier	Unmanned Vehicle
Collection	1. Receive collection instructions; 2.Plan collection routes based on experience; 3.Collect items from customers and deliver to the contact point; 4. Inspect items; 5. Package and label items; 6. Receive loading instructions; 7.Open containers and load items according to regulations when the unmanned vehicle arrives; 8.Exchange package information with the unmanned vehicle.	1.Receive collection instructions; 2. Plan driving routes; 3.Send loading instructions to the contact point based on distance and time; 4. Arrive at the contact point; 5. Open containers and load items according to regulations; 6.Proceed to the next contact point or branch based on loading volume.
Delivery	1. Receive unloading instructions; 2.Unload items according to regulations when the unmanned vehicle arrives; 3.Exchange package information with the	1.Receive delivery instructions; 2. Plan driving routes; 3. Send unloading instructions to the contact point based on distance and time;

	unmanned vehicle; 4.Organize packages and plan delivery routes; 5.Organize customer pick-up packages and place them on shelves; 6. Deliver items to the door.	4. Arrive at the contact point; 5.Open containers and unload items according to regulations; 6.Execute collection tasks based on the aforementioned collection instructions.

3.2.2 The path planning and scheduling of unmanned vehicles

Compared with the unmanned vehicle logistics with fixed routes and shuttle bus nature, or the unmanned vehicle passenger transportation on the routes specified by customers the path planning and scheduling of the unmanned vehicle transportation between the urban business department (FC) and the community "contact points" (TP) are more dynamic. The dynamic nature is mainly reflected in the fact that the demands of each community "contact point" are independent demands. The parcels accumulated at each TP are characterized by uncertainties in terms of arrival time (t), quantity (q), weight (w), and volume (v). Similarly, the parcels requiring delivery to each TP also present uncertainties in these parameters (t', q', w', v'). For the same unmanned vehicle, each time it completes a closed-loop operation, that is, starting from the urban business department and finally returning to the urban business department, the contact points it passes through and the routes it runs may be different.

Assumption: The carrying capacity of the unmanned vehicle is (W, V), where W is the load-bearing capacity of the unmanned vehicle and V is the loading capacity of the unmanned vehicle, and the utilization rate target of the carrying capacity of the unmanned vehicle is above 85%. The urban business department (FC) covers n grid community "contact points" (TP_i（$i=1, 2, 3, \ldots, n$). The quantity of parcels accumulated at each community "contact point" within the time interval [t_j, t_{j+s}] is $q_{i,j+s}$, and the quantity of parcels that need to be delivered to each community "contact point" is $q'_{i,j+s}$ respectively.

Among them, t_j is a random time point, which is the time when the unmanned vehicle departs from a certain contact point or the urban business department, and s is a random time step, which is determined by the command system of the unmanned vehicle according to the remaining carrying capacity of the unmanned vehicle, that is, the remaining load-bearing capacity and the remaining space, as well as the quantity q_i , weight w_i and volume v_i of the parcels accumulated at the "contact point". That is, within a certain time period, the uncertainty problem is transformed into a deterministic problem by adjusting the departure frequency of the unmanned vehicle.

Therefore, the path planning and scheduling of the unmanned vehicle can be discussed in three situations.

Scenario 1: Delivery-Only Operations

In this mode, the vehicle exclusively handles parcel delivery from the FC to TPs, prioritizing delivery efficiency without considering collection demands en route. This aligns with typical parcel flow patterns where regional distribution centers dispatch large volumes to FCs in the morning, and urban recipients predominantly receive parcels around midday or evening. Given the concentrated nature of parcel receipt times, vehicle routing can be optimized based on the arrived parcel quantities at the FC, delivery requirements at each TP, and their physical attributes (weight and volume).

Scenario 2: Collection-Only Operations

Here, the vehicle focuses solely on collecting parcels from TPs, disregarding delivery demands along its route. This mirrors the pattern where urban customers predominantly place orders around midday or evening, and collected parcels are typically transported from FCs to regional distribution centers in the evening. Similar to Scenario 1, the concentrated timing of parcel dispatch allows for optimized routing based on collection quantities and parcel characteristics at each TP.

Scenario 3: Integrated Collection and Delivery Operations

This scenario represents a combined operation, analogous to urban *milk run*, which maximizes vehicle utilization and offers the highest economic efficiency for express delivery companies.

In this context, the vehicle's remaining capacity after unloading at TP_i must be calculated when departing fully loaded from the FC.

Scenario 3.1:

If the remaining carrying capacity after unloading is insufficient to accommodate the accumulated parcels, the community "contact point" TP_i must implement queuing management based on the "first in, first out" (FIFO) principle, prioritizing the loading of parcels that arrived earliest. Upon reaching the next community "contact point," if the remaining capacity after unloading is still insufficient to load the accumulated parcels, the same method as applied at TP_i will be followed. Ultimately, the unmanned vehicle returns to the urban business department.

Scenario 3.2:

If the remaining carrying capacity after unloading is sufficient to load the accumulated parcels and achieves full load status, the same approach will be adopted at the next community "contact point." Specifically, if the remaining capacity after unloading at the subsequent TP is also sufficient to load the accumulated parcels and reaches full load, the method used at TP_i will be replicated.

Scenario 3.3:

If the remaining carrying capacity after unloading is sufficient to load the accumulated parcels but does not achieve full load status, priority must be given to the quantity of parcels accumulated at the next community "contact point." Should the accumulated parcels at the next TP still fail to achieve full load, secondary priority should be assigned to the coordination level of capacity evacuation and reuse during the unloading and loading processes at other community "contact points" within the delivery plan. If the overall coordination level of capacity evacuation and reuse across these TPs exceeds 90%, the unmanned vehicle will proceed according to the planned delivery route.

Scenario 3.4:

If the overall coordination level of capacity evacuation and reuse at other community "contact points" within the delivery plan is low, the system must search for parcels accumulated at TPs outside the delivery plan based on the "proximity principle." This ensures that the unmanned vehicle can return to the business department fully loaded, optimizing resource utilization.

In most small and medium-sized cities, the volume of outgoing parcels is often significantly lower than that of incoming parcels. As a result, Scenario 3.4 occurs more frequently in such cities.

3.2.3 Information Interaction and Cargo Delivery

Under the mature technological conditions of Global Positioning Systems (GPS), Biometric Identification, Automation, and Waybill Labeling, the scientific design of information interaction and cargo delivery processes plays a decisive role in the success or failure of unmanned delivery vehicle applications.

The fundamental workflows for information interaction and cargo delivery discussed in this study are structured as follows:

Information Interaction: City branches bind community "Contact Point" couriers to their designated service areas, while the binding mechanism between courier information and unmanned vehicles is activated when the system issues operational instructions to both parties. Within a specific geographic address and time window, the opening or closing of cargo compartments and loading or unloading operations can only be executed by the authorized courier (via facial recognition) who has received the operational instructions. Crucially, the unmanned vehicle is programmed to operate exclusively at predefined addresses . Any attempt to manipulate the vehicle outside these designated locations—even by an authorized courier—will be rejected by the system. The Operational

Management System (OMS) validates the consistency of the triplet (Human H, Vehicle C, Address A) before enabling cargo compartment operations.

Cargo Delivery: The cargo delivery process involves unloading and loading operations facilitated by the unmanned vehicle's integrated scanning system. During unloading, the vehicle scans the waybill to determine whether the cargo should be unloaded at the current community "Contact Point." If the system confirms that unloading is appropriate, a voice prompt is issued, and the inventory database is updated in real time to reflect the inbound transaction. Conversely, if the system determines that unloading is not warranted, a voice alert is triggered, and an abnormal operation log is generated to document the discrepancy and deter non-compliant behavior by the courier. Similarly, for loading operations, which account for Scenarios 1 through 3 as previously outlined, the vehicle scans the waybill to assess whether loading is permissible at the current time. A valid loading confirmation results in a voice prompt and the synchronization of the outbound logistics record, while a rejection triggers an alert and logs the anomaly to prevent unauthorized forced loading attempts by couriers. The Operational Management System (OMS) enforces a quadruple validation of (Vehicle C, Time T, Address A, Package P) to authorize any loading or unloading activity, ensuring that all operations are conducted under strict compliance with predefined parameters.

4. Conclusion

Unmanned vehicle technology holds significant potential to enhance delivery efficiency, reduce operational costs, and improve user experience. However, to further advance this technology, it is essential to explore and integrate more advanced systems into unmanned vehicle operations, thereby increasing their feasibility and reliability. Additionally, it is crucial to develop differentiated operational models tailored to various application scenarios. As the technology continues to evolve, it is equally important to intensify public awareness campaigns to improve societal understanding and acceptance of unmanned vehicle systems. These efforts should focus on educating users about the proper usage methods and safety precautions associated with unmanned delivery services, ensuring a smooth and effective adoption of this innovative technology.

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