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"Passenger Transportation + Logistics" Practice Based on Urban-Rural Public Transportation: A Case Study of Yongkang in Zhejiang Province

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Abstract: The increasingly closer links between urban and rural areas increase the circulation demand of production and goods of daily use, while traditional rural logistics is far from satisfactory. The new service mode of "passenger transportation + logistics" based on urban-rural public transportation in Yongkang of Zhejiang province, meets the transportation demand with low cost, high efficiency and reliability. To make the follow-up application more mature and efficient, it is necessary to select typical cases for in-depth study. Taking the K303, the first line with "passenger transportation + logistics" service in Yongkang of Zhejiang province as the example, this paper analyzes the positive benefits of the service from the perspectives of residents, city managers and operating companies. Using field observation, questionnaire survey, interview, big data analysis, and other methods, the paper quantitatively analyzes the existing problems such as inadequate logistics outlets, inconvenient delivery, simple packaging, opaque logistics information, poor service experience when discussing logistics network layout in both urban and rural areas and service quality throughout the whole process of logistics. Based on the concept of synchronous improvement of passenger transportation and logistics service quality, the paper puts forward the methods and optimization scheme in several aspects: logistics outlets increase, layout optimization, operation mode adjustment, service quality improvement throughout the whole process with intelligent logistics. Finally, the paper suggests achieving the long-term development goal of the integration of "city-town-village" passenger transportation and logistics based on village buses and community buses. **DOI:** 10.13813/j.cn11-5141/u.2021.0205-en

Keywords: urban-rural logistics; urban-rural public transportation; passenger transportation + logistics; network layout; service quality; Yongkang

0 Introduction

Promoting the healthy development of rural logistics, as well as building an efficient and convenient circulation channel for agricultural products and rural production or goods of daily use, is of great significance to the social and economic development in rural areas. The overall foundation of rural logistics development in China is weak, as reflected in low coverage of logistics station facilities, incomplete logistics system, and popular problems such as "inaccessible goods, low efficiency, poor benefits, and discontinuous operation." The Central Committee of the Communist Party of China and the State Council has highlighted the great importance of rural logistics development, with specific policies and requirements in the No. 1 Central Document during the past three years [1–3]. Express delivery services of "passenger transportation + logistics" (hereinafter referred to as "public transit logistics"), designed as a pilot development based on urban-rural public transportation and inter-county coach buses since 2018 in Xinchang county and Yongkang city of Zhejiang province, have been implemented to improve flow of passengers and goods between urban and rural areas with low freight cost, high efficiency, and excellent quality. In 2019, the Ministry of Transport in China officially proposed to promote express delivery on rural passenger vehicles to build a three-level rural logistics service system for counties, townships (towns) and villages [4].

Domestic and international researchers have carried out a wide range of studies on rural logistics; however, the research content and findings vary because of different relationships between urban and rural areas in different countries. Foreign transport service modes can be roughly classified into the following three categories. 1) North American mode of "contract system + cooperative + agricultural-industrial-commercial complex" with direct selling as the primary approach; 2) Europe mode of "auction market + cooperative + distribution center" with a dominant way of public welfare

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wholesale market combined with direct selling; 3) Southeast Asia mode of "peasant association + wholesale market + auction" [5–6] with the dominant approach of wholesale market supplemented by auction. In foreign studies on the location of logistics nodes and optimization of channels, researchers have proposed different methods and strategies for the location of logistics nodes and the construction of regional logistics network using gravity models [7] and network analysis models [8]. The postbus in Europe is a typical practice related to public transit logistics, which ran between railway stations and remote villages in the early stage and provided mail services to rural areas. Nowadays, given its wide postal coverage and flexible layout [9], postbuses have gradually developed into public transportation for urban-rural commuting, tourist travelling, as well as rural mail delivery.

Most domestic studies were conducted under the development background of urban-rural dual structure and growing e-commerce economy. Serving as a connector of delivering agricultural products to cities and moving industrial products and agricultural supplies to the countryside, rural logistics can be classified into three basic types: business extension, intermediary bridge, and professional service [10]. Currently, the operation of rural logistics consists of major modes with four bases: postal service, commercial express enterprises, ordinary logistics outlets, and rural passenger coach buses [11]. Numerous studies based on practical cases in different areas have focused on the current problems of rural logistics development [12], and proposed strategies from the perspectives of government planning, information construction, resource sharing. These strategies include promoting rural logistics upgrade based on big data [13–14], internet of things [15] and e-commerce [16], increasing logistics convenience [17] and solving the "last kilometer" distribution problem of rural logistics through the application of modern information technology and the construction of local logistics information service platform, and forming a two-way circulation logistics system [6] based on the cooperation between postal service stations in villages and passenger transport enterprises.

Previous studies have shown that the integrated development of urban-rural logistics is of great significance for rural areas and rapid growth in advanced technology such as big data, cloud computing, internet of things, etc. provides an excellent opportunity for quality improvement. Either the introduction of passenger transportation into postbus in Europe or the practice of rural goods movement based on passenger vehicles in China has indicated that the combination of passenger transportation and logistics is an important approach of urban-rural integration and integrated development in the future. Given the special urban-rural dual structure in China and the regional differences in geographical environment, economy, society, and culture, it is immature to propose a universal public transit logistics planning theory. However, a detailed analysis of practical cases in various areas is still needed to offer specific optimization strategies and support future studies.

In Yongkang of Zhejiang province, public transit logistics services were opened based on a number of urban-rural public transportation lines between the East passenger station and over 10 townships (towns), such as Xixi, Silu, and Gushan; similar services have been proposed to cover the whole administrative region of the city in the next three years. It is necessary to identify and address problems in time with specific strategies. Preliminary surveys showed that the type of goods delivered and the operation mode of public transit logistics are similar along different bus lines. Therefore in this paper the urban-rural bus line K303 (the East passenger station—Xixi station with a length of 27.6 km), the earliest practice of public transit logistics, was used as an example in an in-depth study.

1 Introduction and method of the Yongkang "public transit logistics" K303 line case study

1.1 Overview

Yongkang is a strong county-level industrial manufacturing city in the middle of Zhejiang province, with an urban radius of approximately 3 km and a permanent population of about 350,000. The urban area is dominated by agglomeration areas of high-tech manufacturing enterprises, modern trading markets, and comprehensive public service areas. The Xixi town is a township area with mechanical processing as the leading industry. The distribution of workforce in the industry induces transport demand for frequent flow of raw materials, intermediate products and finished products between urban and rural areas. Meanwhile, young people growing up in towns and villages, in pursuit of high-quality life, prefer to work or live in urban areas, which leads to the coexistence of urban-rural job-housing separation ① and intergeneration separation ②. Workforce needs or connection between relatives demands transportation of business and office goods or goods of daily use between urban and rural areas. The poor efficiency, high freight cost, and low service quality of the existing third-party logistics are not satisfying. A common phenomenon of entrusting an acquaintance or a passenger bus driver to deliver goods confirms the existence of the above demand. However, such informally organized goods movement has resulted in problems in terms of potential safety hazards, unreliable schedule, and difficult dispute, which require reform and innovation of logistics services

① The phenomenon of people who live in township (towns) and work in the urban area commuting for a long distance between urban areas and townships (towns).

② The phenomenon of intergenerational geographical separation due to child living independently in urban areas and parents living in townships (towns).

between urban and rural areas.

The address the urban and rural residents' needs for small goods movement [①], since March 2019, Zhejiang Shuangfei Transportation Co., Ltd. has been placing logistics boxes on buses to provide transportation services ("shipping goods immediately and delivering within 2 hours") of small goods without breaking through the existing transportation regulation; the service has been using the remaining capacity of urban-rural bus line K303 and its stations [②] during non-peak hours, with the East passenger station as the urban logistics outlet and Xixi station as the rural logistics outlet (see Fig. 1). The specific operation mode is shown in Fig. 2.

a) Logistics boxes on the bus b) Mailroom of goods in the logistics outlets

Fig. 1 Logistics operational scenarios on K303 buses

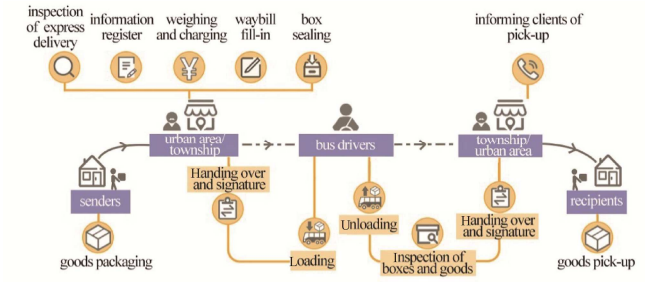


Fig. 2 Operation mode of passenger transportation + logistics service

1.2 Methodology

The basic characteristics of passenger flow were assessed through on-bus tracking, on-board GPS, and surveillance video data. A field survey of Xixi station and East passenger station was conducted to understand the space design of logistics outlets and the operation and management procedures of public transit logistics. On April 2019, a census survey was performed with residents who used services at the above two stations to understand their goods delivery type, travel characteristics, service evaluation, problems encountered in use, and desired improvements. All delivery receipts were collected on the following month, with a total of 53 copies and effective response rate of 100%. In order to understand the future development ideas of public transit logistics and potential problems difficult to track and observe in the operation process, the researchers also performed an in-depth interview with the management team of Zhejiang Shuangfei Transportation Co., Ltd. and the technical staff leading the logistics outlets.

1.3 Basic information of study objects

The results of the survey have indicated that 47% and 32% of the service users are 36 to 49 years old and 18 to 35 years old, respectively; most of them are self-employed (51%). In terms of the composition of goods, productive goods such as hardware accessories account for the largest proportion (57%), followed by goods of daily use (32%) such as daily necessities, fresh food, and goods of documents as the smallest proportion (11%). These results have suggested that the current public transit logistics mainly meet the circulation demand of productive goods; in addition, transportation of goods of daily use and time-sensitive office goods has certain demand.

2 Benefit analysis from multiple perspectives

2.1 Perspective of residents

2.1.1 Cost of time

When urban and rural residents ship small goods, they can choose one of the following four modes—private express delivery, public transit logistics, self-delivery, and consignment-based delivery. The characteristics of transportation mode determine the obvious difference in total time consumption. Taking the transportation route between Xixi town and Yongkang urban area as an example, this paper presents a comparative analysis of total time consumption associated with the whole logistics process (see Fig. 3). Private express delivery adopts the mode of centralized transport with a departure schedule of twice per day, 7.5 hours interval, and a long time window for goods assembly. Public transit logistics adopts the mode of scattered transport, with the departure interval consistent with bus schedule (about 15 min on average) and the goods will be delivered as soon as they are available. Self-delivery mode has no goods collecting or intermediate stopping, and therefore has the fastest one-way transport under the same distance; however, it requires round-trip driving. The consignment-based delivery is an informal transport mode; consignors have to deliver the goods in advance to the consignees, whose departure time is uncertain. Given the consignor's compromise on labor and

[①] According to the relevant regulations of Yongkang public transit logistics, small goods refer to goods less than 20 kg in weight and less than 0.006 m^3 in volume.

[②] Through the analysis of on-board GPS and surveillance video data, it is found that the peak of passenger commuting flow of the bus line appears from 6:00 to 8:00 (in the direction from town to urban area) and from 16:00 to 18:00 (in the direction from urban area to town) on weekdays, and that the peak of passenger living trip flow of the bus line appears from 15:00 to 16:00 (in the direction from town to urban area) and from 17:00 to 18:00 (in the direction from urban area to town) on Sundays. At other times, the actual bus occupancy rate is below 60%, with sufficient remaining capacity.

time saving, the total time consumption usually fluctuates between the one-way time consumption of self-delivery and the total time consumption of private express delivery.

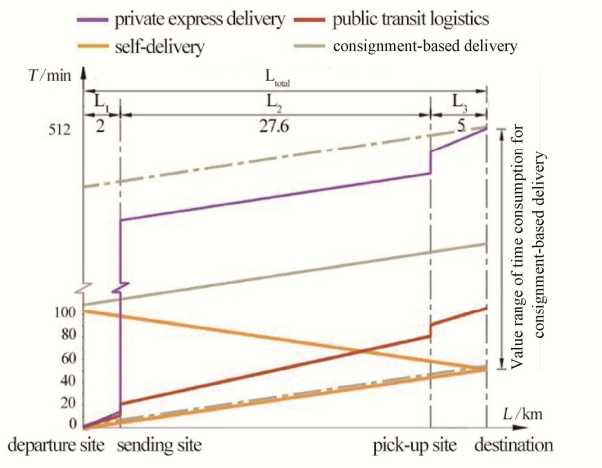


Fig. 3 Time consumption by different delivery modes

As shown in Fig. 3, the distance between departure site and delivery site (L_1) and the distance between pick-up site and destination (L_3) represent average distance estimated based on questionnaire statistics; the distance between shipping site and pick-up site (L_2) is the actual distance between two public transit logistics outlets. For self-delivery and consignment-based delivery, cars or motorcycles are used throughout the journey with average transport speed as $V_s = V_c = 40 km \cdot h^{-1}$. In sections L_1 and L_3, electric bikes are mainly used for private express delivery and public transit logistics. For private express delivery, goods are collected and distributed by shipping route with average transport speed as $V_{pr1} < V_{pu1} = 20\ km \cdot h^{-1}$. In section L_2, trucks are used for private express delivery with average transport speed of $V_{pr2} = 40\ km \cdot h^{-1}$, while the transport speed of public transit logistics is $V_{pu2} = 28 km \cdot h^{-1}$. In terms of the total time consumption of various modes, for private express delivery, $T_{pr} = 60L_1/V_{pr1} + T_{pr\text{-}collect} + 60L_2/V_{pr2} + T_{pr\text{-}pick} + 60L_3/V_{pr1} > 512.4$ min; for public transit logistics, $T_{pu} = 60L_1/V_{pu1} + T_{pu\text{-}collect} + 60L_2/V_{pu2} + T_{pu\text{-}pick} + 60L_3/V_{pu1} = 92$ min (the collecting and picking time consumption at logistics outlets is about 10 minutes); for self-delivery, $T_s = 2 \times 60\ (L_1 + L_2 + L_3)/V_s = 103.8$ min; for consignment-based delivery, $T_c = T_{wait} + 60(L_1 + L_2 + L_3)/V_c = T_{wait} + 51.9$ and $51.9\ min < Tc < 512.4$ min. Based on measurement data, it is easy to see advantages of public transit logistics in terms of saving total delivery time.

2.1.2 Cost of expenses

The 53 items sampled from the questionnaires have an average weight of 5.63kg, which is assumed as a typical weight value for small goods to conduct the comparative analysis on cost of expenses (see Table 1). The results have shown the lowest cost of expenses associated with public transit logistics.

Table 1 Cost by different delivery modes

Delivery mode	Charging standard	Single delivery charge / yuan
Private express delivery	flag-fall price of 9 yuan, overweight price of 3 yuan · kg^{-1}	24
Public transit logistics	3 yuan if weight < 5 kg; 5 yuan if 5 kg ≤ weight < 10 kg; 7 yuan if 10 kg ≤ weight < 15 kg; 10 yuan if 15≤ weight < 20 kg	5
Self-delivery	(city-village distance × car fuel consumption) × oil price × 2 + C_{others} (e.g. parking fee)	35
Consignment-based delivery	free of charge for transportation, but with the generation of human relationship cost hard to quantify[18]	

The questionnaire also included a survey item on "recognition of service advantage" to collect feedback from users of public transit logistics on ranking importance of service advantage from strong to weak by assigning 3, 2, and 1 point. The aggregated ranking scores suggested the top three advantages as fast delivery speed, low price, and safety of goods (see Fig. 4); these results are completely consistent with the main influencing factors of the residents' choice of delivery modes.

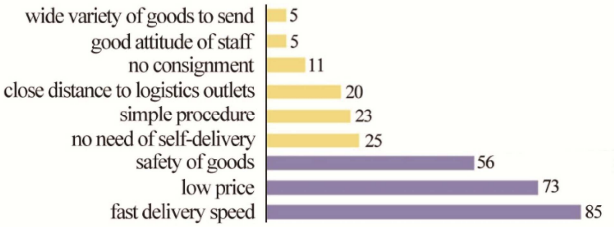


Fig. 4 Recognition of the advantages of the service from users of passenger transportation + logistics

2.1.3 Satisfaction in meeting personalized transportation demand

Most of the senders of productive goods are self-employers (66%), who pay great attention to cost control. The implementation of public transit logistics attracts certain senders to transfer their delivery mode from self-delivery or consignment-based delivery; 54% of these senders have used public transit logistics for many times, which has suggested that such service can well meet the self-employers' demand for production goods movement in small batches.

Senders of office goods and goods of daily use are more concerned with the speed of logistics and the variety of goods that can be delivered. In terms of willingness of shipping, the proportion of goods of daily use (fresh food + daily necessities) has increased by 24 percent (see Fig. 5) and the demand of aquatic products shipment is growing. Due to large time consumption of logistics for private express delivery, deterioration of vegetables and fruits is quite common and ensuring timely delivery of emergency goods is difficult. In contrast, public transit logistics has the advantage of shipping goods

immediately and delivering within 2 hours, which is highly consistent in meeting urban and rural residents' miscellaneous, scattered, and urgent shipment needs for goods of daily use.

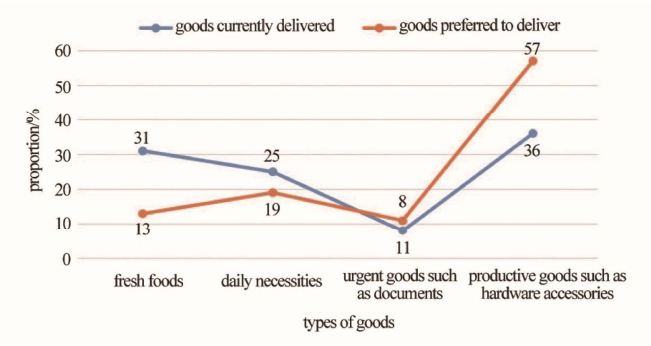


Fig. 5 Change of residents'preference for delivering items

2.2 Perspective of urban managers

2.2.1 Equalization of urban and rural public services

Under a long-term influence of the urban-rural dual structure, the performance of the logistics system in towns and villages is much lower than that in cities. Towns and villages usually have fewer operating enterprises, insufficient number of outlets, low transportation efficiency, poor service quality; rural residents and urban residents have unequal logistics services. Public transit logistics address the weakness of logistics services in towns and villages, and effectively promote equalization of urban and rural public services by meeting the actual demand of residents with stable, reliable, and convenient logistics services.

2.2.2 Public transportation subsidy

Due to the fundamental travel characteristics of urban and rural residents, urban-rural public transportation involves capacity waste to certain extent during non-peak hours. Public transit logistics meet the transportation demand of small goods in short and medium distances with the remaining capacity, improve the utilization rate of spatial resources, increase enterprises' source of income given the same number of operating vehicles, reduce the government's pressure on providing subsidies to public transportation, and promote the maximization of the social benefits of public services.

2.2.3 Urban environment

Before the opening of public transit logistics, residents in towns and villages and self-employers preferred to transport goods through self-delivery (48%) or consignment-based delivery (38%) with cars and motorcycles as the travel mode. The round-trip driving and unavoidable detours not only use road resources, but also increase energy consumption and pollutant emissions.

Public transit logistics allow for shipment of a large amount of goods at one time and transport for many times in one day. The impact of additional energy consumption and pollutant emissions of buses from carrying one unit of goods with a passenger can be ignored. The survey results have shown that 73.5% of residents use green transportation modes such as walking and non-motorized vehicles when sending and picking up goods, which has no negative environmental impact. The promotion of public transit logistics will be helpful to improve the quality of urban environment.

2.3 Perspective of operating enterprises

Private express delivery adopts scaled loading transportation, which requires the payment of labor cost, direct material cost, indirect operating cost, and other types of cost. The shipment demand from residents in towns and villages is limited, and it is difficult to reach the threshold of economies of scale. The logistics cost per unit of goods is relatively high, which leads to an unattractive market of towns and villages for the private express delivery business. Based on the existing urban-rural bus lines and station resources, public transit logistics only increase simple steps such as inspection and loading-unloading with almost negligible cost, which greatly reduces all kinds of other types of cost. Such logistics service can effectively use the remaining capacity to meet the market demand and create a new source of income.

3 Analysis of existing problems

3.1 Logistics outlets: quantity, location, and distance of goods delivery

3.1.1 Logistics in cities

Urban residents use electric bikes as the first choice of travel mode for sending or picking up goods (see Fig. 6a). Based on an average value of the actual biking data collected from respondents using this mode (i.e., 20 $km \cdot h^{-1}$ overall travel speed, 14.7 min of travel time, and a nonlinear coefficient of cycling routes at 1.3), the corresponding service radius of the logistics outlet is estimated to be 3.77 km. The existing study shows that the distance of living trips in small and medium-sized cities with a single center cluster is usually 2 to 3 kilometers [19]. Therefore, the service scope of current urban outlets is large. Data from the questionnaire have confirmed this assessment conclusion; 38% of the users report that the outlet is too far and it is inconvenient to send or pick up goods, while 33% of the users suggest to increase the number of outlets (see Fig. 7).

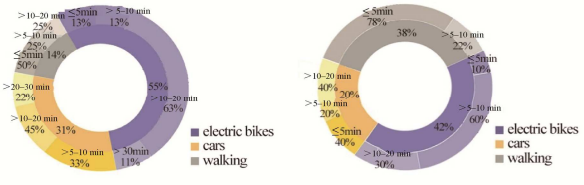
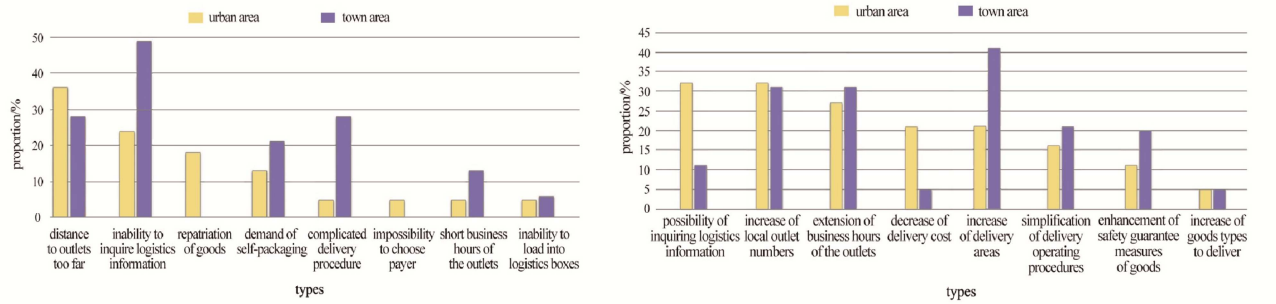


Fig. 6 Distribution of accessing mode and time consumption to delivery sites

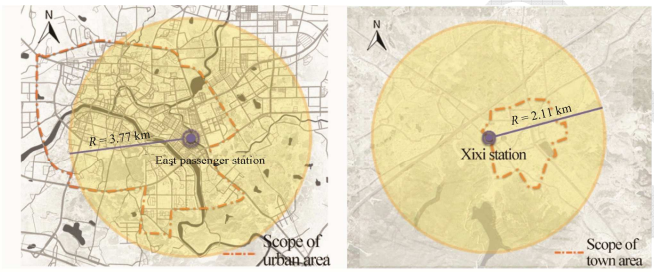


a) Delivery problems

b) Willingness to improve

Fig. 7 Evaluation of passenger transportation + logistics by senders

Currently Yongkang's public transit logistics service is only operating in the East passenger station based on part of the urban-rural bus lines with this station as the origin or destination. However, even with a service radius of 3.77 km, the outlet of the East passenger station can only cover 80.8% of the urban area (see Fig. 8a), because this station is located in the southeast part of Yongkang and its coverage includes a large amount of industrial and undeveloped land outside of urban areas. Considering either the lack of coverage or the demand of residents, increasing the number of logistics outlets become imperative.



a) East passenger station

b) Xixi station

Fig. 8 Coverage of the logistics outlets and its positional relation with the city (town) area

Studies of residents' travel characteristics in small and medium-sized cities in developed areas have shown that, for medium- or low-frequency living trips similar to trips of sending and picking up goods, it would be ideal to control travel time within 10 to 15 minutes on foot or 5 to 8 minutes by electric bikes [19]. If an electric bike is the dominant travel mode, the corresponding maximum travel distance is about 2.6 km. Considering the non-linear coefficient of the actual travel route, it is suggested that logistic outlets should be increased with a service radius of 2 km in the short term and transitioned to 0.8 to 1 km in the long term for further improvement in service level to meet the demand of walking to send or pick up goods.

3.1.2 Logistics in towns

The main travel modes of residents in towns for sending and picking up goods are walking and riding electric bikes. Most walking residents live near logistic outlets with travel time within 5 minutes; electric bike riders usually have travel time between 5 and 10 minutes (see Fig. 6b). Using an average value of actual biking data collected from survey respondents (i.e., an overall travel speed at 20 km·h^{-1}, travel time of 9.5 min, and a nonlinear coefficient of biking routes at 1.5), the estimated service radius of the logistics outlet is 2.11 km. The existing outlet can therefore cover 100 percent of the town area (see Fig. 8b). However, for town-level units that are much smaller than those in urban areas, walking is the most common travel mode for residents, unless they travel by electric bikes when their perceived travel distance is far away. The current average distance that residents travel in towns to logistics outlets has exceeded the upper limit of advantageous walking distance of 1 km, which is the reason why electric bikes are preferred over walking. In the questionnaire, 29% of the users report that outlets are too far; 32% of the users support increasing the number of outlets in the local area (see Fig. 7). To adapt to residents' travel habits of walking and improve the quality of logistics services, the number of logistics outlets in towns should be increased.

3.2 Service quality throughout the whole logistics process

3.2.1 Packaging and damage of goods

Currently goods packaging are completed by senders without a unified specification. The most common packaging materials are plastic bags and cartons, with virtually no special packaging for fresh or fragile goods, or goods with special odor that likely cause problems in the process of transportation. Logistics boxes provided by outlets have large capacity, but are one size without internal separation and fail to meet the need for packaging goods of different sizes. Moreover, no devices for securing logistics boxes is available on buses, so the boxes may easily slide when buses are running. These limitations lead to potential damage of goods and reduced service life of logistics boxes.

3.2.2 Logistics information collection

Public transit logistics adopt manual delivery mode and users are not able to know the shipment, in-transit or receipt

status of goods in real time. People who highlight this problem are mainly self-employers (64%) and enterprise employees (27%). They have higher requirements on transportation timeliness and are more sensitive to the real-time status of logistics. Later delivery in a day is associated with higher proportion of people reporting the problem (9% before 9:00, 27% between 9:01–12:00, 27% between 12:01–15:00, 37% after 15:00). Users' main concern is whether the goods can be delivered on the same day.

According to the queuing theory, unknown waiting time can be annoying and may even result in psychological panic [20]. The failure of inquiring logistics details in real time gets users under an uncertain waiting situation, which leads to an increase in perceived total time consumption; reducing users' satisfaction and willingness to use is not conducive to the promotion of public transit logistics.

3.2.3 Time of picking up goods

The current business hours of public transit logistics outlets are from 7:30 to 17:30, which coincide with the working hours for most residents. Within the outlet business hours, 29% of the recipients (mainly enterprise employees who sign to receive goods of daily use) are unable to pick up the delivered goods, which is one of the reasons for low delivery proportion of goods of daily use. About 28% of urban residents and 32% of town residents have expressed a strong willingness to extend the business hours of the outlets, and have even suggested the use of intelligent express cabinets to avoid any pick-up time limit.

4 Design of optimization scheme

One of the important characteristics of public transit logistics is the spatiotemporal consistency between passenger transport and logistics. The improvement of passenger service quality is the main task of public transportation development. The improvement of logistics service should not be implemented with the expense of reduced passenger transportation service level. Instead, improvements of both passenger transportation quality and logistics service quality should be achieved to the most extent. Firstly, the layout of logistics outlets should be coupled with the original and terminal stations in bus lines. To avoid increased travel time for passengers, the operation procedure is implemented to "load goods first before boarding passengers at the original station and unload goods after dropping off passengers at the terminal station." The spatial layout of bus stations and loading and unloading sites should be consistent with the above procedure. The site selection of newly-increased logistics outlets (the original and terminal bus stations) should be assessed to meet the diversified and normalized travel needs of passengers. The adjustment of bus operation (including schedule, route, station settings etc.) should also enhance a synchronous improvement of passengers and goods transportation efficiency. Secondly, in order to ensure the comfortableness of passengers, the serving buses used for public transit logistics should be selected during non-peak hours and match well with the remaining capacity (passenger flow is generally required to be less than 60% of the rated passenger capacity). At the same time, the quality of goods packaging and design of logistics boxes should be improved to ensure sanitary conditions of buses and transportation safety. Finally, the idea of "Mobility as a Service" (MaaS) is used as reference to implement "Internet + Urban-Rural Passenger Transportation + Urban-Rural Logistics" services, build an integrated service platform, and also improve the degree of intelligence for passenger transport and logistics services.

4.1 Adding logistics outlets and optimizing public transit operation

4.1.1 Strategies in cities

1) Increasing the number of outlets

Based on the development plan that promoted public transit logistics in Yongkang from 2018 to 2020 (with actual progress slower than expected), the West passenger station (the origin and terminal urban-rural bus stations connecting the western towns in the administrative region and the city) is selected as the second public transit logistics outlet in the urban area. According to the 2 km service radius setting in the short term, the service scope of the East passenger station and West passenger station together covers 73% of the urban area. Since currently there are only two origin and terminal stations for urban-rural buses operation in Yongkang, it is suggested to add another logistics outlet in uncovered areas based on the existing origin and terminal stations for city buses, and to extend public transit logistics service in the form of continuous transportation of "urban-rural buses + city buses" ⑤. The specific process and method of outlet site selection are shown in Fig. 9.

Using the above method, the Social Welfare Institute is selected as the third public transit logistics outlet in the urban area (see Fig. 10). After adding outlets, residents can choose the nearest outlet to send goods and their travel distance and time can be reduced. The management staff at the outlets can select the nearest delivery location based on pick-up addresses to reduce the residents' travel distance and time consumption.

① Subsidiaries of Yongkang Transport Bureau are responsible for the operation of city public transportation (Yongkang Yuantong Public Transit Co., Ltd.) and urban-rural public transportation (Zhejiang Shuangfei Transportation Co., Ltd.). The unified superior administration provides conditions for the continuous transportation of city buses and urban-rural buses.

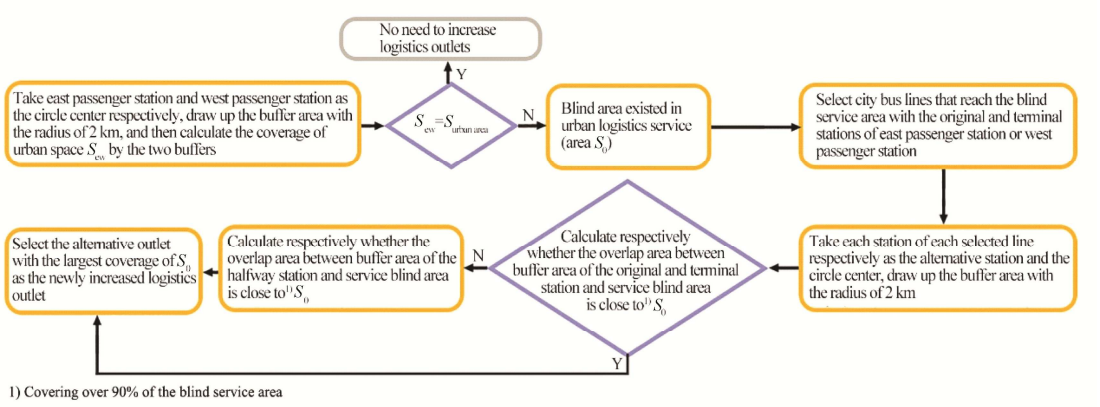


Fig. 9 acility location selection process of added outlets for passenger transportation + logistics in city areas

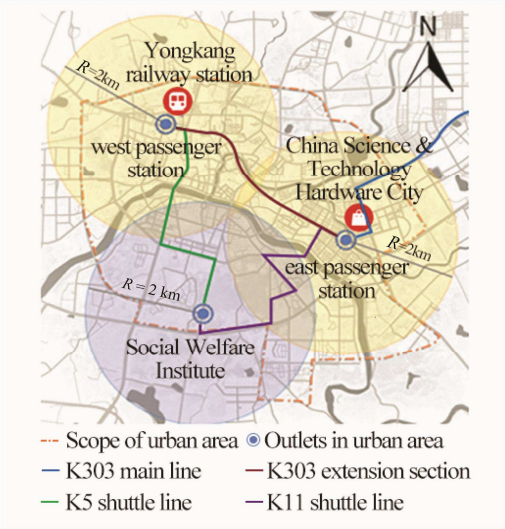


Fig. 10 Optimized logistics outlets layout in city areas and bus routes

2) Adjusting bus lines and stations

Firstly, optimization of urban-rural bus operation is needed. The East passenger station and the West passenger station in Yongkang are close to China Science & Technology Hardware City and Yongkang Railway Station, respectively; these two locations are important destinations for residents of towns and villages in their typical trips. Such travel demand has no direct bus services between the eastern towns and villages and the railway station or the western towns and villages and the Hardware City. In order to reduce transfer of goods, improve transportation efficiency, and simultaneously meet the direct travel needs of residents in towns and villages, it is suggested to adjust part of the bus schedule in the original operation plan of urban-rural bus lines through the implementation of "east route departing from the west and west route departing from the east" strategy. Taking line K303 as an example, certain bus services will be extended from the East passenger station to the West passenger station as departure and arrival stations (loading and unloading goods only at the West passenger station in the city for the extended bus services). The adjustment plan is shown in Fig. 10 and Fig. 11.

Secondly, city shuttle bus lines are useful. No urban-rural bus lines can directly reach the newly added Social Welfare Institute outlet and no bus lines with origin and terminal stations connect the West or East passenger station. Therefore, city shuttle bus lines should be opened to address the connection problem. Currently, both K5 (West Passenger Station—High-speed Railway Station) and K11 (East Passenger Station—High-speed Railway Station) pass the Social Welfare Institute, with a departure interval of approximately 10 minutes. The passenger flow of the two lines is obviously affected by the arrival and departure time of high-speed trains. During the non-arrival and departure time, the passenger flow between the Social Welfare Institute and the high-speed railway station is limited. It is considered to create a shuttle bus line of "West Passenger Station/East Passenger Station—Social Welfare Institute" by shortening a small part of the bus lines during non-peak period; this approach can not only meet the urban-rural transfer needs of small goods, but also minimize its impact on passenger transportation and reduce the low-efficiency mileage of bus lines. The adjustment plan is shown in Figs. 10 and 11.

4.1.2 Strategies in towns

1) Increasing the number of outlets

To encourage walking-oriented travel of sending and picking up goods, the service radius of 500 m is taken as criteria for adding outlets in towns based on the requirement of placing postal businesses within 10-minute living circle [21]. The specific process and method of outlet site selection are shown in Fig. 12. To ensure coordination between the logistics outlets and the original and terminal stations of urban-rural buses, a portion of the urban-rural bus line services will be extended to the new outlets and public transportation accessibility will be increased through the lines going into the town areas, so that the service quality of both passenger transportation and logistics can be improved together.

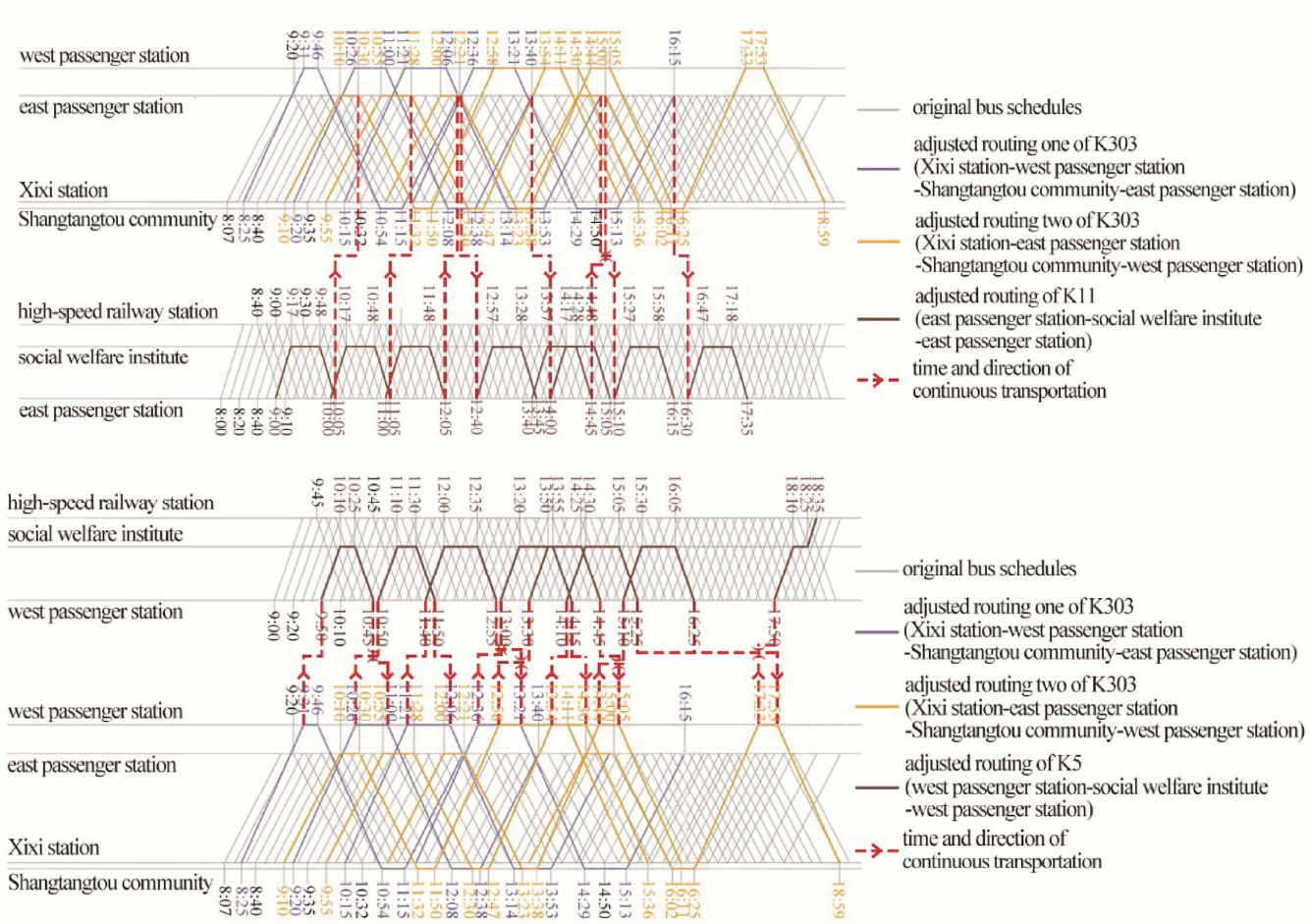


Fig. 11 Operational optimization scheme for line K303, K11, and K5

Note: In order to ensure the efficiency of the continuous transportation of goods, the operation plan takes into account that the whole process of two-way transshipment of items at the east passenger station and the west passenger station takes no more than 30 min; only some schedules for one day are intercepted.

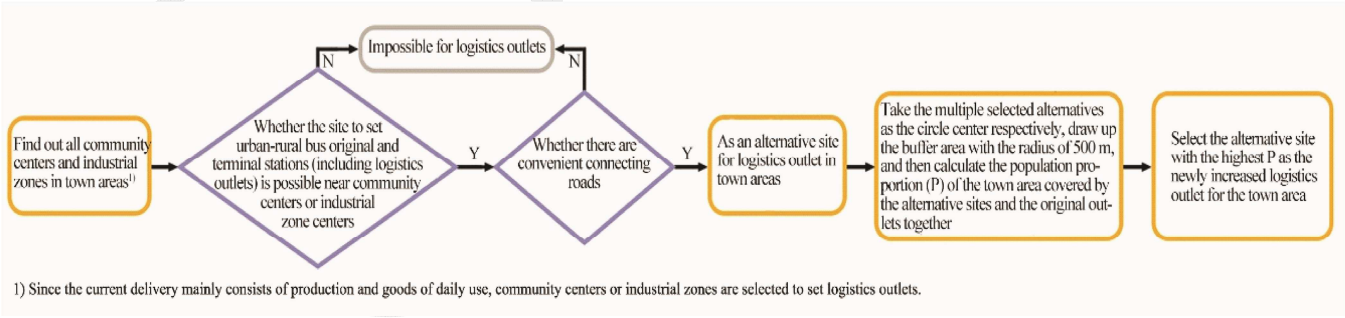


Fig. 12 Location selection process of newly added outlet for passenger transportation + logistics in town areas

Xixi town is used as an example, where the convenience store at the center of Shangtangtou community is selected as the newly added outlet (see Fig. 13). Convenience stores serve as supporting commercial facilities in towns and can also provide life services for residents to send or pick up goods. Current public transit logistics users include those who use electric bikers or cars for 10–20 minutes to send and pick up goods. This suggests that the demand of public transit logistics has already existed in villages outside the town area. Therefore, adding logistics outlets closer to the village region can effectively shorten travel distance of users in villagers distance for sending and picking up goods.

2) Adjusting bus lines and stations

The strategy is to set urban-rural bus origin and terminal stations at the newly added outlet and extend some K303 buses to the Shangtangtou community as departure or arrival stations (for the extended buses, goods are loaded and unloaded only at the Shangtangtou community). The adjustment

Fig. 13 Optimized logistics outlets layout in town areas and bus routes

plan is shown in Figures 11 and 13. After the adjustment, passengers or senders can choose the nearest station to get on bus or the nearest outlet to send goods, thus reducing walking distance and time. Staff at the outlet can select the nearest delivery outlet based on pick-up addresses to save users service time.

4.2 Optimization of service quality throughout the whole process of logistics

Providing intelligent and high-quality services with integration of passenger transport and logistics is required to enhance the competitiveness of public transit logistics. With regards to the current problems such as poor service quality in the whole process of logistics, low level of informatization and intelligence, and insufficient passenger transportation service function, optimization should be implemented from both offline and online perspectives.

4.2.1 Offline improvement measures

Different packaging measures can be applied based on characteristics of the classified goods. Vacuum sealing is applied for packaging vegetables, fruits, meat, and other foods with special smell and requirements for fresh preserving. Polyfoam filling is used for packaging fragile products (e.g., glass products). Paper bag sealing is applied in packaging goods with clean and crease-free requirements (e.g., documents). Plastic bags or cartons are used for packaging other types of goods. All these packaging measures are implemented at the outlets with 1 to 2 yuan charging paid by senders.

Fixed buckles are set on the sides of the logistics boxes to connect the poles and the walls on the bus. Pump-in movable clapboards are applied to divide the space inside the boxes to ensure the stabilization of logistics boxes and goods when the bus is in operation (see Fig. 14).

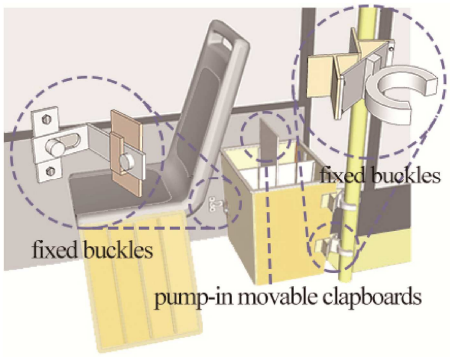


Fig. 14 Optimization of logistics boxes and fixed methods

To meet the needs of different users, 24-hour self-service pick-up cabinets are also set up near each outlet to extend pick-up service time.

4.2.2 Online improvement strategies

As an online platform for travel services in Yongkang, the current version of Yongkangtong App can only provide basic passenger transportation services, such as public transit information inquiry. In the design of Yongkang's integrated service platform for public transit logistics, the function of "route planning, fare payment, user evaluation" has been added recently based on the Yongkangtong App (see Fig. 15) to cover every step of passengers travel. The convenience and satisfaction of public transportation will be improved through an improved "internet + bus passenger transport" service.

On this basis, a logistics section is added to provide functions of "sending goods, freight payment, information inquiry, user evaluation, and information announcement" (see Fig. 15). After the outlet receives the goods, the system will track and release real-time logistics information; senders and recipients can obtain delivery information, in-transit location, and sign-in status of the goods in real time using the "information inquiry" function, which helps reduce uncertainties of waiting by offering anticipated goods arrival time. Staff in charge of the outlets monitor the number of passengers to be served at urban-rural bus departure stations in real time, select buses with sufficient remaining capacity for logistics, and load the goods to be transported in time before boarding passengers. The function of "user evaluation" provides a communication channel for managers and users of public transit logistics. Through the public participation mechanism, managers can respond to users' actual demand in time and continuously improve service quality.

Admittedly, the construction of online platforms requires initial investment and maintenance costs. However, the platform can effectively respond to residents' demand on improved services, achieve quality improvement of both passenger transportation and logistics, and induce the growth of passenger flow and logistics. The platform will also be able to provide online services for all the subsequent routes with public transit logistics. The construction of online platforms can effectively recover costs and even make profits quickly in the long run.

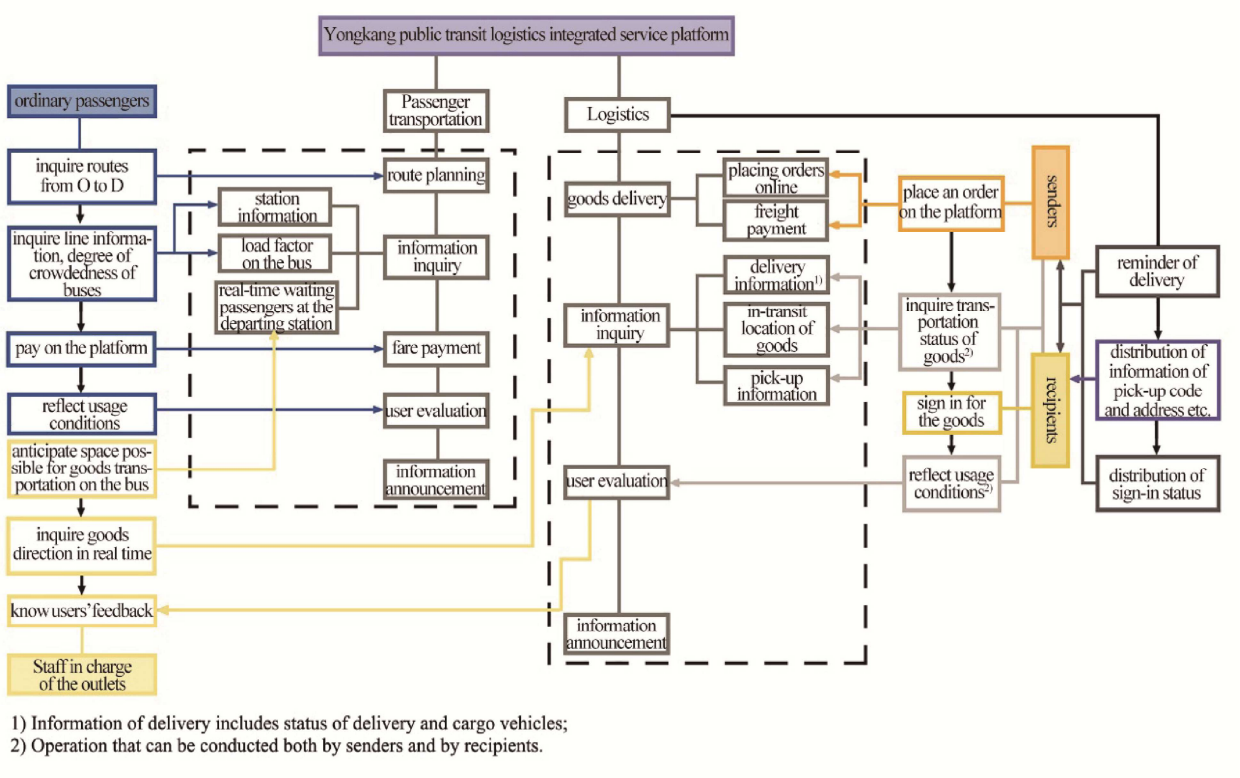


Fig. 15 Integrated service platform design for passenger transportation + logistics in Yongkang

5 Conclusion

Public transit logistics can address residents' demand for moving their small production and goods of daily use between urban and rural areas with low cost, high efficiency, and high reliability. Offering public transit logistics is significant to promote equal access to basic public services in urban and rural areas, improve the quality of life of urban and rural residents, and support rural revitalization. The number and location of logistics outlets, the refined design of multiple bus lines, and the synchronous service quality improvement in the whole process of passenger transportation and logistics are core elements to increase the competitiveness of public transit logistics. The K303 line in Yongkang is a typical case of public transit logistics practice; the discussion and results from this paper can be extended to other similar areas.

It should be noted that the current public transit logistics in Yongkang mainly cover the township level; grassroots level villages have not been involved. It is urgent to improve the level of basic public services in the vast villages where logistics services are almost unavailable. The survey has suggested needs for going to logistics outlets in towns over long distance to send small goods, which deserve further assessment. Yongkang has achieved full coverage of bus services in rural areas. For the next step, public transit logistics can be experimented based on village buses and interconnect with the existing public transit logistics to meet the basic demand of shipping scattered and seasonal small goods in rural areas, get through the logistics channels among cities, towns and villages, and offer a strong support on rural revitalization.

To further improve the service quality of public transit logistics in urban areas of Yongkang and to achieve the logistics service radius of 0.8 to 1 km in the long term, at least 11 outlets should be added. With the promotion of classified public transportation services, community bus can serve as a branch bus for short-distance living trips and integrate with public transit logistics at the beginning phase of bus lines design. For each of the three public transit logistics outlets implemented recently in the urban area, it is suggested to open 1 or 2 community bus lines (with reserved space for logistic boxes on the selected type of buses) based on survey results of passenger flow demand to set bus stations and 24 h self-service pick-up cabinet together near public facilities that can provide convenient life service [①]. After the implementation, some residents can walk to closer outlets to pick up goods and their multiple living needs can be addressed within one trip.

[①] Public transit logistics outlets are only allowed to be set at 1 or 2 halfway stations with relatively larger passenger flow on community bus lines to reduce the negative impact on passenger transportation efficiency.

Finally, the successful promotion of public transit logistics relies on a reliable operation and management system, such as the benefit distribution in the interconnection of different lines, land ownership of logistics outlets, disposal methods of public transit logistics disputes, and support of intelligent transportation information technology. Further study will be needed.

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