A Feasibility Study of Urban Underground Logistics System --
A Case Study of Shanghai

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Abstract. With rapid development of e-commerce, new retail and other new Internet business models, the requirements of the higher package handling efficiency and lower delivery cost are put forward in logistics industry. However, due to the lack of logistics facilities, the limitation of ground roads and the land use, the service of express delivery cannot satisfy the logistics demand, which makes the express delivery a "bottleneck" that restricts the development of urban logistics. Underground Logistics System (ULS) can be a new way to handle it. ULS refers to a logistics system which uses specific vehicles to realize the seamless connection of automatic loading, unloading, transportation, sorting and delivery of goods in the underground based on information technology. Firstly, we have studied ULS and explored its system architecture and advantages. Then, we have combined it with Shanghai Master Plan 2017-2035 and its express facilities planning, and provided a forecast of the express delivery demands in Shanghai in 2035. Based on the findings, we have proven the necessity of ULS corridors in the city. It is likely that the increase of logistics demand will bring about some urban problems such as traffic congestion, environmental pollution and resource waste, if no timely action is taken. As a new mode of urban express delivery, ULS can reduce the above negative effects and promote the sustainable development of the city.

1. Introduction
Urban logistics refers to the logistics activities that delivering the goods to the designated place at the appointed time through a series of logistics operations such as cargo collection, loading, transportation and information service according to the requirements of customers [1]. Nowadays, with the integration of big data, artificial intelligence and logistics technology, urban logistics is not limited to traditional warehousing and transportation functionalities and will be given new definitions.

In the past 10 years, with the rapid development of new Internet business models such as e-commerce and new retail, consumer demand has changed to be different and customized. The logistics demand is showing the characteristics of small batch and high frequency [2]. At the same time, the growth of the business volume of the logistics industry puts forward requirements for higher package processing efficiency and lower transportation costs. However, due to the shortage of logistics infrastructures, including the truck traffic restrictions, the newly increased demand of logistics cannot be satisfied, and urban logistics has become a "bottleneck" restricting the development of efficient urban transportation of goods.

At the same time, the urban underground space (UUS) is also developing constantly, providing new opportunities for the urban logistics. In China, metropolises such as Shanghai, Tianjin, Chongqing, Guangzhou, have exceeded 5 million m² in recent three years [3], and it continues to increase. It is a
trend to systematically develop UUS with multiple functions, which is also an effective solution to the current "first-come-first-served" problem of UUS [4–6]. Transferring urban logistics to underground can promote the efficiency of UUS utilization, alleviate the land use pressure, promote the improvement of urban surface environment, and maintain the compact and livable development of the city.

Considering these constraints, the Chinese Government has issued policies to actively encourage the intelligent and innovative development of the logistics industry. In September 2019, the State Council issued the outline for the construction of a strong transportation network [7]. The outline pointed out that “we should speed up the expansion, efficiency and digital transformation of express delivery, expand the supply chain service, cold chain express delivery, instant delivery and other new formats, and promote the construction of intelligent delivery terminal facilities and public service platform. Actively develop unmanned aerial vehicle, underground logistics system (ULS) and etc.” Among them, ULS has been written into the national major strategic decision for the first time, which represents the important step for ULS.

To achieve the development goals of urban logistics as part of this strategy, it is important to study the ULS for urban logistics. Therefore, this paper takes Shanghai, an international metropolis, as the object to study its ULS scheme, in order to meet the larger scale express delivery demand in the future, Also, this study could be used as a ULS demonstration scheme for other cities.

2. Underground Logistics System

2.1. Concept

ULS refers to a logistics system that uses specific vehicles to realize the seamless connection of automatic loading and unloading, transportation, sorting and delivery of goods in the underground space through information technology [8,9]. The urban ULS especially serve the logistics activities within the scope of city. The main transportation objects of the system are small batch and high-frequency goods such as express packages. ULS has the advantages which are different from the ground logistics system as follows:

- Benefit for urban environment. Significant reduction of the air and noise pollution from the ULS because that its logistics activities are carried underground and use green energy vehicles. Also, ULS can place in Utility Tunnels, which could co-locate more than one utility underground facilities, and can reduce the construction damage of surface infrastructure [10].
- Improve the function of UUS. ULS can improve the UUS system and enhance the toughness, safety and sustainability of it.
- Higher logistics efficiency for enterprises. The logistics activities of ULS can run continuously, 24 hours per day. Hence, the enterprise using ULS will improve the logistics service competitiveness and be more efficient.
- Better logistics services for customers. The ULS goods transportation is grade separated to avoid the traffic congestion, so that the ULS transportation is faster, and could meet higher customer demands [11].

2.2. Architecture

ULS adopts a two-level logistics architecture composed of the logistics center and the distribution center [12]. And the logistics corridors are divided into the trunk corridor and the branch corridor (see Figure 1).
Figure 1. Architecture of ULS.

The logistics center (LC) is the assembly place for goods transportation. It has the functionalities of distribution, storage, receiving, sending, security inspection, container standardization, information processing and etc. It is generally located at the suburb where can be the key node for the transformation of ground transportation to underground transportation. Also, it can link up the regional logistics hub such as railway stations and airports.

The distribution center (DC) is the intermediate node connecting LCs and users. It owns the functionalities of cargo distribution and loading, and disassembling the standard container to single package. It is usually constructed with the urban public service facilities.

ULS trunk corridor is mainly building the connection between LCs and DCs. It is a dedicated logistics lane, which is used to transport goods by automatic vehicles.

ULS branch corridor connecting DCs and end users. It is mainly used for the "last mile" delivery of packages.

3. Analysis on the necessity of developing ULS in Shanghai

3.1. Planning background
Shanghai Master Plan (2017-2035) [13] puts forward a clear strategy for the development of ULS. The planning document indicate that exploring the establishment of ULS based on subway, automated vehicle and other traffic modes to improve logistics efficiency. And the construction spaces of ULS are reserved in the deep underground space which is more than 50 meters below the ground.

Moreover, the facility system and spatial layout of Shanghai Express Facilities Plan (2017-2035) [14] also provides the basis for ULS planning. According to the planning document, Shanghai is planning to form the spatial layout of express logistics facilities with "Three Areas, Two Parks and Multiple Centers". The spatial layout of express delivery facilities is shown in Table 1.

Table 1. The spatial layout of express delivery facilities

| Area          | Park                             | Center                   | Location       | Business Source                           |
|---------------|----------------------------------|--------------------------|----------------|-------------------------------------------|
| Eastern area  | Pudong zhuqiao express logistics park | Pudong-air logistics center | Pudong Airport Shanghai East Railway Station | International, Hong Kong, Macao and Taiwan air express business |
|               |                                  | Pudong-rail logistics center |                | Domestic railway express business       |
| Area          | Logistics Park                  | Service Type                              |
|--------------|---------------------------------|-------------------------------------------|
| Western area | Qingpu express logistics park   | Domestic highway express business         |
|              | Pudong-road logistics center    | Domestic highway express business         |
|              | Fengxian logistics center       | Intra-city express service                |
|              | Huaxin logistics center         | Domestic highway express business         |
|              | Zhaozhong logistics center      | Domestic highway express business         |
|              | Xujing logistics center         | Domestic highway express business         |
|              | Hongqiao transportation hub     | Domestic air express service              |
|              | Baoshan logistics center        | Intra-city express service                |
|              | Jiading logistics center        | Intra-city express service                |

**Figure 2.** Spatial layout of express facilities in Shanghai.
3.2. Demand forecast of express delivery

Based on the resident population and express business volume of Shanghai over the years [15], this paper forecasts the express delivery demand in 2020 and 2035 according to the development trend of express logistics. The revenue and volume of express delivery business in Shanghai over the years are as follows:

| Year   | The revenue of express (million yuan) | The volume of express (million pieces) |
|--------|--------------------------------------|---------------------------------------|
| 2013   | 2575921.30                           | 95012.40                              |
| 2014   | 3613060.40                           | 128366.10                             |
| 2015   | 4552476.20                           | 170778.00                             |
| 2016   | 7095143.50                           | 260274.40                             |
| 2017   | 8688851.60                           | 311503.70                             |
| 2018   | 10202806.00                          | 348648.80                             |

According to the planning of express delivery facilities in Shanghai (2017-2035), it is planning to achieve more than 150 million yuan of express business revenue in 2020. Basing on the goal and the current development trend of express delivery industry, the revenue and volume of express business in 2020 and 2035 are predicted as follows:

![Figure 3. Revenue and volume forecast of express delivery business in 2020 and 2035.](image)

As is shown in Figure 3, it is predicted that in 2020, the total revenue of express delivery business in Shanghai will reach 15 million yuan, and the total volume of express business will be 5126.45 million pieces; in 2035, the total revenue of express delivery business will be 173548.37 million yuan, and the total volume of express business will be 5931.25 million pieces.

To predict the precise express demand, the population volume is necessary. According to Shanghai Master Plan (2017-2035), there is the requirement to strictly control the population scale of Shanghai, so the permanent population in 2020 and 2035 is calculated on the basis of 25 million people.

According to the data above, it can be predicted that the daily per capita express business volume in Shanghai is 0.56 in 2020 and 0.65 in 2035.

3.3. ULS proposal

According to the express delivery facilities planning in Shanghai, ULS in Shanghai can be planned as a two-level logistics architecture composed of LC and DC.

We propose to set up 12 LCs in Shanghai (see Figure 4). Among them, two LCs are located at Qingpu and Pudong logistics parks, and the other 10 LCs are placed close to the locations that express delivery
facilities shown in Shanghai Master Plan. The three areas of Shanghai are served by several LCs. LCs in Qingpu, Hongqiao, Huaxin, Xujing and Zhaozhong serve the western area. LCs in Jiading and Baoshan serve the northern area; LCs in Pudong, Pudong-rail, Pudong-air, Pudong-road and Fengxian serve the eastern area.

Several DCs are also planned in this proposal according to their service radius. The service radius of the DC is 800-1000 meters. In order to ensure the high service level of the DC, the service area of all DCs needs to cover more than 80% of the urban land. At the same time, the DC should give priority to place in the community public service facilities.

ULS trunk corridors are planned to established between LCs. According to the requirements of Shanghai Master Plan, the ULS trunk corridor is constructed in the deep underground space within 50 meters, which can directly connect with each LC. There will be a total length of corridors about 150 km. The average length of the corridor between the LCs is 4.7 km in the west, 18 km in the north and 14 km in the east. The trunk corridor is directly connected with the LCs of Hongqiao center and Pudong airport, which is conducive to realize the combined transportation of highway, railway, aviation and other transportation modes.

The ULS branch corridor is planned between the LC and the DC. The ULS branch corridor can be located in the 50m deep underground space, but the total length of the branch line is far greater than that of the trunk line, so the cost of the branch line will be very high if all the branch lines are built in the deep underground space. At the same time, more shallow underground space has been developed in the urban area where the branch line passes through. Therefore, ULS branch corridor is able to construct together with underground facilities such as subway, utility tunnel and underground road, in order to save cost and enhance practicability.

![Spatial layout of ULS in Shanghai](image)

**Figure 4.** Spatial layout of ULS in Shanghai.

### 4. Conclusion

Considering raise of e-commerce and new retail, urban logistics, as an important element for the sustainable development of the business model, will face more large-scale logistics demand. However,
the increase of logistics demand will bring some urban problems, such as traffic congestion, environmental pollution and resource waste. As a new mode of urban logistics, ULS can reduce the above negative effects and promote the sustainable development of the UUS. Taking Shanghai as an example, this paper makes a feasibility study that propose a spatial layout of ULS for express delivery in Shanghai by combining with Shanghai Master Plan. In the follow-up, it is necessary to conduct in-depth research on facility location and routing selection.

Acknowledgments
The research was supported by the National Key Research and Development Project (2019YFB2101600), China Postdoctoral Research Fund (K2018J022) and National Natural Science Foundation of China (71631007).

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