RESEARCH ARTICLE

Exploratory Research on the Construction Models of China's Rail Logistics System

Zejun Dai
Tsinghua University, China Construction Technology Consulting Co., Ltd., Singapore CPG Corporation, Beijing, 100044, China

Abstract: In consideration of the development trend of comprehensive utilization of aboveground and underground space resources in China's megacities and many problems arising during the bottleneck period of rapid development of logistics in megacities, several construction models of rail transit logistics system suitable for China's urban development are studied and explored in the present research. By analyzing the characteristics of international and domestic logistics methods and the construction of rail transit facilities system, using research analysis and data comparison, etc., and finally combining the current level of China's economic development and future development direction, the paper analyzes and proposes in details, a scientific and reasonable construction model for the future rail logistics system of megacities in China, in which the main network is established by fully modifying and making use of existing aboveground and underground lines, transforming suburban railways, and it is partially supplemented by new special lines.
Keywords: Logistics; Underground space; Underground facilities; Megacities

Citation: Zejun Dai. 2021. Exploratory Research on the Construction Models of China's Rail Logistics System. *Journal of Smart Cities*, 6(1): 25-31. http://doi.org/10.26789/JSC.2021.01.005

1. Strategic Significance of Building Underground Logistics System

China is rapidly ushering in the information era of the 21st century, with the continuous prosperity of electronic commerce and a sharp increase in logistics demand, while the emergence of megacities and urban agglomerations has increased the demand for urban resource replenishment significantly. These new characteristics of urban development have greatly promoted the rapid development of the urban logistics industry, and also brought a series of challenges to megacities. For example, the massive increase in logistics space has made urban limited traffic space over-crowded, leading to an increase in traffic accidents, as well as an aggravation in urban noise and environmental pollution, all of which run counter to the goal of sustainable urban development. It is shown from the statistics, the air haze at 2 a.m. and more than 65% of the serious ground traffic accidents in Beijing are mostly directly related to logistics and the transportation of urban resources at night.

In this background of urban development, targeting at the opportunity from the current rapid development of rail transit and increasingly mature high-speed rail technologies in China, developing a green aboveground and underground rail transit logistics system energetically is expected to become a new opportunity to solve a series of problems such as the supply of urban resources. The rail transit logistics system is not only capable of greatly reducing a large amount of energy consumption and costs from the traditional ground logistics consumption, but also promoting the improvement of urban air quality and reducing traffic accidents caused by ground freight, which is very beneficial to the development of China's megacities and urban agglomerations in the new era. In addition, fully exploring and utilizing the underground logistics space will reduce the urban allocation of land for the logistics industry and release more urban land, thereby providing more scarce land resources for urban development and urban renewal; however, developing the underground logistics system energetically, for most cities in China, especially Beijing, Shanghai, Guangzhou, Shenzhen and other megacities and the surrounding urban agglomerations, is of great strategic and livelihood significance.

2. Classification of the Major Rail Logistics System Models

2.1 Advantages and Disadvantages of Newly-built Integrated Underground Logistics System

The so-called newly-built underground logistics network model herein refers to newly building and constructing underground space, such as underground pipeline networks and tunnels, to meet the needs of freight transportation. Generally, such underground logistics space is constructed at a depth of more than 30 meters under the urban ground, using AGVs, DMTs, and other load-bearing tools for transportation, and the pipeline for its underground special transport space network has a diameter of about 5 meters, at an operating speed of 60~100 km/h. This underground logistics network system can connect all important urban buildings, such as commercial offices, residential communities, as well as hospitals and schools, according to the requirements of urban planning. In terms of construction cost, a new underground logistics system requires a rate of about RMB 80-100 million/km. This urban logistics underground pipeline network can certainly enhance the efficiency of transporting strategic materials and livelihood resources in modern high-density cities, however, due to large construction scale, the high difficulty of construction and huge capital investment, as well as the availability of efficiency and return on investment depending on a certain network and scale, the network requires higher capital investment and longer payback period.

2.2 Logistics Space Model Based on Existing Rail Transit

Urban rail transit and rail transit-based logistics systems aim to transport people and cargo respectively and target at different service objects, but they have great similarity as a means of transport. In the underground logistics space model based on the existing rail transit, the existing urban rail transit network is applied and used for cargo transportation. Specifically, during the vacant period when the rail transit stops running at night, the existing urban rail transit network is used for logistics transportation. It is available to develop special rail freight trains or retrofit existing trains, thereby meeting the passenger and cargo transportation demand both day and night. This comprehensive utilization of the rail transit system model not only requires less initial modification costs, shortens the payback period, stabilizes predictable income gradually, with obvious economic benefits, maximizes the effectiveness of the aboveground and underground space of the rail transit system, but also it is conducive to the night rail transit maintenance efficiency with obvious advantages. However, during the detailed survey stage, some practical difficulties arise from modification and utilization activities, such as the need to solve the different standards and coordination between systems such as rail transit and logistics companies; and how to minimize interference with the convenience and safety of daytime rail passenger in the process of station modification, design and installation of mechanized loading and unloading equipment.

2.3 Underground Special Line Model

As a partial pilot of the overall network model, underground special line model can be used as a pilot line of the urban underground logistics system, connecting the city's airport freight center or national railway freight center, and the city-level logistics distribution base together to facilitate the first level of freight logistics on the city scale, to quickly reach the logistics distribution base for sorting. The model is advantaged in obvious local benefits, and doesn't require a network, upon completion a line can be put into use and as a one-time project, it is characterized by small scale and low investment; however, it is disadvantaged in some aspects, such as single point-to-point delivery of goods, failure in completely solving all the problems caused by urban road freight, only suitable as a pilot line for the initial development of underground logistics system. It also has similar problems such as high requirements for inherent urban facilities and coordination and communication between various departments.

2.4 Transforming Existing Air-raid Shelters or Underground Pipe Corridors to the Underground Logistics System

The underground air-raid shelters projects and partially completed underground pipe corridor systems in large-/medium-sized cities in China are often connected to the most important functional blocks of the cities and they are widely distributed but rarely used at ordinary times. If it is allowed to make use of them and build the corresponding intelligent logistics and transportation system in the existing air-raid shelters projects or underground pipe corridors, another function of them will also come into play. By connecting the system to large warehouses, retail and wholesale commercial facilities, urban supermarkets and residential areas, a wide and huge subway pipeline transportation network will be established, and spread to all corners of the city, as an option worth researching and studying. Such a system does not interfere with the daytime high-intensity operation of the subway system, may be constructed in a more flexible way, with a fast network construction cycle and low construction cost. As special underground lines involving air-raid shelters projects, national defense safety confidentiality and how they can be transformed should be taken into account [1-6].

3. Difficulties in New Urban Underground Logistics System at the Current Stage

3.1 The Deep Space Required for the New Underground Logistics has not been Developed

According to the relevant research on the flatted development of underground space, it is recommended urban underground logistics systems are constructed in the deep space at a depth of more than 30 m generally, while at present for most of China’s urban underground space; there is huge potential in the underground 0-30 m development space. Even in economically developed cities like Beijing, Shanghai and Guangzhou, the depth of underground developed space is mostly concentrated between 0-15 m underground. In the case that the underground space of 15-30 m is not yet fully used, priority will be given to developing the middle depth in the near future, i.e., 15-30 m underground, rather than immediately developing urban underground space at 30 m or deeper. In addition, the deep space development in China is still in the initial stage without relevant national technical standards and geographical attribute division, and it is still urgent to solve many technical difficulties for the underground space deep development in China.

3.2 Disproportionation between Early Stage Capital Investment and ROI for New Underground Logistics System

Urban underground logistics system requires a high initial cost, with ambiguous marginal benefit and few investors intend to invest underground logistics system is composed of various works, such as tunnels, tracks, automated means of transport, mechanized loading and unloading platform and other hardware equipment, as well as the logistics system information management system, scheduling system, information control system, navigation system and other software systems. The investment in both hardware and software makes the construction of an underground logistics system cost a lot of money.

Compared with the new passenger-carrying subway system, the new underground logistics system for transporting cargo is less expensive, but its network density far exceeds that of the subway system, so the total cost of ownership is still very high. According to statistics, the cost of underground logistics system construction is about RMB 80 to 100 million per kilometer. According to calculations, it is shown the direct economic benefits from the construction of underground logistics system is disproportionate to the cost of consumption costs; compared with the trucking system, it is difficult to achieve economic viability, no country has not yet built a formal urban underground logistics system worldwide, and those local and experimental underground logistics systems haven’t obtain economic benefits yet. Therefore, if an urban underground logistics system relies entirely on a new construction model, this system will face the risk of huge investments and uncertainty of future revenues.

In addition, as a sustainable project, the newly-built urban underground logistics system has an extremely high cost when it is put into operation. It is needed to consider many expenses such as maintenance of mechanical equipment and upgrading of software systems. The system has a low profit margin and a long payback period when the system has not been put into use on a large scale in the early stage.

3.3 Engineering Construction Risk of New Underground Logistics System

The newly-built urban underground logistics system may involve more engineering fields and specialties, such as engineering geology, urban planning, architectural design, traffic engineering, logistics engineering and electronic information. In addition, for the purpose of management, it also involves urban planning and management, logistics management, engineering construction, transportation safety and automatic control, and it is also required to take into account the interrelationship with other urban infrastructures. All these professional requirements and integration make the construction of the city’s underground logistics system extremely complicated. At present, relevant research is also rapidly following up on the development demand of urban underground logistics systems, but most of them are still in the stage of experimental research; there is still little practical experience in this field worldwide, and both the potential and difficulty of research remains a high level.

3.4 Newly-built Underground Logistics System Has High Requirements on Urban Geological Conditions

As it is needed to develop deep underground space for the underground logistics system of newly-built cities, such development is greatly affected by geological conditions. The geological conditions are different from place to place, it is necessary to accelerate research on how to deal with the local geological conditions, develop a reasonable engineering construction plan and determine a reasonable engineering construction technology.

3.5 Newly-built Underground Logistics System is Limited by Existing Underground Pipeline System

As the "blood vessel" of a city, the underground water, heat and electricity pipelines & cables and subway lines are densely distributed; the invisible underground space network becomes more complicated. How to avoid the existing underground infrastructure as much as possible in the process of building a new underground logistics system is regarded as a technical problem, and how to reduce the accidents that cause the existing pipelines to be broken or collapsed is an unavoidable problem.

3.6 Relevant Laws and Regulations for the Urban Underground Logistics System are Seriously Lagging Behind

As the underground logistics system is a brand-new concept system, the systematic relevant laws, regulations and rules fail to provide comprehensive restraint. This problem also existed in the early stage of urban transportation development. However, as the hidden interactive professional system involved in the underground space is more complex, the governmental decision-makers are expected to solve the problem clearly define the relevant laws and regulations in advance, in guiding and organizing the construction of urban underground logistics system [7-13].

4. Proposal of Logistics System Based on the Existing Urban Rail Transit

4.1 Concept of Logistics System Based on Existing Urban Rail Transit

In recent years, the development of China's urban rail transit system has been in full swing. Urban planning and urban rail transit construction activities have increased rapidly, and the network has been established initially. Rail transit is characterized by high efficiency, punctuality, less pollution and less influence by climate, and meets the development direction of the modern logistics system. Therefore, with the development of the time, the vertical and horizontal network of urban rail transit will be gradually constructed and formed. In some cities, the development of logistics system based on urban rail transit has indeed provided a realistic basis for feasibility.

To control the early stage construction cost and make use of the existing track facilities by modification and transformation, the construction costs, including time costs and money costs, should be minimized in the initial stage of construction. As the operation time of urban rail is generally from 5:00 to 23:00, logistics transportation is feasible and available during a shutdown period of about 6 hours. It is available to research and develop special freight trains, similar to German Cargo-Cap, modify track lines appropriately to reduce night maintenance time or rotating maintenance, thereby striving for more logistics transportation time.

In addition, some megacities, such as Beijing, Shanghai, Guangzhou and Shenzhen, have begun to transform some of the abandoned national railway lines around the cities into suburban railway lines. The suburban railway is characterized by low utilization rate and low passenger traffic; therefore it can be used for transportation of both "passenger" and "commodity" to improve economic efficiency.

4.2 Feasibility Study on the Implementation of Logistics System Based on Urban Rail Transit

China has formed a dense, network-like urban rail transit system in megacities with the following features, providing these cities with the possibility of establishing an aboveground and underground logistics system:

(1) Stable, efficient and punctual operation; excluding the overhaul time, there are still 5-6 hours of idle shutdown period every day;

(2) Green and environment-friendly, with low energy consumption, available to reduce harmful gas emissions;

(3) Low noise, less noise interference to urban environment;

(4) Less affected by the weather, few urban underground rail logistics systems are affected by bad weather, resulting in failure in operation [14-16].

5. Analysis on Advantages of Logistics System Based on the Existing Urban Rail Transit

5.1 The Existing Rail Lines Can be Fully Utilized, with Low Initial Capital Investment and Stable Revenue

Urban rail logistics system and rail transit share similar means of transportation, which enables the rail logistics system to make use of the existing rail for transportation of both passengers and cargo. Shown from the comparison, it is not necessary to excavate the tunnel again by making full use of the existing rails. The initial investment is only limited to the expansion of the subway stations and the addition of mechanical loading and unloading equipment, therefore the corresponding capital investment may be reduced. In addition, as a public product which operation is subsidized by the government, the subway is still at a loss. Expanding its use function will provide more support to the subway system.

It is reported in 2018, only four cities in China, namely Shenzhen, Beijing, Hangzhou and Qingdao, achieved a balance of revenue and expenditure in subway operation, while the other 24 cities with subway network traffic operation, including Shanghai, an international metropolis, are all in a deficit state. The operating income-expense ratio for 2018 was only 78%. If the subway logistics system is used, although investment is still required in the early stage, under the publicity and guidance of the government and the reasonable planning and use of the relevant departments, the system is expected to bring huge and stable revenue in the future, which will be beneficial to the revenue subsidy of urban public transportation, and its long-term construction has positive and great significance.

5.2 The Existing Rail Transit Network Can be Fully Utilized

The ultimate development goal of the urban rail logistics system is to become an urban logistics transportation network connecting the logistics center and the distribution terminals. The design strategy of China's rail transportation is similar to the development goal of the rail logistics system: to pursue the networked construction and to coordinate and cooperate among all lines. The first-tier cities represented by Shanghai, Beijing and Guangzhou have a high degree of the network-based urban rail transit system. Taking Beijing as an example, a full-coverage network, in which rail stations can be covered from any location within a 750 m radius, can be realized in the urban central area in 2020. It can be used as a basis reference for the rail logistic network planning. In addition, the rail transit network has been closely integrated with other transportation systems, such as public transportation. The existing transportation planning may be utilized for rail logistics system to connect it with other cities' infrastructure and efficiently complete the logistics operation. Therefore, from the perspective of structural layout, the two are highly similar and joint operation can maximize the advantages of the existing transportation network.

5.3 "Last Kilometer" Model Based on Urban Rail Logistics Transportation System

The distribution costs within the last kilometer account for about 30% of the logistics costs. If urban rail transit is used to transport goods and the networked stations are used as terminal outlets, the transportation model will be optimized more effectively. It is available to imagine the operation process under this model:

(1) Receiving process

Customers can choose to pick up their own goods at the time of shopping online. After the express company accepts the order, the goods are transported to the storage space of the corresponding rail station through the urban rail logistics system. Customers can pick up the goods at their receiving points by presenting corresponding codes and certificates, and the picking-up space can be properly planned according to the route of public transportation that customers must take, thereby solving the problem of "last kilometer" for small parcels to be picked up by the major rail vehicles.

(2) Delivering process

After receiving the order, merchants deliver the corresponding freight parcels to the city terminal through the urban rail transit center, go through the relevant formalities, and submit the goods to storage for night logistics transportation after passing the security check [17-19].

6. Implementation Issues of Logistics System Based on the Existing Urban Rail Transit

6.1 The Rail Transit and the Urban Rail Logistics System Have Different Requirements for Passengers and Cargo

If the existing rail transit is used for cargo transportation, the bearing capacity and wear degree of the rail should be considered first. Generally, the metro rail line bears about 30 tons, therefore the subway logistics system shared with passenger subway trains is only capable of transporting small-/medium-sized goods. The existing rail transit system needs to be modified and optimized, thereby expanding the bearing capacity for goods with larger tonnage and weight and meeting the demand of all-round logistics.

6.2 Lack of Logistics Space and Mechanical Loading & Unloading Tools and Equipment for Logistics

The existing rail stations are targeted at the function of carrying passengers. Logistics function was not included at the initial stage of design. Therefore, they aren't provided with functions required for logistics receiving and dispatching space, storage space and mechanical loading & unloading tools and equipment, which is very unfavorable for the circulation of a large volume of goods. It is necessary to transform these subway stations and equip them with the necessary functions to meet demand. Automatic conveyors can be installed, for example, the goods are conveyed to the designated truck parking sites via automatic conveyors, and then to the unloading platform via automatic conveyors, and finally to the ground using vertical freight ladders.

6.3 Lack of Relevant Specifications

As a new thing, the rail logistics system has no applicable construction standards, fire prevention standards, disaster prevention standards, design standards and construction standards. In addition, different standards and requirements of multiple professions and systems need to be connected and integrated in engineering construction activities.

6.4 How to Coordinate between Various Communities and Systems

Rail logistics system is a new type of system, which is a huge system across different communities. It is needed to break down the barriers between communities and create common interests. We believe that further cooperation and in-depth discussion between government, urban planners, architects, logistics & transportation scholars from various disciplines, and city managers are required in future practice and research [20,21].

7. Conclusions

In conclusion, in combination with China's future economic development and the demand for urban logistics and e-commerce, it is necessary to construct an urban rail logistics system. It is suggested to establish a scientific and reasonable construction model for the future rail logistics system, in which the main network is established by fully modifying existing aboveground and underground lines, suburban railways, and it is partially supplemented by new special lines. This model will make comprehensive use of urban underground and aboveground space resources more effectively; in particular, it is strategically significant to the development of China's megacities in the next few decades.

References

[1] Qian, Q.H., Guo, D.J., December 2015. Planning and Design of Underground Warehousing and Logistics Facilities. Tongji University Press.

[2] Wang, H.D., December 2015. Planning and Design of Urban Underground Municipal Public Facilities. Tongji University Press.

[3] Xu, Y.D., Li, H.F., Zhou, Y., et al., November 2018. Detection and Repair of Rail Structure for Urban Rail Transit. Tongji University Press.

[4] Shu, Y., December 2015. Urban Underground Space Environmental Art Design. Tongji University Press.

[5] Jia, J., December 2015. Urban Underground Complex Design Practice. Tongji University Press.

[6] Yu, M.J., Fan, Y.Q., Hu, H., December 2015. Low Carbonization Design and Evaluation of Urban Underground Space. Tongji University Press.

[7] Zhang, X., Ye, W., Xu, L., November 2018. Urban Underground Space Ventilation and Environmental Control Technology. Tongji University Press.

[8] Shu, Y., Lu, Sh., Ruan, Y.J., December 2015. Planning and Design of Urban Underground Space. Tongji University Press.

[9] Lu, J.W., Zhuang, N., December 2015. Urban Underground Public Space Design. Tongji University Press.

[10] Fan, Y.Q., Zhang, Zh., Yang, C.X., December 2015. Planning and Design of Urban Underground Transportation Facility, Tongji University Press.

[11] Wang, W., June 2016. Research on the Connection Between the Entrance and Exit of Beijing Subway and Surrounding Space, a master's dissertation, Beijing Jiaotong University.

[12] Liu, Y., December 2011. Research on the Legal System of Urban Underground Space, a doctoral dissertation, Nanjing Agricultural University.

[13] Su, Ch.P., September 2008. Research on Urban Underground Space Intensive Design Strategy, a doctoral dissertation.

[14] Kong, L.X., February 2006. Research on Evaluation Model and Countermeasures for Urban Underground Space Sustainable Development, a doctoral dissertation.

[15] Chen, X.H., October 2017. Research on Management Mode and Key Strategies of Urban Underground Comprehensive Pipe Gallery Construction, a doctoral dissertation.

[16] Wan, H.B., May 2013. Research on Development Strategy of Underground Space in High-density Urban Areas, a doctoral dissertation.

[17] Li, Y.S., October 2016. Research on the Interaction Between Urban Rail Transit and Urban Spatial Form, a doctoral dissertation.

[18] Dong, H.X., March 2008. Urban Three-dimensional Research, a doctoral dissertation.
[19] Shang, Q., December 2015. Research on Underground Space of Contemporary Beijing Old City, a doctoral dissertation.
[20] Liu, W., 2016. Research on Commercial Complex in Subway Station Area from the Perspective of City.
[21] Jia, H.B., December 2016. Research on the Establishment of the Underground Space Utilization Right System in China.