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A study of Analysis and Review of Cargo Urban Railway Stations of Korea for Underground Logistics Systems

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Abstract

Recently, as mega-urbanization progresses, urban logistics centered on large cities is growing rapidly, and logistics transportation is increasing due to the lack of logistics infrastructure and the operation of a delivery system using cargo trucks in the city center. being cited as a cause. In order to solve this problem, domestic researchers are conducting research on the development of " Urban Underground railway Logistics System" that minimizes the initial infrastructure construction cost by utilizing the existing urban railway facilities in the city. Therefore, this paper analyzed the usage environment of the actual urban railway station to which the system will be applied in order to derive candidates for the test bed selection of "Urban Underground railway Logistics System". The evaluation criteria for test bed candidate role selection were established, and the candidate group derived from the Brown & Gibson model was used to evaluate the candidate group and derive the candidate role. A review of the results was conducted to contribute to the establishment of a test bed for the " Urban Underground railway Logistics System" under development.

Keywords: *Urban Underground railway Logistics System, Brown & Gibson model, Logistics systems, Test-bed*

1. INTRODUCTION

1.1 Background

In recent years, as mega-urbanization progresses, urban logistics centered on large cities is growing rapidly. The purchasing patterns of residents of large cities are rapidly changing along with the growth of e-commerce. In Korea, 50.2% of the total population resides in the metropolitan area, which includes Seoul, Incheon, and Gyeonggi-do [1]. As the city's population increases, the increase in single-person and dual-income households has accelerated small-volume, frequent delivery of small households, increased online orders by the elderly, and increased non-face-to-face consumption due to COVID-19. This indicates that the consumption trend of

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modern society is changing and has a great influence on the parcel delivery industry. Recently, the daily logistics demand has increased by 11.1% per year on average for the past 10 years, and the number of times of use of parcel delivery per person has also increased rapidly by an annual average of 17.4%, and is expected to continue to increase [2]. The figure 1 expresses single-person and dual-income households has accelerated.

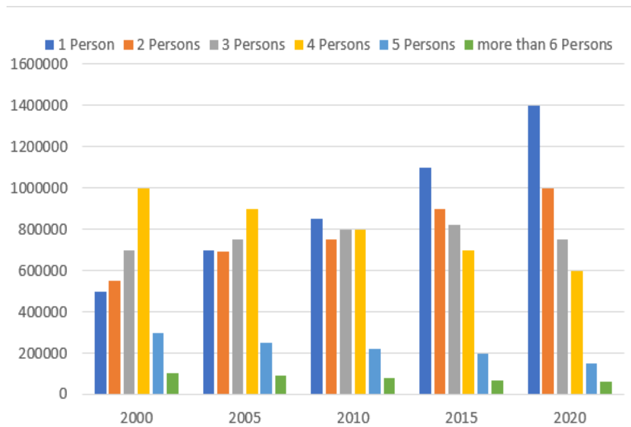

Figure 1. Trends in the number of households in Seoul by number of household members (Source: Statistics Korea)

Despite the explosive increase in demand, half of the logistics distributed nationwide are distributed within Seoul. Logistics complexes and warehouses in Seoul account for only 5.3% of those in Gyeonggi-do, and due to the lack of logistics infrastructure, parcels from Seoul are delivered inefficiently via other regions [3]. In addition, as the logistics transportation within the city increases as much as the increasing volume of parcel delivery, it is emerging as a cause of traffic and environmental problems in the city center. The existing urban logistics system operates a delivery system using cargo trucks centered on roads, leading to problems with high-cost and inefficient logistics structures that increase along with social costs such as road traffic congestion, noise pollution, and environmental problems. A new concept to improve them It is necessary to apply the system [4].

In order to solve these problems, the Ministry of Land, Infrastructure and Transport is conducting research on the development of “ Urban Underground railway Logistics System” utilizing the existing urban railway facilities and underground space infrastructure in the city. This “ Urban Underground railway Logistics System” technology development project is a research on a new transport concept and an urban logistics system that transports logistics using urban railway facilities and underground spaces operated in the city center, maximizing the existing operating space. It minimizes the initial infrastructure construction cost and enables transportation of cargo to various places in the city by utilizing the station space located in the main hub in the city. This system aims to contribute to the reduction of traffic and environmental problems, which have emerged as problems in logistics transportation, and to provide a service that can quickly and reliably transport urban cargo, which is constantly increasing according to market changes [5].

In this study, in order to derive candidates for test bed selection for the demonstration project of “ Urban Underground railway Logistics System”, the actual use environment of the urban railway station to which the system will be applied is analyzed, and the evaluation for test bed candidate selection is conducted. Criteria were established and final candidate groups were drawn.

Related Work

In this section, previous research analysis was conducted to derive a candidate group for selecting a test bed for the " Urban Underground railway Logistics System ". Lee et al used the Hierarchical Analysis Method (AHP) to derive and prioritize major factors through annual statistical annual and on-site verification within the Korea Railroad Corporation to build and practical test beds for real high-speed and general railways and unmanned stations to evaluate and verify the performance of safety management automation system technology [6]. Song et al aimed to derive the optimal location selection method in the process of building a test bed for spatial information technology experiments in order to derive proven research results that can be applied directly to the actual site of the intelligent national information technology innovation project. As a result of the study, cases of domestic and foreign test bed construction were investigated, and a plan for location selection was derived by analyzing the characteristics of the results applied to the test bed [7]. J. H. Kim proposed a logistics system using a subway line network and trains based on the concept of modal shift to reduce greenhouse gases. It was attempted to verify through examples whether it is possible to reduce logistics costs, social costs caused by road transport, and greenhouse gas emissions. As a result of this study, the overall travel distance decreased, resulting in higher-than-expected cost savings and reduced greenhouse gas emissions [8]. H.Y. Lee proposed to extract more objective, scientific, and flexible candidate locations by using multi-standard evaluation techniques to select the location of waste incinerators, which are public facilities. In this study, after standardizing various location factors, weights reflecting the relative importance of each factor were calculated to determine how they affect the suitability ranking of candidate locations through sensitivity analysis [9]. The Korea Transportation Research Institute reviewed the current status of the urban logistics system and related legislation to analyze the applicability of the future cargo transport system and suggested the direction of the construction [10].

1.2 Problem Definition

As urbanization accelerates, consumption trends are changing as small-scale households and online orders for small households and elderly people increase, while non-face-to-face consumption increases due to COVID-19. Logistics transportation in the city center is increasing as much as the amount of delivery increases, which is emerging as a cause of traffic problems and environmental problems in the city center. The existing urban logistics system is mainly operated by a freight truck system, which mainly transports cargo from the outskirts of the city to the city, and it is necessary to apply a new concept system to improve the shortcomings of the high-cost and inefficient logistics structure. The results of this are having a great impact on the delivery industry.

The Urban Underground railway Logistics System is a new concept system and is expected to contribute a lot to solving the problems of the existing logistics system cargo transportation mentioned above. The Urban Underground railway Logistics System builds a logistics space by utilizing the existing station located in the city center of the metropolitan area and transports cargo by a cargo-only urban railway through a cargo platform. It aims to establish a system that performs functions for classification of cargo and terminal delivery processing based on idle space in stations. In order to realize this urban logistics system using underground space, a test bed is first established to analyze the actual use environment of urban railway station to be applied, and a test operation is required to select a test bed candidate station

1.3 Composition of this paper Urban Underground railway Logistics System

This paper consists of: Chapter 2 derives major candidates for urban logistics testbeds using underground space through analysis of external and use environment of urban logistics system and analyzes and selects evaluation techniques and considerations to select testbed evaluation techniques. Chapter 3 uses the Brown & Gibson model to evaluate the candidate group and derive candidate roles and review the results accordingly. Finally, Chapter 4 draws conclusions. he figure 2 expresses this series of procedures.

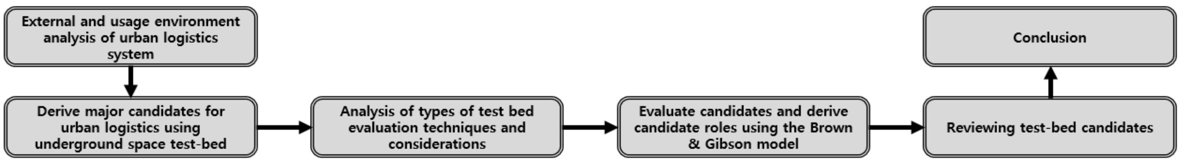

Figure 2. Research procedures and objectives

2. SELECTION OF CANDIDATES FOR URBAN UNDERGROUND RAILWAY LOGISTICS SYSTEM

2.1 Concept of Urban Underground railway Logistics

Urban Underground railway Logistics System operates dedicated urban railway freight cars for freight transportation and collection to designated delivery destinations by utilizing urban railway infrastructure rail car depots outside the city center and subway station space built underground in densely populated areas in the city center. By doing so, it aims to operate logistics cargo transportation and linkage services with sub-delivery systems. It is expected that this will replace the transportation of freight vehicles in the city center. The joint logistics terminal built by utilizing the vehicle depot-based urban railway infrastructure collects and sorts the cargo that needs to be transported from the consignor to the consignee when trunk line moving cargo vehicles are stored at the depot, and transports them to the destination, the downtown cargo station. Load the required cargo onto the freight train. Urban railway freight trains exclusively for cargo transportation are developed as urban railway vehicles exclusively for cargo transportation, not conventional passenger transportation trains for transporting people, so that cargo can be brought in and out. When the transportation to the downtown station, the destination, is completed through this freight train, it is transported to the cargo loading and unloading platform in the downtown station space through the vertical/horizontal cargo transfer device for transportation in the downtown station space. Cargoes transported through freight trains are transported to a dedicated space where cargoes that need to be unloaded and retrieved are loaded and unloaded. The transported cargo is delivered to the terminal delivery, that is, it is stored in a small cargo vehicle and delivered to the transport destination. The Urban Underground railway Logistics System is expected to contribute to solving the problems of the existing system and technical differences from the existing logistics system in performing cargo transportation and collection using dedicated freight trains. Figure 3 shows the main equipment of the underground urban railway logistics system [11].

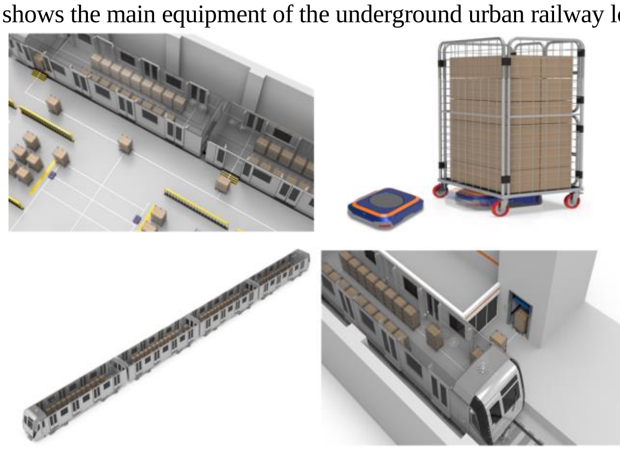

Figure 3. Major equipments of the underground railway logistics system

2.2 Existing urban railway system system external and use environment analysis

A) Analysis of usage environment

Currently, the urban railway station operated by Seoul Metro manages and operates a total of 277 stations on lines 1 to 8 located in Seoul and Gyeonggi-do, and most of the stations are located underground. For the idle space inside and outside the station, an appropriate size must be secured to handle the movement and storage of cargo. As for the idle space inside the station in the urban railway facility, a site survey was conducted targeting vacant spaces because construction plans were canceled in the past, or spaces that could be secured above a certain size among waiting rooms and transfer passages in the station currently in operation.

B) Analysis of the external environment of the urban logistics test bed using underground space

Currently, there are a total of 238 outdoor idle spaces (buildings) owned by Seoul Transportation Corporation, which are used as office spaces such as the headquarters and annex, or as inspection warehouses and material warehouses in vehicle depots. Idle land managed by Seoul Transportation Corporation is 57,678 ㎡ in total, accounting for 2.2% of the total land in the case of the upper part of the station, and most of it is used as a pedestrian space and parking lot near the entrance to the station. A total of 135,095 ㎡ of land in the station section is managed, accounting for 5.0% of the total land. Currently, most of the land in the main line section is used as roads above branch tracks and under elevated tracks, and as track sites for ground tracks. Since the size of the idle space in the urban railway station is the most important selection criterion in the 'Urban Logistics Utilizing Underground Space' system, it is considered essential to secure a space that is more than an appropriate size. the figure 4 and table 1 expresses procedures of.analysis.

Under-Used Spaces at above the railroad station	Under-Used Spaces at track of the railroad station

Figure 4. Field inspection of idle space outside the station

Table 1. Size of Under-Used space in Seoul Transportation Corporation facilities

Title		*Size*
Under-Used Spaces	Land size of above the railroad station	57,678㎡
	Land size of track of the railroad station	135,095㎡

In order to select test bed candidate areas for the urban railway logistics system, based on internal data of Seoul Metro, the history of idle spaces is reviewed, and the location, current status and characteristics of idle spaces are investigated for six stations with idle spaces. did The survey of idle space was conducted on three types: idle space in the station section and main line section, and idle space in the station. The criteria for selecting idle space are as follows. The standard for selecting the land area for idle space was 100 ㎡, which is 87% of the warehouse facilities in Seoul. the table 2 expresses these results.

Table 2. Criteria for selecting idle spaces inside/outside the station

Title	*Criteria for selecting*
Under-Used Spaces at above the railroad station	· Unused space excluding roads, sidewalks, parking lots, parks, etc · A space with a land area of or 100㎡ more
Under-Used Spaces at track of the railroad station	· Unused space excluding currently used spaces such as roads and track sites · A space with a land area of 100㎡ or more
Under-Used Spaces in the railroad station	· Long-term vacancy or unused space · A space that does not cause inconvenience to passengers and station use · A space with a total floor area of 100㎡ or more

According to the selection criteria, a total of 7 idle spaces that can be used as logistics facilities were derived as shown in the table below. Looking at each type, it was found that 1 idle space in the station building and 6 idle spaces in the station can be used as logistics spaces. the table 3 expresses these results of on-site inspection.

Table 3. Results of on-site inspection of Under-Used space inside and outside the station

Title		*Location*	*Land size (㎡)*	*Note*
Under-Used Spaces at above the railroad station	Magok Station	Gangseo-gu, Seoul	3,000	-
Under-Used Spaces in the railroad station	Sindang Station	Jung-gu, Seoul	3,075	B1
	Nambu Terminal Station	Seocho-gu, Seoul	5,629	B1~B3
	City Hall Station ~ Euljiro 1-ga Station	Jung-gu, Seoul	3,182	B2
	Yeongdeungpo Market Station	Yeongdeungpo-gu, Seoul	914	B4
	Dongmyo Station	Jongno-gu, Seoul	375	B1
	Jongno 5-ga Station	Jongno-gu, Seoul	1,490	B1
	Haknyeoul Station	Gangnam-gu, Seoul	3,684	B1~B5

2.3 Urban railway logistics system test bed evaluation method selection

″Urban railway logistics system” is a system that transports cargo using an existing urban railway, and is a new logistics system that has never been built or operated in Korea. Therefore, in order to build and operate such a system, it is necessary to establish a test bed that can directly transport cargo by applying the developed detailed technologies. In order to select one of the urban railway stations in the city center as a test bed, it must be selected as a station that satisfies the conditions required by the system, and the final test bed station selection is made after evaluating the candidate urban railway stations. Afterwards, a review is conducted by collecting expert opinions to confirm whether the selected candidates are appropriate. The figure 5 expresses this series of procedures.

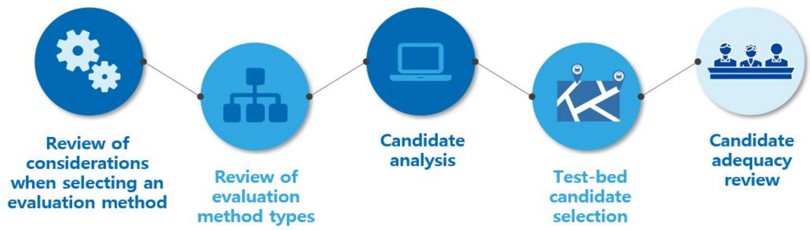

Figure 5. Procedure for selecting candidates for urban railway logistics system test bed

As in the above procedure, prior to evaluating the candidate urban railway stations, various evaluation techniques related to location selection should be considered, and what factors should be considered to select the evaluation technique should be considered first.

Considering the evaluation factors, the location selection evaluation method for selecting a test bed for the "urban railway logistics system" is based on qualitative factors (qualitative factors) because there are quantitative factors (quantitative factors) that are difficult to measure due to the introduction of a new system. It is necessary to select an evaluation technique that can measure quantitative factors (quantitative factors) with weight. In addition, considering the operating scenario, it is necessary to assign weights to each candidate station and to compare them with each other in applying the "urban logistics system using underground space" within the existing urban railway stations. When considering the evaluation method considering field needs, more qualitative factors such as accessibility and connectivity were derived as field needs than factors such as quantitative cost, so an evaluation method that can consider these factors in a complex manner should be selected. Therefore, considering the above three classification evaluation techniques, the Brown & Gibson model, which can handle both qualitative and quantitative factors, and can compare and analyze each other by assigning weights to each candidate history, is the test bed candidate role in this task. It is judged to be the most appropriate evaluation technique in deriving, and it is judged that the most appropriate evaluation technique is to select the test bed station for "Urban Logistics System Using Underground Space" using the Brown & Gibson model. The analysis of comparison items for each evaluation technique is shown in the table 4 [12].

Table 4. Analysis of comparative items by evaluation method

Method	*Evaluation method comparison items*			
	Consideration of quantitative factors	Consider qualitative factors	Set Weighting	Compare multiple candidates
Total Cost Calculation	√			√
Break-even analysis	√			√
transportation planning	√			√
center of gravity method	√			√
Factor Rating Method		√	√	√
Brown & Gibson models	√	√	√	√
Decision tree approach		√		√

3. URBAN RAILWAY LOGISTICS SYSTEM TEST BED CANDIDATE SELECTION

3.1 Evaluation Method: Brown and Gibson Model Analysis

In order to select a test bed candidate area for “urban railway logistics system”, this chapter intends to select a final test bed candidate area by utilizing the Brown & Gibson model derived from various comparative analyzes in the stomach. In the Brown & Gibson model, a location is selected through a total of 10 steps, and each step is shown in the table 5.

Table 5. Brown and Gibson Model Analysis results

No.	*Analytical procedure*	*Study result*
1	Definition of essential/objective/subjective factors	•Essential Factors - Utilization of existing stations, applicability of developed technology, dispatch interval •Objective factors - test bed construction cost, access distance cost (center, logistics base) •Subjective factors- Availability of existing facilities, conflict with existing station facilities, possibility of expansion, distribution of nearby commercial areas, and transportation connectivity
2	Calculation of essential factor evaluation index	Calculation of satisfaction of essential factors of stations Magok Station, where it is difficult to apply development technology because there is no idle space inside the station, is excluded.
3	Objective factor evaluation index	•Monetizable Factors •Test bed construction cost •Consideration of cost of access distance between center and candidate station
4	Set Weighting of subjective factors	As a value obtained by determining the subjective factor weight for each factor through decision-making by 10 experts, it is calculated that the availability of existing facilities and the utilization of existing station facilities have the greatest weight
5	Weight for subjective factors by candidate history	Calculated by utilizing factors such as scalability, availability of existing facilities, and conflicts with existing station facilities through decision-making by 10 experts
6	Calculation of evaluation index by subjective factor	As a result of calculating the evaluation index for each subjective factor, it was found that Haknyeoul Station had the highest subjective factor evaluation index (SFM) at 0.2005.
7	Determination of reflection rate by evaluation index	In order to make a fair comparison of each site alternative by combining the two indicators, it is necessary to determine the reflection ratio for each evaluation index, which determines how many percentages of the subjective factor evaluation index and the objective factor evaluation index will be reflected.
8	Evaluation index calculation	In the site evaluation index (LM), when the ratio is 0.8 to 0.2, Haknyeoul Station is derived as having the highest evaluation index value.
9	Sensitivity analysis	Analyzing the comparative advantage in selecting test bed candidate history according to the change in the decision weight of objective factors
10	Test bed candidate selection	The final test bed candidate role using the Brown and Gibson model was drawn as Hakryeoul Station

3.2 Reviewing candidate station

In this chapter, as Hangyeoul Station is selected as a test bed candidate for “Urban Logistics System Using Underground Space”, we will analyze whether it is appropriate as a test bed candidate through a site review of the actual Hangyeoul Station.

Hakryeoul Station is a station on Line 3 of the Metropolitan Subway and is located on the side of the intersection of Hakryeoul Station, and the ground part is used as a SETEC parking lot. Haknyeoul Station is an excavation station with a 5-story underground structure. The 1st basement floor was previously used as a shopping mall, but it is currently vacant. The usable idle area on the first basement floor of Hangyeoul Station is 3,684m2, which is the second largest idle area after Nambu Terminal among the eight stations previously considered as test bed candidates. In addition, at Hangyeoul Station, there is a 5-story underground structure on the terminal side of the station (section B-B in the lower figure), and access facilities for the Hangyeoul public parking lot are installed. It is judged that there will be The plan and cross section of Hangnyeoul Station are shown in the figure 6.

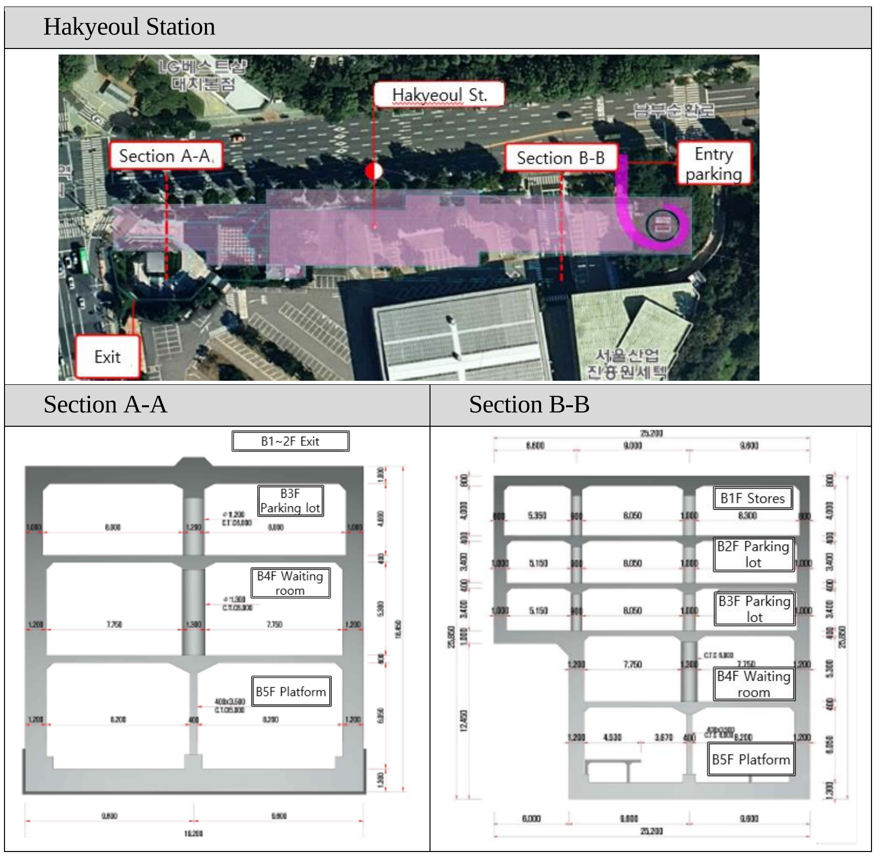

Figure 6. Plat and cross-section of Haknyeoul Station

In order to build a test bed for the “urban railway logistics system”, a review of the logistics space within the train station and platform in the train station should be conducted, and additionally, the application of detailed technology devices constituting the system should be reviewed as well.

The platform at Haknyeoul Station is a relative platform with a length of 205m. In addition to the 200m space for trains on Line 3, there is a free space of 2.5m each at the starting and ending point, making full use of this space to transport cargo and move horizontal transfer devices. It is considered that this can be achieved sufficiently. In addition, in the case of the third basement floor, which is used as an underground parking lot in Hakyeoul Station, the passage height is currently 2.1m, and as a result of additional field investigation, it was analyzed that small trucks for terminal delivery would be able to pass through. In addition, in the case of the idle space on the first basement floor, since it was previously used as a shopping mall, transportation facilities such as materials have already been installed, so it is possible to utilize existing facilities without installing separate entry facilities and transportation facilities. It is judged that it will be possible to build a test bed for “one city logistics system”. In addition, since the idle space on the first basement floor is connected to the outdoor entrance, it is judged that it can be usefully used as a space for cargo transportation. The pictures of each basement floor of Haknyeoul Station reviewed through the field survey are as follows.

Through a field survey, the applicability of the idle space on the 1st basement floor of Hakyeoul Station, the platform, and the logistics space (terminal delivery preparation space) in the station was confirmed, so it can be applied without problems to the movement of horizontal transfer devices and the movement and storage of cargo transport containers. it is considered possible In addition, with respect to the dispatch of the freight-only urban railway at Hangnyeoul Station, the current dispatch interval during off-peak hours on weekdays is 6-7 minutes on average, and it was analyzed that there will be no problem in dispatching and transporting freight. However, in installing the vertical transfer device in Hakryeoul Station, as shown in the figure 7, interference with facilities and piping of the existing station may occur. It is considered that alternatives should be prepared.

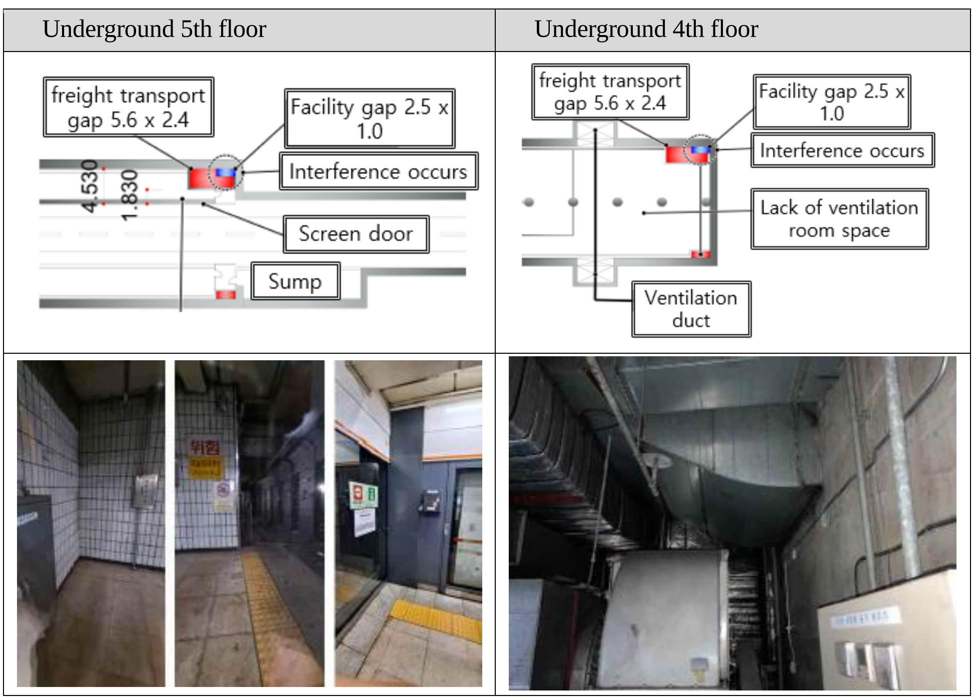

Figure 7. Space review for vertical transfer device in the underground section of Hangnyeoul Station

4. CONCLUSION

The domestic logistics industry is continuously increasing due to social changes and technological development, and activities for logistics transportation are expected to steadily increase in the metropolitan area where the majority of the population is concentrated. Logistics-related technologies are being developed due to the advancement of technology, but the existing system that transports goods using transportation means using internal combustion engines has not solved the problem of road traffic congestion and environmental problems caused by exhaust gas. Accordingly, a proposal for a new concept logistics transportation system using trains and urban railway infrastructure built for passenger transportation in the city center is being proposed, and it is being developed under the name of urban underground railway logistics system.

To solve this problem, domestic researchers are developing an urban underground railway logistics system.

The urban underground railway logistics system aims to connect from cargo transportation to terminal delivery system by utilizing underground space. Building a logistics space by utilizing the infrastructure of the existing urban railway station and transporting cargo through a cargo-only urban railway through a freight platform. Therefore, it is necessary to prepare a demonstration project to develop idle space in the station into a logistics space and apply a new technology system. In order to realize an urban underground railway logistics system, it is first necessary to establish a test bed, analyze the usage environment of the actual urban railway station to which the system will be applied, and conduct a test operation to demonstrate the selection of test bed candidates. To enable improvement and efficient development.

Therefore, in order to derive candidates for the test bed selection of urban underground railway logistics system, this paper examines the use environment of the actual urban railway station to which the system will be applied. Issues were reviewed by analyzing facilities and infrastructure, evaluation criteria were established for selection of test bed candidates, and the derived candidates were evaluated using the Brown and Gibson model. As a result of this, the final candidate station was derived as Hakryeoul Station, and a review was conducted to analyze whether the system could be applied to Hakryeoul Station. Through the results derived from these results, the development and test bed construction of the urban underground railway logistics system under development was carried out smoothly, and furthermore, it was intended to contribute to solving logistics problems in the city center and building a new concept logistics system.

Acknowledgement

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