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A Study on How Urban Rail Operators Can Secure New Growth Engines for the Future Approach: The Case of Underground Urban Logistics System

Su Min Hong[1,2], Oek Seok Jeon[1] and Young Soo Na[1]

1. Metro Research Institute, Seoul Metro, Seoul 04806, Korea

2. Department of Transportation Engineering, University of Seoul, Seoul 02504, Korea

Abstract: Seoul Metro is Seoul's leading metro company, transporting up to 3 billion people annually. However, future ridership is expected to plummet due to an aging and shrinking population with one of the fastest declining total fertility rates in the world. The COVID-19 pandemic in 2019 accelerated this phenomenon. On the contrary, the e-commerce and home delivery industries have developed significantly since COVID-19. Seoul's current logistics infrastructure cannot handle it. Under the inflection point of declining passenger transportation demand and increasing urban logistics demand, urban rail operators need new growth engines. Therefore, it is necessary to consider the introduction of an UULS (underground urban logistics system) that transports parcels instead of passengers through urban railways. If the UULS becomes a reality, it can be expected to secure scarce logistics land in cities, protect the environment and prevent traffic congestion by operating eco-friendly mass urban transportation, and acquire new revenue sources for urban rail operators. The UULS's B/C ratio is 1.32. The sensitivity analysis shows that the ratio is above 1 in most cases where the unit cost of transportation is not significantly reduced.

Key words: UULS, metro, new growth engines, COVID-19, traffic congestion, environment.

1. Introduction

Recently, there have been many changes in urban life in the post-COVID-19 era. The most notable of these are the decrease in travel and the increase in personal transportation. This has led to a decrease in public transportation demand and an increase in daily logistics centered on home delivery. In South Korea, the pandemic was declared over on 23rd, May, 2023. However, once the lifestyle was changed, it has been not easily reversed. We need to prepare for the post-COVID era, a new paradigm.

Seoul Metro has grown by leaps and bounds since its establishment in 1974. In 2019, its annual transportation capacity reached about 3 billion passengers [1]. However, due to the impact of the coronavirus pandemic that began in late 2019 annual passenger numbers are now around 2 billion.

Parcel logistics, on the other hand, was first introduced in South Korea in 1992. The industry has experienced explosive growth since 2000 due to the development of e-commerce and the impact of COVID-19 in 2019. Currently, around 1.7 billion parcels are delivered in Seoul alone [2].

The challenges of the post-COVID era could provide a new opportunity for the transformation of the urban rail industry. Urban logistics is an emerging issue in South Korea due to the explosive growth of the parcel delivery market. Urban logistics technology that utilizes underground space could be an alternative to solving traffic congestion and environmental pollution caused by freight cars on the ground.

Corresponding author: Su Min Hong, senior researcher, senior researcher, research fields: metro system, transportation policy.

This study identifies the problem of declining urban passenger demand and increasing urban freight demand after COVID-19, and proposes the possibility of developing underground urban logistics as a countermeasure. We will analyze new business models for urban rail freight transportation and ways to improve profitability.

2. Literature Review

Many studies have been conducted to improve profitability in the railroad industry, including urban railroads, general railroads, freight railroads, and high-speed rail. However, most of the studies deal with ways to increase revenue from the existing passenger business, such as reducing costs, improving structure, and increasing fares to improve profitability, and there are no studies on new business areas. Among railroads, studies on improving the profitability of urban railroads are as follows.

Lee et al. [1] conducted a study on how to increase revenue by analyzing domestic and international urban rail fare systems. The study compared the advantages and disadvantages of uniform, zonal, and sectional fare systems in Paris, New York, London, and Tokyo along with the distance-proportional fare system in Korea. Through a comparative analysis of government subsidy systems and discount systems such as free transportation, we analyzed the problems of the current domestic fare system and ways to increase revenue. The Seoul Metro has contributed significantly to alleviating chronic urban transportation problems with its high punctuality, safety, and eco-friendliness. However, it is facing operational difficulties due to simple fare structures, average fares that do not cover transportation costs, and lack of government support. To solve these problems, the author suggests introducing various ticket systems, improving the free ride system, ensuring autonomy in the management of railroad operators, and implementing policies to improve customer loyalty such as point accumulation.

Yoon [3] conducted a comparative analysis of the operating costs of eight urban rail operators in Korea. The study identified the causes of operational efficiency between private and public organizations and suggested ways to benchmark between organizations and reduce operating costs. Data envelopment analysis was used to measure the operational efficiency of eight representative urban railroad operators. As a result, the author proposed improvement measures to improve the management efficiency of the operating agencies, such as staffing and operation according to the characteristics of each job, introducing a non-overnight work system, introduction of a one-person crew system by improving the old system, and outsourcing of station-related tasks. The author also suggested government should implement differential support for operating deficits through operational performance evaluation, legislation to raise fares in line with inflation, and institutionalization of subsidies for operating deficits should be implemented.

Kim et al. [4] used DEA (data envelopment analysis) to analyze the transportation efficiency of 17 urban rail lines operated by public institutions nationwide. As a result, first, to increase the profitability of urban rail lines, it is necessary to activate economies of scale by extending urban rail lines at an appropriate scale. Second, the introduction of express trains should be considered to improve punctuality and comfort, which are the advantages of urban railroads. Finally, it was suggested that efforts should be made to reduce the cost per line, such as the introduction of light rail and streetcars, in addition to the extension of lines.

Lee and Jeong [5] examine the application of Japan’s railroad industry reform to Korea. The study found that Japan’s private railway companies, most of which are more than 100 years old, have been efficiently running localized businesses. The study analyzes that various businesses such as department stores, travel, and distribution businesses centered on stations are the secret to the profitable management of the railway business. The business diversification strategy can concentrate the flowing population

through various businesses and aim for synergy effects that can increase not only passengers in the railway business but also customers in the retail business. Group management also has the advantage of reducing common costs and efficiently utilizing human resources. Therefore, it was suggested that domestic railway operators should also conduct various ancillary businesses such as bus business, various tourism businesses and logistics businesses in conjunction with railways based on long-term relationships and trusted brand image in the region.

3. Seoul Metro's Operational Status and Adverse Effects of COVID-19

The Seoul Metro has grown by leaps and bounds since the opening of Line 1 on August 15, 1974, a 7.8-km stretch between Seoul Station and Cheongnyangni [6]. In 2017, Seoul government promoted the integration of the two existing urban railroad companies and now Seoul Metro operates the largest urban railroad company in the world in terms of scale. As of 2019, it has an annual budget of about 2.2B$, total sales of about 1.5B$, and about 17,000 employees, with an annual transportation capacity of about 3 billion people [7]. The Seoul Metro serves as the central public transportation system for the city of Seoul, which is home to approximately 9.5 million people.

However, the COVID-19 pandemic, which began in late 2019, has been particularly devastating for Metro. Metro ridership and profitability have been severely reduced. As shown in Fig.1, the annual ridership of Seoul Metro has grown moderately over the past 50 years. In 2019, the ridership reached an all-time high of approximately 3 billion people [8].

However, in 2020, the ridership plummeted by approximately 30% to 2.1 billion passengers, which was entirely due to COVID-19, and the impact has continued into 2022 and beyond. It is expected to show a modest recovery in the future, but it will be difficult to reach the previous level of ridership.

The Seoul Metro charges about a dollar per ride, which is below the cost of transportation due to government policy. This has created a chronic problem for Seoul Metro's profitability. COVID-19 has exacerbated this problem. The deficit, which was previously around 441 million dollars per year, has grown to more than $855m, as shown in Fig. 2, and is expected to continue for the foreseeable future [7].

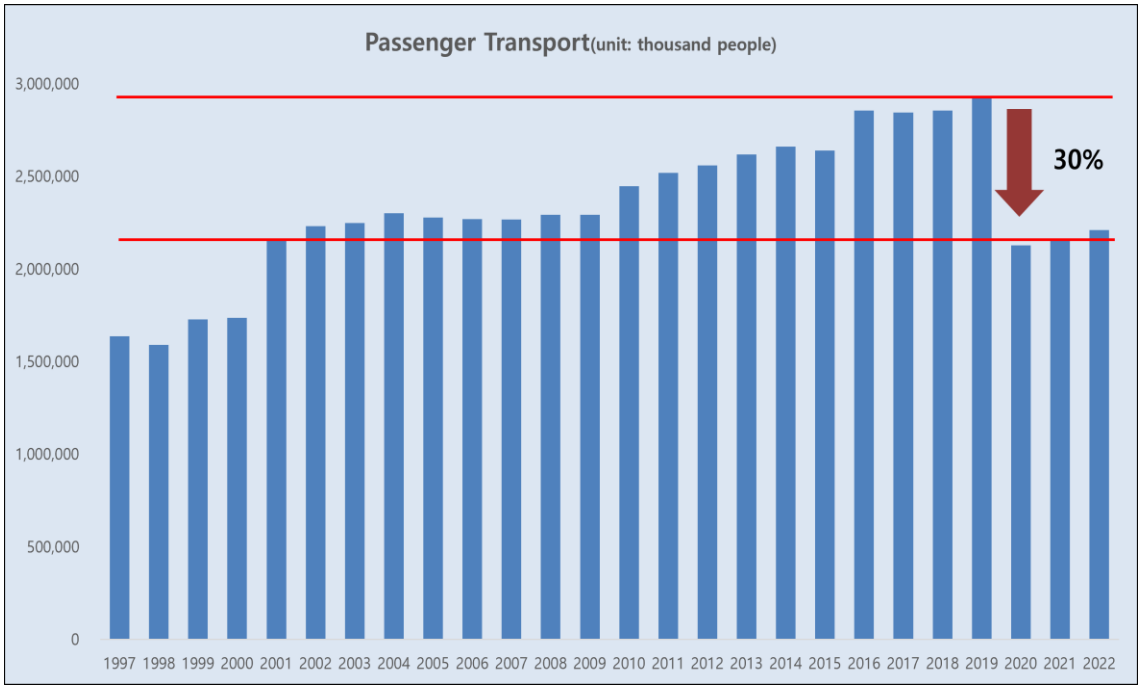

Fig. 1 Changes in the number of passengers transported by Seoul Metro.

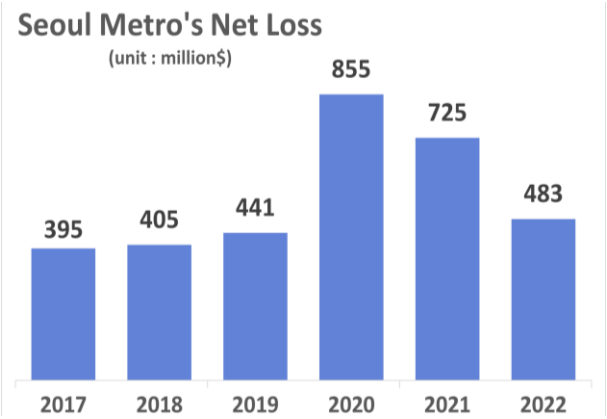

Fig. 2 Current net loss status of Seoul Metro.

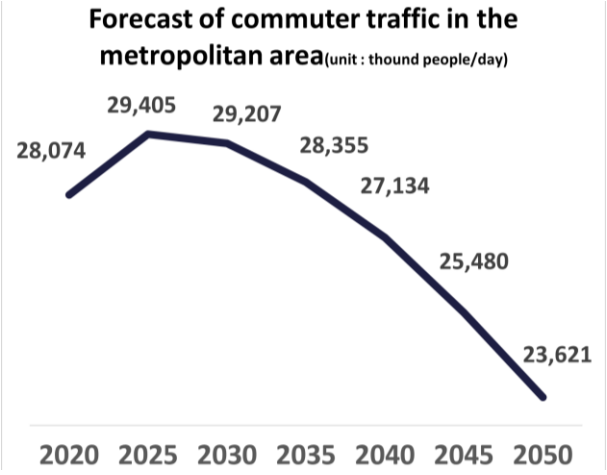

Fig. 3 Forecast of commuter traffic in the metropolitan area.

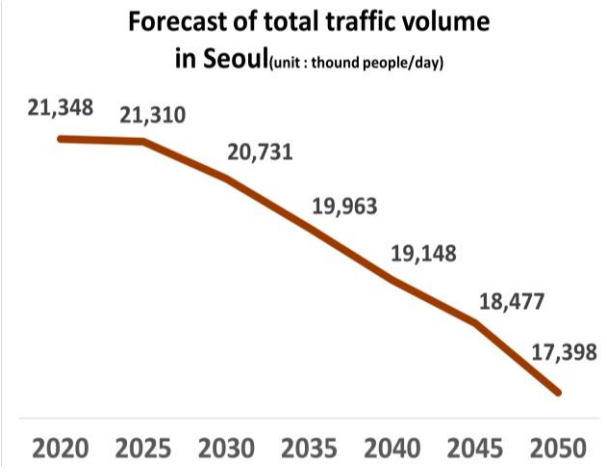

Fig. 4 Forecast of total traffic volume in Seoul.

First, this is due to the inertia of our changed lifestyles due to the pandemic. COVID-19 has changed people's lifestyles from public to private transportation. It takes a lot of energy to go back to a lifestyle that people are already used to.

The pandemic has led to changes such as working from home, avoiding gatherings, encouraging online shopping, and establishing a one-day delivery system. This has been accepted by South Koreans as a much more convenient culture than before. According to Lee et al. [9], the happiness factors of the new normal have been labeled as "reduced interaction" and "passivity".

Based on this, it is expected that systems that have been invested and built to take advantage of the pandemic will be actively operated, and it will be difficult to fully return to the previous lifestyle. This can be expected with public transportation ridership, which has yet to recover since the pandemic was declared.

Second, Seoul's urban planning trend is shifting toward compact cities. "The Seoul 2040 Urban Basic Plan", which was published in 2023, has as its first goal the creation of pedestrian safe culture [10]. This means that people can live, work, and play within a 30-min walk. As the paradigm of urban management shifts to the so-called "hyperlocal", the value of using urban rail to connect home and work is bound to diminish.

Finally, the largest factor is the decline in expected future transportation demand. Fig. 3 shows the forecast of commuter traffic in the Seoul metropolitan area [11].

As Fig. 3 shows, commuter traffic in the Seoul metropolitan area is expected to continue to decline over the next 25 years. This phenomenon is even more serious when looking at Seoul alone, rather than the metropolitan area. Fig. 4 is a projection of future total traffic in Seoul [11]. Total traffic in Seoul has already started to decline and is expected to fall to about 80% of its current level by 2050. This is due to South Korea's rapid aging and population decline.

As shown in Fig. 5, South Korea's declining fertility rate, which recently dropped to 0.7, has led to an "aging" and "shrinking population", which is a structural problem that cannot be solved in a short period of time [12]. For the Seoul Metro, which is optimized for rush-hour commuting, the future is bleak.

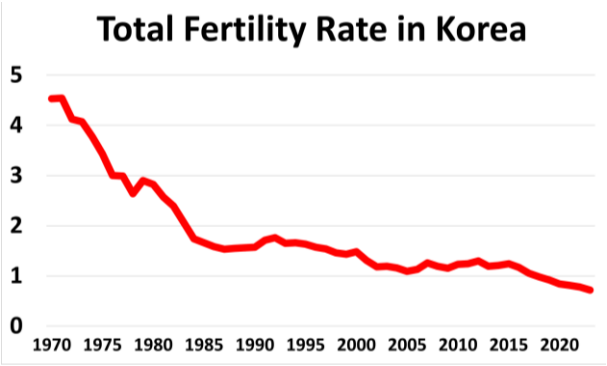

Fig. 5 Changes in total fertility rate in Korea.

Table 1 Changes sales in e-commerce (unit: billion $).

Types	2017	2018	2019	2020	2021	2022
Online mall	47	56	69	88	110	122
On-offline mall	24	29	34	31	33	36
Sum	71	85	103	119	143	158

COVID-19 has acted as a powerful catalyst to further accelerate a future where transportation demand is expected to decline. It is imperative that Seoul Metro find a way to deal with the inevitable decline in transportation demand and deteriorating profitability.

4. The Growing Trend of Urban Logistics with the Development of E-Commerce

On the other hand, with social distancing due to COVID-19, the preference for in-store shopping has decreased and online shopping sales have skyrocketed

As shown in Table 1, domestic e-commerce sales more than doubled from 71 billion dollars to 158 billion dollars in 2022 compared to 2017 [13]. Among them, the increase in sales of combined online and offline malls is relatively small at about 50%. However, the increase in online-only malls was about 2.6 times (47 billion dollars → 132 billion dollars). This is due to the remarkable growth of the online commerce market represented by Coupang, Naver, etc.

The logistics environment in South Korea is characterized by a stable security environment and dense residential environment centered on apartments. This has led to a reduction in the cost of daily logistics. Building on this, the COVID-19 phenomenon has led to an explosion in online shopping. Stable sales growth led to reinvestment in the domestic online consumer market, including the construction of smart distribution centers. The improved logistics environment in turn led to better quality delivery services such as one-day delivery and early morning delivery, completing a virtuous cycle. The domestic e-commerce market has experienced explosive growth. It is expected that it will be difficult for customers who have become accustomed to high-quality online delivery services over the past two years to return to their previous offline-centered lifestyle. The same principle will work as public transportation demand has yet to recover. This is evidenced by the fact that several major Korean hypermarkets, including Lotte Mart, E-Mart, and Homeplus, are planning to close one after another [14].

In this environment, the volume of the domestic home delivery market is also growing by leaps and bounds. As shown in Fig. 7, domestic parcel delivery volume in 2022 is 4.1 billion, an increase of approximately 2.9 times compared to 2012 [15]. The number of parcel deliveries per person is about 80, and 320 for a family of four, meaning that most households in Korea use courier services almost every day. This upward trend is expected to continue in the future. Consumers who have become accustomed to the convenience of door-to-door online shopping services are unlikely to revert back to offline consumption.

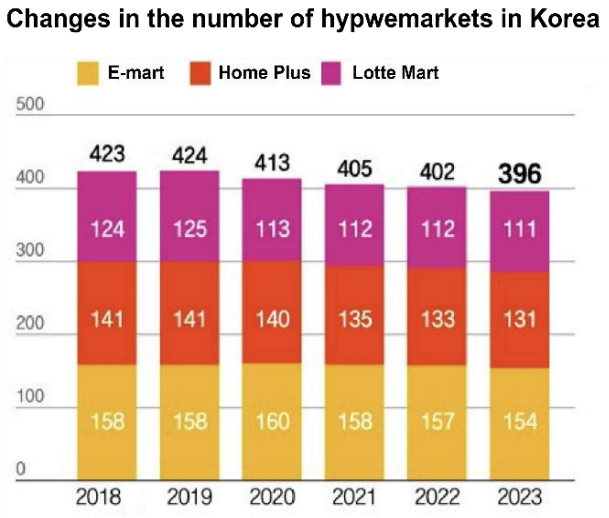

Fig. 6 Changes in the number of hypermarkets in Korea.

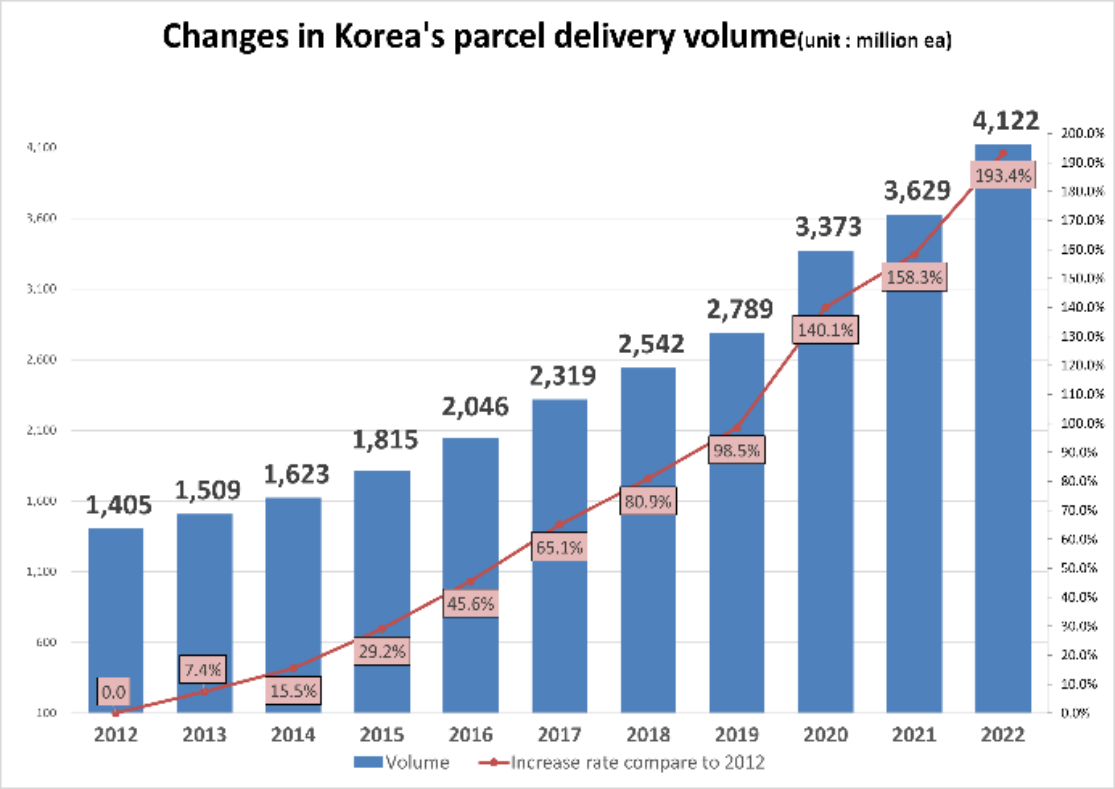

Fig. 7 Changes in Korea's parcel delivery volume.

South Korea is currently undergoing changes such as the rise of single-person households, the development of e-commerce, and the addition of new product categories that can be purchased online. The logistics industry market is also undergoing a period of sophistication, with the emergence of 3PL (third-party logistics) and 4PL (fourth-party Logistics) companies specializing in logistics. Based on this, the domestic courier industry is expected to increase to 5 billion packages per year within the next five years. It is time to prepare for social problems caused by a short-term surge in volume.

Seoul accounts for about 50% of the total volume of parcel delivery in South Korea. To handle the volume in Seoul, it is crucial to have sufficiently large logistics terminals and work sites. However, land in Seoul is already saturated with residential and commercial uses. Land prices in Seoul are relatively high for logistics facilities. There is a limit to the amount of land available for new logistics facilities in Seoul. Therefore, the scale of logistics facilities in Seoul has remained largely unchanged over the past 20 years [2]. Most of the logistics centers are located in the outlying areas of Gyeonggi Province, far away from Seoul. This has resulted in increased travel distances and increased delivery distances. Increasing distances are contributing to increased social costs and conflicts, including higher logistics costs, air pollution, road congestion, and deteriorating working conditions.

As shown in Table 2, the cost of traffic congestion in the Seoul metropolitan area reached a peak of 312 billion dollars in 2019 [16]. Although it temporarily decreased due to the coronavirus pandemic in 2020, it is expected to rise to a higher level than before after the endemic in 2023.

This is because overall traffic is quickly returning to normal, but public transportation ridership is still low. The issue of greenhouse gas emissions from freight cars in Seoul is also a major concern. Since the Paris Climate Agreement, South Korea has made many efforts to reduce greenhouse gas emissions, including national policies to reduce greenhouse gas emissions

Table 2 Traffic congestion cost in metropolitan area (unit: Billion $).

Region	2016	2017	2018	2019	2020
Total	220	232	265	312	261
Seoul	81	86	98	115	102
Incheon	25	26	29	32	26
Gyeonggi	114	120	138	165	133

Table 3 Ratio of freight cars to greenhouse gases in Seoul (unit: tons).

Type	2015	2017	2019
Total	49,445	46,685	45,960
Freight cars	10,652	9,063	8,840
Ratio (%)	21.5	19.4	19.2

and the deployment of electric freight trucks. However, as shown in Table 3, the share of freight cars in total greenhouse gas emissions has not decreased from 19% [17]. The challenge is to reduce the cost of environmental pollution caused by freight trucks.

5. Proposal of an UULS (Underground Urban Logistics System) as a New Urban Logistics Policy

To solve the challenges of urban logistics in Seoul described above, it is difficult to find a clue with conventional approaches. The limited amount of land in Seoul makes it difficult to expand logistics facilities. It is also difficult to improve traffic congestion due to road conditions. Therefore, it is time to think outside the box. For example, using the green infrastructure assets of the Seoul Metro could be an alternative.

First of all, as shown in Table 4, the Seoul Metro has 10 vehicle bases with a total area of about 220,000 m^2 of idle land [18]. According to Yoo et al. [2], the logistics site area required by Seoul is at least 180,000 to 430,000 m^2. Seoul's logistics land needs can be met to some extent by taking over the use of the Seoul Metro's vehicle bases. As shown in Fig. 8, these vehicle bases are distributed in a circular pattern along the outer perimeter of Seoul. Therefore, they are located in areas that can cover the entire city, including the northeast, southeast, southwest, and northwest regions of Seoul.

There is only one logistics site in Seoul. The Seoul Complex Logistics Center, located in Songpa district, is about 140,000 m^2. By using the idle land in the vehicle base as a logistics space, Seoul could easily secure twice as large logistics site as it currently has.

In addition, there are many underground stations in Seoul that have idle spaces that can be utilized. Table 5 introduces examples of underground stations with large idle spaces over 1,000 m^2 under the jurisdiction of Seoul Metro [19]. In addition to these, there are many other stations with logistics spaces that can be connected to nearby residential or commercial areas. According to the Seoul Metro's own survey, there are 117 stations with more than 100 m^2 of logistics space, totaling 21,000 m^2 [19].

Table 4 Available land for logistics space in the train depot.

Name	Number of locations	Size (m^2)
Gunza	2 locations	4,000
Shinjeong	2 locations	6,000
Suseo	1 location	30,000
Jichuk	5 locations	43,000
Goduck	1 location	10,000
Banghwa	2 locations	33,500
Shinae	1 location	7,800
Chungwang	2 locations	15,000
Dobong	6 locations	36,000
Moran	3 locations	41,000
Total		226,300

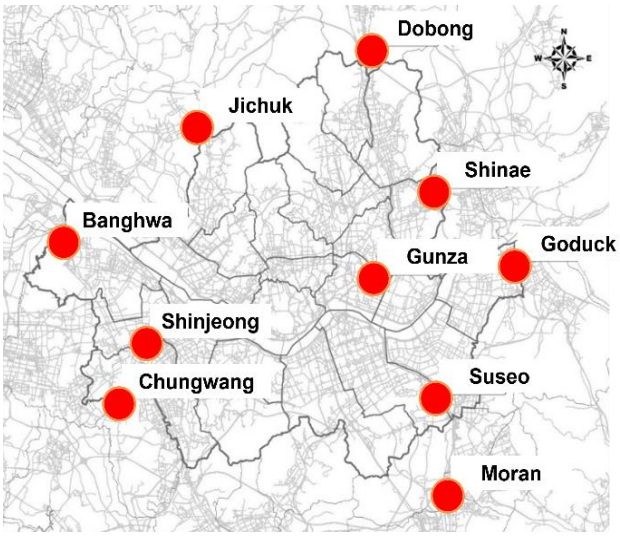

Fig. 8 Seoul Metro's train depot location.

Table 5 Available space for logistics in the station.

Station name	Location	Size (m^2)
Magog	Gangseo-gu	3,000
Sindang	Jung-gu	3,075
City Hall	Jung-gu	3,182
Jongno 5-ga	Jongno-gu	1,490
Hakyeowool	Gangnam-gu	3,684
Total		14,431

Fig. 9 shows an overview of the composition of the "UULS".

Cargo departing from the Mega-Hub terminal in Gyeonggi-do arrives at the Urban Railroad depot on the outskirts of Seoul. The cargo is sorted at the depot's logistics center and transported by freight train to the micro-hubs at each station. Cargo from the micro-hubs is then delivered to nearby residences or offices via last-mile delivery method.

If established, the system could dramatically improve the inefficient delivery environment using existing small trucks. Previously, thousands of small trucks traveled dozens of kilometers each day from dozens of Sub-Hub terminals located in the outskirts of Gyeonggi Province to reach Seoul. With the UULS, however, parcels can be delivered in bulk via freight trains from the Middle-Hub, built on five train depots, to almost all of Seoul.

The number of passengers is expected to decrease in the future. Therefore, it is necessary to find an alternative way to utilize the rail infrastructure of the Seoul Metro, which may remain idle in the future. In response to the future era of urban logistics, the Seoul Metro is conducting a national R&D project on "Underground Urban Logistics Technology Development" with the Ministry of Land, Infrastructure, and Transport. Building and utilizing an UULS can be an effective response to many of the challenges facing Seoul after COVID-19.

First, it is possible to replenish the scarce logistics land in Seoul. Logistics sites in Seoul have not been replenished since the 1990s. It is unlikely to be replenished in the future through conventional means. However, using the rail infrastructure of the Seoul Metro could be a good way to overcome this.

Second, it is possible to build an eco-friendly logistics system in line with the ESG (environmental, social, governance) era. Railroads are the most representative eco-friendly means of transportation. Historically, freight railroads have been limited to large-scale, long-distance transportation on a national scale. However, with the advancement of logistics technology, the era of smart logistics based on Logistics 4.0 has arrived. It is possible to overcome the limitations of the past and build urban logistics facilities. If the UULS is introduced, it will be possible to build the world's first urban logistics system using freight trains.

Fig. 9 Schematic diagram of UULS.

Lastly, it can help improve the profitability of urban railway operating companies, which has been deteriorating. Currently, urban rail fares in Korea have been kept below cost due to political and economic limitations, but new businesses using freight trains can pursue profits without such restrictions. If freight trains can achieve economies of scale due to their high volume, they can replace passenger traffic, which is expected to continue to decline in the future, which could serve as a new source of revenue for the Seoul Metro.

6. Profitability Analysis of UULSs

If one station can cover a 3-km radius of terminal deliveries, it is estimated that 5 vehicle bases and 30 stations will be required to deliver the entire Seoul area. The total project cost estimate, citing the cost of building a logistics center estimated by KDI (Korea Development Institute) in Korea, is as follows in Table 6 [20]. Next, the following procedure was performed to calculate the expected revenue. The delivery volume in the first year of the business was assumed to be 60 million packages, which is about 3% of the total number of packages currently delivered in Seoul. The annual growth rate was assumed to be 5%, which is less than half of the average annual growth rate over the past 10 years. The delivery unit cost per package was conservatively assumed to be 0.4$. The delivery price increase rate is conservatively calculated as 0%. The projected business revenue is shown in Table 7. The B/C is calculated to be 1.32 considering the results of both analyses.

The UULS is still unprecedented in the world, so many assumptions must be made in the feasibility analysis. To improve the accuracy of the feasibility analysis, a sensitivity analysis was conducted.

Tables 8 and 9 are the results of the sensitivity analysis of the underground urban logistics business. First, the sensitivity analysis was conducted by varying the operating cost, which is the most important part of the total business cost, the price per unit, and the annual growth rate of parcel delivery volume. The B/C ratio was found to be close to 1 when the unit price was very low (less than 0.3$) or when the operating cost increased by more than 30%. For a deeper analysis, we ran the sensitivity analysis again using only operating costs and unit costs.

Table 6 30-years total project cost of UULS (unit: m$).

Business cost ($/m^2)		Distribution center destination sites		
Type	Cost	Type	Size (m^2)	Object
Construction	731	Train depots	20,000 m^2	5
Incidental expenses	72	Stations	300 m^2	30
Equipment	368	Sum	109,000 m^2	
Operating	7,679			
Total	8,850	Total cost	1,197 m$	

Table 7 30-year revenue for underground urban logistics (unit: m$).

Year	Parcel (million pcs)	Price ($)	Revenue (M$)
1st	60 m	0.4$	23.9
10th	93 m		37
20th	151 m		60.4
30th	246 m		98.4
Total			1,588
B/C			1.32

Table 8 Sensitivity analysis of underground urban logistics business 1 (unit: m$).

Type	Condition	Cost	Benefit	B/C
Operating expenses	10% up	1,301	1,588	1.22
	20% up	1,405	1,588	1.13
	30% up	1,509	1,588	1.05
Unit price	0.3$	1,197	1,198	1.00
	0.5$	1,197	1,978	1.65
Yearly Growth rate	4%	1,197	1340	1.12
	6%	1,197	1,890	1.58

Table 9 Sensitivity analysis of underground urban logistics business 2 (unit: m$).

B/C		Operating Cost		
		10% up	20% up	30% up
Unit price	0.3$	0.92	0.85	0.79
	0.35$	1.08	1.00	0.93
	0.4$	1.22	1.13	1.05
	0.45$	1.38	1.28	1.19
	0.5$	1.52	1.41	1.31

The results showed that for a unit cost of 0.3$ or less, the B/C is less than 1 if the operating cost increases. The assumed numbers were calculated as conservatively as possible because the system is unprecedented. It is judged that the analysis shows the possibility of the underground urban logistics business that it is uneconomical only under more stringent conditions than the assumed figures.

7. Conclusions

The COVID-19 pandemic has had many effects around the world. People's lifestyles have also changed a lot. Among them, the number of passengers on urban railways in Korea has decreased by about 30% due to the high density and closure compared to other transportation methods. Due to the inertial tendency of people's lifestyles, it is unlikely that they will return to their old ways in the near future. The fastest aging and population decline in the world is fueling this.

The e-commerce market, on the other hand, has benefited reflexively from COVID-19. Korea's courier market is developing by leaps and bounds. Following the same logic as the decrease in transportation capacity, the size of the Korea's courier logistics market is expected to continue to develop even after COVID-19. Therefore, we are at an inflection point where the demand for facilities for passengers will continue to decrease in the future, while the demand for facilities for urban logistics will continue to increase.

It is necessary to proactively respond to these changes. UULS will be an important future growth engine for policy makers, including world's urban rail operators. If the UULS can be successfully built, many effects can be expected, including securing scarce logistics land in cities, protecting the environment and preventing traffic congestion by operating eco-friendly mass urban transportation, and acquiring new revenue sources for urban rail operators.

The business feasibility analysis of the UULS showed a B/C of 1.32 under basic assumptions. As this is an unprecedented system, sensitivity analysis was also conducted in a rigorous environment. In most of the analyzed results, the B/C was calculated to be more than 1. In the case of increasing the operating cost by more than 10% and reducing the unit price by more than 25%, the B/C was less than 1.

This paper analyzed the causes and future of the decline in ridership due to COVID-19 and proposed countermeasures for the decline in urban railroad operating revenue. However, the construction of an underground logistics system requires large-scale investment, rich experience in the logistics business, and accurate demand analysis. It is hoped that follow-up research will be conducted to complement these points in the future, so that the logistics industry can become a new growth engine for urban railroad operators in Korea and abroad.

Acknowledgments

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References

[1] Lee, H. S., Kim, H. N., Shin, S. Y., and Park, J. S. 2010. "A Plan to Increase Export by Domestic and Foreign Urban Railway Fare System." In *Korean Railway Society Academic Conference Paper Collection*, pp. 397-407.

[2] Yoo, G. S., Kim, W. H., and Kim, Y. B. 2021. *Expansion and Support Plan for Urban Service Facilities in Seoul: Focusing on Parcel Service*. Seoul: The Seoul Institute.

[3] Yoon, J. H. 2012. *A Research on Efficiency Improvement of the Urban Railway Operation.* Seoul: The Korea Transport Institute.

[4] Kim, S. H., Jung, H. Y., and Lee, W. G. 2014. "Transport Efficiency Analysis of the Lines of Urban Railway Using Data Envelopment Analysis." *Journal of the Korean Society of Civil Engineers* 34 (2): 605-16.

[5] Lee, Y. S., and Jeong, B. H. 2018. "A Study on Management Diversification and Profitability of Private Railways." *The Korean Association of Asian Studied* 21 (2): 187-210.

[6] Yoo, K. S., Kim, W. H., and Kim, Y. B. 2021. *Expansion and Support Plan for Living Logistics Service Facilities in Seoul*. Seoul: The Seoul Institute.

[7] Seoul Government Subway Construction Headquarters. 2003. “30-Year History of Seoul Subway Construction.”

[8] Seoul Metro. 2024. “Passenger Transportation Performance.” http://www.seoulmetro.co.kr/kr/board.do?menuIdx=548

[9] Lee, Y. J., Kin, T. H., and Hwang, S. H. 2021. “COVID-19 Leisure Consumption Analysis Using Big Data.” *Korean Journal of Leisure, Recreation & Park* 45 (2): 21-36.

[10] Seoul Metropolitan Government. 2023. “‘Seoul 2040 Comprehensive Plan’ for New Urban Spatial Structures amidst Digital Transformation.” https://english.seoul.go.kr/seoul-2040-comprehensive-plan-for-new-urban-spatial-structures-amidst-digital-transformation/.

[11] The Korea Transport Institute. 2021. *Nationwide Passenger O/D Supplementation and Renewal*. Seoul: Seoul Metro.

[12] Statistics Korea. 2023. “Current Population Survey.” https://www.index.go.kr/unity/potal/main/EachDtlPageDetail.do?idx_cd=1428.

[13] Statistics Korea. 2023. “Online Shopping Trend Survey.” https://kosis.kr/statHtml/statHtml.do?orgId=101&tblId=DT_1KE10051&conn_path=I3.

[14] Choi, E. K. 2023. “Fewer than 400 Hypermarkets.” *Joong Ang Newspaper*.

[15] National Logistics Information Center. 2023. “Current Status of Domestic Parcel Delivery Volume.” https://www.nlic.go.kr/nlic/parcelServiceLogistics.action.

[16] The Korea Transport Institute. 2023. “Road Traffic Congestion Costs.” https://www.index.go.kr/unity/potal/main/EachDtlPageDetail.do;jsessionid=FKj_EDvqlt6yqd3Dk6ITjBr16taQQuwJ29YdW8GK.node11?idx_cd=1248.

[17] Seoul Government. 2019. “Greenhouse Gas Emission Statics.” https://news.seoul.go.kr/env/archives/516220.

[18] Seoul Metro. 2019. *Plan to Build an Urban Railway Joint Logistics Platform.* Seoul: Seoul Metro.

[19] Seoul Metro. 2021. ‘Report on the possibility of using idle spaces and platforms in major downtown stations’

[20] The Korea Development Institute. 2011. Preliminary Feasibility Study Report for Integrated Logistics Center Construction Support Project. Seoul: The Korea Development Institute.