A Comparative Study on the Passenger's Time Saving Effects of Urban Express Railway Service

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ABSTRACT

The goal of the transportation policy of Seoul is to increase the ridership of the subway system by constructing the public transportation network, the subway system. To accomplish this goal, the city of Seoul has been constructing the Metropolitan Subway System. Currently, seven subway lines which connect major areas in Seoul are operating. However, the ridership of subway system was not increased as much as we expected, even though more subway lines have been implemented. It seems that although the length of the subway line was extended, the current way of the subway operation that trains stop at every station cannot satisfy the passenger's need. Thus, we should try to increase the demand by providing quicker services and diversifying the subway operations; changing the point of view is required.

This paper introduces the distinctive features of the express subway system and the model for analysing the effects of that system. This paper also presents the results for the feasibility study of the express subway system on the 5th Subway Line and Kyong-Eue Railway Line.

Based on the results of the case studies, We can conclude as :
First, the express system reduces a total travel time by about 13%; in particular, the Kyong-Eue Line is more effective than the subway Line #5.
Second, the shorter headway of express trains increases the time saving effects on subway system although it requests more waiting time to low-speed train passengers. When the service frequency is increased from 5 to 7.5 times/hour, total saved time ratio is about 10% in the Subway Line #5 and about 18% in the Kyong-Eue Line.

1. Introduction

1.1. Background and Objects

The goal of the transportation policy of Seoul is to increase the ridership of the subway system by constructing the public transportation network, the subway system. To accomplish this goal, the city of Seoul has been constructing the Metropolitan Subway System. Currently, seven subway lines which connect major areas in Seoul are operating. However, the ridership of subway system was not increased as much as we expected, even though more subway lines have been implemented. It seems that although the length of the subway line was extended, the current way of the subway operation that trains stop at every station cannot satisfy the passenger's need. Thus, we should try to increase the demand by providing quicker services and diversifying the subway operations; changing the point of view is required.

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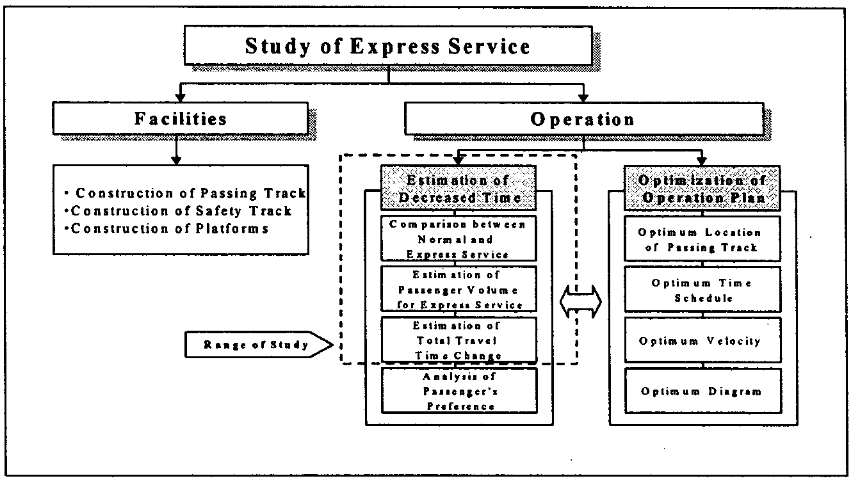
It is known that the subway is more punctual than other transportation modes such as passenger cars and buses in terms of travel time. However, the subway system is inferior to automobile and bus for the following reasons. First, in terms of trip convenience, a great portion of subway passengers would be required to transfer to use other transportation modes in order to reach their destination. Furthermore, the subway passengers may be required to transfer between the subway lines in order to



<Figure 1> Range of Study

reach their destination. It may decrease the use of the subway system. Secondly,

although the average travel speed of the subway which is about 33km/h is higher than that of the other on-road transportation modes, the travel time of the subway is not less than that of the other modes. It is due to the fact that the travel time of the subway which includes the access time to the subway station, the egress time from stations, and the transferring time is similar to the travel time by buses. It means that the subway is not always faster than buses even though the average travel speed of the subway is faster than buses.

In Seoul, there are exclusive lanes for the buses on most major arterial roads and the subway lines are generally overlapped with the bus routes along these roads. Due to this, the subway system is not very attractive, so in order that the subway can be competitive on all links the travel speed of the subway needs to be increased by decreasing the access time and egress time. To do so, for instance, Tokyo in Japan has applied the express subway system and is implementing the renovation plan that passengers could reach 50km from CBD within one hour. Seoul should consider to apply the express subway system not only to the 3rd Subway Project but also to the current subway lines.

This paper introduces the distinctive features of the express subway system and the model for analysing the effects of that system. This paper also presents the results for the feasibility study of the express subway system on the 5th Subway Line and Kyong-Eue Railway Line.

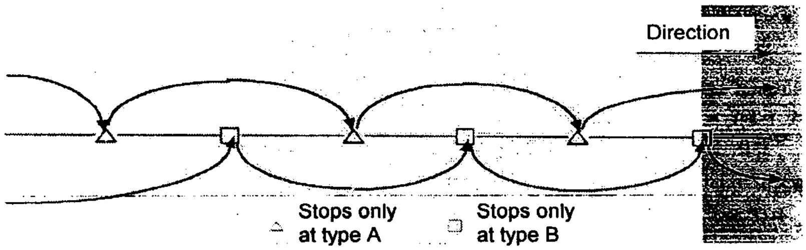
1.2 Contents and Range

In this paper, the train operations and the train facilities are studied. Train operations deal with how to operate the current subway lines or new subway lines. The effect of express subway system on the travel time is assessed.

The train facilities are associated with how to change platforms and how to make a new safety track for passing the normal and express trains. To do so, a new model which can estimate the change of the total travel time is introduced. Basically, the model estimates the change of the total travel time by measuring passenger volumes of the normal and express trains and the passenger volumes are dependent on the travel time of each train and the travel time between two subway stations interested.

2. Research Review

Won and Hwang 1997 studied the time-saving effects of the express subway system. They analyzed the time-saving effects under the condition where the express service is applied to Subway Line #3 in Seoul. They assumed that the trains stop at every two stations one by one, using the only existing facilities as shown in Figure 2. As a result, the passengers' waiting time increased, while the trains' running time decreased.



<Figure 2> Concept of one by one stop system

Japan Society of Civil Engineering analyzed the ratio of probable trip distribution of all trains which can be selected on the lines of both the express service and normal service by the travel cost and the time value according to travel purposes.

$$P_r = \frac{R_r^{-n}}{\sum_r R_r^{-n}}$$

$$R_r = C + WT$$

P_r : ratio of distribution
R_r : transportation resistance of transportation mode r
n : survey data(6)
W : value of time
T : time(transferring time, seats availability, etc.)
C : travel cost

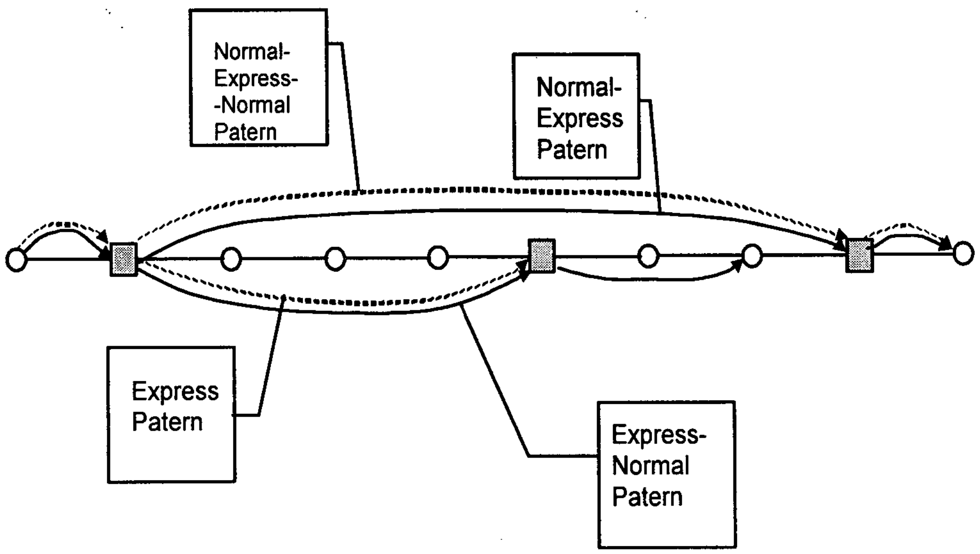
Express subway systems are in service in Japan, France, and New York. The passing-tracks were applied to some links of Shinjukusen and New York Subway, and the separate line for the express subway was applied to the other portion of them. In general, the passing tracks are constructed at every three to five stations, and the travel times are in the range between seven and ten minutes.

3. Model for Calculating the Express Service Effects

3.1 Express Service Use Patterns

The express subway system can be divided into two groups. One is associated with using passing tracks at the subway stops for the express trains. Another is associated with using separate tracks for them. Providing passing track is that the normal train stops at the short separate track beside the main track in order to wait for passing the express train. The separate tracks mean that both the normal and express trains' tracks are entirely separated. Regardless of the passing and separate tracks, the express trains can pass normal trains ahead and the express trains stop only at some important stations. Therefore, the express train can reduce the travel time by reducing waiting and running times. In fact, the number of stations for the express trains should be fewer in order to maximize the effects of the express service. It should be, however, considered that the demand of users will decrease when the number of stations is too small.

The pattern of using the express service can be divided into four categories as shown in Figure 3. If the number of express stations is limited, the passengers from the stations where the express service is not available may need to move to the stations where express service is available. In this case, the overall travel time of the passengers is increased. Table 1 summarizes the patterns and characteristics of express subway service.



<Figure 3> Patterns of Express Service Use

<Table 1> Patterns and Characteristic of Express Service Use

Pattern	Origin	Destination	Frequency of Transferring	Order of Use	Characteristics
Express	Express Station	Express Station	0	Express	If the waiting time for Express Service is too long, passengers will use normal service
normal→ express→normal	Express Station	Express Station	2	Normal Express Normal	The decreased travel time should be shorter than the total transferring time
normal→ express	Normal Station	Express Station	1	Normal Express	The decreased travel time of express service should offset the transferring time
express→normal	Express Station	Normal Station	1	Express Normal	In addition to the waiting time for express service, the waiting time for normal service is added

3.2 Estimating the Running Time

(1) Estimating Travel Time

The total travel time of subway system consists of accessing time to the stations and travel time on the trains. The travel time on subways consists of waiting, running, and transfer time as follows:

$$T_{ij} = t_{ij} + w_{ij} + f_{ij}$$

Tij : total travel time

tij : running time(on subway)

wij : waiting time(in station)

fij : transfer time

The travel time from origin station i to destination station j is as follows:

$$t_{ij} = \sum_{i}^{j-1} t_{k,k+1}$$

$$t_{k,k+1} = \triangle t + \frac{d_{k,k+1}}{V} + \frac{V}{2}\left(\frac{1}{a} + \frac{1}{b}\right)$$

$\triangle t$: k station dwelling time

$d_{k,k+1}$: distance between station k and k+1

V : velocity

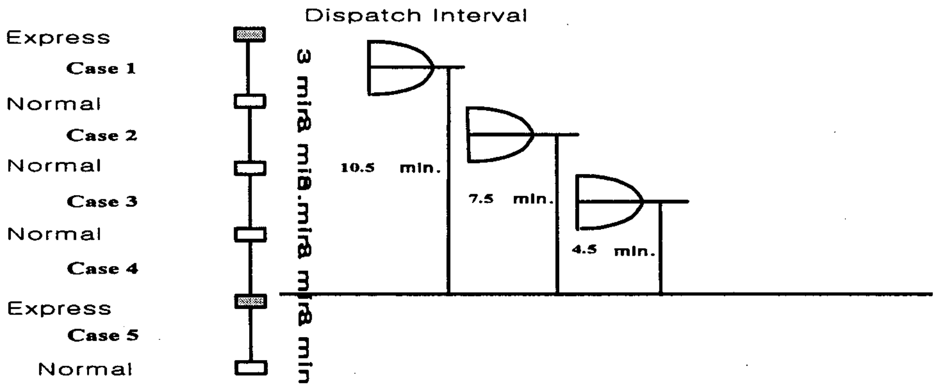
a,b : acceleration, deceleration

(2) Changes of passenger volume according to waiting time

Generally, express service has fewer service frequency than normal service. The express service is provided for the passengers who travels at least 10 km long.

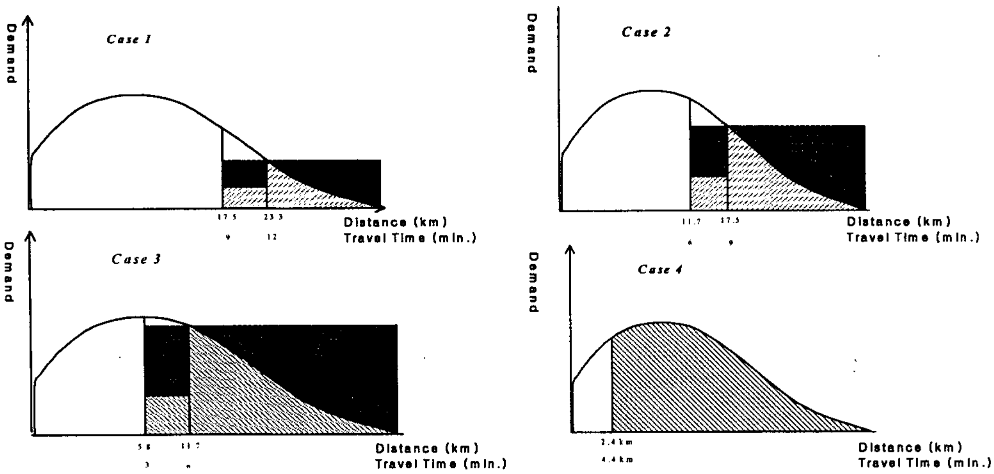
However, the longer the intervals are, the longer passengers should wait. Therefore, the passengers are limited to ones who will travel for a long distance.

Supposing that all the dispatch intervals are three minutes and frequency of express service is 5 times/hour and that of normal service is 15 times/hour, the dispatch plan for express trains and normal trains is shown in Figure 4. The passenger volume arriving at platform during each time interval is assumed to have a normal distribution. Each express trains arrive at every station after three normal trains pass that station, so passengers are required to wait for express trains on the average 4.5 minutes more than normal trains.



<Figure 4> Dispatch Interval & Waiting Time for Express Service

Assuming that passenger volume arriving at the station for every three minutes, passengers should wait for 1.5 minutes on the average, so the passengers who will use express service in Case I should wait for 10.5 minutes. In Case III, the passengers should wait for 4.5 minutes to take express trains. In Case IV, the passengers for express service should wait for 1.5 minutes, while the passengers for normal service should wait for 4.5 minutes.

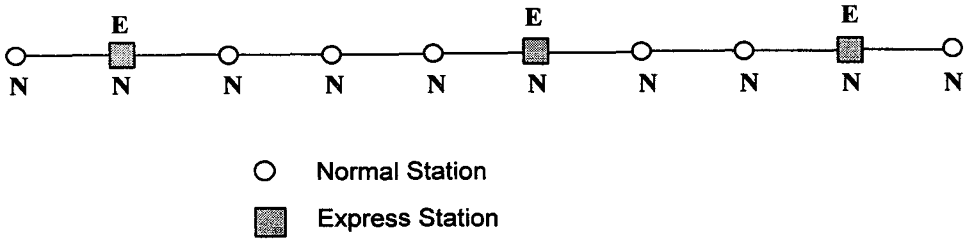


<Figure 5> Express Service Demand of Each Case

The subway stations of each subway line to which express service is applied are classified as the stations were both normal and express trains stop and the stations where only normal trains stop.

3.3 Building the Model

The running time between origin station i and destination station j changes according to the trip patterns as shown in Figure 3. Since passengers use express service when running time takes less than when they use normal service, passenger demand should be estimated by comparing the running time of express service with that of normal service.



<Figure 6> Express Stations and Normal Stations

Total travel time of normal service is:

$$t^{s}_{ij} = \sum_{i}^{j-1} t^{s}_{k,k+1} + w_s$$

However, in case of using express service, the total travel time should be calculated with variables due to the diversity of travel patterns.

$$t^{e}_{ij} = \rho_1\left(\sum_{i}^{e'} t^{s}_{k,k+1} + w_s\right) + w_e + \sum_{e'}^{e''} t^{e}_{k,k+1} + \rho_2\left(w_s' + \sum_{e''}^{j-1} t^{s}_{k,k+1}\right)$$

$t^{s}_{k,k+1}$: travel time from normal station k to the very next station

$t^{e}_{k,k+1}$: travel time from express station k to the very next station

w_s : waiting time for normal service

w_e : waiting time for express service

w_s' : waiting time for normal service while transferring to normal service from express service(normal train dispatch interval)

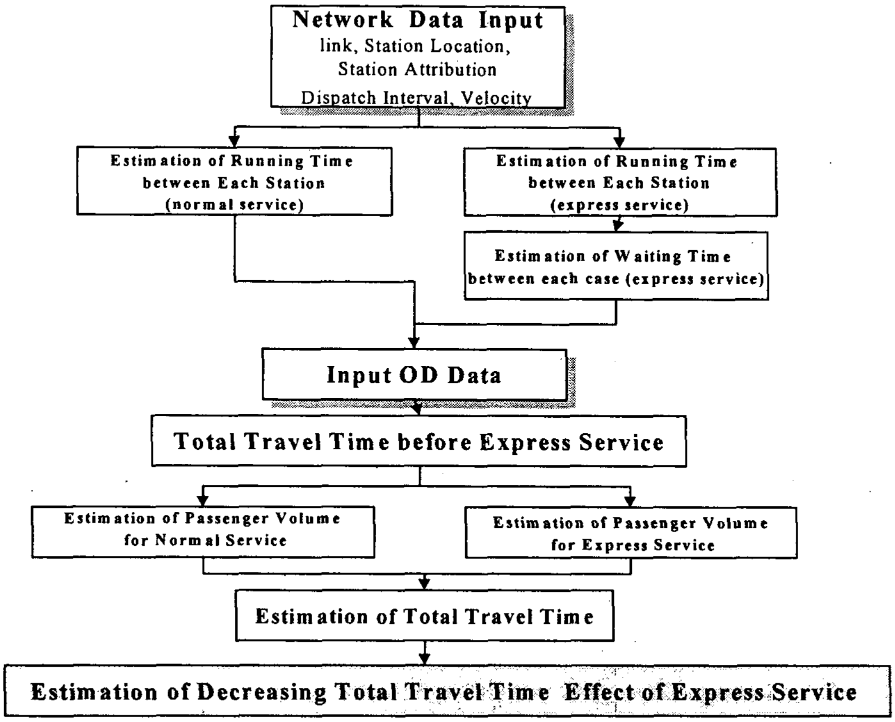
e' : the closest express station from i

e'' : the closest express station from j

ρ_1 : 0 if i is a express station ,or 1 if not

ρ_2 : 0 if j is a express station ,or 1 if not

After calculating running time of express service and normal service while iterating that process by the case, passenger volume of express service was estimated. As shown in Figure 7, the effects of time saving of express service is estimated by measuring the total travel time associated with the estimated passenger volume and travel time.



<Figure 7> Analysis of Express Service Travel Pattern

4. Case Studies

4.1 Synopses and Premises

(1) Lines for Case Study

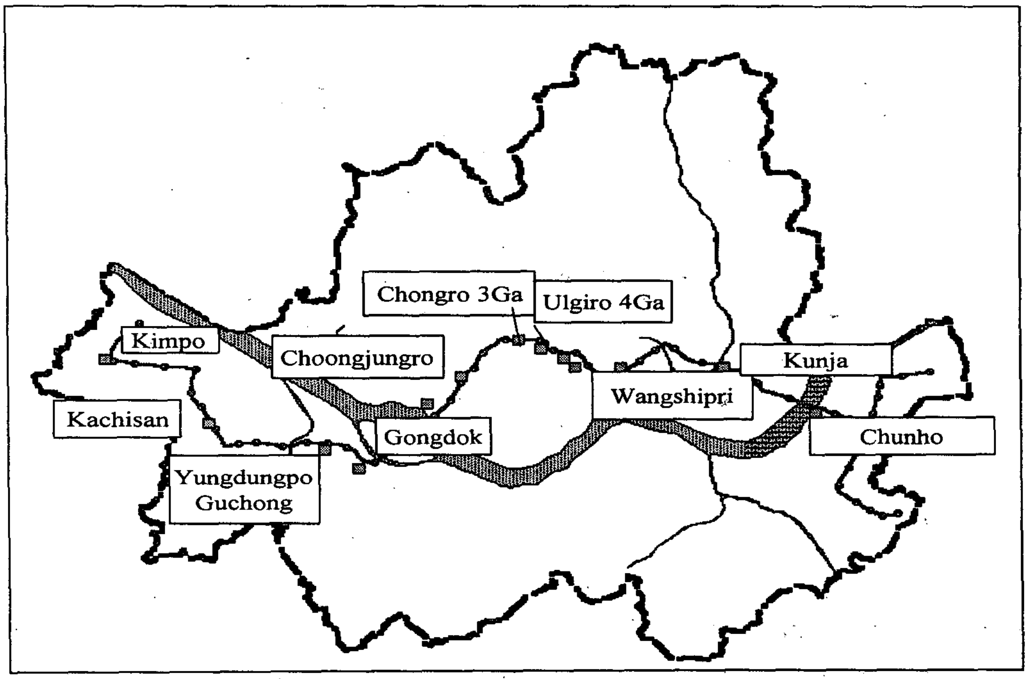
This research implemented case studies on the subject of Subway Line #5 in Seoul and Kyong-Eue Line.

a. Subway Line #5

This line is the longest subway line in Seoul and connects the western Seoul, CBD, and eastern Seoul. The line is, especially, connected to Kimpo Airport, so that a lot of long distance passengers use this line comparing to the other lines. Table 2 summarizes some characteristics of the subway line.

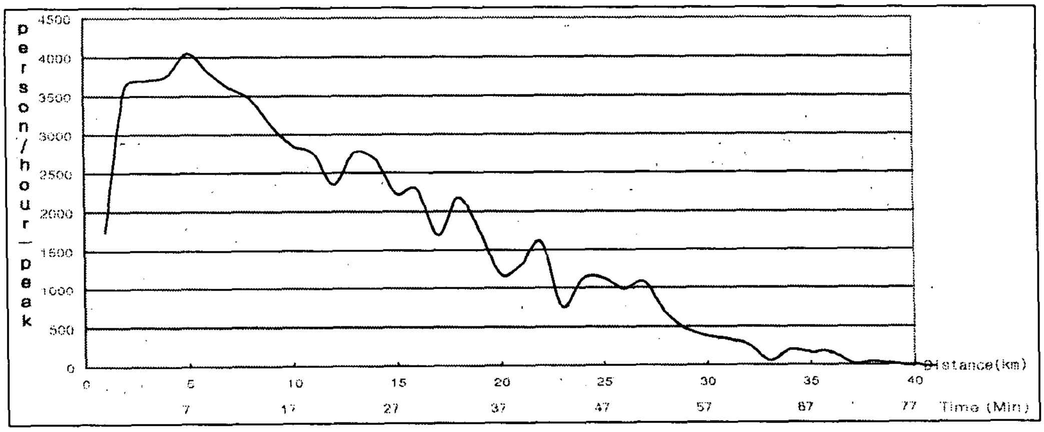
<Table 2> Status of the 5th Line

Number of Stations	51
Number of Stations for transferring	13
Distance	52.1㎞
Commercial Velocity	32.6㎞/h
Service Volume	320,000/day



<Figure 8>Virtual Express Stations of The 5th Line

As shown in Figure 9, current - Nov, 1997 - passenger trip pattern of this subway line is that over the half of all passengers goes below 15 km. The average trip distance is 11.9 km and average travel time is about 19 minutes. It is noteworthy

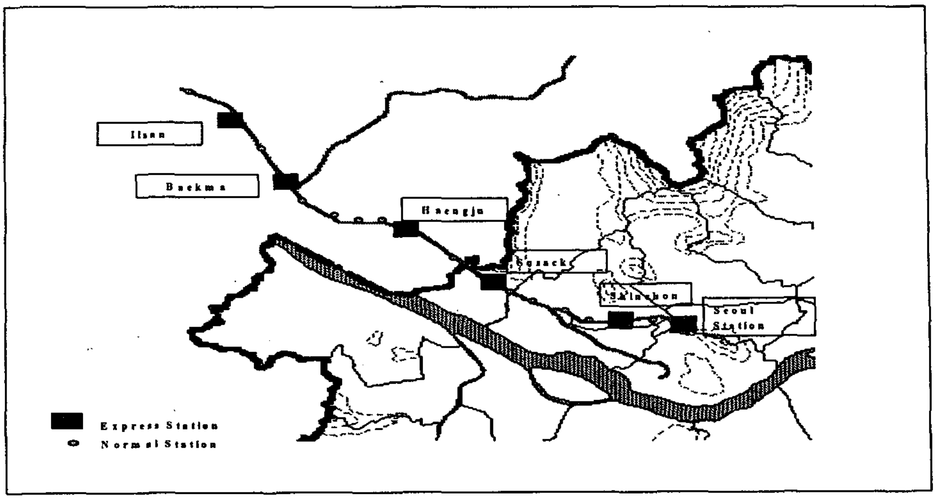


<Figure 9> Distribution of Travel Distance of the Subway Line #5

that the average trip distance of Subway Line #5 is 2 km longer than that of other subway lines. Thus, if express service is applied to this line, it is anticipated that the effect of time saving will be more maximized than that of the other lines.

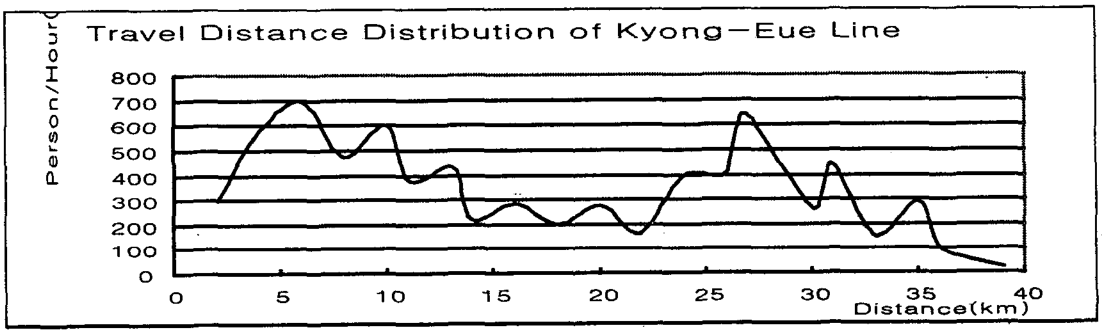
b. Kyong-Eue Line

Kyong-Eue Line is considered for providing express service from Seoul to Ilsan New Town. Once the construction of this line is done, this line is expected to be a main corridor connecting Seoul and Ilsan, and it will serve most of long distance commuters. Therefore, this line will make a great effect by applying the express service.



<Figure 10> Virtual Normal Stations of Kyong-Eue Line

In the Kyong-Eue Line passenger patterns consist of a long distance trip from Ilsan to Seoul and a short distance trip in Seoul as shown in Figure 10. The figure shows two peaks. Average travel distance of this line is 16.3 kms and average travel time is about 24 minutes. The average trip distance is 6 km longer than the average travel distance in Seoul, 10 km. This result indicates that commuters have long distance trips, comparing to inbound trip to Seoul. The time saving effect will be large if the express service is applied to Kyong-Eue Line than Seoul Subway, because a number of long distance commuters use Kyong-Eue Line.



<Figure 11>Distribution of Travel Distance of the Kyong-Eue Line

(2) Premises of Analysis

For the analysis of the effect of express service, the following preassumptions are employed.

1) Urban railway passengers choose the trip pattern that travel time can be reduced.
2) Increment of demand is none by applying express service to the Line.
3) The study section for Subway Line #5 is limited from Bang-Wha station to Kang-Dong station.
4) The study section for Kyong-Eue Line is limited from Ilsan to Seoul, which is 38 km long.
5) For Subway Line #5, the express trains stop at 13 stations including transfer stations and Kimpo Airport station.
6) Express trains stop in the Kyong-Eue Line at the current transfer stations and major stations - the number of stations available for express service is five.
7) Passenger arriving pattern at platform is assumed to have normal distribution.

8) Supposing the half of passengers have train time tables and their waiting time is less than 1.5 minutes.
9) Initial data are given in Table 3.

<Table 3> data for the analysis of the express service in the 5th Line

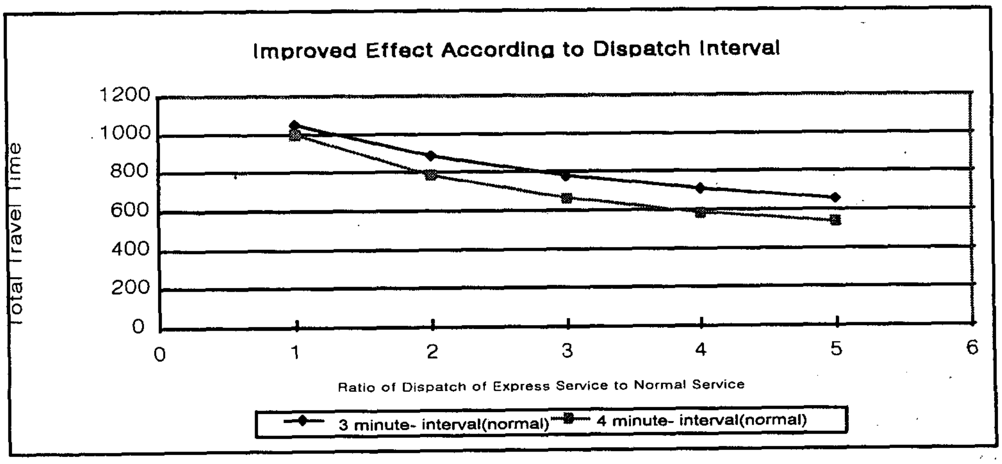
Data	Normal Service	Express Service
Velocity	50km/h	60km/h
Acceleration	3.0km/h/s	3.0km/h/s
Deceleration	3.5km/h/s	3.5km/h/s
Dwelling Time	30 Sec.	30 Sec.
Dispatch Intervals	3 Min.	12 Min.
O-D data	Monthly Data of Subway Operation(Nov 1997)	

4.2 Results of Analysis

1) The effect of Express service when the frequency is changed

The effect of total travel time saving and passenger volume are analyzed for several operation intervals of express trains such as 5 times/ hour (12 minutes interval), 7.5 times/hour (8 minutes interval), and 10 times/hour (6 minutes interval). For the model, the passenger volume during the peak periods is required. In this study, the passenger volume is assumed to be 20% of daily volume. This data is obtained from daily OD data. When express service is applied to Subway Line #5, a total of 3,174 hours/hour, which is 13% of total travel time is saved in case that the interval is 5 times/hour. When the interval is 10 times/hour, about 16 % of total travel time is reduced. It seems that the effect of express service is not very sensitive to service interval. This is not surprising. The reason for this is that if the express service interval is reduced, the travel time of express trains will be reduced, but that of normal trains will be increased.

In Kyong-Eue Line, when the express trains are operating 5 times/hour (12 minutes interval) and 15 times/hour, the total travel time is improved 10.98% and 22.96%, respectively.

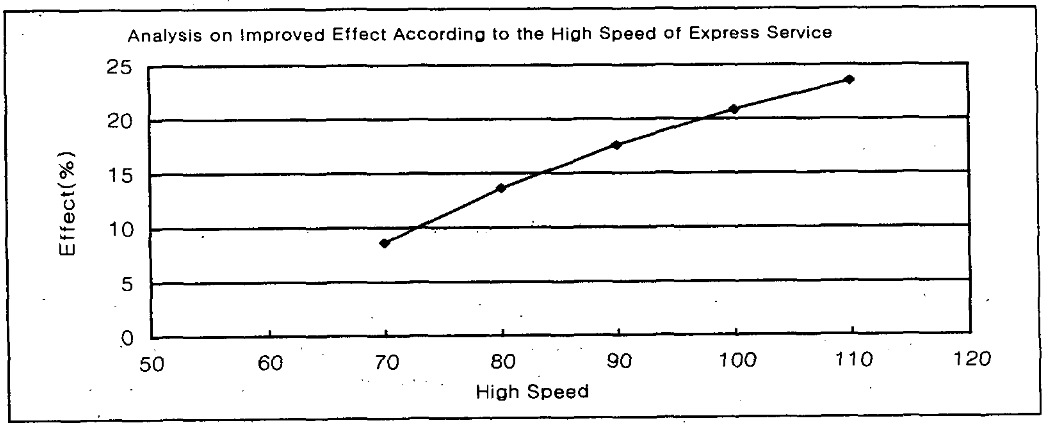


We analyzed the effect changing the dispatch ratio of express service and normal service. The total travel time decreased by about 40% when the ratio of normal service interval to express service interval is five.

2) The effect on total travel time when the travel speed is changed

The effect of express train's travel speed on the total travel time is assessed under two conditions. The first condition is that the travel speed of normal

trains is 60 km/h and that of express train varies between 60 and 110 km. In this case, as the travel speed of express train increases, the total travel time reduces from 8% to 24% at the two study lines.



The second condition is that the travel speed of normal train is 50 km/h and that of express train varies from 50 to 115km. In this case, the total travel time reduces from 5% to 35%, as the travel speed of express train increases.

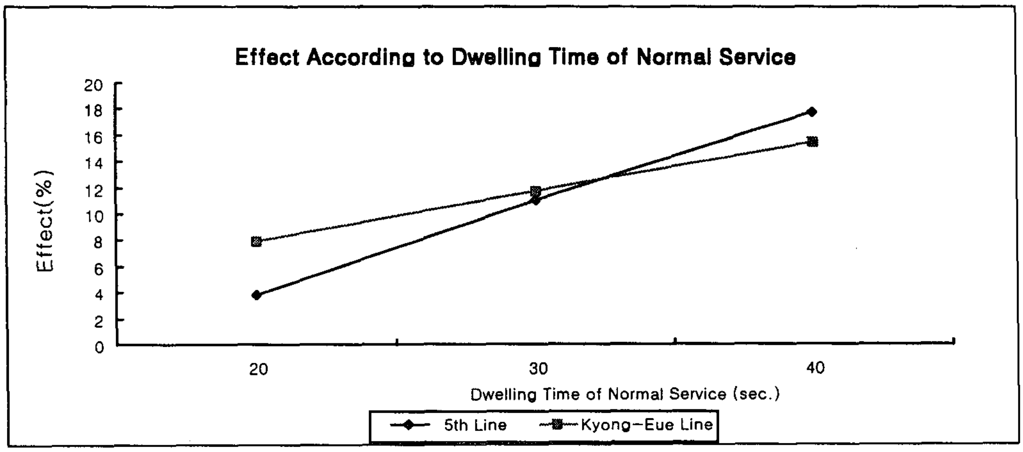
3) The effect on total travel time when the dwelling time is changed

If express service is available, the dwelling time of normal service will be increased. The effect of express service on the total travel time is estimated with the assumption that the travel speed of express trains is 80km/h and the dwelling time of normal train varies between 20 seconds to 40 seconds. The analysis results are summarized in Table 4.

	Dwelling Time		
	20 sec.	30 sec.	40 sec.
5th Line (within Seoul)	7.1	14.5	21.7
Kyong-Eue Line (to and from Seoul)	9.64	13.73	16.94

<Table 4> Effect by Dwelling Time

Figure 12 shows the changes of total travel time of the two subway systems. It can be seen that, in general, as the dwelling time of normal train increases, the effect of express service increases. It is interesting to note that the effect of express service on Subway Line #5 is more sensitive to the dwelling time of normal train than Kyong-Eue Line. This is due to the fact that the average distance between subway stations on Subway Line #5 which exists in urban area is much shorter than that of Kyong-Eue Line which exists rural area mostly. This is true, since if the average distance between subway stations is short, the effect of dwelling time on the subway service in terms of overall travel time will be increased.



5. Conclusion

The total travel time saving effect by applying the express service to the existing system has been analyzed. As a result the total travel time is decreased more than 13% though the effects are changing by intervals. Although the waiting time is increased totally, the total travel time saving effect by increasing the speed is more than that of waiting time. Improvement of the travel speed is resulted by not stopping every stations and by only stopping at major stations and transferring stations.

Based on the results of the case studies, We can conclude as :

First, the express system reduces a total travel time by about 13%; in particular, the Kyong-Eue Line is more effective than the subway Line #5.

Second, the shorter headway of express trains increases the time saving effects on subway system although it requests more waiting time to low-speed train passengers. When the service frequency is increased from 5 to 7.5 times/hour, total saved time ratio is about 10% in the Subway Line #5 and about 18% in the Kyong-Eue Line.

In order to optimize the system more effectively, post research tasks are needed to be taken as follows; 1) considering the antipathy to a crowded subway with the Index of Travel Crowd; 2) gathering the information about passengers' ages, jobs, incomes, among others in order to reflect the distinctive features of individual behaviors; 3) inferring the diverted demand from other transportation models when the express service is applied by analyzing the whole transportation system in Seoul Metropolitan Area; 4) optimizing dispatch intervals, service frequency, position of passing track, and the number of stations before estimating demand of express service.

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