The Application of Network Theory to Subway Transportation in Seoul, Korea

Chae-Bogk Kim* · Hak Soo Kim** · Seong-in Kim**

ABSTRACT

Network approch is used to find the shortest paths and transportation time between the subway stations in Seoul, Korea. Because of transfer stations, we reconstruct the subway network to compute the shortest routes and corresponding transportation times. The reconstructed network is useful to obtain desired information because it can handle the transfer time between tracks. Time and route information about the subway system is obtained and it will be displayed in the subway guide board at each station. Then, all passengers can have the information of shortest route to a destination and corresponding transportation time.

1. Introduction

Seoul is the biggest city in Korea and more than 12 million people live in Seoul. Because of the increase of automobiles and population, traffic zam is very popular and it will take more and more time to move from one place to another place by vehicles (e.g. bus or taxi) in Seoul. Therefore, the subway in Seoul has received a great preference because of the cheap fare and quick transportation time.

The subway (track 1) was firstly constructed in 1974 and it consisted of 9 stations. After then, subwayline had extened and new subway tracks (track 2, 3 and 4) had been constructed. At present, another four tracks (track 5, 6, 7 and 8) are underconstruction and the construction will be finished by 2000. Then, about 75 percent of people will use the subway system (about 32 percent of people use the subway system at present).

There are 152 stations and 16 transfer stations in the subway system. Since the subway system is very complex to analyze because of waiting time and moving time, it is not easy to find all the shortest paths as well as transportation times between any two stations. Also, one can not know how much time will be taken for the transportation between stations in advance. There are subway guide

* Department of Technology Education, Korea National University of Education
** Department of Industrial Engineering, Korea University.

boards which indicate the paths from one station to other stations at several subway stations. But, paths represented in subway guide board are found by simply counting the number of intermediate stations if there are more than one route. Also, it can not provide the information of transportation time.

For the strangers as well as persons who live in Seoul, it is desirable to present precise information about the subway oute and transportation time. In order to find the shortest path as well as transportation time between subway stations, interarrival times of subway train in each track, moving time (by foot) from one track to another track at transfer stations, and the number of transfer stations in the path are needed. Interarrival time and moving time mean that arriving time interval between two consecutive tiains and transit time to move from one track to another track by foot, respectively.

In this paper, a network model is constructed to find the shortest path as well as transportation time between subway stations. From the subway network (nodes represent stations and arc values denote transportation time), to add the transfer time if any, we reconstruct the subway network suitable for computing the shortest path as well as the transportation time. Then, the algorithm by Floyd [1] is employed to obtain the desired information.

The reason why we reconstruct the subway network is as follows. Since the objective of this paper is to find the shortest path as well as transportation time between subway stations, information about moving time between tracks is needed. Note that the moving time from a track, say X, to another track, say Y, may be different the moving time from track Y to track X. The complexity of Floyd algorithm is dependent on the number of nodes in the network. Even though we can use the conventional node splitting method, it increases the number of nodes in the network as the number of transfer station increases. After finishing the construction of track 5 through 8, there will be more transfer stations. Note that the number of nodes increases dramatically as the number of tracks for a transfer station increases. Another reason why we reconstruct the subway network (nodes represent stations and arc values denote transportation time) is to use the reconstructed subway network in Seoul, Korea for the future. With a little modification, we can obtain the shortest path as well as transportation time between subway stations even though new track is added or a track is extended.

2. Solution Methodology

There are four subway tracks in Seoul. To explain the network configuration, each subway track is shown in Figure 1 through Figure 4. The subway track 1 and 2 have loops, and the shape of other tracks is a single line. In Figure 1, in order to move from any stations in box 1 (box 2) to any stations in box 2 (box 1), we need to transfer subway trains. Also, to move from each station in box

3 (box 4) to each station in box 4 (box 3), transferring subway trains is essential. In Figure 1 and 2, if we want to move from a station not in the dotted line to any station in the dotted line, we need to transfer subway trains. Of course, we do not need to transfer trains if we want to move from a station to any station, where both stations are in dotted line or not in dotted line except above cases. Also, there is no transfer time if both departure station and destination station are in track 3 or in track 4 (see Figure 3 and 4).

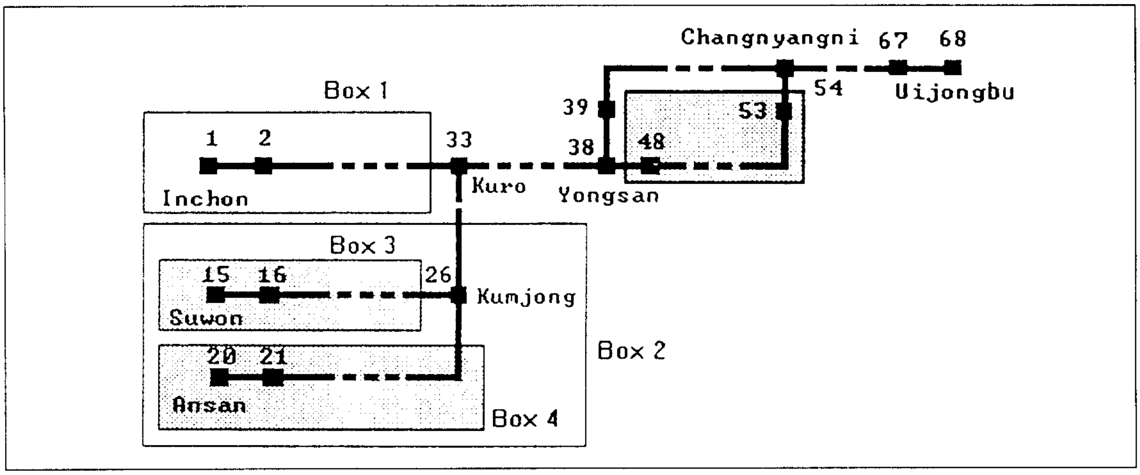


Figure 1. Configuration of subway track 1

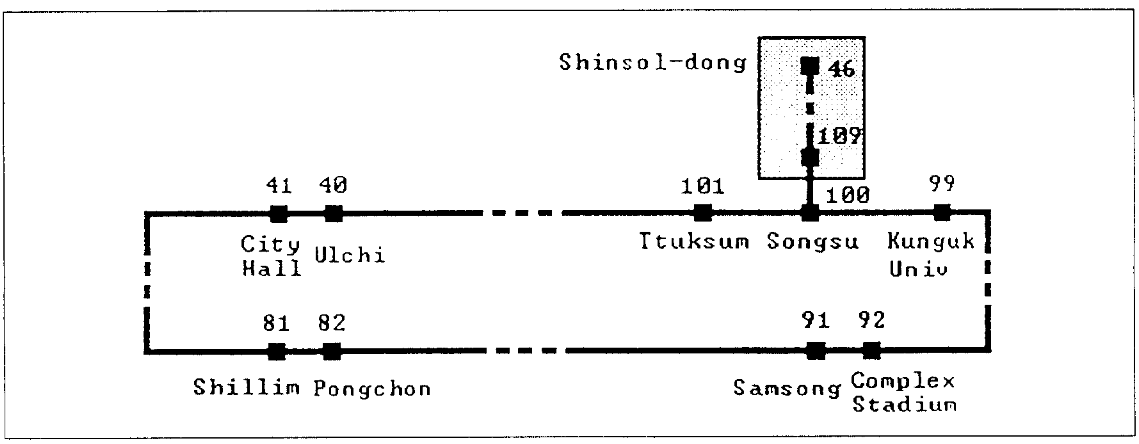


Figure 2. Configuration of subway track 2

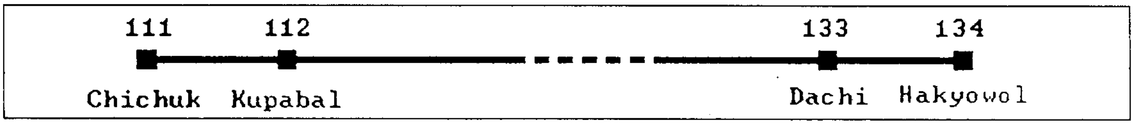
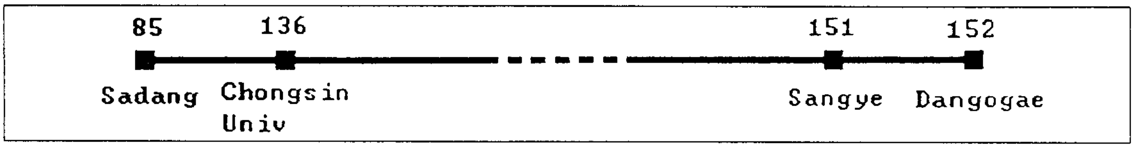


Figure 3. Configuration of subway track 3



Fiture 4. Configuration of subway track 4

Figure 5 represents the total subway system in Seoul (actually, synthesis of Figure 1 through 4). Each node represents subway station and arcs are drawn from a station to all the adjacent stations. Arc values denote transportation times. The arcs without arc values in Figure 5 have are value two. To move from a station to other stations not in the same track, we need to transfer subway trains of course.

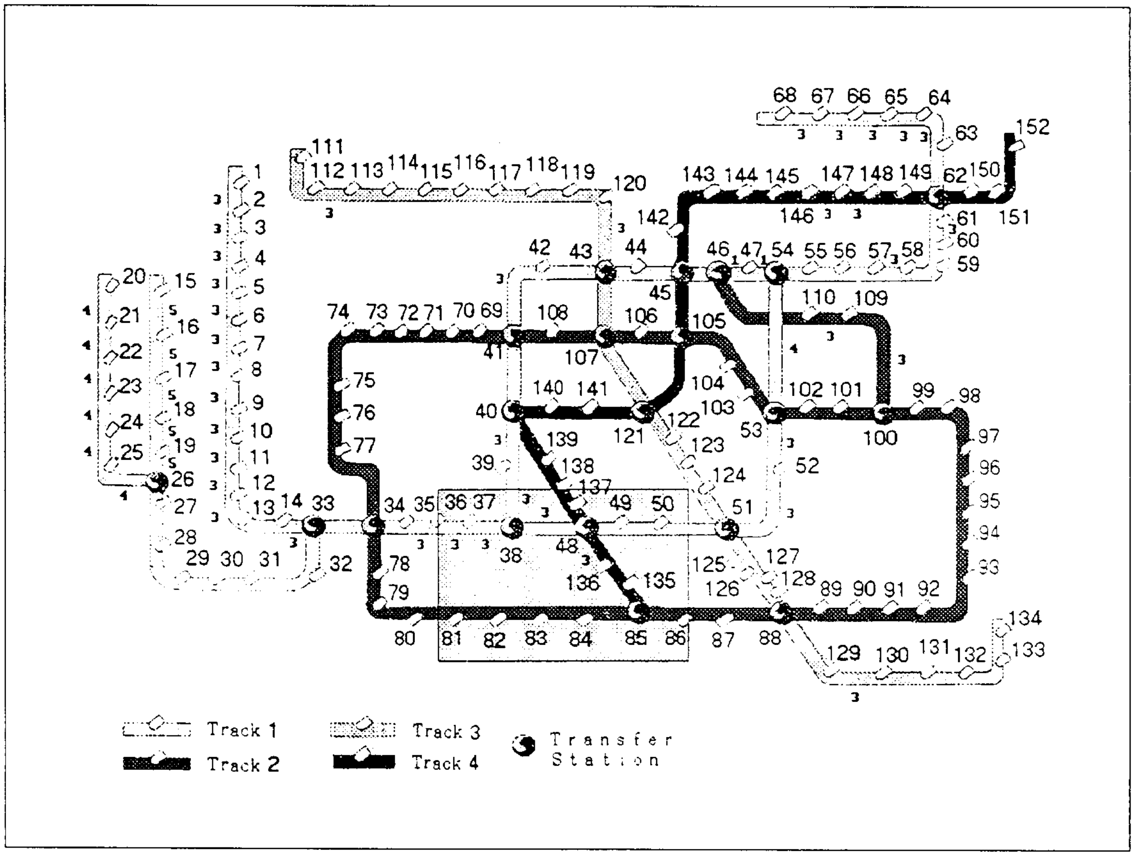


Figure 5. Subway network in Seou, KOREA

Because of transfer time, reconstruction of the subway network is needed to find all the shortest paths as well as transportation times. When there is a fixed charge (e.g. turning penalty), a conventional approach by Frank and Frisch [2] can be employed if we want to find the shortest path between two specific stations. But, the information what we need is all the shortest paths between any two nodes, Therefore, it is necessary to construct a general subway network suitable for finding the shortest paths as well as transportation times between every pair of subway stations. There are four typical cases (linear, cycle, intersection 1, intersection 2) in the original subway network. Following modifications are needed to reconstruct the subway network suitable for the Floyd algorithm [1]. Comparing with conventional node splitting method, the proposed method generates less number of nodes. That means the computational time for the reconstructed network will be less because we employed Floyd algorithm whose complexity is dependent on the number of nodes.

Case 1. Linear type

Two pseudo nodes are added to reconstruct the network and each node in the reconstructed subway network represents arc in the original subway network. An example is shown in Figure 6 and corresponding reconstructed subway network is represented in Figure 7. Each node in the reconstructed subway network denotes arcs in the original subway network, The values on the arcs in the reconstructed subway network represent the transportation times.

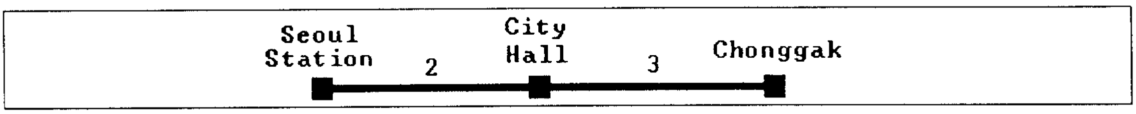


Figure 6. Linear type example

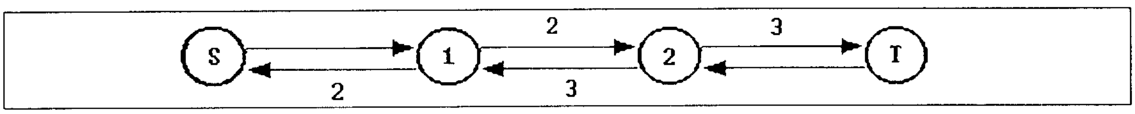


Figure 7. Reconstructed network of linear type

Case 2. Cycle type

The number of nodes in the original network is equal to the number of nodes in the reconstructed subway network (there is no pseudo node). An example is shown in Figure 8 and corresponding reconstructed subway network is represented in Figure 9. It is a simple case to modify from the original subway network to the reconstructed subway network.

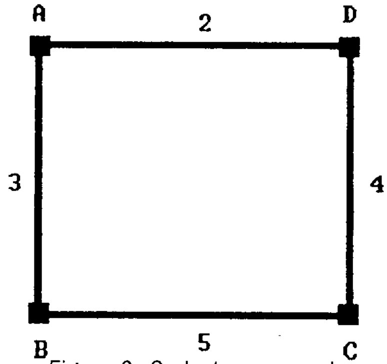


Figure 8. Cycle type example

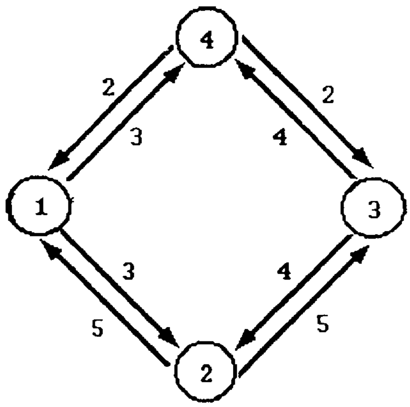


Figure 9. Reconstructed network of cycle type

Case 3. Intersection type 1

When the last station of a track, say station X, is the same as a station of any other tracks, this is called an intersection type 1. In this case, a pseudo node is needed to illustrate the transportation time between the station X and any other stations in the same track. Also, the information about interarrival time and moving time from a track to the other tracks is needed to provide arc values when transferring trains is necessary. An example is shown in Figure 10 and corresponding reconstructed network is represented in Figure 11.

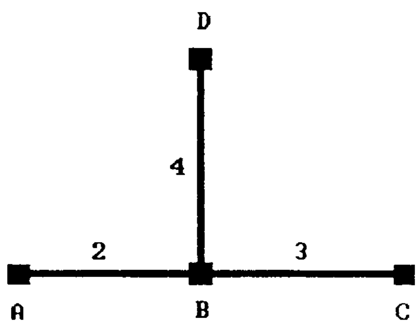


Figure 10. Intersection type 1 example

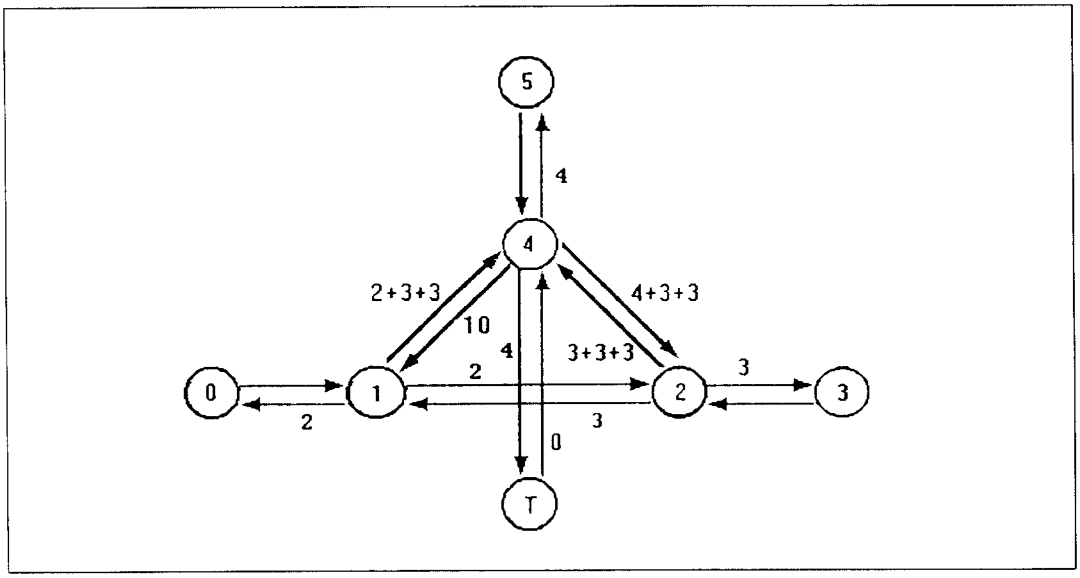


Figure 11. Reconstructed network of intersection type 1

Case 4. Intersection type 2

When two tracks are crossed each other, the reconstructed network should illustrate the transportation time, interarrival time and moving time. Pseudo node is not needed in this case but 8 additional arcs are needed to compute the transfer times from a track to other tracks. An example is shown in Figure 12 and corresponding reconstructed network is represented in Figure 13.

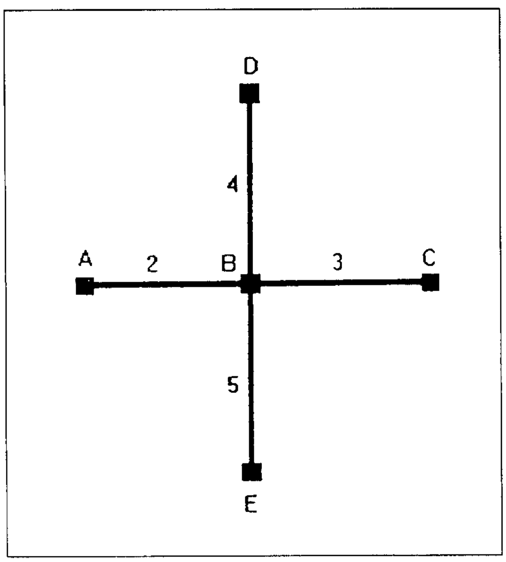


Figure 12. Intersection type 2 example

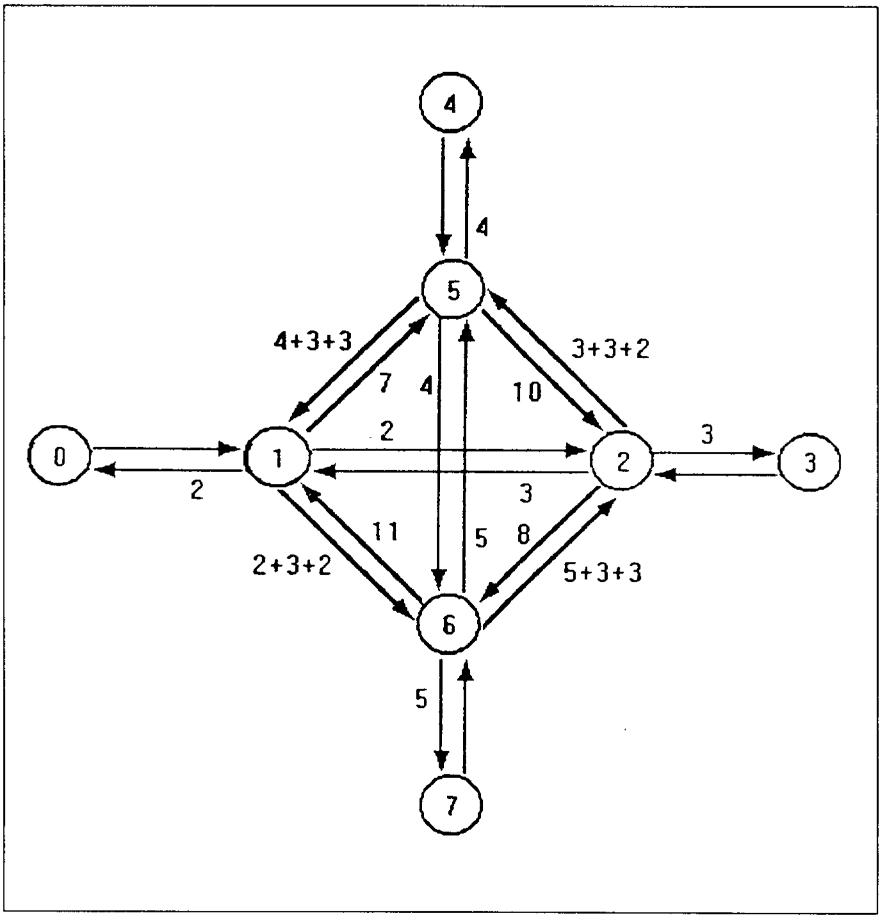


Figure 13. Reconstructed network of intersection type 2

Figure 14 shows a part of reconstructed subway network in Seoul. It is a reconstructed network of the region enclosed by the dotted line in Figure 5. The final reconstructed subway network in Seoul is formulated by using the procedures explained before (from Case 1 to Case 4).

Since the information what we need is all the shortest paths and corresponding transportation times between all pair of nodes, Floyd algorithm [1] is employed to obtain the desired results. By using the triple operation, all the shortest paths as well as transportation times are computed and desired results are obtained in the form of the distance matrix and route matrix. Of course, to obtain correct information about transportation times, average waiting time of each station (half of subway interarrival time) is added. Table 1 represents some results obtained by Floyd algorithm. The algorithm is coded in Turbo C and provides solutions in a few seconds in IBM PC 486.

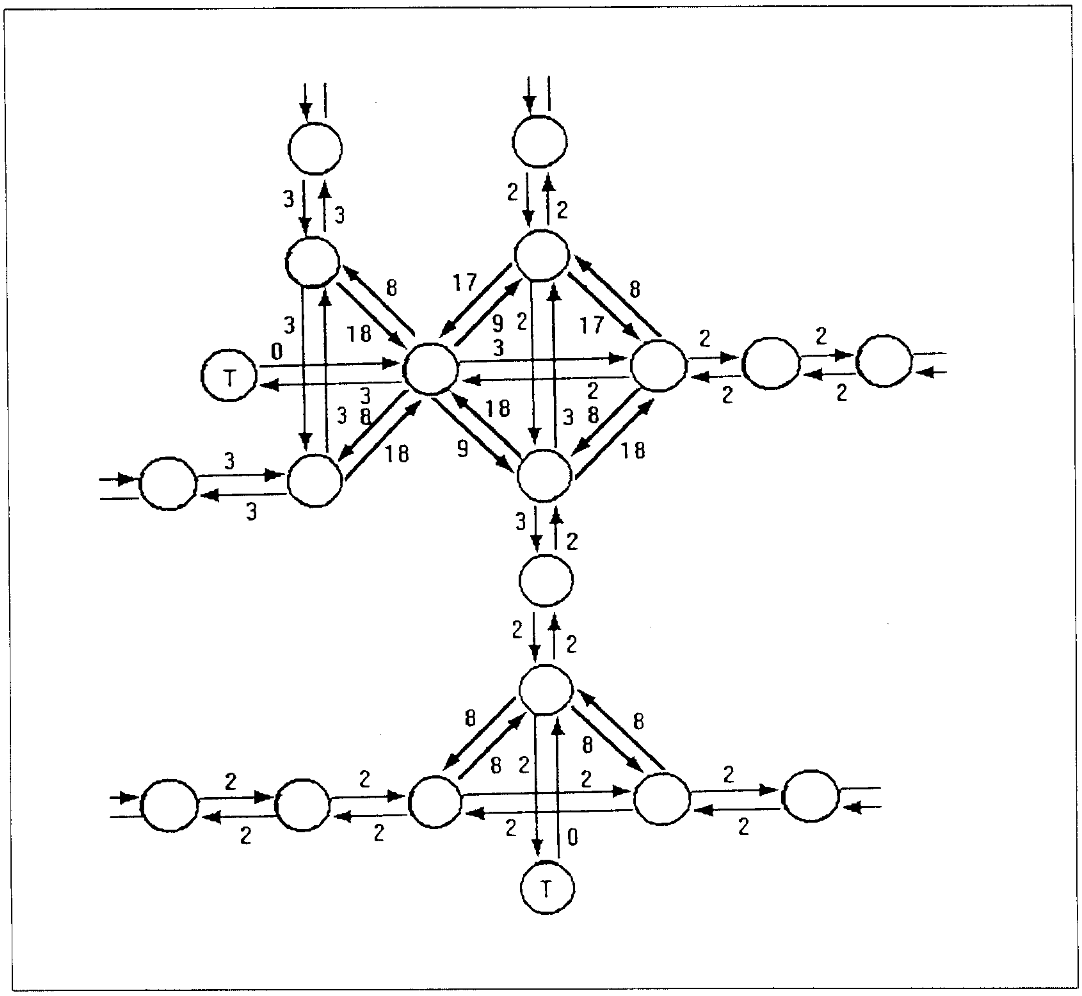


Figure 14. An example of reconstructed network

Table 1. The shortest routes and transportation times obtained

departure	destination	time(minite)	route
33	98	50	33-34-78-79-····-97-98
33	99	49	33-34-····-42-43-107-121-122-123-124-51
33	51	44	33-34-····-42-43-107-121-122-123-124-51
33	125	44	33-34-78-79-····-87-88-128-127-126-125
33	136	34	33-34-78-79-····-84-85-135-136
33	48	33	33-34-····-39-40-139-138-137-48
42	77	27	42-41-69-70-····-76-77
42	81	36	42-41-····-35-34-78-79-80-81
42	83	36	42-41-40-139-138-137-48-136-135-85-84-83
42	88	33	42-43-107-121-122-123-124-51-125-126-127-128-88
42	92	45	42-41-108-107-····-104-103-53-102--101-····-93-92

3. Conclusion

To provide information about the subway transportation in Seoul, a network approach is used. Because of the transfer time, we reconstructed the subway network in order to obtain the desired information. Typical four cases are illustrated and the procedures to change the original subway network to the reconstructed subway network are presented. By using Floyd algorithm, we obtained all the shortest paths as well as corresponding transportation times between every pairs of subway stations. The results obtained in this paper can be used in constructing a data base of subway guide board at each station. After construcing 4 more tracks by 2000, the approach in this paper can also be employed to obtain the subway information for traveller.

Reference

[1] Floyd, R.W. 1962, "Algorithm 97: Shortest path", *Communications of the ACM,* Vol. 5, No.6, pp. 345.

[2] Frank, H. and Frisch, I. T., 1971, "Communication, transmission and transportation network", Reading Mass., Addison-Wesley, Publishing Co. INC.