A Development of Operation Model for Express-Rail in Line 7

2017-06-02

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01 Topic Selection

- Since many people are using line 7, it is very crowded and causing much inconvenience
- There are as many as 51 stations in line 7, so it takes long for the train to make a round trip

→ So there is certain needs for the express-rail

02 Prior Study Analysis

- Prof. Jeong's method

i,j: station index, I,j=1,⋯,N
K: stop-schedule index, k=1,⋯,K
f_{ij}: number of customer whose OD is (i,j)
y_{ik}=1: if station i is open for stop-schedule k. Otherwise it is zero.
x_{ijk}=1: if demand for OD (i,j) is assigned to stop-schedule k. Otherwise it is zero.
z_{ik}: total number of customer who passes station i in-vehicle at stop-schedule k

Min $\sum_{i=1}^{N}\sum_{k=1}^{K} z_{ik}$

St $\sum_{k=1}^{K} x_{ijk} = 1,\ \forall i,j$

$2x_{ijk} \le y_{ik} + y_{jk},\ \forall i,j,k$

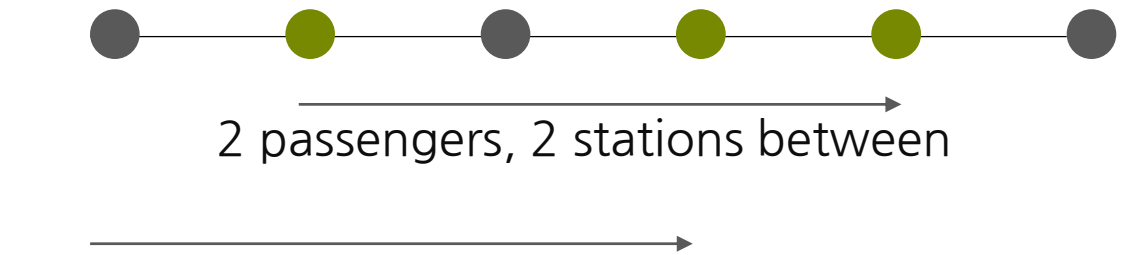
$z_{ik} \ge \sum_{j=1}^{i}\sum_{l=i+1}^{N} f_{jl}x_{jlk} - M(1-y_{ik}),\forall i,k$

$x_{ijk}, y_{ik} = \{0,1\},\forall i,j,k$

$z_{ik} \ge 0,\forall i,k$

02 Prior Study Analysis

- Prof. Jeong's method



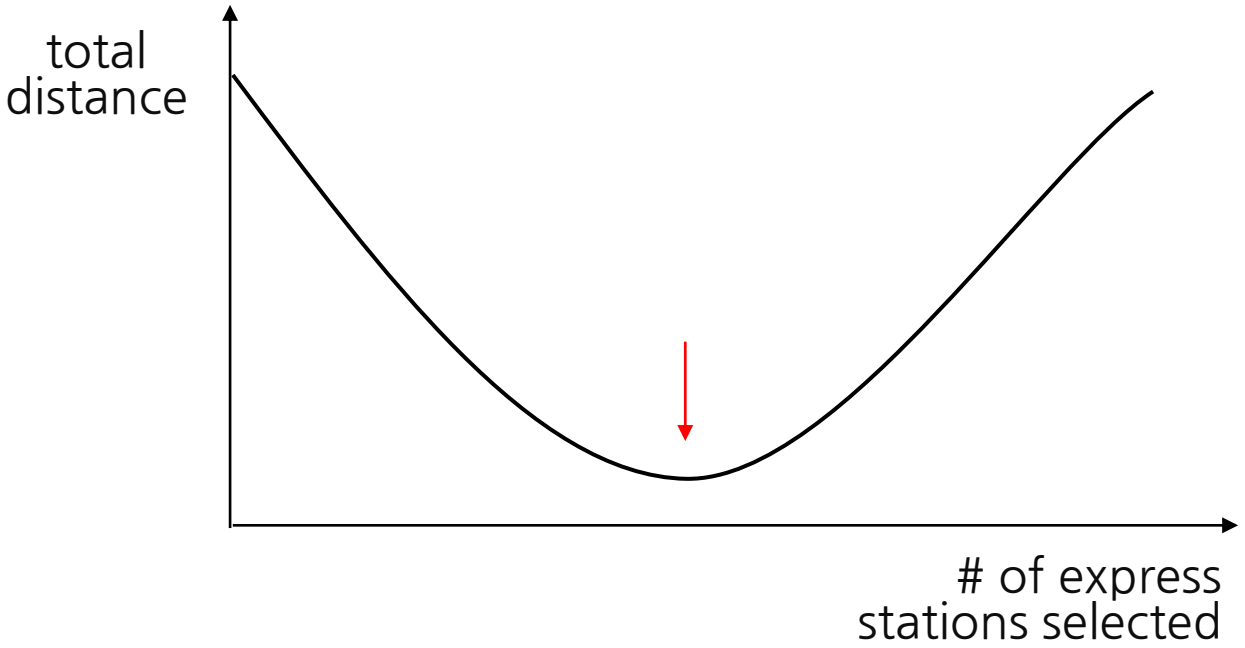
$$\text{Min} \sum_{i=1}^{N} \sum_{k=1}^{K} z_{ik}$$
$$= 2 \times 2 + 4 \times 3 + \ldots$$

→ **We decided to use the same objectives, but create new algorithm because it will not work for more than 7 stations**

03 The Algorithm

- Basic assumptions

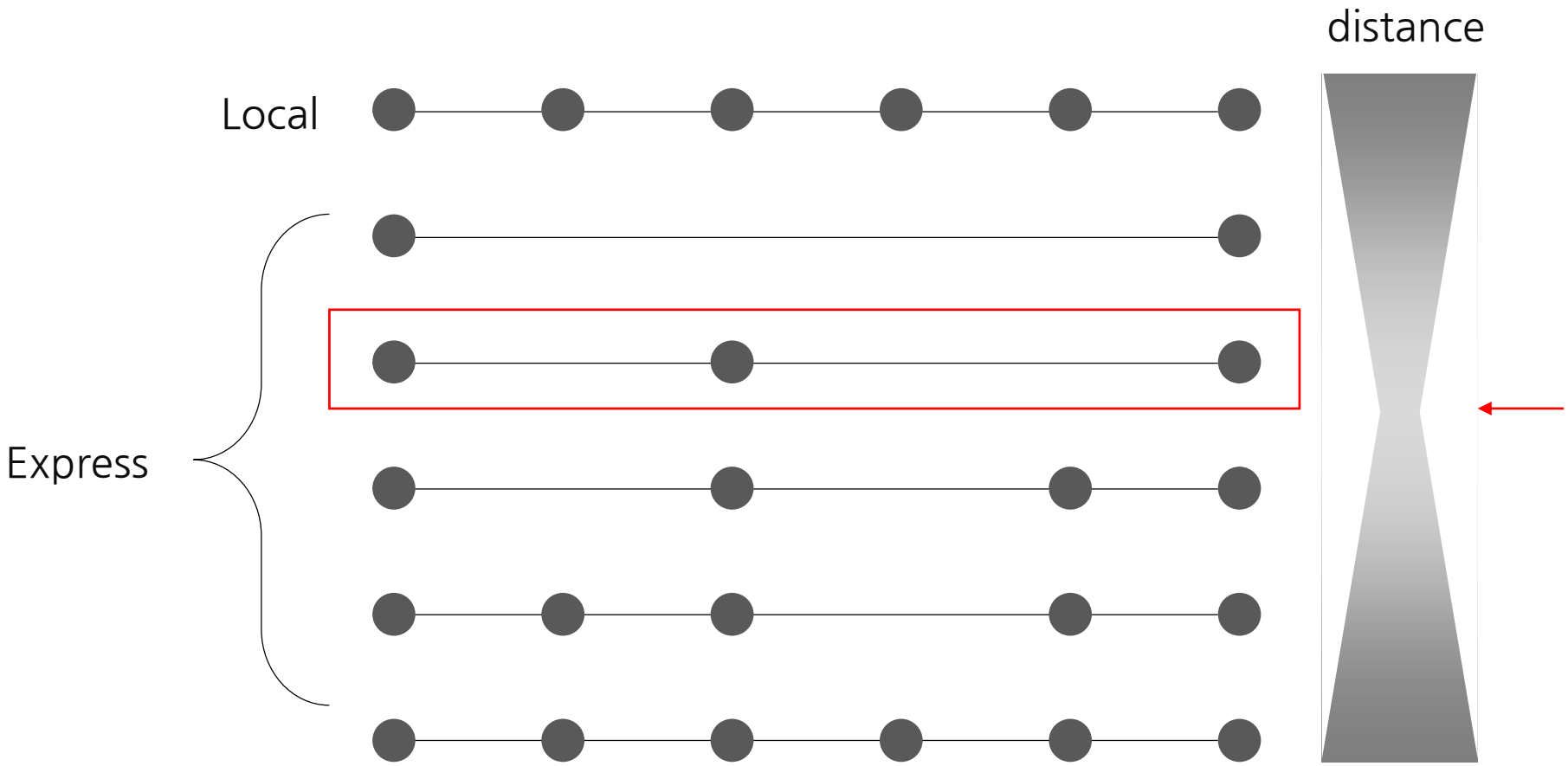
1) Relationship between total travel distance and number of stations selected are assumed like the graph below:



→ So we select the point where the total distance begin to increase

03 The Algorithm

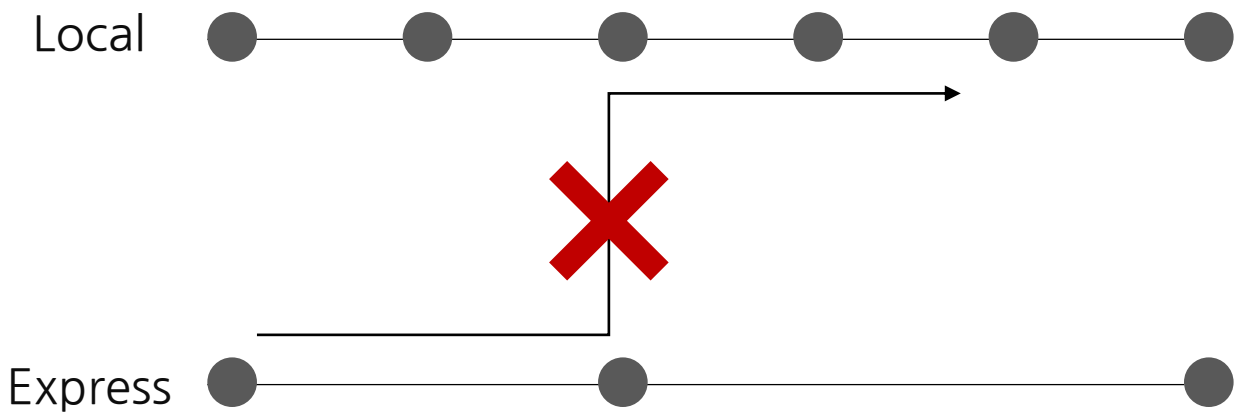
- Basic assumptions



03 The Algorithm

- Basic assumptions

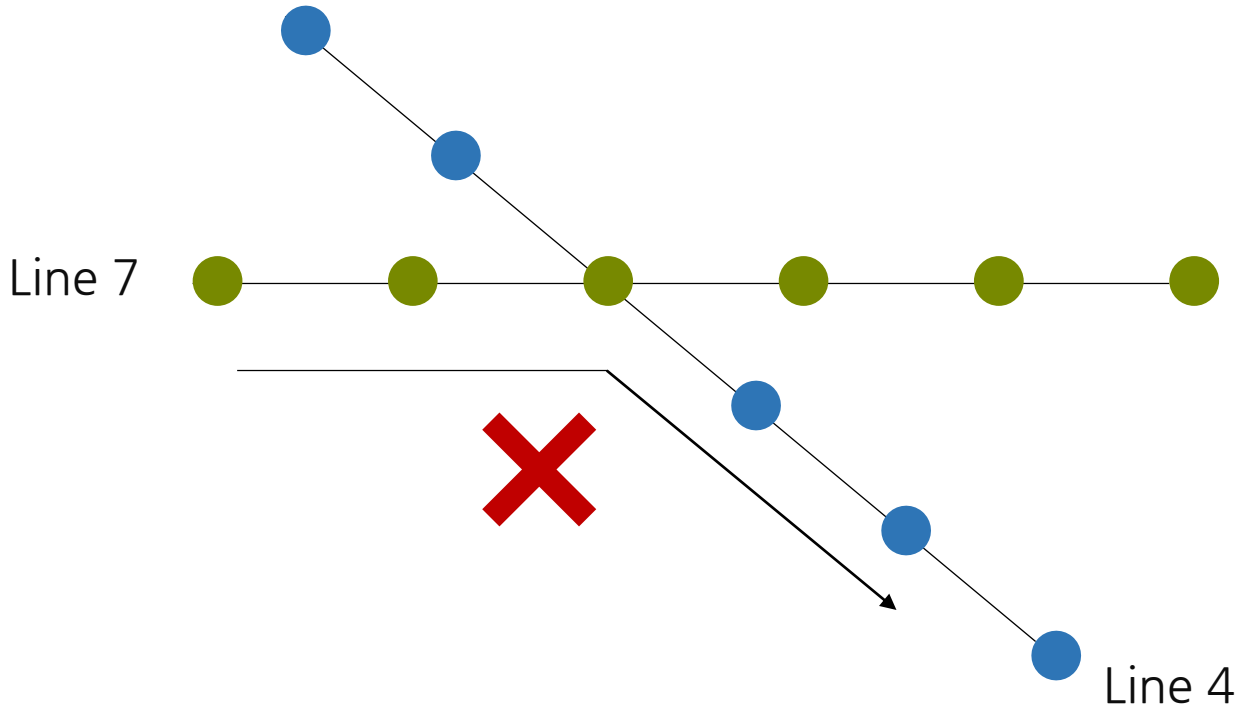
2) Passengers would not transfer from local train to express train nor vice versa



03 The Algorithm

- Basic assumptions

  3) Transfer between line 7 to other line is not considered nor vice versa



03 The Algorithm

Set a random 5x5 O-D matrix. The initial objective value is 94.

	1	2	3	4	5
1	0	2	3	5	3
2	2	0	2	8	6
3	3	1	0	4	2
4	4	7	2	0	1
5	5	3	6	3	0

Z = 94

03 The Algorithm

- Selecting the initial two express stations

1) Sort the total data and find a few large O-D values

	1	2	3	4	5
1	0	2	3	5	3
2	2	0	2	8	6
3	3	1	0	4	2
4	4	7	2	0	1
5	5	3	6	3	0

03 The Algorithm

- Selecting the initial two express stations

2) Calculate the distance between origin station and destination station and multiply it by O-D value

	1	2	3	4	5
1	0	2	3	5	3
2	2	0	2	8	6
3	3	1	0	4	2
4	4	7	2	0	1
5	5	3	6	3	0

Data	Distance	Data X Distance
8	2	16
7	2	14
6	3	**18**
6	2	12

03 The Algorithm

- Selecting the initial two express stations

3) Set the station 2 and 5 as initial express station
and calculate the sum of distance between all stations

	1	2	3	4	5
1	0	2	3	5	3
2	2	0	2	8	6
3	3	1	0	4	2
4	4	7	2	0	1
5	5	3	6	3	0

2-5	1	2	3	4	5
1	0	1	2	3	4
2		0	1	2	1
3			0	1	2
4				0	1
5	sum = 18				0

03 The Algorithm

- Selecting the further express stations

1) Sort the few large O-D values, having station 2 or 5 as origin or destination

	1	2	3	4	5
1	0	2	3	5	3
2	2	~~0~~	2	**8**	~~6~~
3	3	1	0	4	2
4	4	**7**	2	0	1
5	**5**	~~3~~	**6**	3	~~0~~

03 The Algorithm

- Selecting the further express stations

2) Consider the other stations that have a large O-D data as a third express station and calculate the sum of distance between all stations.
Then, select the station with smallest value. (In this case, station 1)

1-2-5	1	2	3	4	5
1	0	1	2	3	2
2		0	1	2	1
3			0	1	2
4				0	1
5	sum = 16				0

2-3-5	1	2	3	4	5
1	0	1	2	3	4
2		0	1	2	2
3			0	1	1
4				0	1
5	sum = 18				0

2-4-5	1	2	3	4	5
1	0	1	2	3	4
2		0	1	1	2
3			0	1	2
4				0	1
5	sum = 18				0

3) Continue this procedure and ***stop*** when the sum is larger than the prior step.

04 Results

- Apply the algorithm to the actual O-D data of line 7 (March 6, 2017)

합계 : 열												
행	2711	2712	2713	2714	2715	2716	2717	2718	2719	2720	2721	2722
2711	13	24	14	5	25	23	20	15	17	7	18	17
2712	27	41	234	255	621	346	420	318	234	143	192	290
2713	11	135	85	348	844	400	586	364	308	155	218	324
2714	11	156	311	57	542	294	475	287	254	121	228	278
2715	41	545	934	505	164	422	1076	914	741	393	513	662
2716	33	262	439	274	427	73	216	305	347	211	343	555
2717	32	317	604	494	967	203	94	320	371	297	322	559
2718	40	225	406	269	825	350	363	96	154	132	146	398
2719	31	144	278	261	556	322	389	126	35	70	124	274
2720	22	87	142	109	416	228	298	150	72	63	147	405
2721	37	124	239	261	518	351	354	160	144	174	57	235
2722	30	190	317	256	672	550	541	390	267	424	221	161
2723	42	144	188	145	432	329	434	282	214	342	347	132
2724	33	131	201	198	451	312	421	283	267	343	346	299
2725	9	35	48	50	102	67	124	74	69	74	113	101
2726	16	49	91	76	149	132	178	94	80	119	164	177
2727	28	126	122	101	164	166	227	122	96	138	190	190
2728	59	183	209	216	288	343	409	209	218	214	255	433
2729	36	167	168	158	246	230	335	221	270	220	258	418
2730	7	33	44	30	63	58	67	57	57	51	70	95

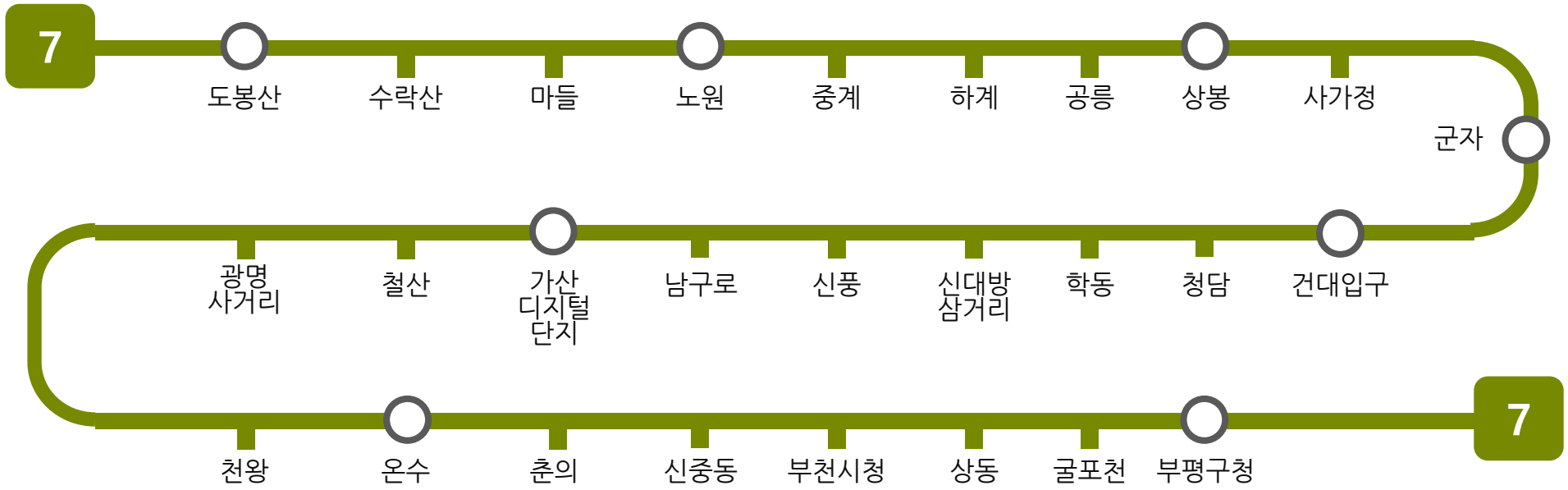
O-D value

	2711	2712	2713	2714	2715	2716	2717	2718	2719	2720	2721	2722	2723	2724	2725
2711	-	1	2	3	4	5	6	7	8	9	10	11	12	13	14
2712		-	1	2	3	4	5	6	7	8	9	10	11	12	13
2713			-	1	2	3	4	5	6	7	8	9	10	11	12
2714				-	1	2	3	4	5	6	7	8	9	10	11
2715					-	1	2	3	4	5	6	7	8	9	10
2716						-	1	2	3	4	5	6	7	8	9
2717							-	1	2	3	4	5	6	7	8
2718								-	1	2	3	4	5	6	7
2719									-	1	2	3	4	5	6
2720										-	1	2	3	4	5
2721											-	1	2	3	4
2722												-	1	2	3
2723													-	1	2
2724														-	1
2725															-
2726															
2727															
2728															
2729															
2730															
2731															
2732															
2733															
2734															
2735															
2736															
2737															
2738															

Distance

04 Results

- Final Express-Rail stations are these:

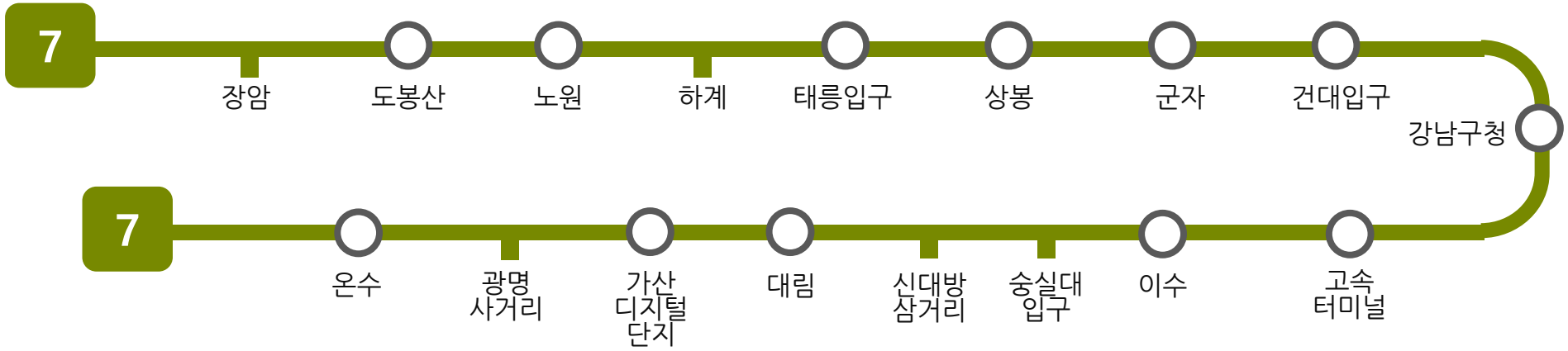


→ The final objective value of this result is 2891193.

This is *22% decrease* from the original value, 3677121.

04 Results

- Compare with Korea Railroad Research Institute's research data



→ The final objective value of this result is 3340420.

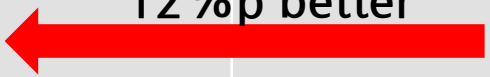
This is 10% decrease from the original value, 3677121.

Our algorithm's result is *12%p better*.

04 Results

- Compare with Korea Railroad Research Institute's research data

	Algorithm	Research data
Objectives	Minimize passengers' travel distance	Transfer station & popular station
# of express station	29	17
Improvement z	22%	10%
# of transfer station (total 13)	8	12



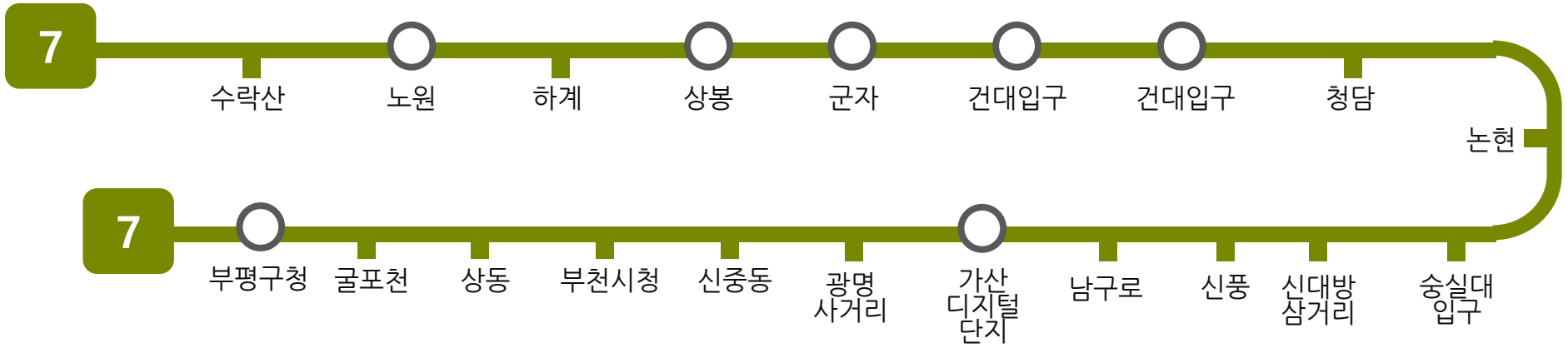
05 Limits & Improvements

- Limits

  1) Passengers at transfer station are not considered
  2) Passengers' needs are not considered
     - They might want short travel time
     - They might want lower complexity

- Improvements

  1) Too many stations are selected as express stations
  2) Too many stations are selected in a row



→ **The final objective value of this result is 3197607.**

This is *13.1% decrease* from the original value, 3677121.

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Thank you!
Any questions or suggestions?