Rajasangari Rajagopal Achary
Shannon Foss
December 15, 2008

552 – Simulations - Final Project

Light Rail Model –

The city of Short Beach requires a rail system and 60 million dollars has been allocated for this project. The money must be spent on track and trains to run between stations. This simulation is to be used to decide which is the best possible configuration to get the most people to their destination in the least amount of time.

There are 6 stations in different locations around the city:

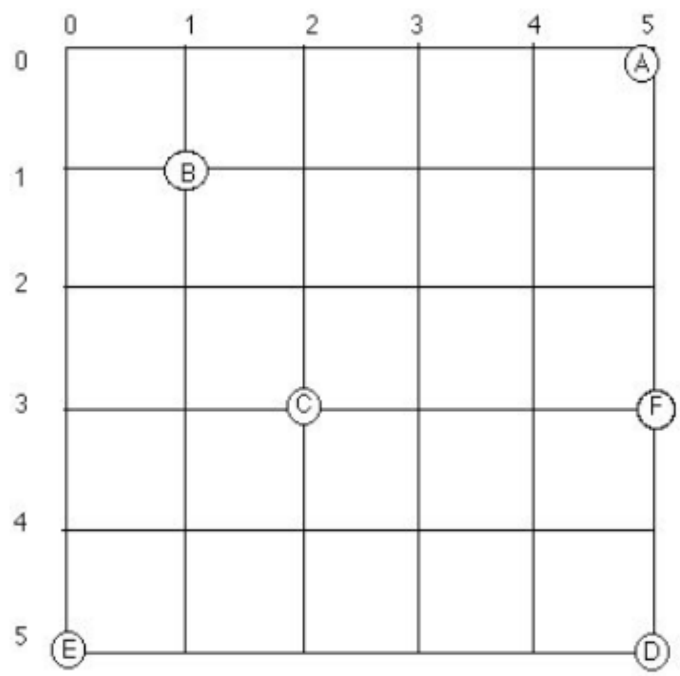


Figure 1: Station Locations

The first task is to create the connections and lay the track between the stations in the most efficient way possible.

Track Mappings:

Knowing that each horizontal or vertical track costs 1 million dollars, each diagonal track costs 2 million dollars and that it takes on average 2 minutes to traverse each track segment we can calculate the most efficient track layout using the given rider stats for each station.

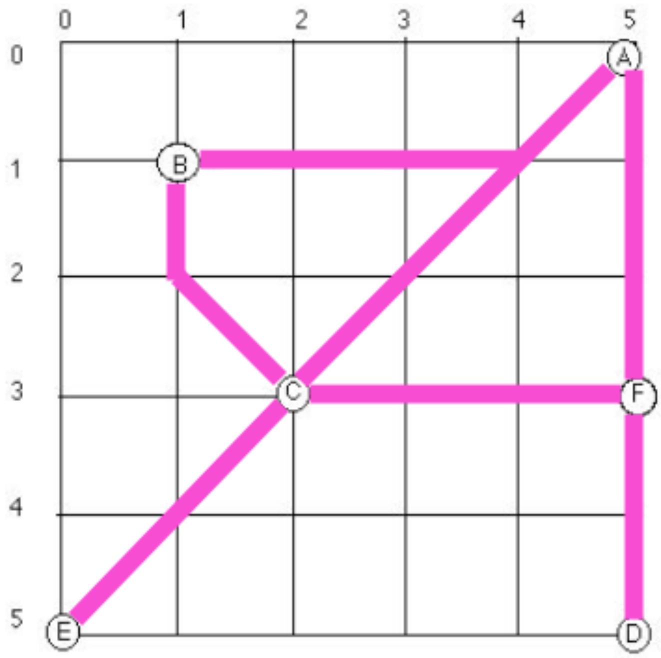
	a	b	c	d	e	f	total
a	0	4	1	0.5	1.5	3	10
b	4.5	0	4.5	0.75	3	2.25	15
c	4	4	0	3	5	4	20
d	0.5	0.5	1	0	1.5	1.5	5
e	5	5	5	5	0	5	25
f	5	5	5	5	5	0	25
total	19	18.5	16.5	14.25	16	15.75	100

Table 1: percentage of people going between stations.

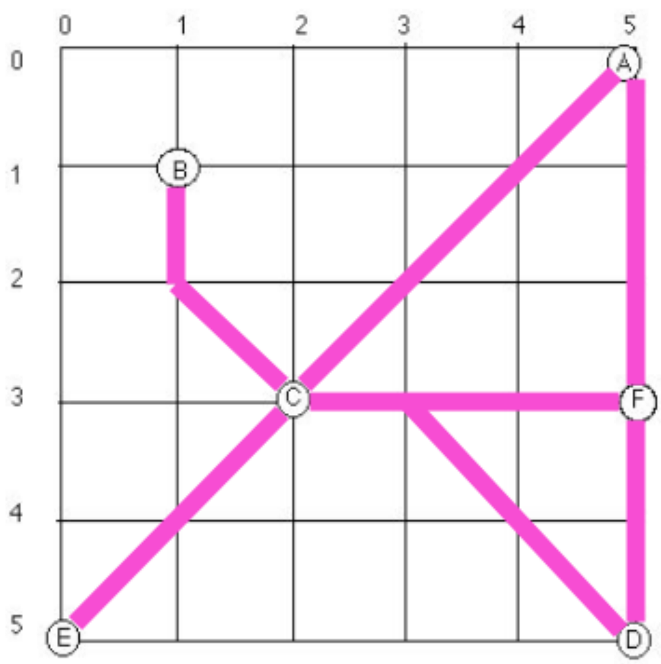
Using with the percentages of people wanting to go from one station to another, we can find the station connections with the highest number of people, the minimum cost of building the track and the minimum time it will take to traverse it. (t=~2mins).

Segment Priorities:	**Min Cost**:	**Min Time**:	**Map1**:	**Map2**:
A-B = 4+4.5 = 8.5	5M	4t	4t	5t
A-C = 1+4 = 5	6M	3t	3t	3t
A-D =0.5+0.5=1	5M	5t	5t	5t
A-E = 1.5+5 = 6.5	10M	5t	5t	5t
A-F = 3+5 = 8	3M	3t	3t	3t
B-C = 4.5+4= 8.5	3M	2t	2t	2t
B-D = .75+.5= 1.25	8M	4t	7t	5t
B-E = 3+5 = 8	5M	4t	4t	4t
B-F = 2.25+5=7.25	6M	4t	5t	5t
C-D = 3+1 = 4	5M	3t	5t	3t
C-E = 5+5 = 10	4M	2t	2t	2t
C-F = 4+5 = 9	3M	3t	3t	3t
D-E = 1.5+5 = 6.5	5M	5t	7t	5t
D-F = 1.5+5 = 6.5	2M	2t	2t	2t
E-F = 5+5 = 10	7M	5t	5t	5t

From this information, maps of the track can be created and analyzed. The goal is to draw the map as close to the absolute minimum times possible without spending excessive amounts of money. Map 1 was created with a separate connection between stations A and B, whereas Map 2 has a different connection between stations C and D.



Map 1: Total Cost=24M



Map 2: Total Cost=25M

Track Map 1:

Map 1 has a total cost of 24 million dollars and the difference between the minimum time to traverse track segments and the time to traverse track segments for Map 1 is: +3 time units for track segment B-D, +1 for B-F, +2 for C-D, and +2 for t D-E. Which equates to 3.75+7.25+8+13 = 32 people time units lost due to longer segments of track between stations.

Track Map 2:

Map 2 has a total cost of 25 million dollars and the difference between the minimum time to traverse track segments and the time to traverse track segments for Map2 is: +1 time units for track segment A-B, +1 for B-D, and +1 for B-F. Which equates to 8.5+1.25+7.25= 17 people time units lost due to longer segments of track between stations.

And so, Map 2 is nearly twice as efficient as track one, despite how similar they are. Also, since the trains cost 5 million dollars each, the cost of both maps is effectively the same.

<u>Trains</u>:

If we are to go with Map 2's design, then the remaining amount of money will go toward buying trains. After spending 25 million on track, we now have 35 million left of the total 60 million dollars, which gives us enough money to buy 7 trains to place on our tracks.

<u>Routes</u>:

Once the number of trains are known, the routes the trains will take can be decided. Using the earlier amounts calculated for each segment and the paths available from the map we can find the best routes that have the best coverage of all the stations.

Three of the five paths to station C are the most used: E-C, B-C and F-C. It can also bee seen that C-B, C-E, C-A and C-F are the most used paths from station C. The map also shows that stations B and E are only connected to station C, and so it makes sense that these paths need be traversed as quickly as possible to get as many people through as possible. The amount of time for a train to make a round trip between two stations is approximately 18 minutes for a two-segment track and 22 minutes for a three-segment track.

Routes may also travel between multiple stations, this allows for an extra train to be planned because it is no longer being used to connect two of the stations. To create a route that will traverse more than one station, the segments that have the lowest priorities will be chosen so that the train can take a longer period of time to traverse between the stations without the worry of too many people coming and waiting for the train to return. The best candidate for a multi-station route would be path A-F-D, because it has the lowest priorities and it is using paths not already taken by the higher priority segments.

At this point the only path not completed is the segment C-D. Once that connection is made there is still one train leftover to plan.

The final train may be placed wherever would be the most helpful, and in this case, that would probably be a connection between two of the busiest stations. Stations E, B, and F are all extremely busy stations, but after some calculations, a path between E-C-B would seem to be the most efficient.

The final route list that connects all of the stations together comes out to be:

Train0 = E – C => starting at station E

Train1 = B – C => starting at station B

Train2 = C – F => starting at station C

Train3 = A – C => starting at station A

Train4 = A – F – D => starting at station A

Train5 = D – C => starting at station D

Train6 = B – C – E => starting at station B

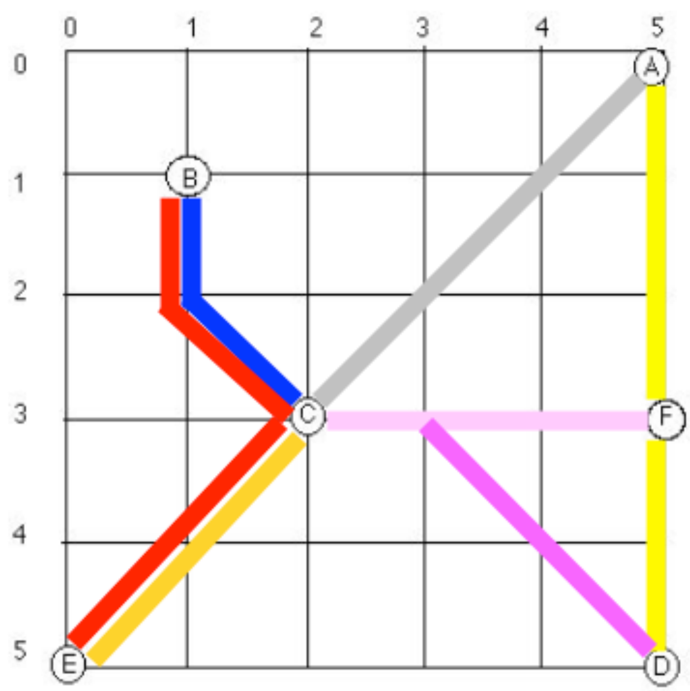


Figure 2: Map showing routes.

Route 1, using Train0, picks up all passengers in the queue at station E and delivers them to station C, which takes approximately 4 minutes to get there. Then the train waits at station C for 5 minutes for the passengers wanting to go to station E. Then the train takes another 4 minutes to return to station E.

Route 2, is similar to route 1 in that it is the same approximate wait times, but it uses Train1 and travels between stations B and C.

Route 3 uses Train2 to travel between stations C and F. There are three track segments between these two stations, and so it now takes approximately 6 minutes to travel between them. The station wait time is still 5 minutes and a round trip takes 22 minutes.

Route 4 is also a three track path, but between stations A and C and it uses Train3.

Route 5 is a multi-station route that traverses between stations A, F and D. At station A it takes any passengers waiting in queues to go to F or D, then it goes to station F to pick up any passengers waiting in the queue to go to station D and drops off any passengers that were going to F. The train travels to D and drops off any people that were going to D and picks up anybody that wants to go to F or A. The train returns to station F and drops off anyone going there and it also picks up anyone wanting to go to station A. The train then returns to station A and drops off anyone wanting to be at A, and then the process repeats.

Route 6 is a three track segment path that spans between stations C and D.

Route 7 is a multi-station route that travels between stations B, C and E. This route was made to deal with the excess of passengers that travel between stations B, C and E. The train starts at station B and picks up all passengers waiting in the queue. The train travels to station C and drops off anyone that wants to get off at C (either because that was their destination or they need to get on a connecting train to another station) and picks up anyone that wishes to go to E. The train then travels to E and drops off everyone that's on the train. It picks up everyone from the queue and then travels back to station C. Anyone wishing to get off at C does so and anyone wanting to go to B gets on the train. Then the train travels to B and drops everyone off, at which time the process starts again.

Results:

The simulation was run for several 12 hour test periods, the 12 hour mark stops any new passengers from entering the system, but the simulation continues until all passengers have arrived at their destinations.

Test Case 1:
Last Event: 809.88
Events Processed: 36081
Number of riders in system: 2181
Avg time spent in system: 30.47

Test Case 2:
Last Event: 811.88
Events Processed: 35800
Number of riders in system: 2155
Avg time spent in system: 30.55

Test Case 3:
Last Event: 802.95
Events Processed: 34143
Number of riders in system: 2040
Avg time spent in system: 31.26

Test Case 4:
Last Event: 799.74
Events Processed: 35387
Number of riders in system: 2147
Avg time spent in system: 30.94

Test Case 5:
Last Event: 801.42
Events Processed: 35110
Number of riders in system: 2114
Avg time spent in system: 30.23

Which produces an average of 2127.4 riders and a passenger system wait time of 30.69 minutes.

This wait time seems slightly high: It is known that 51% of the passengers are only going to a neighboring station, which should only take 4 or 6 minutes for the trip, plus a wait time of 5 minutes for the train to load, for a total time of 9 to 11 minutes. The rest of the passengers are going to stations that are only one stop away and so this doubles their travel time and also adds the wait time of an extra station.

I believe that since the trains are segmented it makes the waiting time for the trains on a multi-station trip to become higher. However, it seems like if too many of the trains were on multi-station routes, such as Train4 and Train6, then more people would be waiting longer times for their train to return to the starting location.