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Course: STMATH 381

Subject: Railway Design for China

Railway Design for China

1. Problem Description

Spring Festival travel rush in China is one of the largest human migrations on the planet. Nearly all Chinese people will go back to their hometown celebrating Chinese Lunar New year as cultural tradition, just like people in America will stay with their families during Christmas. According to CNN[2] reported about 3 billion trips will be made between January 21st and March 1st, 2.46 billion trips will be made by automobile, 413 million by train, and 73 million by airplane. Moreover, around 14.65 million babies were born in China[3], the growth in population further pressures the limitation of transportation. Thus, the Chinese government are planning to build some new high-speed railways between 15 cities in order to save time, and optimize transportation efficiency.

Figure 1. The map of China [1]

Those 15 cities are: Urumqi, Lhasa, Xining, Lanzhou, Yinchuan, Hohhot, Harbin, Beijing, Shanghai, Hangzhou, Changsha, Guangzhou, Hongkong, Chongqing, and Chengdu.

Since these cities are crossing different altitudes, the travelling time between cities are different even though with same distance. Like Lhasa is 3650 meters in elevation while Guangzhou is around 15 meters, and the time cost less from Lhasa to Guangzhou than from Guangzhou to Lhasa. I will consider this situation in the railway model.

2. The Mathematical Model

For the problem illustrated above, we will analyze Figure 2 using appropriate math model(s) and simulate the best paths of high-speed railways between those 15 cities using directed graph. So, assuming the cities as nodes and the railways between them as edges, the travel time be the weights.

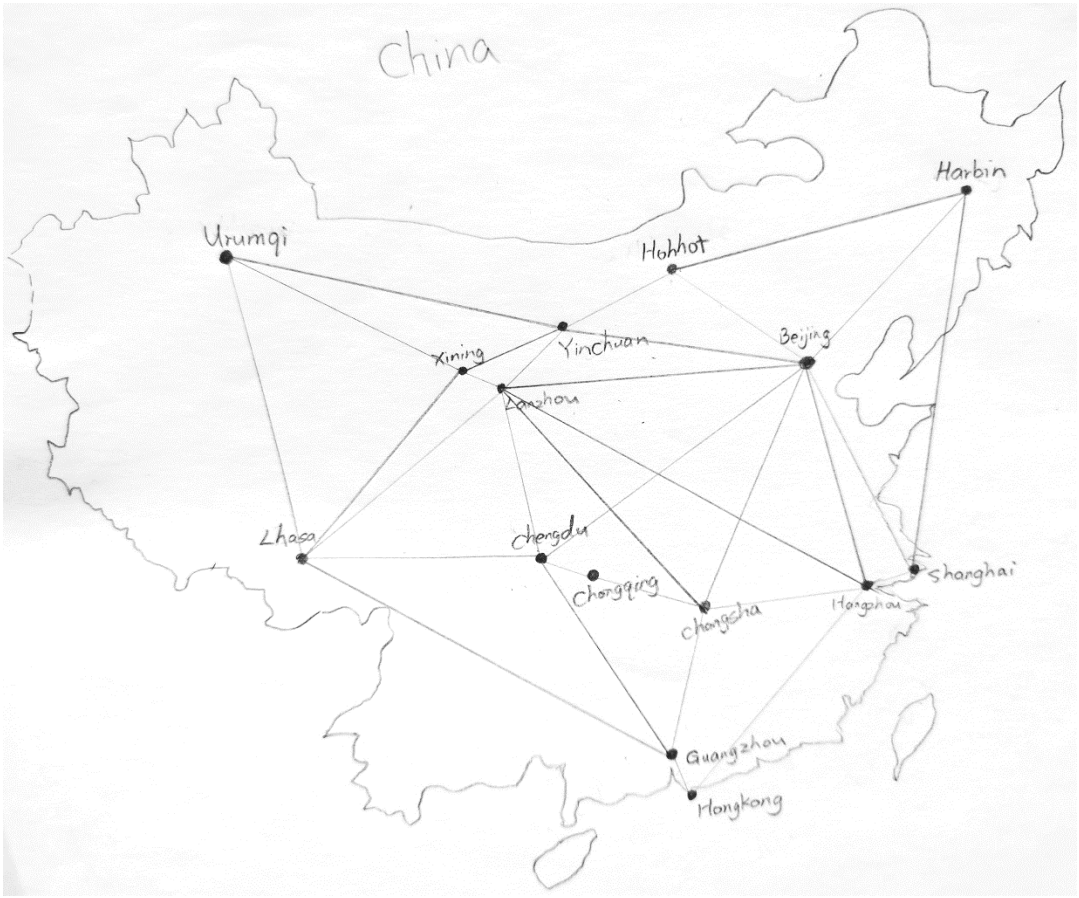

Figure 2. 15 cities with railways

After design for the rails, I initiate the time consuming on rails by using the shortest time in the travelling list provided by TRIP.COM [4]. The time needed for itself is always 0. The graph below is the time weighted in hours from cities to cities in columns. The data are collected based on the fastest time for high-

speed train can reach and tested. If two cities do not connect directly to each other, the time will be initiate as infinity.

Table 1 The shortest time (hour) cost between two connected cities [4]

Cities/Time(h)	Urumqi	Lhasa	Xining	Yinchuan	Hohhot	Harbin	Beijing	Shanghai	Hangzhou	Guangzhou	Hongkong	Changsha	Chengdu	Chongqing	Lanzhou
Urumqi	0	∞	9	21	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞
Lhasa	∞	0	21.5	∞	∞	∞	∞	∞	∞	53	∞	∞	36.5	∞	24
Xining	9.5	22	0	11.5	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	2.5
Yinchuan	21	∞	12.5	0	8	∞	11	∞	∞	∞	∞	∞	∞	∞	8
Hohhot	∞	∞	∞	8	0	26.5	2.5	∞	∞	∞	∞	∞	∞	∞	∞
Harbin	∞	∞	∞	∞	24.5	0	8.5	12.5	∞	∞	∞	∞	∞	∞	∞
Beijing	∞	∞	∞	12	2.5	7.5	0	4.5	4.5	∞	∞	6	8	∞	7.5
Shanghai	∞	∞	∞	∞	∞	12.5	5	0	1	∞	∞	∞	∞	∞	∞
Hangzhou	∞	∞	∞	∞	∞	∞	5	1	0	∞	∞	3.5	∞	∞	11
Guangzhou	∞	55	∞	∞	∞	∞	∞	∞	∞	0	1	2.5	8	∞	∞
Hongkong	∞	∞	∞	∞	∞	∞	∞	∞	∞	1	0	∞	∞	∞	∞
Changsha	∞	∞	∞	∞	∞	∞	6	∞	3.5	2.5	∞	0	∞	5.5	10
Chengdu	∞	36	∞	∞	∞	∞	8	∞	∞	8	∞	∞	0	1.5	7
Chongqing	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	5.5	1.5	0	∞
Lanzhou	∞	24.5	2	8	∞	∞	7.5	∞	11	∞	∞	8	7	∞	0

For finding the least time-consuming path between those cities using Branch and Bond Algorithms, we find the most obvious path from model as greedy path, counts the time cost for all edges. Try to connect with other edges and count the weights, if the weights cost over the greedy cost, stop it. Only find the path bellow the greedy cost and determine the quickest path between cities.

But 15 cities will have 15! railway path needs to be found. More cities will bring a lot more calculate works. Dijkstra's Algorithm will be using for helping to find the path. Set up a beginning node, and find the tentative weights from the node, and mark the cities visited, record the predecessor which the last node it passed with the shortest weights. Then pass to the next shortest weights can be reached city. When there is a node exists that always be the shortest, I can mark it as predecessor point of the next city. Link all the points with their predecessor until the destination and reverse the predecessor list to get the shortest path and get the total weights is called the Dijkstra's Algorithm.

Due to the altitude and difficulties, the railway between Urumqi and Lhasa cannot be built. Due to the policy and transportation restrict, the only direct city from Hongkong is Guangzhou, the planned railway between Hangzhou and Hongkong must be cancelled.

3. The Mathematical Solution

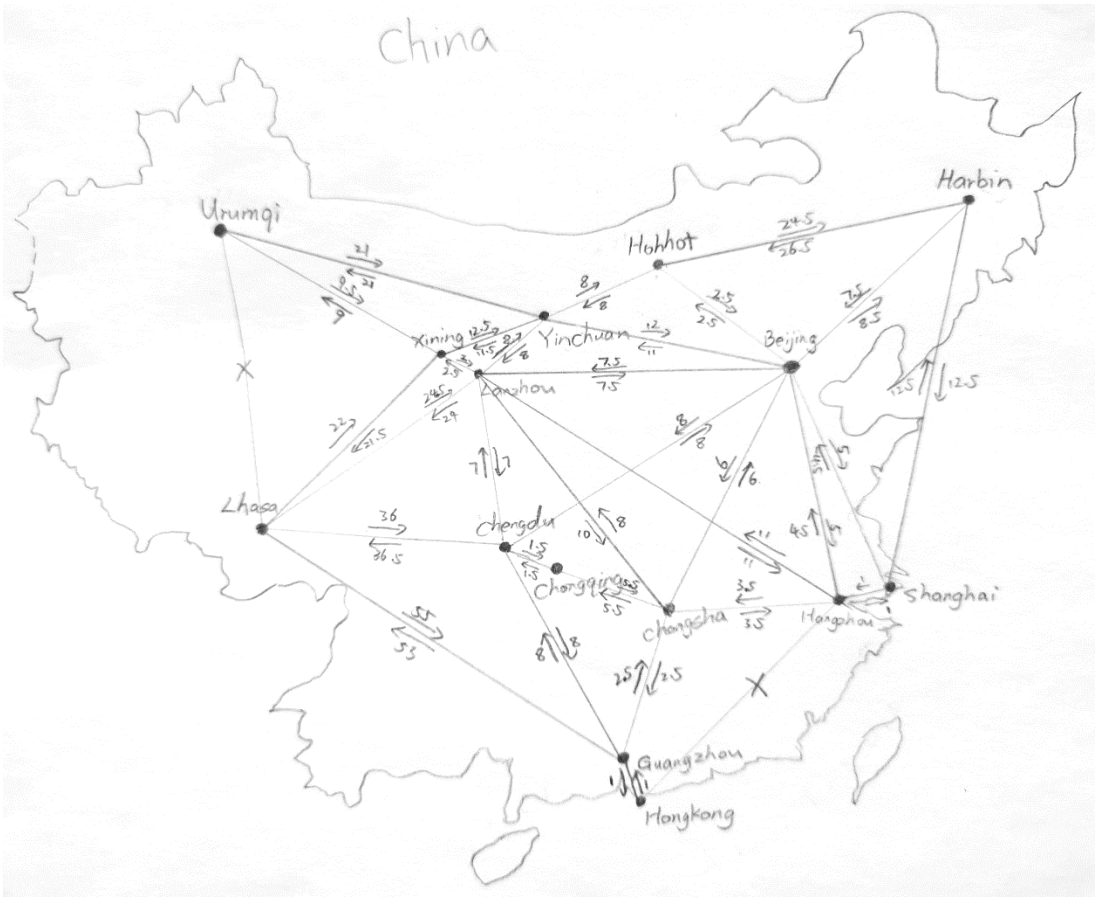

Figure 3 The directed graph between cities with time cost

After finding the shortest path with the directed, weighted graph in Figure 3 using the mathematical method described previously, the shortest path with cost of time are showing in Table 2. Notice, some path directed connected between cities cost even more than transferring from other cities like path directly from Lhasa to Lanzhou cost 24.5 hours while stop by Xining and go to Lanzhou only cost 24 hours. I use the shortest path covered the directed path with new cost of time and updated. The results are showing in Table 2.

Table 2 The shortest time (hours) cost between all cities

Cities/Time(h)	Urumqi	Lhasa	Xining	Yinchuan	Hohhot	Harbin	Beijing	Shanghai	Hangzhou	Guangzhou	Hongkong	Changsha	Chengdu	Chongqing	Lanzhou
Urumqi	0	31	9	21	29	39	31.5	23.5	22.5	24	25	21.5	18.5	20	11.5
Lhasa	30.5	0	21.5	32.5	40.5	40	31.5	36	35	36.5	37.5	34	36.5	33.5	24
Xining	9.5	22	0	11.5	18	17	9.5	14	13	14.5	15.5	12	9	10.5	2
Yinchuan	21	32	10	0	8	18	10.5	15.5	15.5	20.5	21.5	18	15	16.5	8
Hohhot	21.5	40	11.5	8	0	26.5	2.5	7.5	7.5	11	12	8.5	10.5	12	10
Harbin	27.5	39	17.5	18	24.5	0	8.5	12.5	12.5	16	17	13.5	15.5	17	15
Beijing	19	40.5	9.5	12	2.5	7.5	0	5	5	8.5	9.5	6	8	9.5	7.5
Shanghai	23.5	36	14	15.5	15.5	12.5	4.5	0	1	7	8	4.5	11.5	10	11
Hangzhou	22.5	35	13	15.5	7	13	4.5	1	0	6	7	3.5	10.5	9	11
Guangzhou	26.5	39	14.5	18.5	10.5	17	8.5	7	6	0	1	2.5	8	9.5	10.5
Hongkong	27.5	36	15.5	20	12	18	9.5	8	7	1	0	3.5	9	9	11.5
Changsha	21.5	38	12	16	8.5	14.5	6	4.5	3.5	2.5	3.5	0	7	5.5	10

Chengdu	18.5	31	9	15	10.5	16.5	8	11.5	10.5	8	9	7	0	1.5	7
Chongqing	19.5	32.5	10.5	16.5	11.5	18	9.5	10	9	8	9	5.5	1.5	0	8.5
Lanzhou	11.5	24	2	8	10	16	7.5	12	11	12.5	13.5	8	7	8.5	0

4. The Recommendation

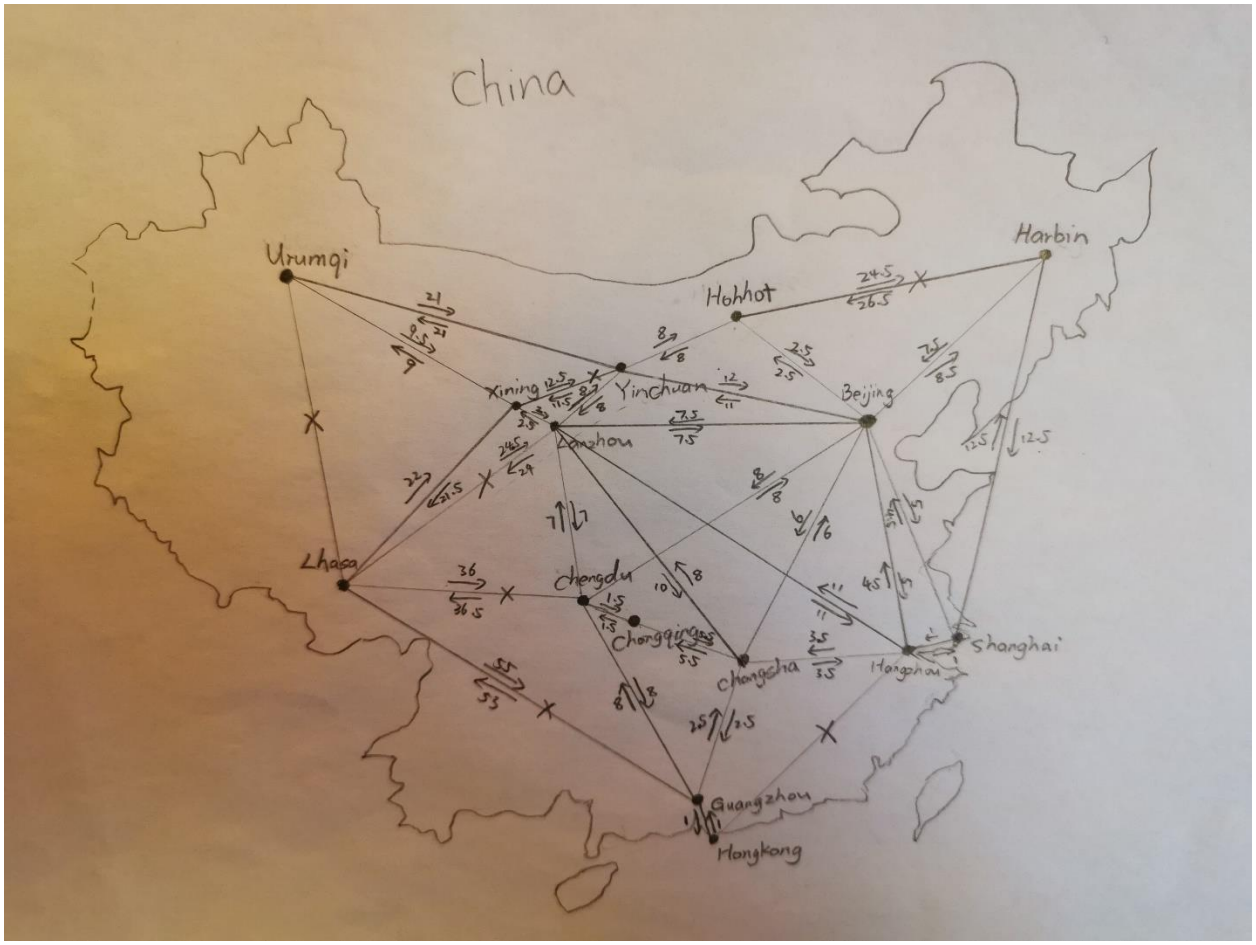

Figure 4 cut railways with results

By finding the shortest path, I will notice that path between Lhasa to Lanzhou, Lhasa to Guangzhou, Lhasa to Chengdu, Xining to Yinchuan, and Hohhot to Harbin are never being used because the substituted path cost less than them. I would not recommend building these paths and save the budget for those high demand routines.

Consider the time cost from Lhasa and Urumqi are extremely high, I would recommend building more airports in these cities instead of railways with high difficulty levels and cost. The huge differences between altitude and mountains becomes very challenging, using airplanes to conquer this problem would be the best results.

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