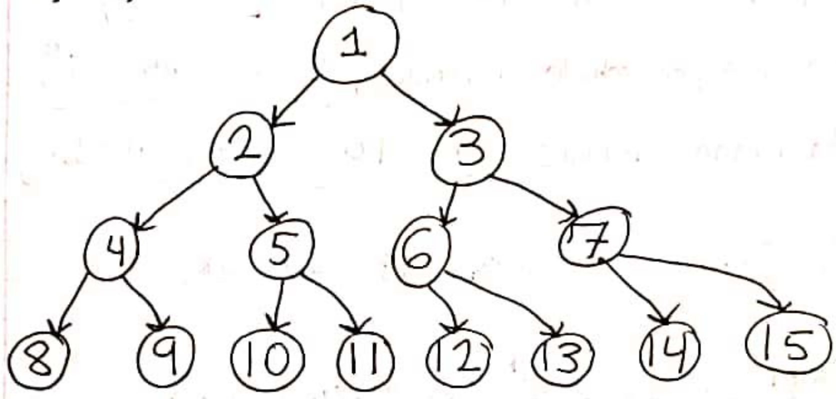
Project #1 Solutions

1) a)



b) Breadth-first search: 1→2→3→4→5→6→7→8→9→10→11

Depth-limited Search (3): 1→2→4→8→9→5→10→11

Iter Deep: 1 ; 1→2→3; 1→2→4→5→3→6→7;
1→2→4→8→9→5→10→11

c) Bidirectional search works well. Forward b=2, backward b=1

d) Yes. Backwards search from goal use floor operator as transition.

e) Binary Representation of Goal state, ignore Most Significant Bit
0 = Left, 1 = Right

ex: 8 → 1000 → 000 → Left, Left, Left
11 → 1011 → 011 → Left, Right, Right
14 → 1110 → 110 → Right, Right, Left

2) a) n vehicles, n^2 spaces, $(n^2)^n = \boxed{n^{2n} \text{ states}}$

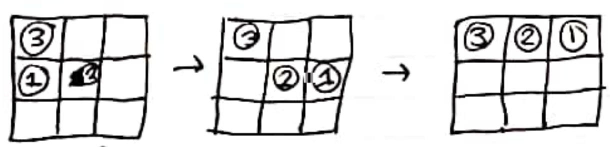
b) 5 actions per vehicle, n vehicles, $\boxed{\text{branching factor} = 5^n}$

c) Manhattan distance - $\boxed{h_i = |(n-i+1) - x_i| + |n - y_i|}$

d)

i) & ii) $\sum_{i=1}^{n} h_i \geq \max\{h_1, \dots, h_n\}$ (if ii) isn't admissible, i) isn't either)

Counter Example



$\max\{\cdot\} = 3$ but only took 2 moves

iii) • Define work, W, as the total distance moved by all vehicles for a given solution.

• At each step the most work that can be done is n

• So, the min # of steps to do work W is $\frac{W}{n}$

• Note that $W \geq \sum_{i=1}^{n} h_i \geq n \min\{h_1, \dots, h_n\}$

• So, $(\text{\# of steps}) \geq \frac{W}{n} \geq \frac{n \min\{h_1, \dots, h_n\}}{n} = \min\{h_1, \dots, h_n\}$

$$\min\{h_1, \dots, h_n\} \leq (\text{\# of steps})$$

So, $\boxed{\text{iii) is the only admissible heuristic}}$

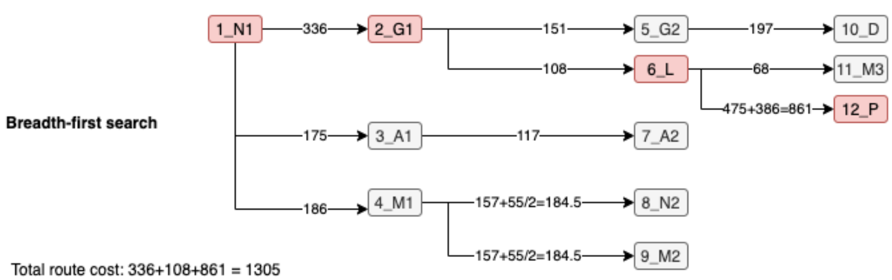
Question 3 (Student submission with one possible correct solution; formatted nicely... It is also OK to assume cities *are* added in the search tree again)

Note: for breadth-first search, depth-first search, and uniform-cost search, assume nodes (cities) that are already in the search tree won't be added again (as suggested by piazza post). Breadth-first and depth-first search are not necessarily optimal, because the search stops at the first solution. Uniform-cost search is optimal in theory, but in this case, since the nodes that are already in the search tree won't be added again, it might not necessarily reach to optimal solution due to the order when nodes are visited (luckily it is still optimal in this example). A* is optimal.

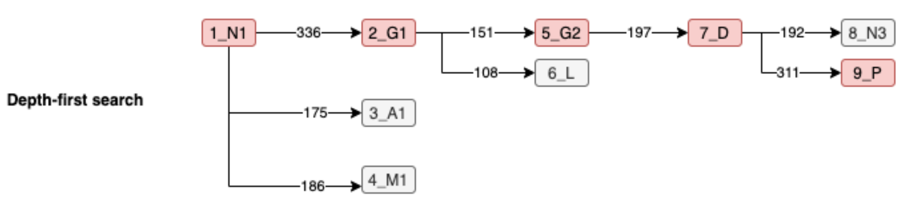
Heuristic used in this example:

City to Paris	
Nice	709
Toulouse	600
Grenoble	490
Aix	654
Marseille	676
Genève	436
Lyon	382
Macon	327
Clermont-Ferrand	354
Avignon	600
Dijon	272
Nimes	600
Montpellier	600

N1 = Nice, N2 = Nimes, N3 = Nancy, N4 = Narbonne,
G1 = Grenobl, G2 = Geneve, M1 = Marseile, M2 = Montpellier, M3 = Macon, A1 = Aix, A2 = Avignon

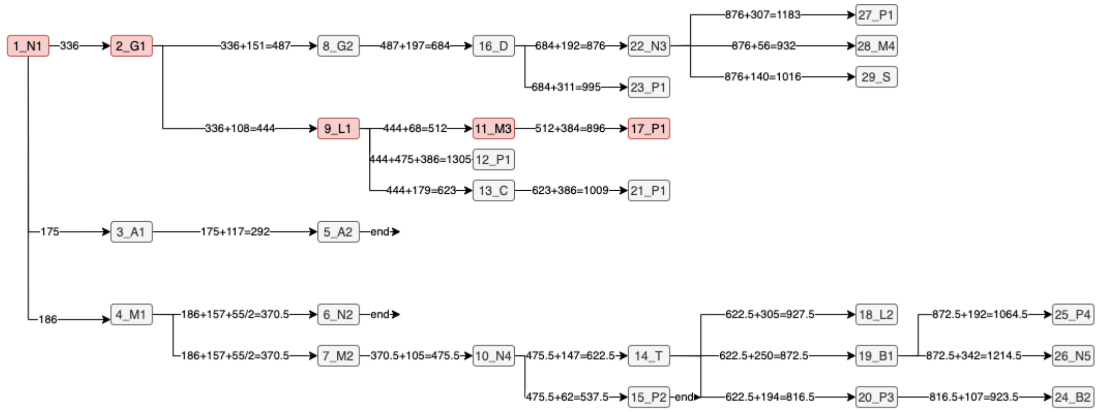


Total route cost: 336+108+861 = 1305



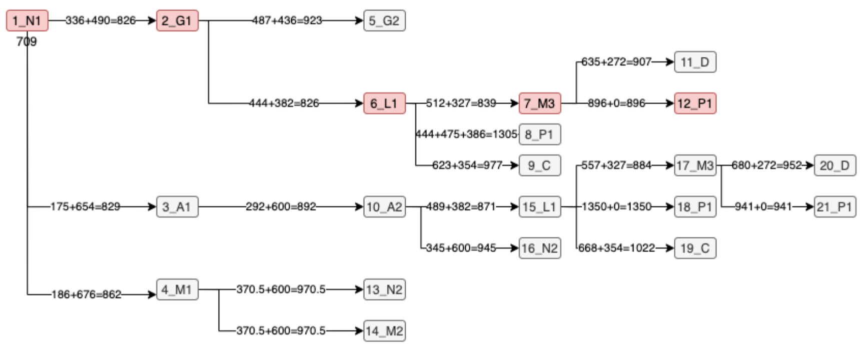
Total route cost: 336+151+197+311 = 995

Uniform cost search



Total route cost: 896

A* search



Total route cost: 896

A1 = Aix, A2 = Avignon,
B1 = Boreaus, B2 = Bayunne
G1 = Grenobl, G2 = Geneve,
L1 = Lyon, L2 = Limoges
M1 = Marseile, M2 = Montpellier, M3 = Macon, M4 = Metz
N1 = Nice, N2 = Nimes, N3 = Nancy, N4 = Narbonne, N5 = Nantes
P1 = Paris, P2 = Perpignan, P3 = Pau, P4 = Paitiers

A_1 = Aix
A_2 = Avignon

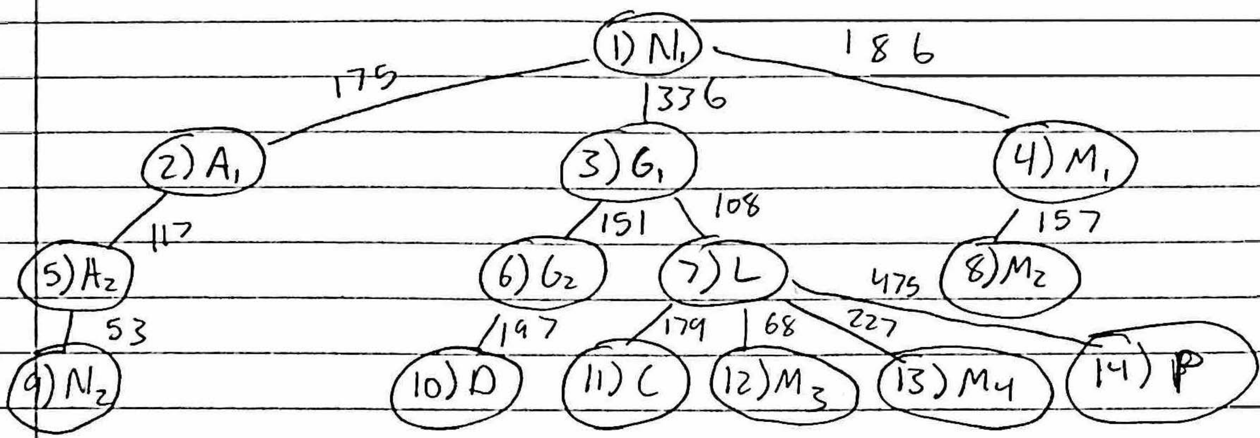
G_1 = Grenoble
G_2 = Geneva

M_1 = Marseille
M_2 = Montpellier
M_3 = Macon
M_4 = Montlucon

N_1 = Nice
N_2 = Nimes

Q3 Solution: Version 2

3 a) Breadth first search



Path: Nice -> Grenoble -> Lyon -> Paris

cost = 336 + 108 + 475 = 919km

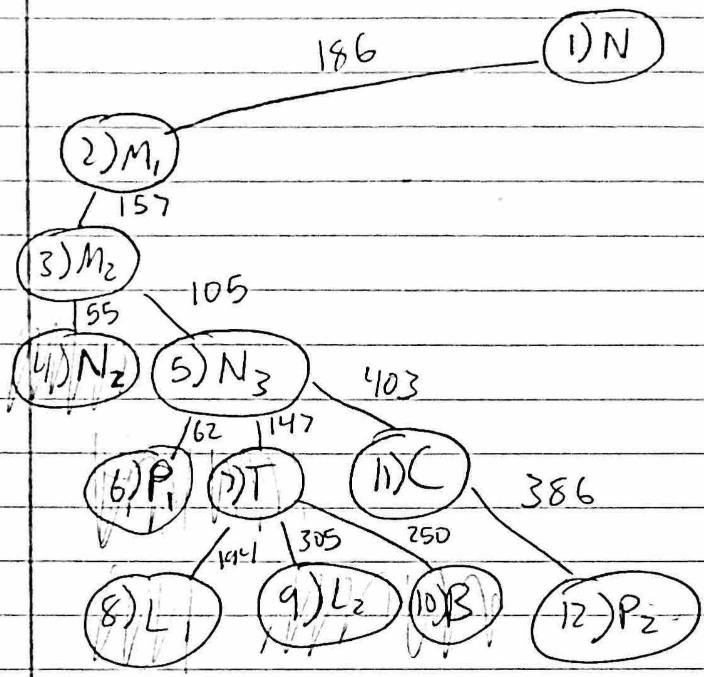
Solution is not optimal

M_1 = Marseille N_1 = Nice P_1 = Perpignan L_1 = Limoges

M_2 = Montpellier N_2 = Nimes P_2 = Paris L_2 = Lourdes

N_3 = Narbonne

3 b) Depth first search: Depth limit = 5



Path: Nice -> Marseille -> Montpellier -> Narbonne -> Clermont-Ferrand -> Paris

Cost: 186 + 157 + 105 + 403 + 386 = 1237 km

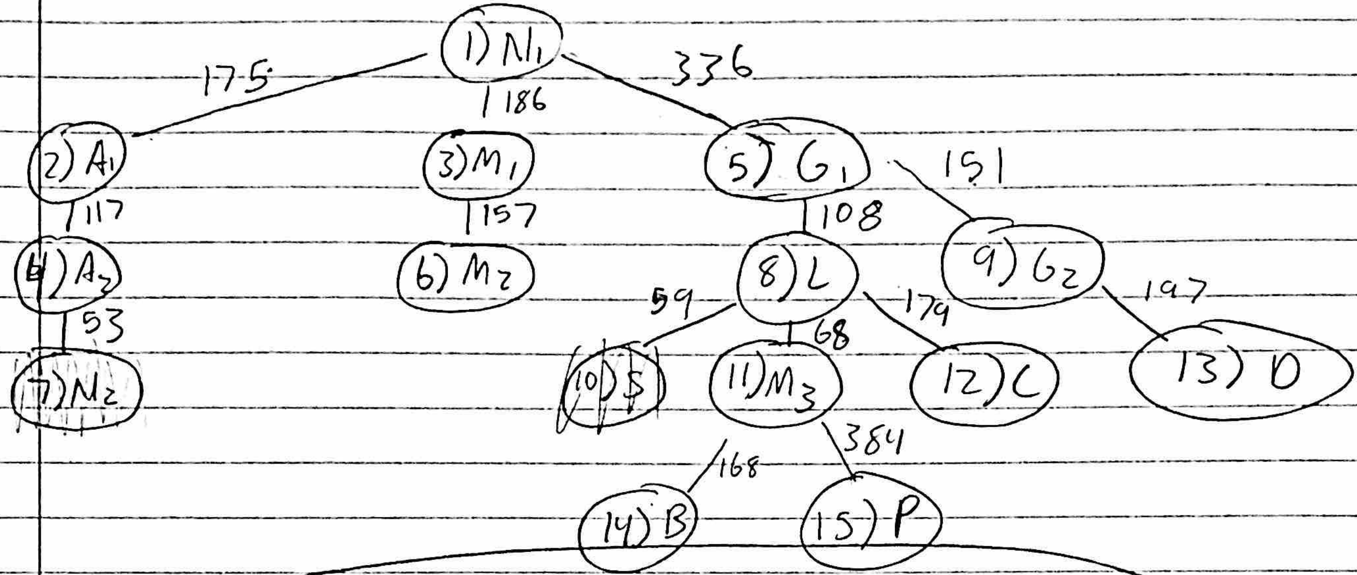
Solution is not optimal

M_1 = Marseille A_1 = Aix N_1 = Nice G_1 = Grenoble

M_2 = Montpellier A_2 = Avignon N_2 = Nimes G_2 = Geneva

M_3 = Macon

3 c) Uniform cost search



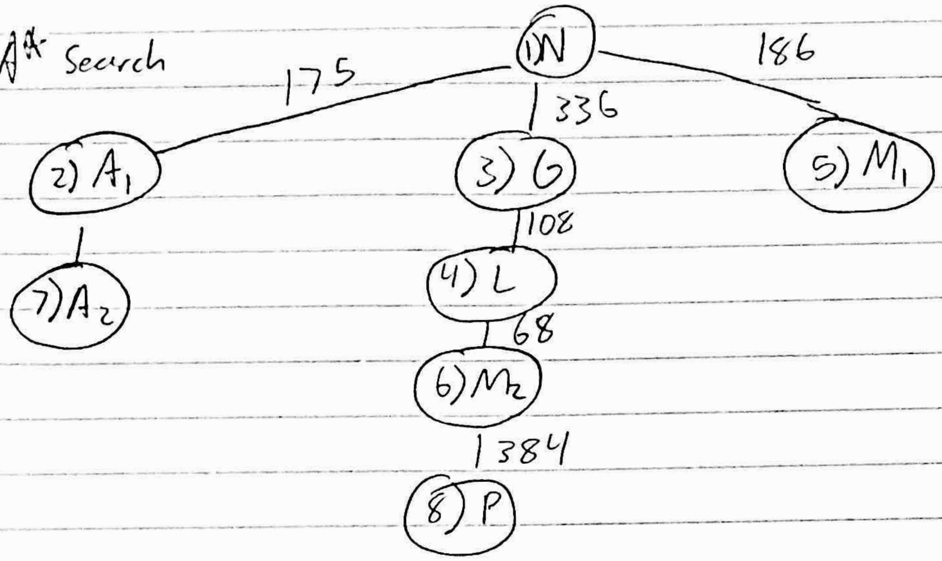
Path: Nice -> Grenoble -> Lyon -> Macon -> Paris

Cost = 336 + 108 + 68 + 384 = 896

solution is optimal

A_1 = Aix M_1 = Marseille
A_2 = Avignon M_2 = Macon

3) d) A* Search



Path: Nice -> Grenoble -> Lyon -> Macon -> Paris

Cost = 336 + 108 + 68 + 384 = 896 km

This is the optimal path

Straight line
Distance to Paris

Grenoble : 481 km
Aix : 638 km
Marseille : 660 km
Avignon : 577 km
Lyon : 391 km
Geneva : 897 km
Macon : 339 km
St-Etienne : 409 km