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The Great American Road Trip

21-393 Operations Research II

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Introduction/Problem Overview

Our group has decided to visit a large number of the major cities in the continental United States. We have pre-determined the 36 cities which we will be visiting: New York City, NY; Niagara Falls, NY; Boston, MA; Washington, DC; Baltimore, MD; Atlanta, GA; Philadelphia, PA; Charlotte, NC; Greensboro, NC; Orlando, FL; Chicago, IL; St. Louis, MO; Madison, WI; Minnesota, MN; Nashville, TN; Oklahoma City, OK; San Antonio, TX; Detroit, MI; New Orleans, LA; Dallas, TX; Phoenix, AZ; Salt Lake City, UT; Denver, CO; Boulder, CO; Flagstaff, AZ; Sedona, AZ; Albuquerque, NM; Yellowstone, WY; San Francisco, CA; Las Vegas, NV; Portland, OR; Seattle, WA; Los Angeles, CA; Reno, NV; San Diego, CA; and Spokane, WA. All four of us will start from Pittsburgh, and depart in different directions to make sure we visit every city. In each city, there are different landmarks and attractions that we want to see (appendix A). Once all of the attractions have been visited, we consider the city to be visited, and move on to the next city. Each city will be visited exactly once, so only one person will visit each city. Lastly, we want to minimize the total time needed to visit all of the cities and have everyone return to Pittsburgh.

Details

Time Constraints:

As stated before, we have 36 cities we want to visit. At each city, we have a number of attractions and landmarks to see before we can leave. Each of these attractions require a certain amount of time, thus each city requires a different amount of time needed to visit. There are 12 hours available for each day, and a person is either traveling to or visiting a city on each day; they are not permitted a combination of the two. For example, if a person spends 6 hours traveling to a city, they cannot spend the remainder of the available time visiting landmarks. This way, our model iterates each timestep as one day. Finally, if traveling between cities requires more than one day, we assume that the person finds a hotel at the end of the 12 hour period.

Visiting Cities:

Since we are visiting multiple locations in each city, we must solve a simple network for each city. For each of the cities, we used the traveling salesperson algorithm to generate optimal solutions for visiting all of the landmarks in the minimum amount of time. (appendix D)

Other Assumptions:

First and foremost, we are not taking the total cost of the trip into consideration. In this problem, we focus on time, and assume that each person budgets enough money to successfully complete their portion of the trip. Also, we are assuming a constant travel speed of 60 miles per hour, and not explicitly accounting for other complicating factors, such as heavy traffic or bad weather. However, given our time constraints (not always using all 12 hours each

day), that extra time can be used to account for any traveling complications one could experience.

The Model:

The multi person traveling salesperson problem is a variant of the traveling salesperson problem. This section will discuss the basic solutions to the one person traveling salesperson problem and we will utilize these techniques to formulate solutions to the multi person traveling salesperson problem. The traveling salesperson problem can be formulated as an assignment based integer linear programming problem with the following criteria:

Graph $G = (V, E)$ where $|V| = n$ and each edge $(i, j) \in E$ has an associated cost $c_{i,j}$. We define a binary value $x_{i,j}$ for each edge $(i, j) \in E$ where $x_{i,j}$ is 1 if the edge (i, j) is in the path.

Objective:

$$\min \sum_{(i,j)\in E} c_{i,j}x_{i,j}$$

Constraints:

Exactly 1 salespersons is leaving the starting city.

$$\sum_{j\in V,(0,j)\in E} x_{0,j} = 1$$

Exactly 1 salespersons is returning to the starting city.

$$\sum_{j\in V,(j,0)\in E} x_{j,0} = 1$$

Exactly one salesperson is entering a city.

$$\sum_{i\in V,(i,j)\in E} x_{i,j} = 1 \ \ \forall j \in V$$

Exactly one salesperson is leaving a city.

$$\sum_{j\in V,(i,j)\in E} x_{i,j} = 1 \ \ \forall i \in V$$

Let S be any collection of cities that is not the entire set of cities, and let T denote the rest of the cities. To remove subtours through S, we add the condition that the sum of the variables corresponding to the edges from S to T must be at least 2.

$$\sum(x_{i,j} : \text{Exactly 1 of } i \text{ and } j \in S) \geq 2$$

NP-Hardness:

The traveling salesperson problem is NP-Hard because it can be reduced in polynomial time to the Hamiltonian cycle problem which is proven to be NP-Complete and verifying solutions can also be done in polynomial time. Because this problem is NP-Hard, finding an optimal solution is very difficult and many optimization techniques can be applied to reduce the computation cost each with respective trade offs.

Solutions

Brute Force:

Given a graph G(V,E), a simple brute force approach can be categorized using the following pseudocode below which just computes all possible paths. This algorithm runs in O(n!) time.

```
def TSP(G):
  best_perm = None
  min_cost = Infinity

  for each permutation of V(G):
    tmp = cost(permutation)
    if (tmp < min_cost)
      best_perm = permutation
      min_cost = tmp

  return (best_perm, min_cost)
```

Branch & Bound:

A better approach compared to checking all possible paths is to prune off paths that have a higher cost than what we have currently seen. An added benefit of this algorithm is that it is easily parallelizable and has a faster asymptotic run time of O(2^n).

```
def find_paths(node, cities, path, distance):
    #add the current city
    path.append(node)
    if len(path) > 1:
        # index -2 because we just added index -1
        distance += cities[path[-2]][node]
    # stop exploring if what we have so far is not optimal
    if distance > min_distance:
        return
```

```
    if (len(cities) == len(path)) and
(cities[path[-1]].contains(path[0])):
        path.append(path[0])
        distance += cities[path[-2]][path[0]]
         if distance < min_distance:
              min_distance = distance
             min_path = path
        return
    for city in cities:
        if (city not in path) and (cities[city].contains(node)):
            find_paths(city, dict(cities), list(path), distance)
```

Multi Traveling Salesperson Solution Attempts

In this section, we apply a few techniques that were not explored in the one person traveling salesperson problem. Similar to the one person traveling salesperson problem, we can formulate the multi person traveling salesperson problem as an assignment based integer linear programming problem:

Graph $G = (V, E)$ where $|V| = n$ and each edge $(i, j) \in E$ has an associated cost $c_{i,j}$. We define a binary value $x_{i,j}$ for each edge $(i, j) \in E$ where $x_{i,j}$ is 1 if the edge (i, j) is in the path.

Objective:

$$\min \sum_{(i,j)\in E} c_{i,j}x_{i,j}$$

Constraints:

Exactly m salespersons is leaving the starting city.

$$\sum_{j\in V,(0,j)\in E} x_{0,j} = m$$

Exactly m salespersons is returning to the starting city.

$$\sum_{j\in V,(j,0)\in E} x_{j,0} = m$$

Exactly one salesperson is entering a city.

$$\sum_{i\in V,(i,j)\in E} x_{i,j} = 1 \ \ \forall j \in V$$

Exactly one salesperson is leaving a city.

$$\sum_{j\in V,(i,j)\in E} x_{i,j} = 1 \ \ \forall i \in V$$

Let S be any collection of cities that is not the entire set of cities, and let T denote the rest of the cities. To remove subtours through S, we add the condition that the sum of the variables corresponding to the edges from S to T must be at least 2.

$$\sum(x_{i,j} : \text{Exactly 1 of } i \text{ and } j \in S) \geq 2$$

Greedy Algorithm:

What we have discussed in the previous section are exact algorithms, algorithms that will return the optimal solution exactly; however, there is a class of algorithms that are approximate. Approximate algorithms will not necessarily return the optimal solution, but as the name suggests, an approximation, and usually can do so with a significantly faster asymptotic run time complexity. The greedy algorithm is an example of such approximate algorithms where each traveling salesperson simply travels to the closest point from it at each time step. The greedy algorithm for the multiple traveling salesperson runs in O(n^2) which is a polynomial time algorithm.

```
def find_paths():
      routes = []
      for each ith salesperson:
            routes.append([ith_closest_city])
            cities = cities - [ith_closest_city]
      for each ith path:
            curr_city = routes[i][-1]
            routes[i][-1].append(closest_city_to_curr)
            cities = cities - [closest_city_to_curr]
```

The greedy algorithm does not return an exact solution but it can be used to approximate solutions, in particular it can be used as a starting minimum cost for branch and bound algorithms.

Swapping Algorithm:

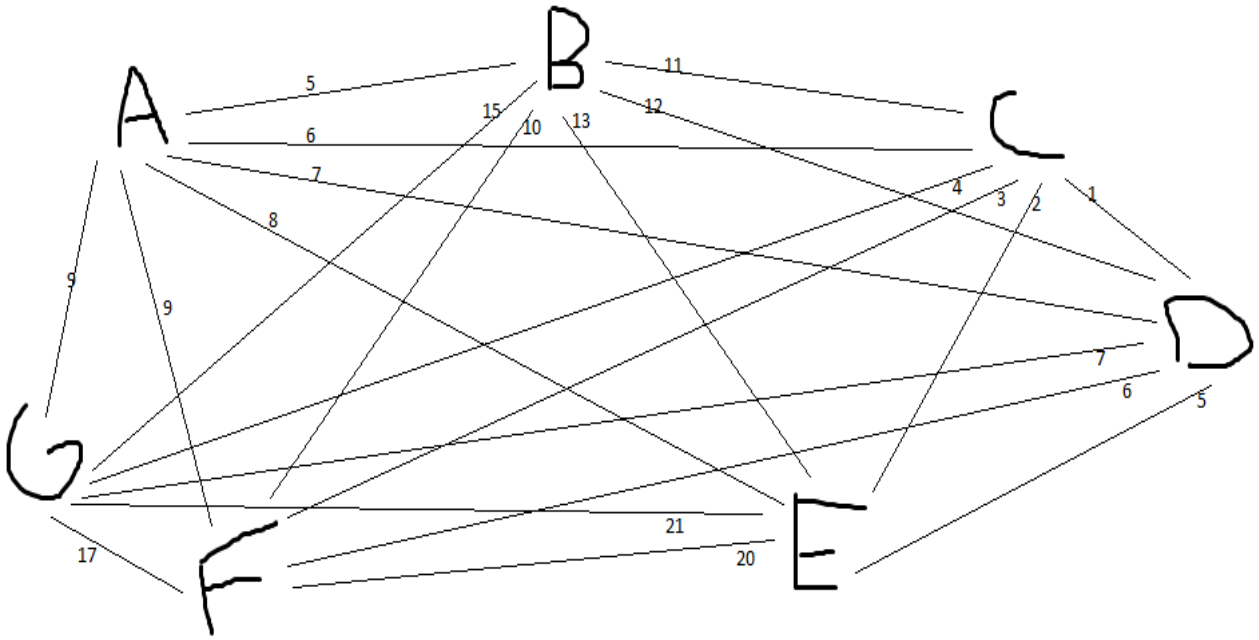
Another approximation algorithm is the swapping algorithm where you continually swap 2 random edges until you have a more optimal solution. This in practice yields a better solution

than the previously mentioned greedy algorithm and also avoids the combinatorial overhead of calculating all possible solutions in an exact algorithm. The swapping algorithm could potentially yield an exact optimal solution but since the edges you choose are random, it could also potentially take longer to find the exact optimal solution.

```
def swap(T): #T = some starting tour
    changed = False
    do:
        T' = swapEdges(T)
        if cost(T') < cost(T)
           T = T'
           changed = True
    while !changed
    return T
```

Results

In summary, there exist a handful of methods for solving the stated problem. Our analysis emphasized the advantages and disadvantages of using a particular model to solve the research problem. Specifically, we observe a tradeoff between speed and accuracy. In order to arrive at an optimal solution, we consider both exact and approximation algorithms. Approximation algorithms such as the greedy and swapping algorithms terminate at a non-optimal solution, but they are significantly more efficient. We can demonstrate this tradeoff with a simplified example:



Consider 4 people denoted by α, β, γ, and δ. With an initial state of city A, we can use the TSP algorithm to get an optimal solution as seen below:

α: A -> B (5)

β: A -> D (7), D -> C (1), C -> E (2)
γ: A -> F (9)
δ: A -> G (9)

The time it takes to visit all nodes is the time of the longest path, which is β at 10 time steps.

Now, we can use the Greedy algorithm and compare to the result of the previous algorithm.

α: A -> B (5)
β: A -> C (6), C -> F (3)
γ: A -> D (7), D -> G (6)
δ: A -> E (8)

The time it takes to visit all nodes is the time of the longest path which is γ at 13 time steps.

This simulation demonstrates that while the (multi-person) TSP results in a better solution, the greedy algorithm is only 30% worse. This loss in solution optimality is generally prefered as the number of cities and number of participants increase, since time complexity of the (multi-person) TSP is much longer than that of the greedy algorithm.

Solution:

Note: parentheses denote (# miles traveled, # days elapsed)

Person A:

Pittsburgh (0, 0) -> Niagara Falls (238, 2) -> Boston (646, 4) -> New York City (836, 6)-> Philadelphia (917, 8) -> Nashville (1600, 10) -> Dallas (2216, 12) -> Sedona (3086, 16) -> Phoenix (3186, 19) -> San Diego (3485, 22) -> San Francisco (3943, 24) -> Pittsburgh (6518, 28)

Person B:

Pittsburgh (0, 0) -> Washington, D.C (238, 2) -> Charlotte (568, 5) -> Orlando (1031, 11) -> New Orleans (1564, 13) -> San Antonio (2071, 16) -> Albuquerque (2686, 18) -> Salt Lake City (3171, 21) -> Portland (3806, 23) -> Pittsburgh (6373, 27)

Person C:

Pittsburgh (0, 0) -> Baltimore (240, 3) -> Greensboro (522, 5) -> Atlanta (828, 8) -> St. Louis (1295, 11) -> Oklahoma City (1754, 13) -> Denver (2258, 16) -> Flagstaff (2739, 19) -> Las Vegas (2947, 21) -> Los Angeles (3172, 24) -> Pittsburgh (5599, 28)

Person D:

Pittsburgh (0, 0) -> Detroit (286, 2) -> Chicago (525, 6) -> Madison (647, 9) -> Minneapolis (1008, 11) -> Boulder (1712, 14) -> Yellowstone (2120, 17) -> Spokane (2516, 19) -> Seattle (2744, 22) -> Reno (3316, 25) -> Pittsburgh (5674, 29)

Conclusion

In conclusion, it took 29 days to visit all of the required locations. Collectively, the group traveled 24,164 miles, or 6,041 miles per person. As seen in our analysis, a combination of fundamental linear programming algorithms can be applied to solve more complex problems. Our work also demonstrates the need to consider practical trade offs when choosing a model, such as time and precision. In the future, we may consider adding more constraints and possibly minimizing cost or allowing for complex modes of transportation. Our model serves as a foundation that could be expanded in many direction to provide a great deal of practical use.

Appendix A: Cities, their respective attractions, time spent in each one

Eastern

1. New York City, NY - 1 day
    a. Times Square
    b. Central Park
    c. Grand Central Station
    d. South Street Pier
2. Niagara Falls, NY - 1 day
    a. Goat Island
    b. Maid of the Mist
    c. Prospect Point
3. Boston, MA - 1 day
    a. Museum of Fine Arts
    b. Freedom Trail
    c. USS Constitution
4. Washington, DC - 1 day
    a. White House
    b. National Mall
    c. Smithsonian National Zoological Park
5. Baltimore, MD - 2 days
    a. National Aquarium
    b. Fort McHenry
    c. Maryland Science Center
6. Atlanta, GA - 2 days
    a. Six Flags Over Georgia
    b. World of Coca-Cola
    c. Centennial Olympic Park
7. Philadelphia, PA - 1 day
    a. Philadelphia Museum of Art
    b. Liberty Bell
    c. Independence Hall
8. Charlotte, NC - 2 days
    a. NASCAR Hall of Fame
    b. U.S. National Whitewater Center
    c. Carolinas Aviation Museum
9. Greensboro, NC - 1 day
    a. Hagan Stone Park

b. Blandwood Mansion and Gardens

10. Orlando, FL - 5 days
    a. Epcot
    b. Magic Kingdom
    c. Animal Kingdom
    d. Hollywood Studios
    e. DisneyQuest

Central

11. Chicago, IL - 3 days
    a. Navy Pier
    b. Willis Tower
    c. China Town
    d. Magnificent Mile - Michigan Ave
    e. Botanical Gardens
    f. Art Museum
    g. Giordanos
    h. Museum of Science and Industry
12. St. Louis, MO - 2 days
    a. Gateway Arch
    b. Six Flags
    c. The Zoo
    d. Forest Park
13. Madison, WI - 2 days
    a. State Capitol
    b. Cascade Mountain Ski & Snowboard Area
    c. Ehlenbach's Cheese Chalet Inc
14. Minneapolis, MN - 1 day
    a. Mall of America
15. Nashville, TN - 1 day
    a. Country Music Hall of Fame
    b. BrigdeStone Arena
    c. Parthenon
16. Oklahoma City, OK - 1 day
    a. White Water Bay
    b. OK City National Memorial
    c. Newcastle Casino
17. San Antonio, TX - 2 days
    a. The River Walk
    b. Seaworld
    c. Alamo Museum
18. Detroit, MI - 1 day
    a. Palace of Auburn Hills

b. Ford Museum
c. Greek Town

19. New Orleans, LA - 1 day
    a. Bourbon Street
    b. Villalobos Pit Bull Rescue Center
20. Dallas, TX - 1 day
    a. Sixth Floor Museum
    b. Dallas Children's Theater
    c. Medieval Times Dinner & Tournament

Mountain

21. Phoenix, AZ - 2 days
    a. Musical Instruments Museum
    b. Hot Air Balloon
    c. Desert Botanical Garden
    d. Heard Museum
22. Salt Lake City, UT - 2 days
    a. Clark Museum
    b. Family History Library
    c. Mormon Tabernacle Choir
    d. Natural History Museum of Utah
    e. FamilySearch Center
23. Denver, CO - 2 days
    a. Mount Evans
    b. Denver Museum of Nature and Science
    c. Denver Botanic Gardens
    d. Coors Field
24. Boulder, CO - 2 days
    a. Flatirons
    b. Chautauqua
    c. Eldorado Canyon
    d. Flagstaff Mountain
25. Flagstaff, AZ - 2 days
    a. Hitchin Post Stables
    b. Coconino National Forest
    c. Wupatki National Monument
    d. Museum of Northern Arizona
26. Sedona, AZ - 2 days
    a. Cathedral Rock
    b. Oak Creek Canyon
    c. Broken Arrow Trail
    d. Bell Rock
27. Albuquerque, NM - 1 day

a. Sandia Peak Tramway
b. Indian Pueblo Cultural Center
c. Rio Grande Zoo

28. Yellowstone, WY - 2 days
    a. Geyser
    b. Hayden Valley
    c. Mammoth Hot Springs
    d. Iamar Valley

Pacific

29. San Francisco, CA - 1 day
    a. Union Square
    b. Golden State Park
    c. Dolores Park
    d. Twin Peaks
30. Las Vegas, NV - 1 day
    a. Fremont Street
    b. Adventuredome
    c. Red Rock Canyon
    d. Las Vegas Motor Speedway
31. Portland, OR - 1 day
    a. Oregon Zoo
    b. Star Theater
    c. Portland Japanese Garden
    d. Crystal Ballroom
32. Seattle, WA - 2 days
    a. Space Needle
    b. Seattle Aquarium
    c. Safeco Field
    d. Seattle Art Musuem
33. Los Angeles, CA - 2 days
    a. LACMA
    b. Hollywood
    c. Beverly Hills
    d. Venice Beach
34. Reno, NV - 2 days
    a. Lake Tahoe
    b. Hidden Valley
    c. Squaw Valley
    d. Fallen Leaf Lake
35. San Diego, CA - 2 days
    a. San Diego Zoo
    b. Balboa Park

    c. Petco Park
    d. SeaWorld San Diego
36. Spokane, WA - 1 day
    a. Riverfront Park
    b. Spokane Civic Theater
    c. Spokane Falls
    d. Avista Stadium

Appendix B: Distances between all cities

Pittsburgh, PA -> New York City, NY | 370
Pittsburgh, PA -> Niagara Falls, NY | 238
Pittsburgh, PA -> Boston, MA | 572
Pittsburgh, PA -> Washington, DC | 238
Pittsburgh, PA -> Baltimore, MD | 240
Pittsburgh, PA -> Atlanta, GA | 685
Pittsburgh, PA -> Philadelphia, PA | 297
Pittsburgh, PA -> Charlotte, NC | 448
Pittsburgh, PA -> Greensboro, NC | 428
Pittsburgh, PA -> Orlando, FL | 971
Pittsburgh, PA -> Chicago, IL | 461
Pittsburgh, PA -> St. Louis, MO | 602
Pittsburgh, PA -> Madison, WI | 607
Pittsburgh, PA -> Minneapolis, MN | 868
Pittsburgh, PA -> Nashville, TN | 561
Pittsburgh, PA -> Oklahoma City, OK | 1100
Pittsburgh, PA -> San Antonio, TX | 1497
Pittsburgh, PA -> Detroit, MI | 286
Pittsburgh, PA -> New Orleans, LA | 1093
Pittsburgh, PA -> Dallas, TX | 1222
Pittsburgh, PA -> Phoenix, AZ | 2058
Pittsburgh, PA -> Salt Lake City, UT | 1845
Pittsburgh, PA -> Denver, CO | 1450
Pittsburgh, PA -> Boulder, CO | 1465
Pittsburgh, PA -> Flagstaff, AZ | 1962
Pittsburgh, PA -> Sedona, AZ | 1990
Pittsburgh, PA -> Albuquerque, NM | 1639
Pittsburgh, PA -> Yellowstone, WY | 1876
Pittsburgh, PA -> San Francisco, CA | 2575
Pittsburgh, PA -> Las Vegas, NV | 2199
Pittsburgh, PA -> Portland, OR | 2567
Pittsburgh, PA -> Seattle, WA | 2523
Pittsburgh, PA -> Los Angeles, CA | 2427
Pittsburgh, PA -> Reno, NV | 2358
Pittsburgh, PA -> San Diego, CA | 2411
Pittsburgh, PA -> Spokane, WA | 2245
New York City, NY -> Niagara Falls, NY | 307
New York City, NY -> Boston, MA | 190
New York City, NY -> Washington, DC | 204

New York City, NY -> Baltimore, MD | 169
New York City, NY -> Atlanta, GA | 746
New York City, NY -> Philadelphia, PA | 81
New York City, NY -> Charlotte, NC | 531
New York City, NY -> Greensboro, NC | 448
New York City, NY -> Orlando, FL | 939
New York City, NY -> Chicago, IL | 711
New York City, NY -> St. Louis, MO | 872
New York City, NY -> Madison, WI | 807
New York City, NY -> Minneapolis, MN | 1109
New York City, NY -> Nashville, TN | 759
New York City, NY -> Oklahoma City, OK | 1324
New York City, NY -> San Antonio, TX | 1581
New York City, NY -> Detroit, MI | 481
New York City, NY -> New Orleans, LA | 1168
New York City, NY -> Dallas, TX | 1371
New York City, NY -> Phoenix, AZ | 2140
New York City, NY -> Salt Lake City, UT | 1968
New York City, NY -> Denver, CO | 1627
New York City, NY -> Boulder, CO | 1638
New York City, NY -> Flagstaff, AZ | 2069
New York City, NY -> Sedona, AZ | 2084
New York City, NY -> Albuquerque, NM | 1808
New York City, NY -> Yellowstone, WY | 1863
New York City, NY -> San Francisco, CA | 2566
New York City, NY -> Las Vegas, NV | 2231
New York City, NY -> Portland, OR | 2439
New York City, NY -> Seattle, WA | 2402
New York City, NY -> Los Angeles, CA | 2446
New York City, NY -> Reno, NV | 2394
New York City, NY -> San Diego, CA | 2428
New York City, NY -> Spokane, WA | 2174
Niagara Falls, NY -> Boston, MA | 408
Niagara Falls, NY -> Washington, DC | 308
Niagara Falls, NY -> Baltimore, MD | 292
Niagara Falls, NY -> Atlanta, GA | 707
Niagara Falls, NY -> Philadelphia, PA | 295
Niagara Falls, NY -> Charlotte, NC | 552
Niagara Falls, NY -> Greensboro, NC | 487
Niagara Falls, NY -> Orlando, FL | 1014
Niagara Falls, NY -> Chicago, IL | 446
Niagara Falls, NY -> St. Louis, MO | 659
Niagara Falls, NY -> Madison, WI | 523

Niagara Falls, NY -> Minneapolis, MN | 804
Niagara Falls, NY -> Nashville, TN | 631
Niagara Falls, NY -> Oklahoma City, OK | 1117
Niagara Falls, NY -> San Antonio, TX | 1431
Niagara Falls, NY -> Detroit, MI | 210
Niagara Falls, NY -> New Orleans, LA | 1093
Niagara Falls, NY -> Dallas, TX | 1198
Niagara Falls, NY -> Phoenix, AZ | 1897
Niagara Falls, NY -> Salt Lake City, UT | 1686
Niagara Falls, NY -> Denver, CO | 1359
Niagara Falls, NY -> Boulder, CO | 1367
Niagara Falls, NY -> Flagstaff, AZ | 1817
Niagara Falls, NY -> Sedona, AZ | 1834
Niagara Falls, NY -> Albuquerque, NM | 1569
Niagara Falls, NY -> Yellowstone, WY | 1567
Niagara Falls, NY -> San Francisco, CA | 2285
Niagara Falls, NY -> Las Vegas, NV | 1967
Niagara Falls, NY -> Portland, OR | 2137
Niagara Falls, NY -> Seattle, WA | 2097
Niagara Falls, NY -> Los Angeles, CA | 2186
Niagara Falls, NY -> Reno, NV | 2109
Niagara Falls, NY -> San Diego, CA | 2177
Niagara Falls, NY -> Spokane, WA | 1870
Boston, MA -> Washington, DC | 394
Boston, MA -> Baltimore, MD | 359
Boston, MA -> Atlanta, GA | 936
Boston, MA -> Philadelphia, PA | 271
Boston, MA -> Charlotte, NC | 720
Boston, MA -> Greensboro, NC | 637
Boston, MA -> Orlando, FL | 1116
Boston, MA -> Chicago, IL | 849
Boston, MA -> St. Louis, MO | 1036
Boston, MA -> Madison, WI | 931
Boston, MA -> Minneapolis, MN | 1197
Boston, MA -> Nashville, TN | 942
Boston, MA -> Oklahoma City, OK | 1493
Boston, MA -> San Antonio, TX | 1765
Boston, MA -> Detroit, MI | 612
Boston, MA -> New Orleans, LA | 1358
Boston, MA -> Dallas, TX | 1549
Boston, MA -> Phoenix, AZ | 2295
Boston, MA -> Salt Lake City, UT | 2093
Boston, MA -> Denver, CO | 1765

Boston, MA -> Boulder, CO | 1774
Boston, MA -> Flagstaff, AZ | 2219
Boston, MA -> Sedona, AZ | 2235
Boston, MA -> Albuquerque, NM | 1965
Boston, MA -> Yellowstone, WY | 1970
Boston, MA -> San Francisco, CA | 2693
Boston, MA -> Las Vegas, NV | 2373
Boston, MA -> Portland, OR | 2533
Boston, MA -> Seattle, WA | 2486
Boston, MA -> Los Angeles, CA | 2591
Boston, MA -> Reno, NV | 2517
Boston, MA -> San Diego, CA | 2579
Boston, MA -> Spokane, WA | 2260
Washington, DC -> Baltimore, MD | 35
Washington, DC -> Atlanta, GA | 542
Washington, DC -> Philadelphia, PA | 123
Washington, DC -> Charlotte, NC | 330
Washington, DC -> Greensboro, NC | 247
Washington, DC -> Orlando, FL | 758
Washington, DC -> Chicago, IL | 594
Washington, DC -> St. Louis, MO | 709
Washington, DC -> Madison, WI | 705
Washington, DC -> Minneapolis, MN | 1042
Washington, DC -> Nashville, TN | 566
Washington, DC -> Oklahoma City, OK | 1149
Washington, DC -> San Antonio, TX | 1386
Washington, DC -> Detroit, MI | 394
Washington, DC -> New Orleans, LA | 965
Washington, DC -> Dallas, TX | 1182
Washington, DC -> Phoenix, AZ | 1976
Washington, DC -> Salt Lake City, UT | 1842
Washington, DC -> Denver, CO | 1489
Washington, DC -> Boulder, CO | 1502
Washington, DC -> Flagstaff, AZ | 1914
Washington, DC -> Sedona, AZ | 1927
Washington, DC -> Albuquerque, NM | 1646
Washington, DC -> Yellowstone, WY | 1760
Washington, DC -> San Francisco, CA | 2435
Washington, DC -> Las Vegas, NV | 2084
Washington, DC -> Portland, OR | 2347
Washington, DC -> Seattle, WA | 2322
Washington, DC -> Los Angeles, CA | 2294
Washington, DC -> Reno, NV | 2268

Washington, DC -> San Diego, CA | 2270
Washington, DC -> Spokane, WA | 2093
Baltimore, MD -> Atlanta, GA | 577
Baltimore, MD -> Philadelphia, PA | 90
Baltimore, MD -> Charlotte, NC | 365
Baltimore, MD -> Greensboro, NC | 282
Baltimore, MD -> Orlando, FL | 791
Baltimore, MD -> Chicago, IL | 605
Baltimore, MD -> St. Louis, MO | 731
Baltimore, MD -> Madison, WI | 714
Baltimore, MD -> Minneapolis, MN | 1044
Baltimore, MD -> Nashville, TN | 596
Baltimore, MD -> Oklahoma City, OK | 1175
Baltimore, MD -> San Antonio, TX | 1417
Baltimore, MD -> Detroit, MI | 396
Baltimore, MD -> New Orleans, LA | 999
Baltimore, MD -> Dallas, TX | 1211
Baltimore, MD -> Phoenix, AZ | 2000
Baltimore, MD -> Salt Lake City, UT | 1857
Baltimore, MD -> Denver, CO | 1506
Baltimore, MD -> Boulder, CO | 1519
Baltimore, MD -> Flagstaff, AZ | 1935
Baltimore, MD -> Sedona, AZ | 1949
Baltimore, MD -> Albuquerque, NM | 1668
Baltimore, MD -> Yellowstone, WY | 1771
Baltimore, MD -> San Francisco, CA | 2451
Baltimore, MD -> Las Vegas, NV | 2103
Baltimore, MD -> Portland, OR | 2356
Baltimore, MD -> Seattle, WA | 2328
Baltimore, MD -> Los Angeles, CA | 2315
Baltimore, MD -> Reno, NV | 2284
Baltimore, MD -> San Diego, CA | 2292
Baltimore, MD -> Spokane, WA | 2100
Atlanta, GA -> Philadelphia, PA | 666
Atlanta, GA -> Charlotte, NC | 226
Atlanta, GA -> Greensboro, NC | 306
Atlanta, GA -> Orlando, FL | 402
Atlanta, GA -> Chicago, IL | 589
Atlanta, GA -> St. Louis, MO | 467
Atlanta, GA -> Madison, WI | 699
Atlanta, GA -> Minneapolis, MN | 1046
Atlanta, GA -> Nashville, TN | 215
Atlanta, GA -> Oklahoma City, OK | 755

Atlanta, GA -> San Antonio, TX | 881
Atlanta, GA -> Detroit, MI | 597
Atlanta, GA -> New Orleans, LA | 424
Atlanta, GA -> Dallas, TX | 720
Atlanta, GA -> Phoenix, AZ | 1589
Atlanta, GA -> Salt Lake City, UT | 1581
Atlanta, GA -> Denver, CO | 1210
Atlanta, GA -> Boulder, CO | 1229
Atlanta, GA -> Flagstaff, AZ | 1551
Atlanta, GA -> Sedona, AZ | 1559
Atlanta, GA -> Albuquerque, NM | 1267
Atlanta, GA -> Yellowstone, WY | 1577
Atlanta, GA -> San Francisco, CA | 2136
Atlanta, GA -> Las Vegas, NV | 1744
Atlanta, GA -> Portland, OR | 2169
Atlanta, GA -> Seattle, WA | 2178
Atlanta, GA -> Los Angeles, CA | 1933
Atlanta, GA -> Reno, NV | 1991
Atlanta, GA -> San Diego, CA | 1887
Atlanta, GA -> Spokane, WA | 1958
Philadelphia, PA -> Charlotte, NC | 451
Philadelphia, PA -> Greensboro, NC | 368
Philadelphia, PA -> Orlando, FL | 864
Philadelphia, PA -> Chicago, IL | 664
Philadelphia, PA -> St. Louis, MO | 808
Philadelphia, PA -> Madison, WI | 766
Philadelphia, PA -> Minneapolis, MN | 1083
Philadelphia, PA -> Nashville, TN | 683
Philadelphia, PA -> Oklahoma City, OK | 1257
Philadelphia, PA -> San Antonio, TX | 1505
Philadelphia, PA -> Detroit, MI | 442
Philadelphia, PA -> New Orleans, LA | 1088
Philadelphia, PA -> Dallas, TX | 1298
Philadelphia, PA -> Phoenix, AZ | 2078
Philadelphia, PA -> Salt Lake City, UT | 1920
Philadelphia, PA -> Denver, CO | 1575
Philadelphia, PA -> Boulder, CO | 1586
Philadelphia, PA -> Flagstaff, AZ | 2010
Philadelphia, PA -> Sedona, AZ | 2024
Philadelphia, PA -> Albuquerque, NM | 1746
Philadelphia, PA -> Yellowstone, WY | 1825
Philadelphia, PA -> San Francisco, CA | 2519
Philadelphia, PA -> Las Vegas, NV | 2175

Philadelphia, PA -> Portland, OR | 2406
Philadelphia, PA -> Seattle, WA | 2373
Philadelphia, PA -> Los Angeles, CA | 2388
Philadelphia, PA -> Reno, NV | 2347
Philadelphia, PA -> San Diego, CA | 2368
Philadelphia, PA -> Spokane, WA | 2145
Charlotte, NC -> Greensboro, NC | 83
Charlotte, NC -> Orlando, FL | 463
Charlotte, NC -> Chicago, IL | 587
Charlotte, NC -> St. Louis, MO | 567
Charlotte, NC -> Madison, WI | 709
Charlotte, NC -> Minneapolis, MN | 1071
Charlotte, NC -> Nashville, TN | 340
Charlotte, NC -> Oklahoma City, OK | 939
Charlotte, NC -> San Antonio, TX | 1104
Charlotte, NC -> Detroit, MI | 505
Charlotte, NC -> New Orleans, LA | 649
Charlotte, NC -> Dallas, TX | 928
Charlotte, NC -> Phoenix, AZ | 1779
Charlotte, NC -> Salt Lake City, UT | 1724
Charlotte, NC -> Denver, CO | 1355
Charlotte, NC -> Boulder, CO | 1372
Charlotte, NC -> Flagstaff, AZ | 1731
Charlotte, NC -> Sedona, AZ | 1742
Charlotte, NC -> Albuquerque, NM | 1451
Charlotte, NC -> Yellowstone, WY | 1690
Charlotte, NC -> San Francisco, CA | 2294
Charlotte, NC -> Las Vegas, NV | 1918
Charlotte, NC -> Portland, OR | 2285
Charlotte, NC -> Seattle, WA | 2281
Charlotte, NC -> Los Angeles, CA | 2115
Charlotte, NC -> Reno, NV | 2143
Charlotte, NC -> San Diego, CA | 2077
Charlotte, NC -> Spokane, WA | 2056
Greensboro, NC -> Orlando, FL | 529
Greensboro, NC -> Chicago, IL | 581
Greensboro, NC -> St. Louis, MO | 598
Greensboro, NC -> Madison, WI | 703
Greensboro, NC -> Minneapolis, MN | 1063
Greensboro, NC -> Nashville, TN | 390
Greensboro, NC -> Oklahoma City, OK | 993
Greensboro, NC -> San Antonio, TX | 1177
Greensboro, NC -> Detroit, MI | 466

Greensboro, NC -> New Orleans, LA | 730
Greensboro, NC -> Dallas, TX | 994
Greensboro, NC -> Phoenix, AZ | 1833
Greensboro, NC -> Salt Lake City, UT | 1757
Greensboro, NC -> Denver, CO | 1392
Greensboro, NC -> Boulder, CO | 1408
Greensboro, NC -> Flagstaff, AZ | 1781
Greensboro, NC -> Sedona, AZ | 1793
Greensboro, NC -> Albuquerque, NM | 1503
Greensboro, NC -> Yellowstone, WY | 1711
Greensboro, NC -> San Francisco, CA | 2337
Greensboro, NC -> Las Vegas, NV | 1964
Greensboro, NC -> Portland, OR | 2306
Greensboro, NC -> Seattle, WA | 2297
Greensboro, NC -> Los Angeles, CA | 2165
Greensboro, NC -> Reno, NV | 2180
Greensboro, NC -> San Diego, CA | 2130
Greensboro, NC -> Spokane, WA | 2070
Orlando, FL -> Chicago, IL | 986
Orlando, FL -> St. Louis, MO | 861
Orlando, FL -> Madison, WI | 1099
Orlando, FL -> Minneapolis, MN | 1448
Orlando, FL -> Nashville, TN | 614
Orlando, FL -> Oklahoma City, OK | 1058
Orlando, FL -> San Antonio, TX | 1035
Orlando, FL -> Detroit, MI | 958
Orlando, FL -> New Orleans, LA | 533
Orlando, FL -> Dallas, TX | 961
Orlando, FL -> Phoenix, AZ | 1842
Orlando, FL -> Salt Lake City, UT | 1916
Orlando, FL -> Denver, CO | 1549
Orlando, FL -> Boulder, CO | 1570
Orlando, FL -> Flagstaff, AZ | 1827
Orlando, FL -> Sedona, AZ | 1831
Orlando, FL -> Albuquerque, NM | 1544
Orlando, FL -> Yellowstone, WY | 1942
Orlando, FL -> San Francisco, CA | 2437
Orlando, FL -> Las Vegas, NV | 2030
Orlando, FL -> Portland, OR | 2526
Orlando, FL -> Seattle, WA | 2546
Orlando, FL -> Los Angeles, CA | 2198
Orlando, FL -> Reno, NV | 2308
Orlando, FL -> San Diego, CA | 2137

Orlando, FL -> Spokane, WA | 2331
Chicago, IL -> St. Louis, MO | 262
Chicago, IL -> Madison, WI | 122
Chicago, IL -> Minnesota, MN | 483
Chicago, IL -> Nashville, TN | 397
Chicago, IL -> Oklahoma City, OK | 692
Chicago, IL -> San Antonio, TX | 1053
Chicago, IL -> Detroit, MI | 237
Chicago, IL -> New Orleans, LA | 835
Chicago, IL -> Dallas, TX | 805
Chicago, IL -> Phoenix, AZ | 1452
Chicago, IL -> Salt Lake City, UT | 1257
Chicago, IL -> Denver, CO | 918
Chicago, IL -> Boulder, CO | 928
Chicago, IL -> Flagstaff, AZ | 1372
Chicago, IL -> Sedona, AZ | 1388
Chicago, IL -> Albuquerque, NM | 1125
Chicago, IL -> Yellowstone, WY | 1167
Chicago, IL -> San Francisco, CA | 1855
Chicago, IL -> Las Vegas, NV | 1524
Chicago, IL -> Portland, OR | 1754
Chicago, IL -> Seattle, WA | 1733
Chicago, IL -> Los Angeles, CA | 1742
Chicago, IL -> Reno, NV | 1684
Chicago, IL -> San Diego, CA | 1731
Chicago, IL -> Spokane, WA | 1505
St. Louis, MO -> Madison, WI | 310
St. Louis, MO -> Minneapolis, MN | 604
St. Louis, MO -> Nashville, TN | 253
St. Louis, MO -> Oklahoma City, OK | 459
St. Louis, MO -> San Antonio, TX | 793
St. Louis, MO -> Detroit, MI | 455
St. Louis, MO -> New Orleans, LA | 599
St. Louis, MO -> Dallas, TX | 548
St. Louis, MO -> Phoenix, AZ | 1270
St. Louis, MO -> Salt Lake City, UT | 1160
St. Louis, MO -> Denver, CO | 795
St. Louis, MO -> Boulder, CO | 810
St. Louis, MO -> Flagstaff, AZ | 1205
St. Louis, MO -> Sedona, AZ | 1219
St. Louis, MO -> Albuquerque, NM | 938
St. Louis, MO -> Yellowstone, WY | 1125
St. Louis, MO -> San Francisco, CA | 1741

St. Louis, MO -> Las Vegas, NV | 1378
St. Louis, MO -> Portland, OR | 1719
St. Louis, MO -> Seattle, WA | 1720
St. Louis, MO -> Los Angeles, CA | 1586
St. Louis, MO -> Reno, NV | 1582
St. Louis, MO -> San Diego, CA | 1561
St. Louis, MO -> Spokane, WA | 1498
Madison, WI -> Minnesota, MN | 361
Madison, WI -> Nashville, TN | 497
Madison, WI -> Oklahoma City, OK | 681
Madison, WI -> San Antonio, TX | 1069
Madison, WI -> Detroit, MI | 327
Madison, WI -> New Orleans, LA | 907
Madison, WI -> Dallas, TX | 817
Madison, WI -> Phoenix, AZ | 1392
Madison, WI -> Salt Lake City, UT | 1164
Madison, WI -> Denver, CO | 838
Madison, WI -> Boulder, CO | 846
Madison, WI -> Flagstaff, AZ | 1305
Madison, WI -> Sedona, AZ | 1323
Madison, WI -> Albuquerque, NM | 1071
Madison, WI -> Yellowstone, WY | 1059
Madison, WI -> San Francisco, CA | 1763
Madison, WI -> Las Vegas, NV | 1447
Madison, WI -> Portland, OR | 1642
Madison, WI -> Seattle, WA | 1617
Madison, WI -> Los Angeles, CA | 1668
Madison, WI -> Reno, NV | 1589
Madison, WI -> San Diego, CA | 1664
Madison, WI -> Spokane, WA | 1389
Minneapolis, MN -> Nashville, TN | 836
Minneapolis, MN -> Oklahoma City, OK | 792
Minneapolis, MN -> San Antonio, TX | 1213
Minneapolis, MN -> Detroit, MI | 648
Minneapolis, MN -> New Orleans, LA | 1185
Minneapolis, MN -> Dallas, TX | 970
Minneapolis, MN -> Phoenix, AZ | 1293
Minneapolis, MN -> Salt Lake City, UT | 950
Minneapolis, MN -> Denver, CO | 708
Minneapolis, MN -> Boulder, CO | 704
Minneapolis, MN -> Flagstaff, AZ | 1186
Minneapolis, MN -> Sedona, AZ | 1207
Minneapolis, MN -> Albuquerque, NM | 1013

Minneapolis, MN -> Yellowstone, WY | 784
Minneapolis, MN -> San Francisco, CA | 1537
Minneapolis, MN -> Las Vegas, NV | 1284
Minneapolis, MN -> Portland, OR | 1336
Minneapolis, MN -> Seattle, WA | 1293
Minneapolis, MN -> Los Angeles, CA | 1508
Minneapolis, MN -> Reno, NV | 1354
Minneapolis, MN -> San Diego, CA | 1528
Minneapolis, MN -> Spokane, WA | 1066
Nashville, TN -> Oklahoma City, OK | 603
Nashville, TN -> San Antonio, TX | 823
Nashville, TN -> Detroit, MI | 470
Nashville, TN -> New Orleans, LA | 470
Nashville, TN -> Dallas, TX | 616
Nashville, TN -> Phoenix, AZ | 1443
Nashville, TN -> Salt Lake City, UT | 1390
Nashville, TN -> Denver, CO | 1020
Nashville, TN -> Boulder, CO | 1038
Nashville, TN -> Flagstaff, AZ | 1393
Nashville, TN -> Sedona, AZ | 1404
Nashville, TN -> Albuquerque, NM | 1114
Nashville, TN -> Yellowstone, WY | 1372
Nashville, TN -> San Francisco, CA | 1958
Nashville, TN -> Las Vegas, NV | 1578
Nashville, TN -> Portland, OR | 1965
Nashville, TN -> Seattle, WA | 1970
Nashville, TN -> Los Angeles, CA | 1776
Nashville, TN -> Reno, NV | 1807
Nashville, TN -> San Diego, CA | 1740
Nashville, TN -> Spokane, WA | 1749
Oklahoma City, OK -> San Antonio, TX | 421
Oklahoma City, OK -> Detroit, MI | 909
Oklahoma City, OK -> New Orleans, LA | 576
Oklahoma City, OK -> Dallas, TX | 190
Oklahoma City, OK -> Phoenix, AZ | 840
Oklahoma City, OK -> Salt Lake City, UT | 861
Oklahoma City, OK -> Denver, CO | 504
Oklahoma City, OK -> Boulder, CO | 527
Oklahoma City, OK -> Flagstaff, AZ | 796
Oklahoma City, OK -> Sedona, AZ | 805
Oklahoma City, OK -> Albuquerque, NM | 513
Oklahoma City, OK -> Yellowstone, WY | 927
Oklahoma City, OK -> San Francisco, CA | 1386

Oklahoma City, OK -> Las Vegas, NV | 989
Oklahoma City, OK -> Portland, OR | 1485
Oklahoma City, OK -> Seattle, WA | 1523
Oklahoma City, OK -> Los Angeles, CA | 1178
Oklahoma City, OK -> Reno, NV | 1251
Oklahoma City, OK -> San Diego, CA | 1138
Oklahoma City, OK -> Spokane, WA | 1323
San Antonio, TX -> Detroit, MI | 1238
San Antonio, TX -> New Orleans, LA | 507
San Antonio, TX -> Dallas, TX | 253
San Antonio, TX -> Phoenix, AZ | 847
San Antonio, TX -> Salt Lake City, UT | 1087
San Antonio, TX -> Denver, CO | 802
San Antonio, TX -> Boulder, CO | 826
San Antonio, TX -> Flagstaff, AZ | 864
San Antonio, TX -> Sedona, AZ | 862
San Antonio, TX -> Albuquerque, NM | 615
San Antonio, TX -> Yellowstone, WY | 1230
San Antonio, TX -> San Francisco, CA | 1487
San Antonio, TX -> Las Vegas, NV | 1072
San Antonio, TX -> Portland, OR | 1719
San Antonio, TX -> Seattle, WA | 1786
San Antonio, TX -> Los Angeles, CA | 1202
San Antonio, TX -> Reno, NV | 1395
San Antonio, TX -> San Diego, CA | 1126
San Antonio, TX -> Spokane, WA | 1614
Detroit, MI -> New Orleans, LA | 940
Detroit, MI -> Dallas, TX | 999
Detroit, MI -> Phoenix, AZ | 1687
Detroit, MI -> Salt Lake City, UT | 1488
Detroit, MI -> Denver, CO | 1154
Detroit, MI -> Boulder, CO | 1164
Detroit, MI -> Flagstaff, AZ | 1608
Detroit, MI -> Sedona, AZ | 1625
Detroit, MI -> Albuquerque, NM | 1359
Detroit, MI -> Yellowstone, WY | 1384
Detroit, MI -> San Francisco, CA | 2087
Detroit, MI -> Las Vegas, NV | 1761
Detroit, MI -> Portland, OR | 1964
Detroit, MI -> Seattle, WA | 1933
Detroit, MI -> Los Angeles, CA | 1979
Detroit, MI -> Reno, NV | 1914
Detroit, MI -> San Diego, CA | 1968

Detroit, MI -> Spokane, WA | 1705
New Orleans, LA -> Dallas, TX | 442
New Orleans, LA -> Phoenix, AZ | 1313
New Orleans, LA -> Salt Lake City, UT | 1433
New Orleans, LA -> Denver, CO | 1080
New Orleans, LA -> Boulder, CO | 1103
New Orleans, LA -> Flagstaff, AZ | 1304
New Orleans, LA -> Sedona, AZ | 1307
New Orleans, LA -> Albuquerque, NM | 1026
New Orleans, LA -> Yellowstone, WY | 1501
New Orleans, LA -> San Francisco, CA | 1922
New Orleans, LA -> Las Vegas, NV | 1510
New Orleans, LA -> Portland, OR | 2060
New Orleans, LA -> Seattle, WA | 2099
New Orleans, LA -> Los Angeles, CA | 1669
New Orleans, LA -> Reno, NV | 1803
New Orleans, LA -> San Diego, CA | 1605
New Orleans, LA -> Spokane, WA | 1897
Dallas, TX -> Phoenix, AZ | 884
Dallas, TX -> Salt Lake City, UT | 999
Dallas, TX -> Denver, CO | 662
Dallas, TX -> Boulder, CO | 686
Dallas, TX -> Flagstaff, AZ | 865
Dallas, TX -> Sedona, AZ | 870
Dallas, TX -> Albuquerque, NM | 585
Dallas, TX -> Yellowstone, WY | 1093
Dallas, TX -> San Francisco, CA | 1481
Dallas, TX -> Las Vegas, NV | 1070
Dallas, TX -> Portland, OR | 1631
Dallas, TX -> Seattle, WA | 1679
Dallas, TX -> Los Angeles, CA | 1238
Dallas, TX -> Reno, NV | 1361
Dallas, TX -> San Diego, CA | 1181
Dallas, TX -> Spokane, WA | 1488
Phoenix, AZ -> Salt Lake City, UT | 505
Phoenix, AZ -> Denver, CO | 586
Phoenix, AZ -> Boulder, CO | 589
Phoenix, AZ -> Flagstaff, AZ | 124
Phoenix, AZ -> Sedona, AZ | 100
Phoenix, AZ -> Albuquerque, NM | 332
Phoenix, AZ -> Yellowstone, WY | 763
Phoenix, AZ -> San Francisco, CA | 653
Phoenix, AZ -> Las Vegas, NV | 255

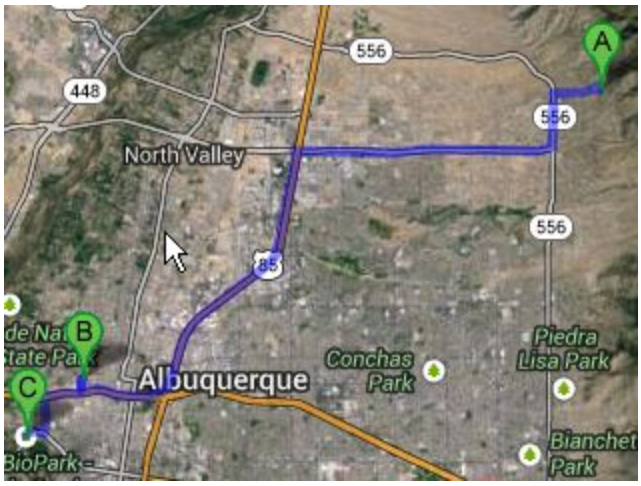
Phoenix, AZ -> Portland, OR | 1006
Phoenix, AZ -> Seattle, WA | 1114
Phoenix, AZ -> Los Angeles, CA | 357
Phoenix, AZ -> Reno, NV | 601
Phoenix, AZ -> San Diego, CA | 299
Phoenix, AZ -> Spokane, WA | 1021
Salt Lake City, UT -> Denver, CO | 371
Salt Lake City, UT -> Boulder, CO | 352
Salt Lake City, UT -> Flagstaff, AZ | 384
Salt Lake City, UT -> Sedona, AZ | 407
Salt Lake City, UT -> Albuquerque, NM | 485
Salt Lake City, UT -> Yellowstone, WY | 262
Salt Lake City, UT -> San Francisco, CA | 599
Salt Lake City, UT -> Las Vegas, NV | 367
Salt Lake City, UT -> Portland, OR | 635
Salt Lake City, UT -> Seattle, WA | 700
Salt Lake City, UT -> Los Angeles, CA | 580
Salt Lake City, UT -> Reno, NV | 427
Salt Lake City, UT -> San Diego, CA | 627
Salt Lake City, UT -> Spokane, WA | 549
Denver, CO -> Boulder, CO | 24
Denver, CO -> Flagstaff, AZ | 481
Denver, CO -> Sedona, AZ | 502
Denver, CO -> Albuquerque, NM | 332
Denver, CO -> Yellowstone, WY | 433
Denver, CO -> San Francisco, CA | 948
Denver, CO -> Las Vegas, NV | 609
Denver, CO -> Portland, OR | 981
Denver, CO -> Seattle, WA | 1020
Denver, CO -> Los Angeles, CA | 830
Denver, CO -> Reno, NV | 788
Denver, CO -> San Diego, CA | 833
Denver, CO -> Spokane, WA | 826
Boulder, CO -> Flagstaff, AZ | 482
Boulder, CO -> Sedona, AZ | 503
Boulder, CO -> Albuquerque, NM | 347
Boulder, CO -> Yellowstone, WY | 408
Boulder, CO -> San Francisco, CA | 934
Boulder, CO -> Las Vegas, NV | 602
Boulder, CO -> Portland, OR | 959
Boulder, CO -> Seattle, WA | 996
Boulder, CO -> Los Angeles, CA | 824
Boulder, CO -> Reno, NV | 772

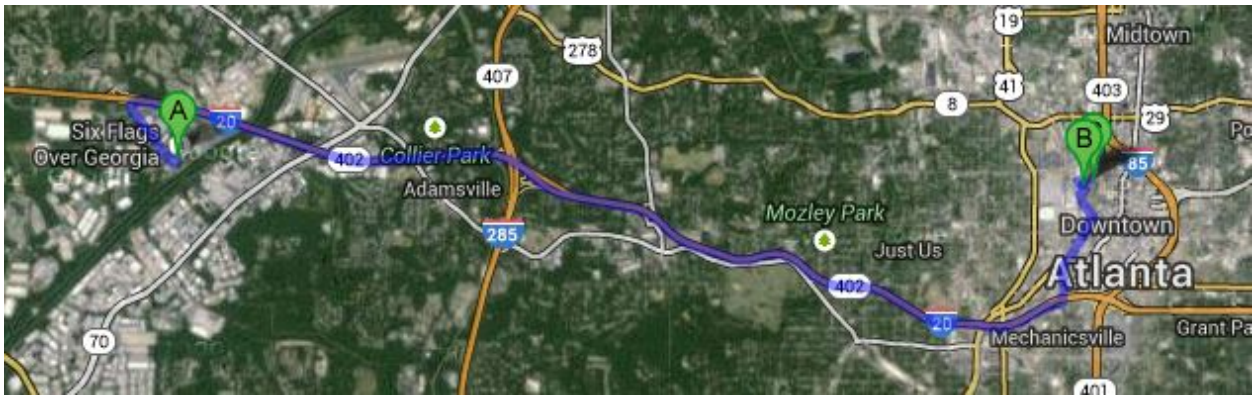
Boulder, CO -> San Diego, CA | 830
Boulder, CO -> Spokane, WA | 802
Flagstaff, AZ -> Sedona, AZ | 24
Flagstaff, AZ -> Albuquerque, NM | 284
Flagstaff, AZ -> Yellowstone, WY | 640
Flagstaff, AZ -> San Francisco, CA | 624
Flagstaff, AZ -> Las Vegas, NV | 208
Flagstaff, AZ -> Portland, OR | 918
Flagstaff, AZ -> Seattle, WA | 1018
Flagstaff, AZ -> Los Angeles, CA | 384
Flagstaff, AZ -> Reno, NV | 539
Flagstaff, AZ -> San Diego, CA | 360
Flagstaff, AZ -> Spokane, WA | 911
Sedona, AZ -> Albuquerque, NM | 292
Sedona, AZ -> Yellowstone, WY | 663
Sedona, AZ -> San Francisco, CA | 626
Sedona, AZ -> Las Vegas, NV | 210
Sedona, AZ -> Portland, OR | 933
Sedona, AZ -> Seattle, WA | 1035
Sedona, AZ -> Los Angeles, CA | 374
Sedona, AZ -> Reno, NV | 547
Sedona, AZ -> San Diego, CA | 344
Sedona, AZ -> Spokane, WA | 931
Albuquerque, NM -> Yellowstone, WY | 677
Albuquerque, NM -> San Francisco, CA | 897
Albuquerque, NM -> Las Vegas, NV | 486
Albuquerque, NM -> Portland, OR | 1107
Albuquerque, NM -> Seattle, WA | 1183
Albuquerque, NM -> Los Angeles, CA | 665
Albuquerque, NM -> Reno, NV | 786
Albuquerque, NM -> San Diego, CA | 627
Albuquerque, NM -> Spokane, WA | 1030
Yellowstone, WY -> San Francisco, CA | 767
Yellowstone, WY -> Las Vegas, NV | 623
Yellowstone, WY -> Portland, OR | 595
Yellowstone, WY -> Seattle, WA | 604
Yellowstone, WY -> Los Angeles, CA | 825
Yellowstone, WY -> Reno, NV | 582
Yellowstone, WY -> San Diego, CA | 883
Yellowstone, WY -> Spokane, WA | 396
San Francisco, CA -> Las Vegas, NV | 416
San Francisco, CA -> Portland, OR | 536
San Francisco, CA -> Seattle, WA | 679

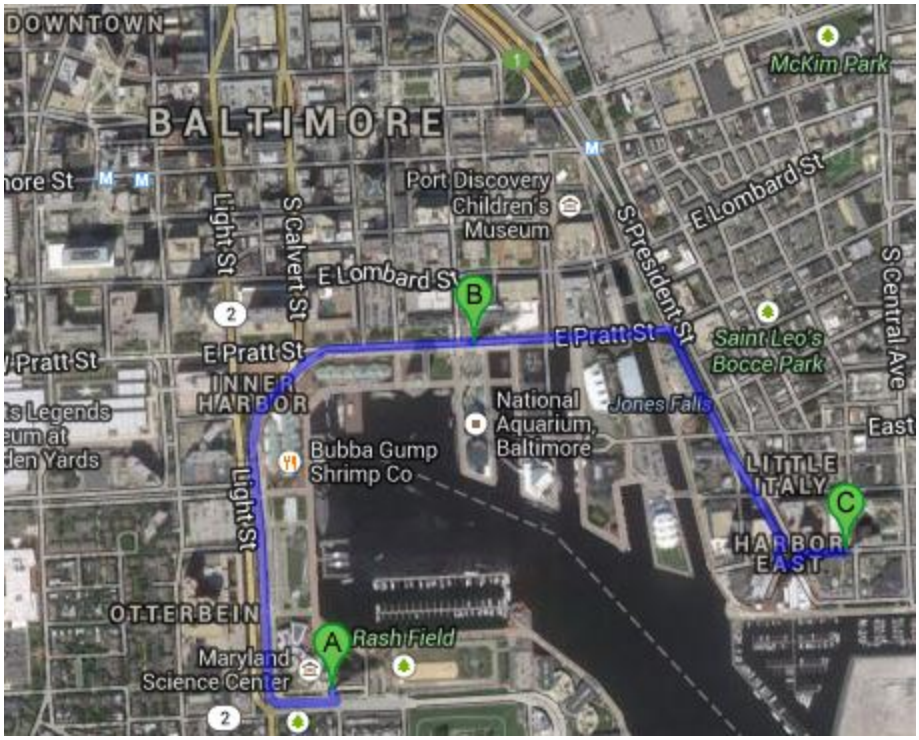
San Francisco, CA -> Los Angeles, CA | 347
San Francisco, CA -> Reno, NV | 186
San Francisco, CA -> San Diego, CA | 458
San Francisco, CA -> Spokane, WA | 728
Las Vegas, NV -> Portland, OR | 759
Las Vegas, NV -> Seattle, WA | 874
Las Vegas, NV -> Los Angeles, CA | 225
Las Vegas, NV -> Reno, NV | 346
Las Vegas, NV -> San Diego, CA | 261
Las Vegas, NV -> Spokane, WA | 806
Portland, OR -> Seattle, WA | 145
Portland, OR -> Los Angeles, CA | 826
Portland, OR -> Reno, NV | 439
Portland, OR -> San Diego, CA | 932
Portland, OR -> Spokane, WA | 290
Seattle, WA -> Los Angeles, CA | 960
Seattle, WA -> Reno, NV | 572
Seattle, WA -> San Diego, CA | 1064
Seattle, WA -> Spokane, WA | 228
Los Angeles, CA -> Reno, NV | 388
Los Angeles, CA -> San Diego, CA | 112
Los Angeles, CA -> Spokane, WA | 941
Reno, NV -> San Diego, CA | 494
Reno, NV -> Spokane, WA | 574
San Diego, CA -> Spokane, WA | 1033

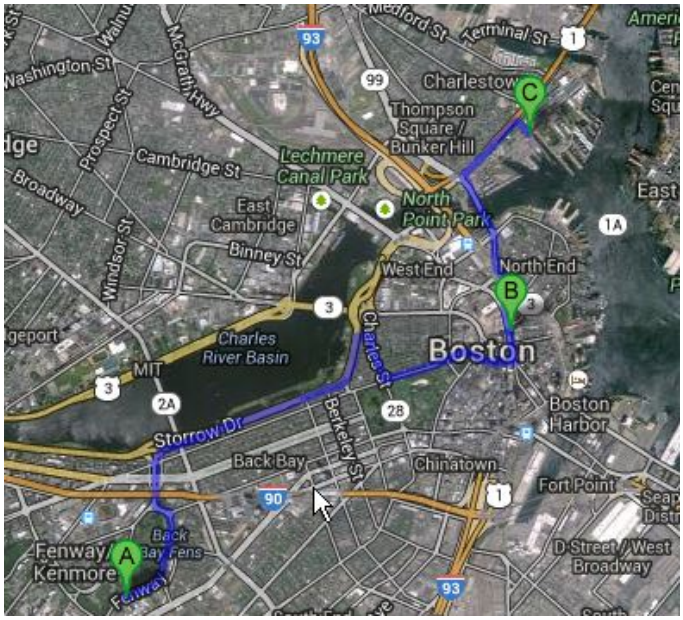
Appendix C: Map of all cities

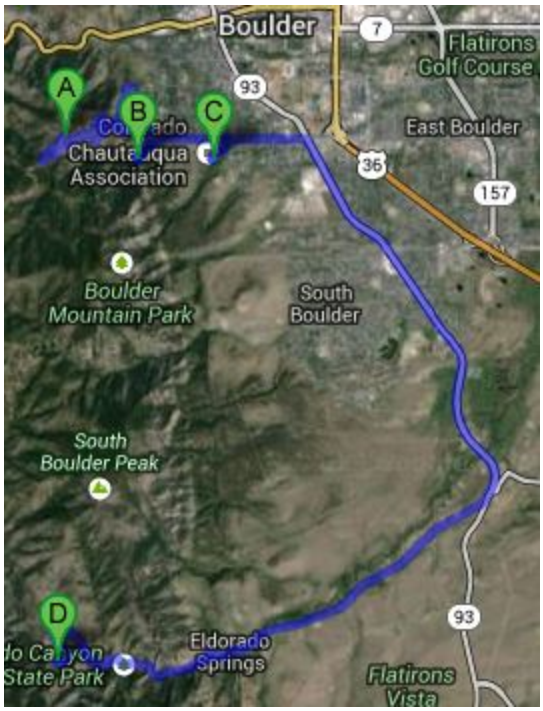
Appendix D: Maps of all attractions within each city



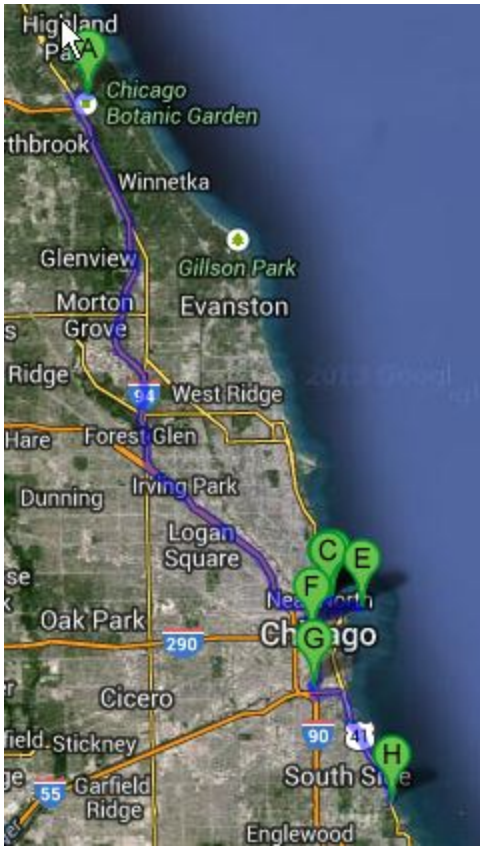



DOWNTOWN
BALTIMORE
McKim Park
Port Discovery Children's Museum
E Lombard St
S President St
S Central Ave
Light St
S Calvert St
E Pratt St
Saint Leo's Bocce Park
INNER HARBOR
National Aquarium, Baltimore
Jones Falls
Bubba Gump Shrimp Co
LITTLE ITALY
HARBOR EAST
OTTERBEIN
Rash Field
Maryland Science Center
A
B
C


Charlestown
Thompson Square / Bunker Hill
Lechmere Canal Park
North Point Park
East Cambridge
Cambridge St
Binney St
West End
North End
Boston
Charles River Basin
MIT
Storrow Dr
Back Bay
Chinatown
Fort Point
Boston Harbor
D Street / West Broadway
Fenway Kenmore
Prospect St
Broadway
Windsor St
McGrath Hwy
Charles St
Berkeley St
A
B
C


Boulder
Flatirons Golf Course
East Boulder
Chautauqua Association
Boulder Mountain Park
South Boulder
South Boulder Peak
Eldorado Springs
Flatirons Vista
A
B
C
D


Charlotte
Robert L. Smith District Park
Fourth Ward Park
A
B
C
85
77
74
485
29
21
16
160
49
277

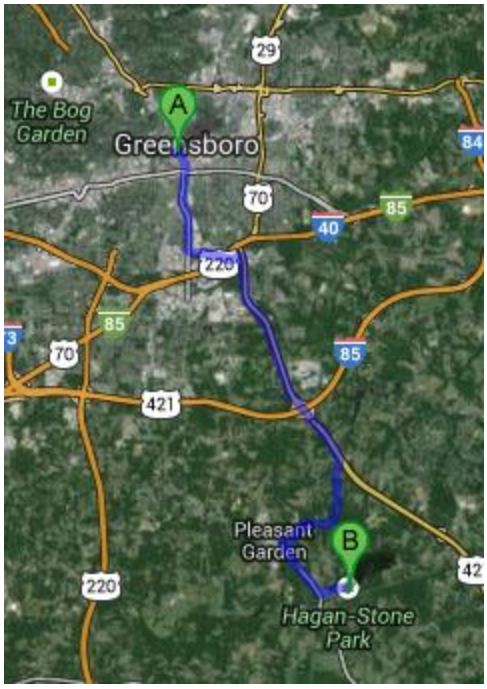

Chicago Botanic Garden
Winnetka
Glenview
Gillson Park
Morton Grove
Evanston
Ridge
West Ridge
Hare
Forest Glen
Dunning
Irving Park
Logan Square
Oak Park
Cicero
Stickney
Garfield Ridge
Englewood
A
C
E
F
H
94
290
90
55

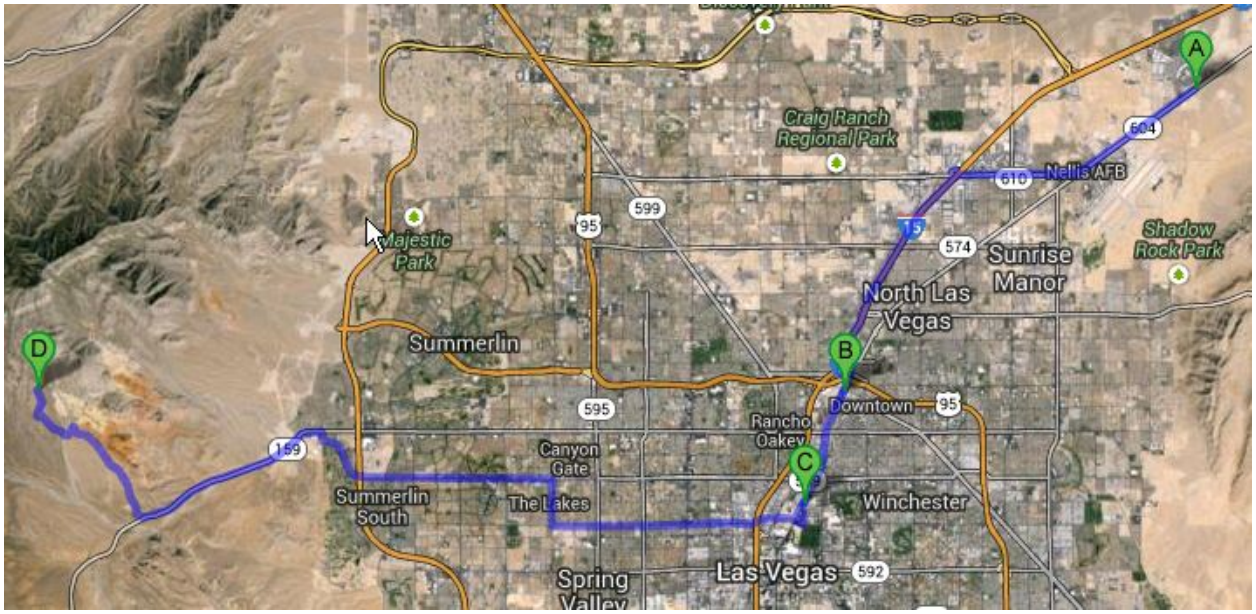

Reverchon Park
N Hall St
Victory P
Arts District
The Perot Museum of Nature and Science
The Sixth Floor Museum at Dealey Plaza
Dallas
Young St
A
B
C
366

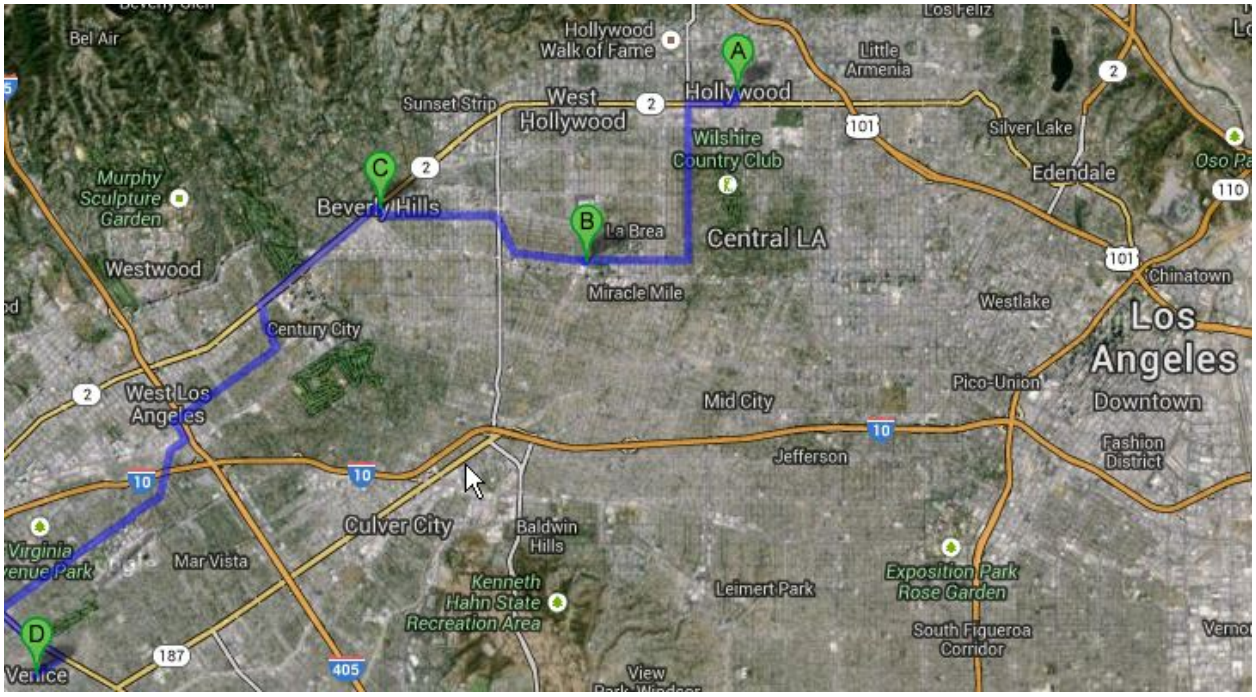

Arvada
Berkley
City
Wheat Ridge
Golden
Applewood
Denve
Idaho Springs
Genesee Park
Genesee
Lakewood
Glendale
Grant Frontier Park
Englewood
Evergreen
Littleton
Ken Caryl
Mt Evans
A
B
C
D

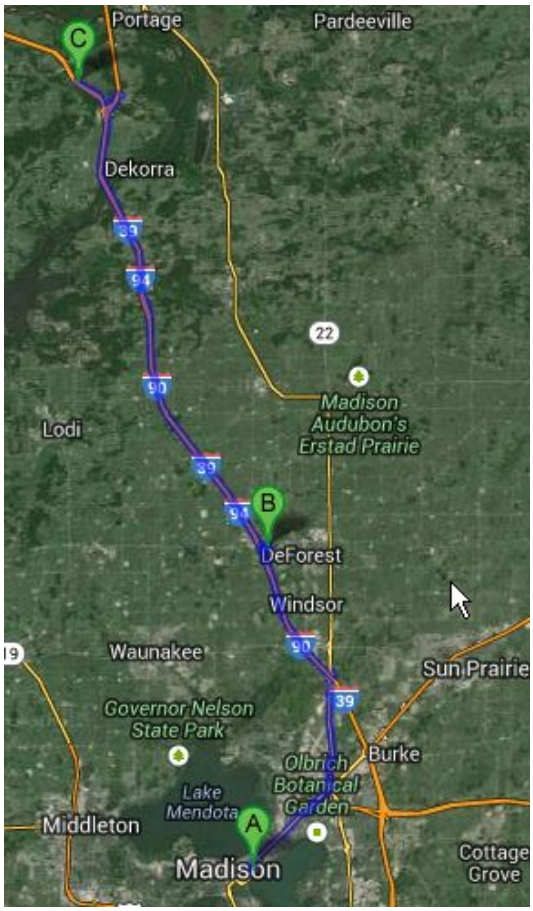

Stony Creek Metropolitan Park
Auburn Hills
Rochester Hills
Shelby Charter Township
Pontiac
Utica
Troy
Bloomfield Hills
Sterling Heights
Birmingham
Beverly Hills
Berkley
Madison Heights
Warren
Southfield
Ferndale
Hamtramck
Dearborn Heights
Dearborn
Detroit
Inkster
Delray
Melvindale
A
B
C

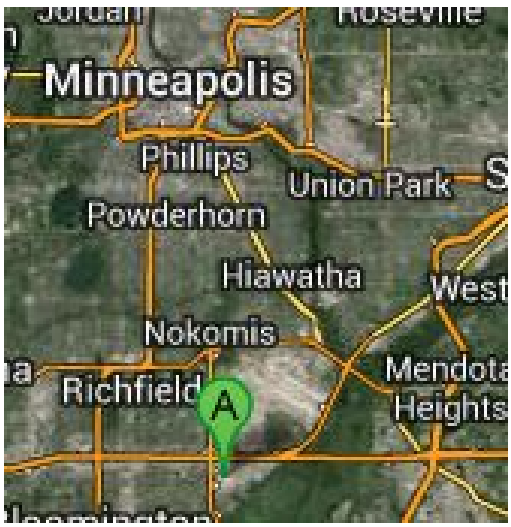

Flagstaff
Fort Tuthill County Park
A
B
C
D

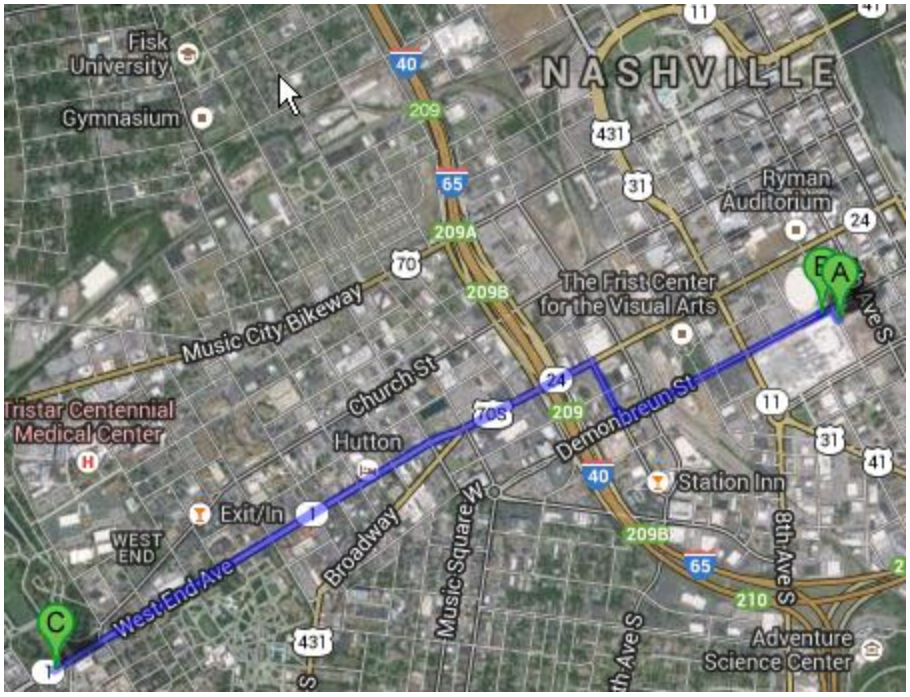

The Bog Garden
Greensboro
A
29
84
70
85
40
220
85
70
85
421
Pleasant Garden
B
220
Hagan-Stone Park

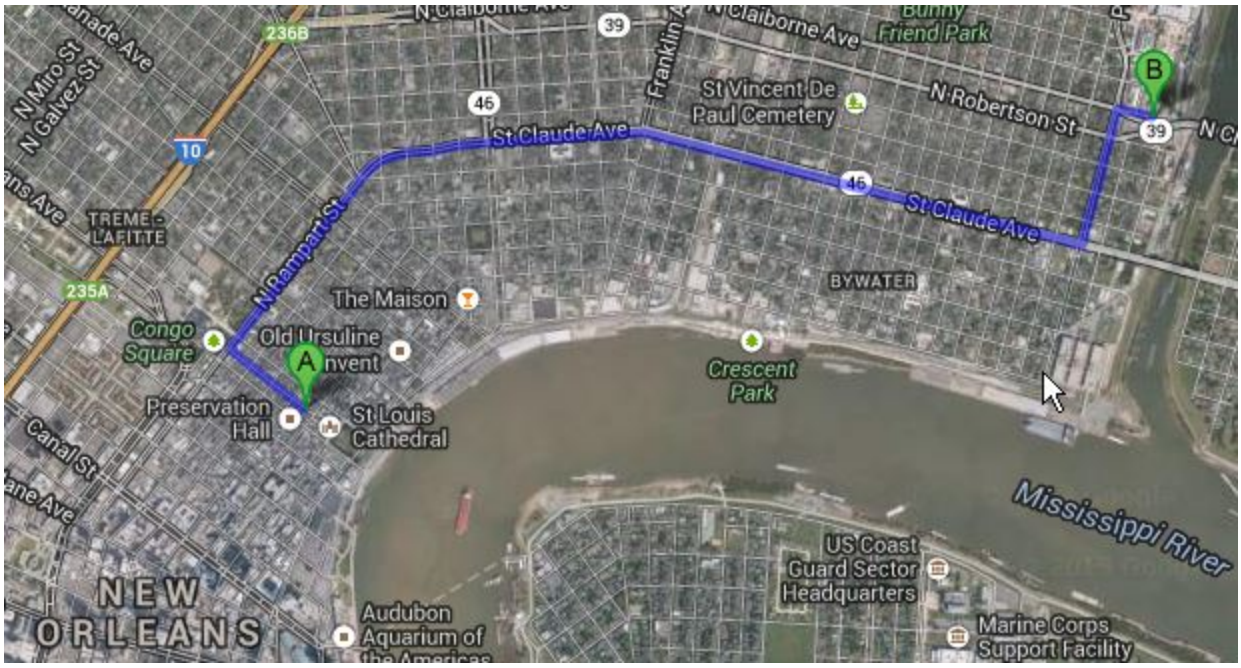

A
Craig Ranch Regional Park
604
610
Nellis AFB
599
95
Majestic Park
15
574
Sunrise Manor
Shadow Rock Park
North Las Vegas
Summerlin
B
D
595
Downtown
95
Rancho Oakey
159
Canyon Gate
C
Summerlin South
The Lakes
Winchester
Spring Valley
Las Vegas
592

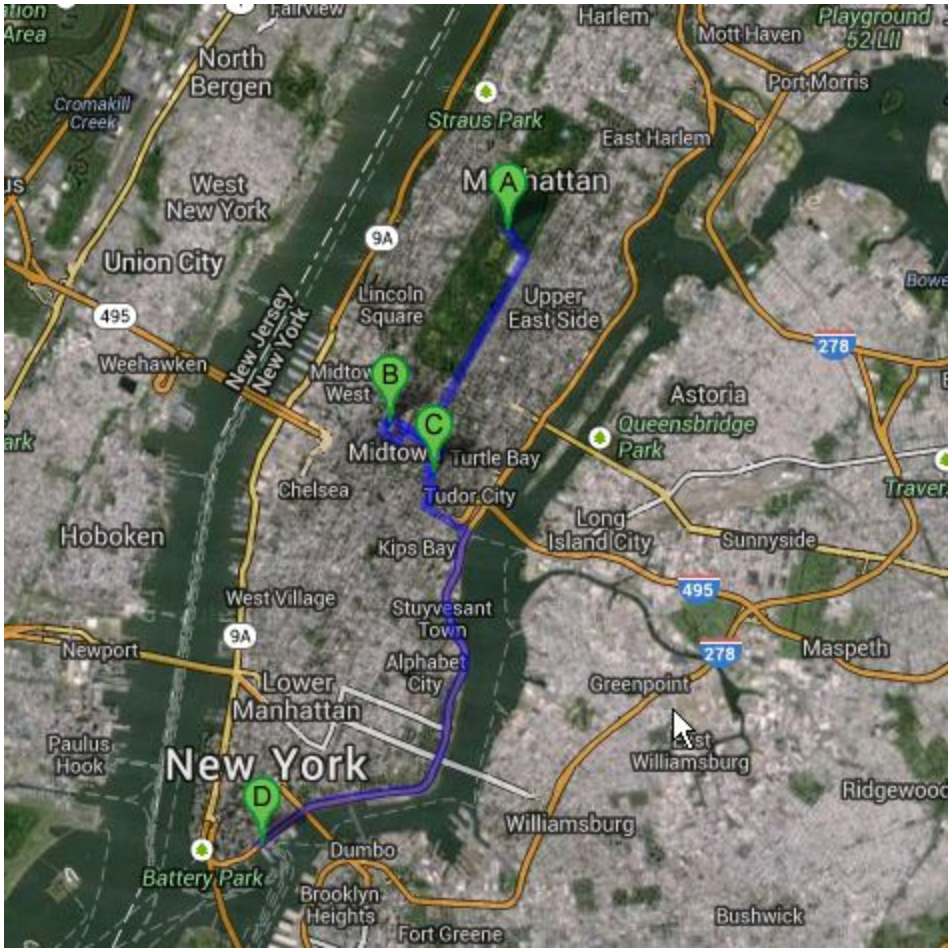

Bel Air
Hollywood Walk of Fame
Little Armenia
Sunset Strip
West Hollywood
Hollywood
Silver Lake
Wilshire Country Club
Edendale
Murphy Sculpture Garden
Beverly Hills
La Brea
Central LA
Westwood
Miracle Mile
Chinatown
Westlake
Century City
Los Angeles
West Los Angeles
Pico-Union
Mid City
Downtown
Jefferson
Fashion District
Culver City
Baldwin Hills
Virginia Park
Mar Vista
Kenneth Hahn State Recreation Area
Leimert Park
Exposition Park Rose Garden
South Figueroa Corridor
Venice
A
B
C
D

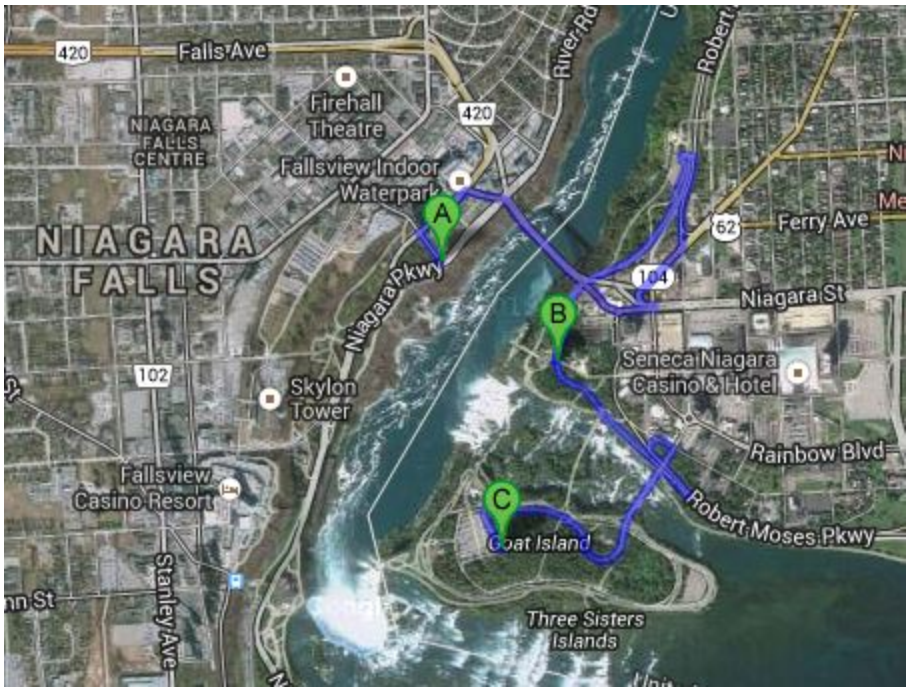

Portage
Pardeeville
Dekorra
Madison Audubon's Erstad Prairie
Lodi
DeForest
Windsor
Waunakee
Sun Prairie
Governor Nelson State Park
Olbrich Botanical Garden
Burke
Lake Mendota
Middleton
Madison
Cottage Grove
A
B
C


Minneapolis
Phillips
Union Park
Powderhorn
Hiawatha
Nokomis
Richfield
Mendota Heights
A

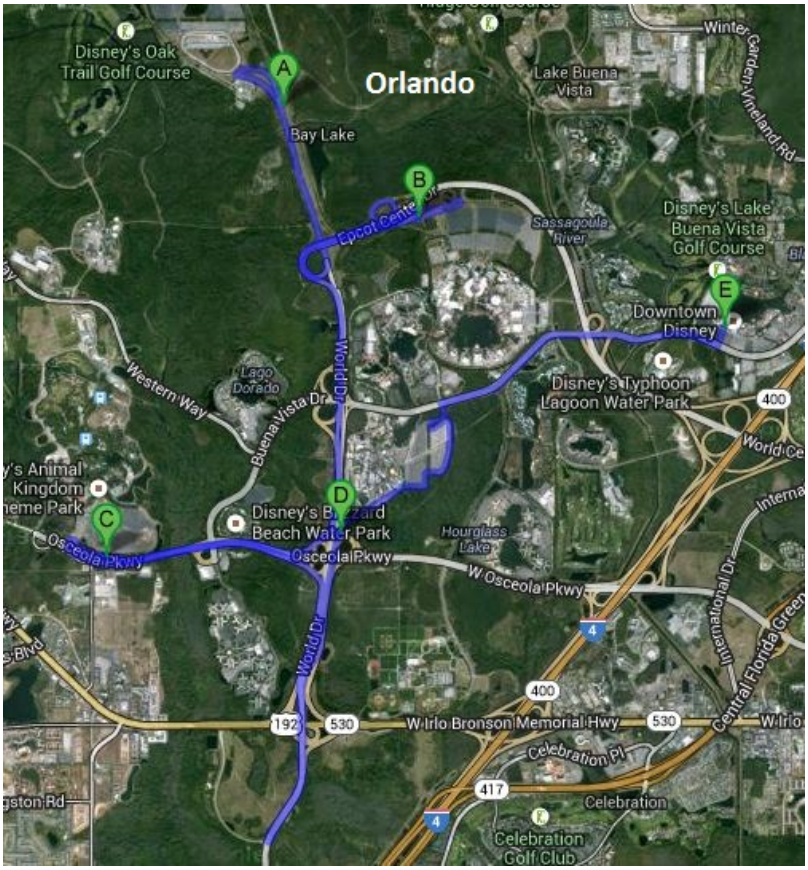

Fisk University
Gymnasium
NASHVILLE
Ryman Auditorium
The Frist Center for the Visual Arts
Music City Bikeway
Church St
Tristar Centennial Medical Center
Hutton
Demonbreun St
Station Inn
Exit/In
WEST END
West End Ave
Broadway
Music Square W
8th Ave S
Adventure Science Center
A
B
C

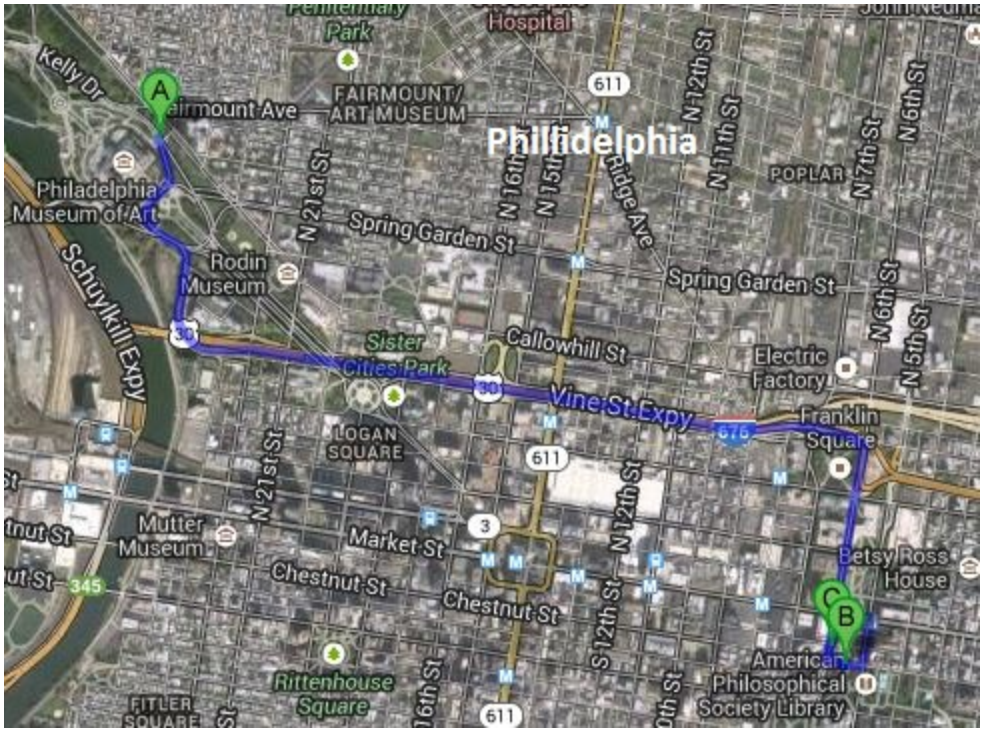

N Claiborne Ave
Bunny Friend Park
St Vincent De Paul Cemetery
N Robertson St
St Claude Ave
N Miro St
N Galvez St
TREME - LAFITTE
N Rampart St
The Maison
BYWATER
Congo Square
Old Ursuline Convent
Preservation Hall
St Louis Cathedral
Crescent Park
Canal St
Mississippi River
US Coast Guard Sector Headquarters
NEW ORLEANS
Audubon Aquarium of the Americas
Marine Corps Support Facility
A
B


A
B
C
D
Harlem
Mott Haven
Playground 52 Lll
Port Morris
North Bergen
Cromakill Creek
Straus Park
East Harlem
West New York
Union City
9A
Lincoln Square
Upper East Side
495
New Jersey
New York
Weehawken
Midtown West
Midtown
Turtle Bay
Chelsea
Tudor City
Astoria
Queensbridge Park
278
Hoboken
Kips Bay
Long Island City
Sunnyside
West Village
Stuyvesant Town
Newport
Alphabet City
Maspeth
Greenpoint
Lower Manhattan
Paulus Hook
New York
Williamsburg
Ridgewood
Dumbo
Battery Park
Brooklyn Heights
Fort Greene
Bushwick

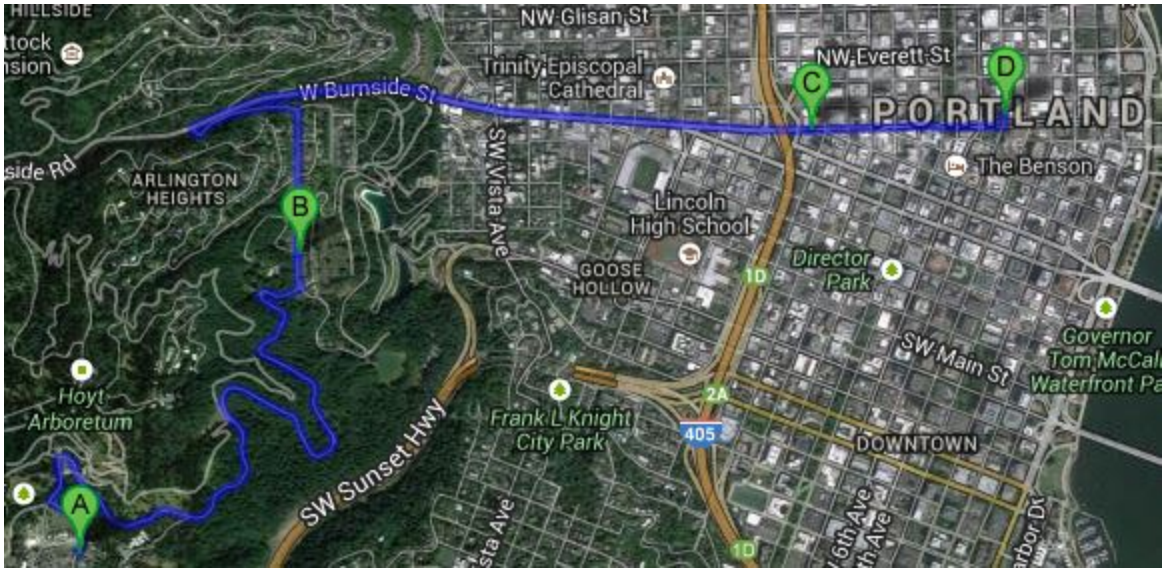

420
Falls Ave
Firehall Theatre
NIAGARA FALLS CENTRE
Fallsview Indoor Waterpark
A
NIAGARA FALLS
Niagara Pkwy
62
Ferry Ave
104
Niagara St
B
Seneca Niagara Casino & Hotel
102
Skylon Tower
Rainbow Blvd
Fallsview Casino Resort
C
Goat Island
Robert Moses Pkwy
Stanley Ave
Three Sisters Islands

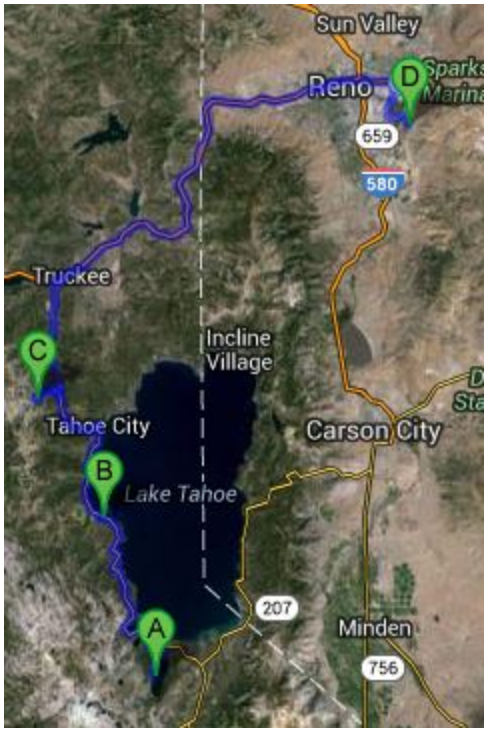

A
B
C
Oklahoma City
South Oklahoma City
44
235
40
3
62
37


A
B
C
D
E
Orlando
Disney's Oak Trail Golf Course
Bay Lake
Lake Buena Vista
Winter Garden-Vineland Rd
Epcot Center
Sassagoula River
Disney's Lake Buena Vista Golf Course
Downtown Disney
Western Way
Lago Dorado
Buena Vista Dr
World Dr
Disney's Typhoon Lagoon Water Park
400
Disney's Animal Kingdom
Disney's Blizzard Beach Water Park
Hourglass Lake
Osceola Pkwy
W Osceola Pkwy
International Dr
Central Florida Green
192
530
W Irlo Bronson Memorial Hwy
Celebration Pl
417
Celebration
Celebration Golf Club

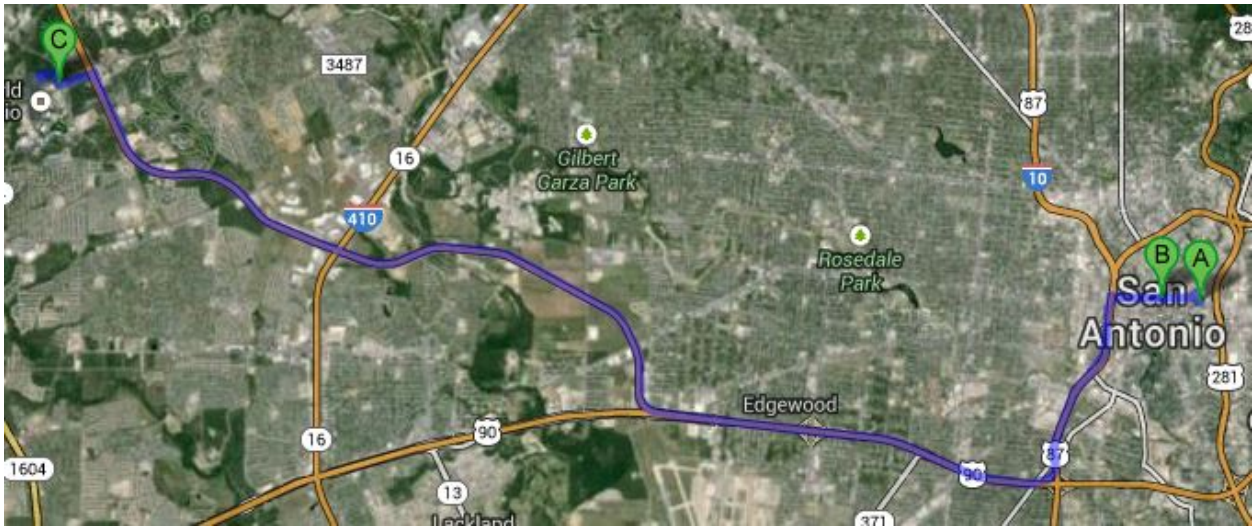

A
B
C
Phillidelphia
Kelly Dr
FAIRMOUNT/ ART MUSEUM
Philadelphia Museum of Art
Rodin Museum
Schuylkill Expy
Spring Garden St
Ridge Ave
POPLAR
N 21st St
N 16th St
N 15th St
N 12th St
N 11th St
N 7th St
N 6th St
N 5th St
Callowhill St
Sister Cities Park
Vine St Expy
Electric Factory
Franklin Square
LOGAN SQUARE
611
Mutter Museum
Market St
Chestnut St
Betsy Ross House
Rittenhouse Square
American Philosophical Society Library
345

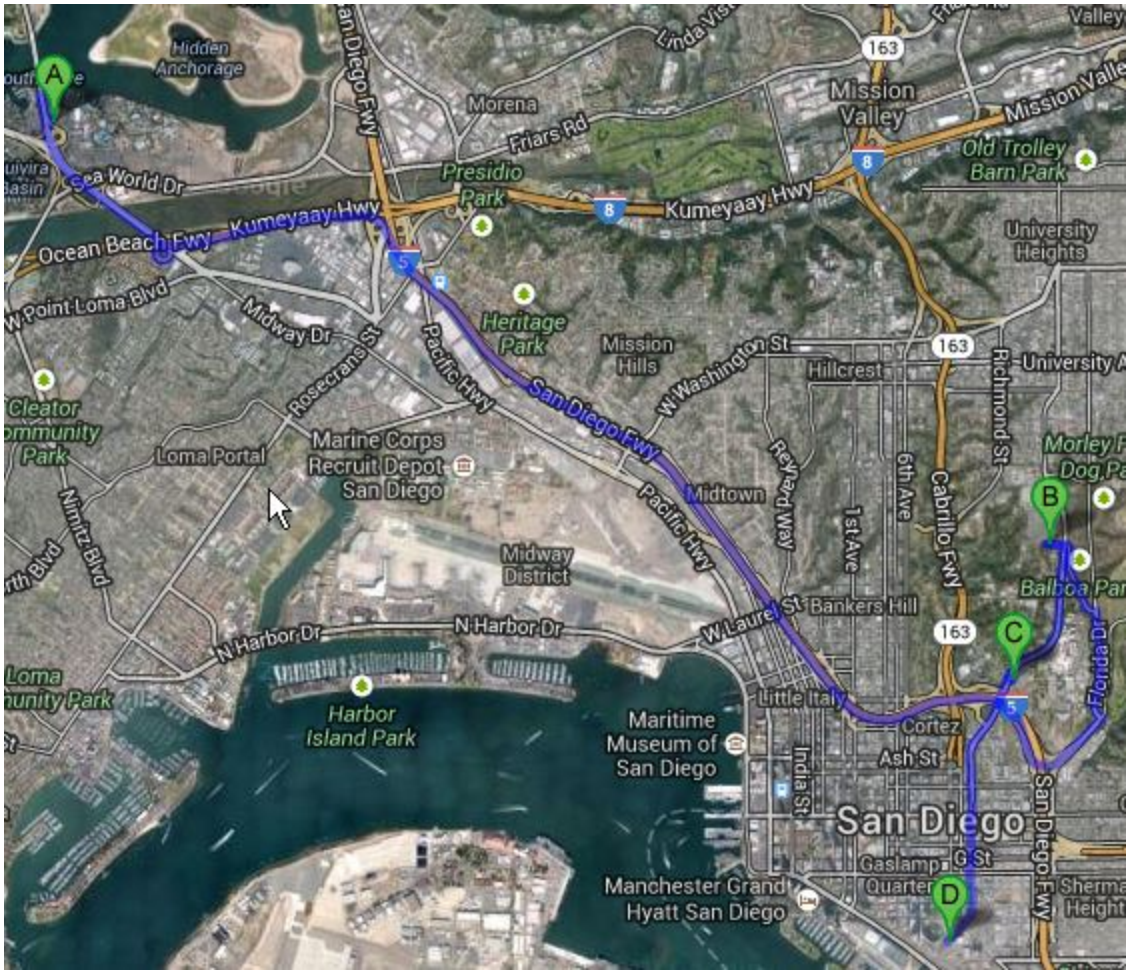

A
B
C
D
Buffalo Ridge Park
Paradise Valley Village
Phoenix Mountains Preserve
Paradise Valley
Camelback East Village
Phoenix
51
202
17


A
B
C
D
NW Glisan St
Trinity Episcopal Cathedral
NW Everett St
W Burnside St
PORTLAND
The Benson
ARLINGTON HEIGHTS
SW Vista Ave
Lincoln High School
GOOSE HOLLOW
Director Park
SW Main St
Hoyt Arboretum
Frank L Knight City Park
SW Sunset Hwy
DOWNTOWN
405
1D
2A

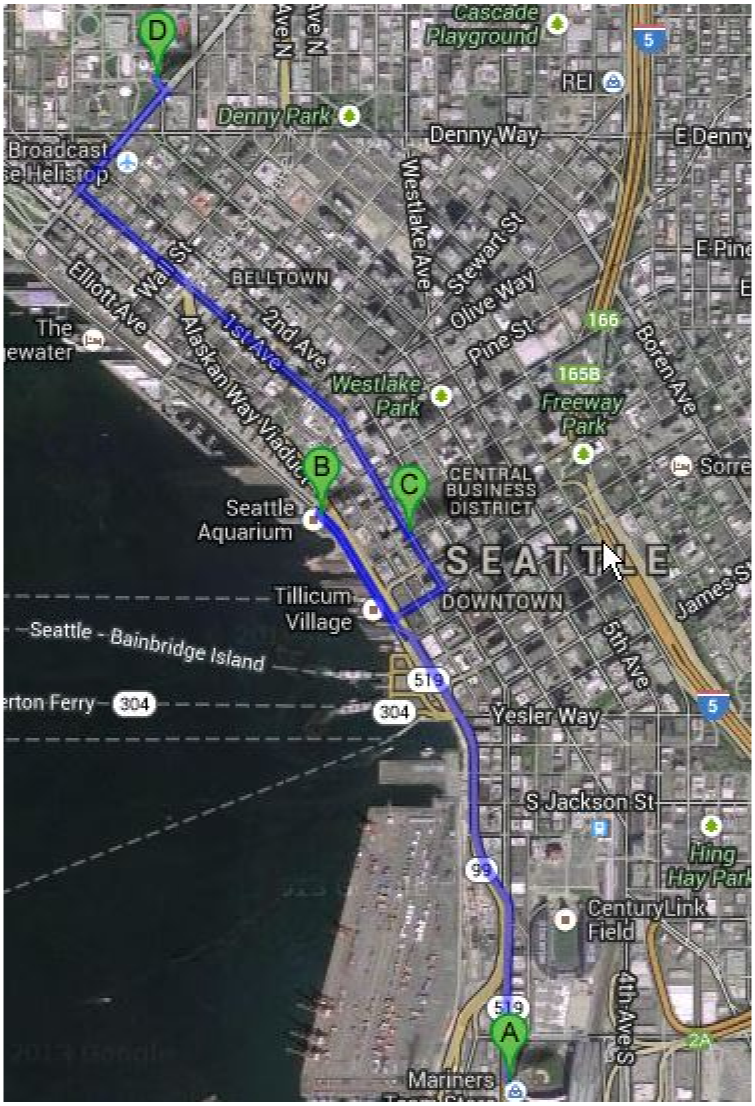

Sun Valley
Reno
D
659
580
Truckee
C
Incline
Village
Tahoe City
Carson City
B
Lake Tahoe
207
A
Minden
756


B
D
E 3rd Ave
2nd Ave
E 2nd Ave
89
A
E South Temple
E South Temple St
S 300 W
S 300 E
S 1100 E
S 1300 E
University of Utah
Disc Golf Course
E
186
Rio Grande
Salt
Lake City
Gilgal Sculpture
Garden
University
269
186
E 500 S
Foothill Dr
W 600 S
E 6th S
S 700 E
S 900 E

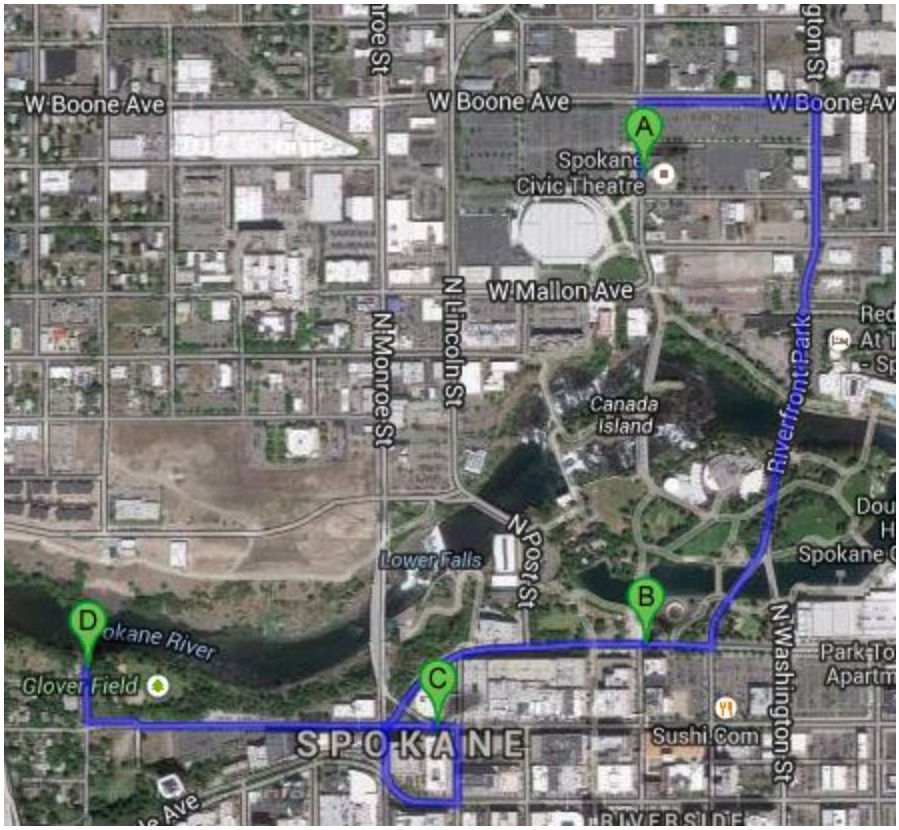

C
3487
16
Gilbert
Garza Park
410
87
10
Rosedale
Park
B
A
San
Antonio
281
Edgewood
16
90
1604
13
90
87

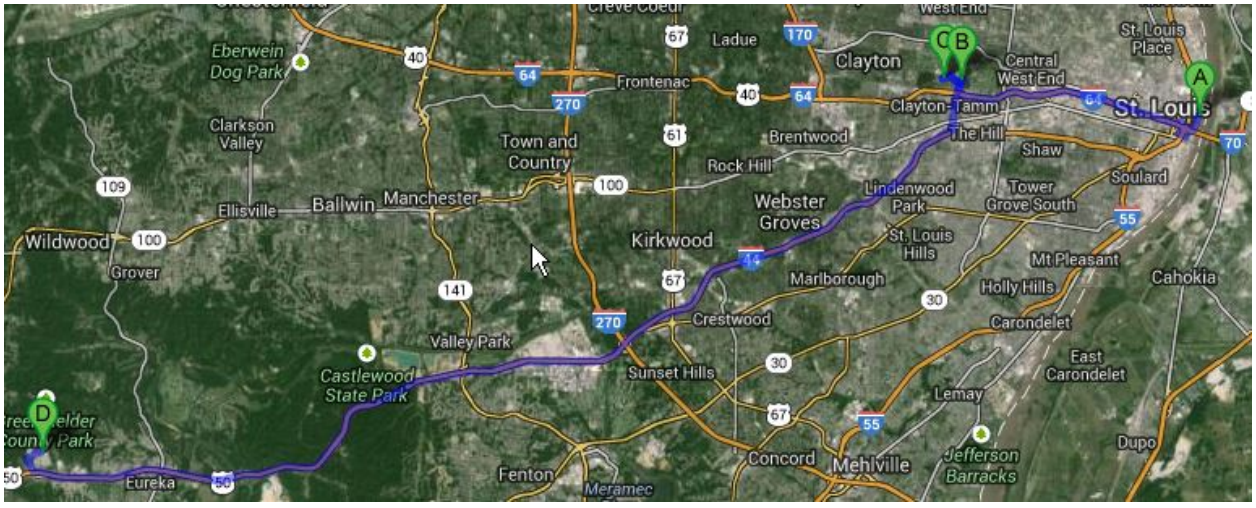

A
B
C
D
Hidden Anchorage
Morena
Friars Rd
Mission Valley
Old Trolley Barn Park
Presidio Park
Kumeyaay Hwy
Ocean Beach Fwy
Point Loma Blvd
Midway Dr
Rosecrans St
Heritage Park
Mission Hills
Hillcrest
University Heights
Pacific Hwy
San Diego Fwy
W Washington St
Richmond St
Gleator Community Park
Loma Portal
Marine Corps Recruit Depot San Diego
Midtown
Reynard Way
6th Ave
1st Ave
Cabrillo Fwy
Nimitz Blvd
Midway District
Bankers Hill
W Laurel St
N Harbor Dr
Balboa Park
Harbor Island Park
Little Italy
Cortez
Ash St
Maritime Museum of San Diego
India St
San Diego
Gaslamp Quarter
G St
Manchester Grand Hyatt San Diego
Florida Dr
San Diego Fwy
163
8
5

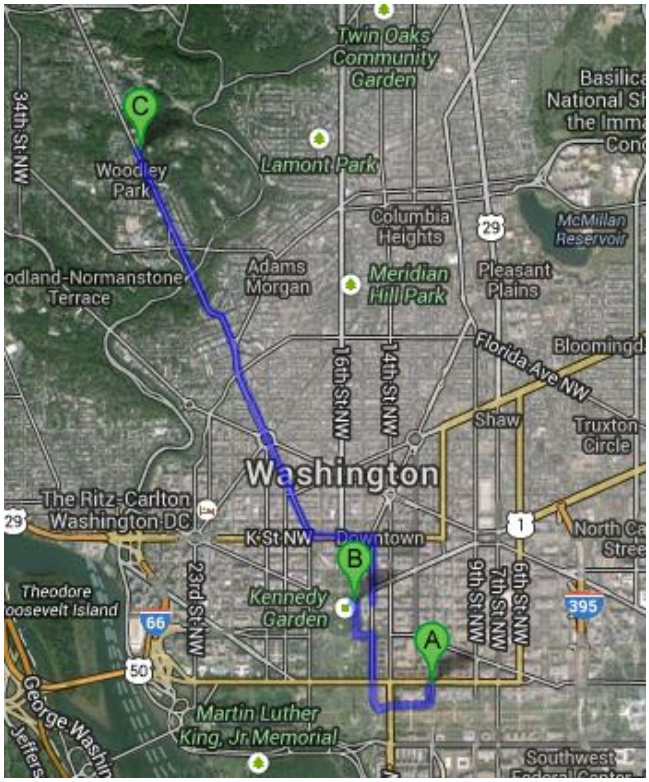

A
B
C
D
Marina District
Presidio
Financial District
Richmond District
San Francisco
Potrero Hill
Sunset District
Bernal Heights
Bayview
Lakeshore
Balboa Park
Visitacion
80
280
1


D
Cascade Playground
REI
Denny Park
Denny Way
E Denny
Broadcast
Helistop
Westlake Ave
Stewart St
E Pine
BELLTOWN
Olive Way
Elliott Ave
Wall St
2nd Ave
1st Ave
Alaskan Way Viaduct
Pine St
166
Boren Ave
165B
Westlake Park
Freeway Park
B
C
Seattle Aquarium
CENTRAL BUSINESS DISTRICT
SEATTLE
James St
Tillicum Village
DOWNTOWN
Seattle - Bainbridge Island
519
5th Ave
304
Yesler Way
5
S Jackson St
Hing Hay Park
99
CenturyLink Field
4th Ave S
A
Mariners

A
Slide Rock State Park
Sedona Dog Park
Sedona
B
C
Village of Oak Creek
17
D
Lake


W Boone Ave
W Boone Ave
W Boone Av
Spokane Civic Theatre
W Mallon Ave
N Monroe St
N Lincoln St
Canada Island
Riverfront Park
Lower Falls
N Post St
N Washington St
Glover Field
SPOKANE
Sushi Com
A
B
C
D


Eberwein Dog Park
Ladue
Clayton
Central West End
St. Louis Place
Frontenac
Clayton-Tamm
St. Louis
Clarkson Valley
Town and Country
Brentwood
The Hill
Shaw
Soulard
Rock Hill
Ellisville
Ballwin
Manchester
Webster Groves
Lindenwood Park
Tower Grove South
Wildwood
Grover
Kirkwood
St. Louis Hills
Mt Pleasant
Cahokia
Marlborough
Holly Hills
Crestwood
Carondelet
Valley Park
Castlewood State Park
Sunset Hills
East Carondelet
Lemay
Eureka
Fenton
Meramec
Concord
Mehlville
Jefferson Barracks
Dupo
A
B
C
D


Twin Oaks Community Garden
Basilica National Shrine of the Immaculate Conception
C
34th St NW
Woodley Park
Lamont Park
Columbia Heights
29
McMillan Reservoir
Adams Morgan
Meridian Hill Park
Pleasant Plains
Bloomingdale
Florida Ave NW
16th St NW
14th St NW
Shaw
Truxton Circle
Washington
The Ritz-Carlton Washington DC
K St NW
Downtown
B
North Capitol Street
Theodore Roosevelt Island
66
23rd St NW
Kennedy Garden
9th St NW
7th St NW
6th St NW
395
A
50
George Washington Memorial Parkway
Martin Luther King, Jr. Memorial
Southwest Federal Center


B
A
212
D
Yellowstone
212
212
Mt Washburn
89
C

Appendix E: Solution to optimal route to visit all cities

Note: parentheses denote (# miles traveled, # days elapsed)

Person A:

Pittsburgh (0, 0) -> Niagara Falls (238, 2) -> Boston (646, 4) -> New York City (836, 6)-> Philadelphia (917, 8) -> Nashville (1600, 10) -> Dallas (2216, 12) -> Sedona (3086, 16) -> Phoenix (3186, 19) -> San Diego (3485, 22) -> San Francisco (3943, 24) -> Pittsburgh (6518, 28)

Person B:

Pittsburgh (0, 0) -> Washington, D.C (238, 2) -> Charlotte (568, 5) -> Orlando (1031, 11) -> New Orleans (1564, 13) -> San Antonio (2071, 16) -> Albuquerque (2686, 18) -> Salt Lake City (3171, 21) -> Portland (3806, 23) -> Pittsburgh (6373, 27)

Person C:

Pittsburgh (0, 0) -> Baltimore (240, 3) -> Greensboro (522, 5) -> Atlanta (828, 8) -> St. Louis (1295, 11) -> Oklahoma City (1754, 13) -> Denver (2258, 16) -> Flagstaff (2739, 19) -> Las Vegas (2947, 21) -> Los Angeles (3172, 24) -> Pittsburgh (5599, 28)

Person D:

Pittsburgh (0, 0) -> Detroit (286, 2) -> Chicago (525, 6) -> Madison (647, 9) -> Minneapolis (1008, 11) -> Boulder (1712, 14) -> Yellowstone (2120, 17) -> Spokane (2516, 19) -> Seattle (2744, 22) -> Reno (3316, 25) -> Pittsburgh (5674, 29)

Solution:

In conclusion, to visit every location and have every person return to Pittsburgh took 29 days, and the total distance traveled by the four people was 24164 miles (average of 6041/person).