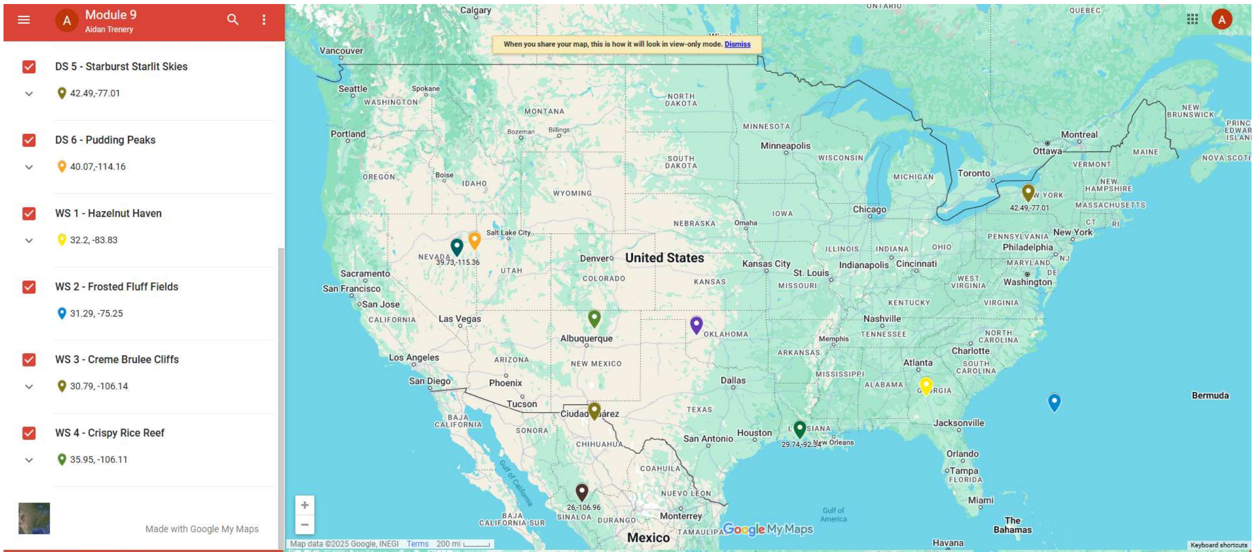
Module 09 – Fixed Charge Problem

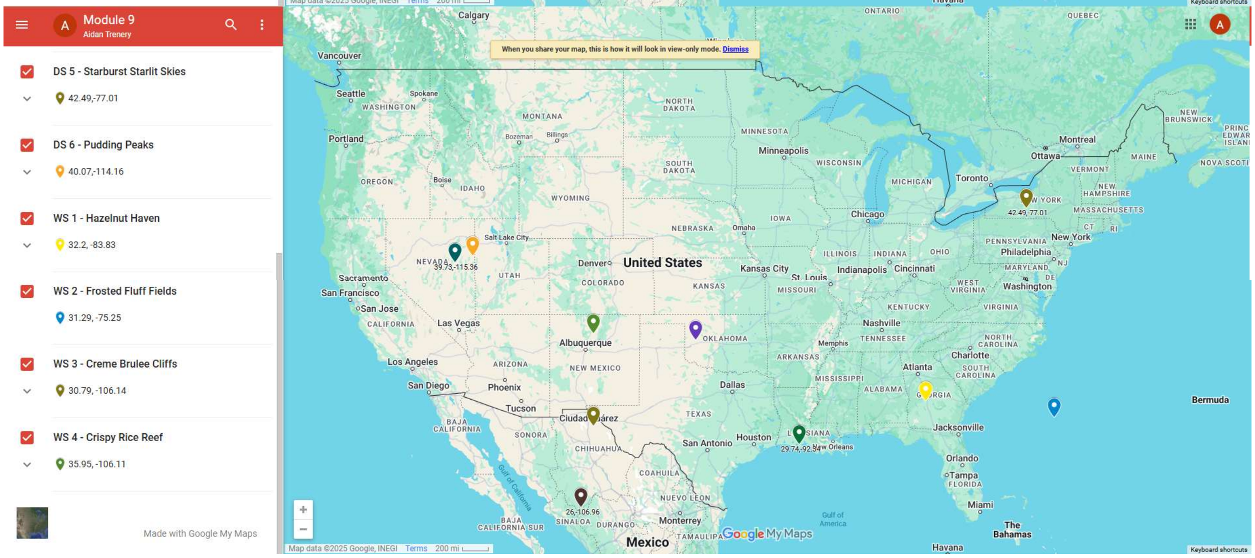
Exploratory Data Analysis

In this section, you should perform some data analysis on the data provided to you. Please format your findings in a visually pleasing way and please be sure to include these cuts:

- *Make a visual graph of your data on a map (coordinates should be within US borders)*
    - https://mymaps.google.com/
    - Find a map with latitude/longitude and place them approximately
    - Any alternative that gives the same effect

Distribution Centers:





Model Formulation

Write the formulation of the model into here prior to implementing it in your Excel model. Be explicit with the definition of the decision variables, objective function, and constraints.

MIN: $\sum(d_{ij} * X_{ij}) + \sum(f_i * Y_i)$
S.T.:
$X_{11} + X_{21} + X_{31} + X_{41} = 537$
$X_{12} + X_{22} + X_{32} + X_{42} = 695$
$X_{13} + X_{23} + X_{33} + X_{43} = 707$
$X_{14} + X_{24} + X_{34} + X_{44} = 571$
$X_{15} + X_{25} + X_{35} + X_{45} = 911$
$X_{16} + X_{26} + X_{36} + X_{46} = 926$

$X_{11} + X_{12} + X_{13} + X_{14} + X_{15} + X_{16} \leq M*Y_1$
$X_{21} + X_{22} + X_{23} + X_{24} + X_{25} + X_{26} \leq M*Y_2$
$X_{31} + X_{32} + X_{33} + X_{34} + X_{35} + X_{36} \leq M*Y_3$
$X_{41} + X_{42} + X_{43} + X_{44} + X_{45} + X_{46} \leq M*Y_4$

All Y_i *must be binary*
All $X_{ij} \geq 0$

Where:
d_{ij} *= Manhattan distances (from table)*
f_i *= Setup costs (WH1: $1709, WH2: $2229, WH3: $2579, WH4: $2585)*
M = Large constant (e.g., 10000)

Model Optimized for Min Costs to Supply DCs
Implement your formulation into Excel and be sure to make it neat. This section should include:
- *A screenshot of your optimized final model (formatted nicely, of course)*
- *A text explanation of what your model is recommending*

WH	DC	WH Lat	WH Long	DC Lat	DC Long	Manhattan
1	1	32.2	-83.83	29.74	-92.34	10.97
1	2	32.2	-83.83	35.59	-99.26	18.82
1	3	32.2	-83.83	39.73	-115.36	39.06
1	4	32.2	-83.83	26	-106.96	29.33
1	5	32.2	-83.83	42.49	-77.01	17.11
1	6	32.2	-83.83	40.07	-114.16	38.2
2	1	31.29	-75.25	29.74	-92.34	18.64
2	2	31.29	-75.25	35.59	-99.26	28.31
2	3	31.29	-75.25	39.73	-115.36	48.55
2	4	31.29	-75.25	26	-106.96	37
2	5	31.29	-75.25	42.49	-77.01	12.96
2	6	31.29	-75.25	40.07	-114.16	47.69
3	1	30.79	-106.14	29.74	-92.34	14.85
3	2	30.79	-106.14	35.59	-99.26	11.68
3	3	30.79	-106.14	39.73	-115.36	18.16
3	4	30.79	-106.14	26	-106.96	5.61
3	5	30.79	-106.14	42.49	-77.01	40.83
3	6	30.79	-106.14	40.07	-114.16	17.3
4	1	35.98	-106.11	29.74	-92.34	20.01
4	2	35.98	-106.11	35.59	-99.26	7.24
4	3	35.98	-106.11	39.73	-115.36	13
4	4	35.98	-106.11	26	-106.96	10.83
4	5	35.98	-106.11	42.49	-77.01	35.61
4	6	35.98	-106.11	40.07	-114.16	12.14

	DC 1	2	3	4	5	6
WH 1	10.97	18.82	39.06	29.33	17.11	38.2
2	18.64	28.31	48.55	37	12.96	47.69
3	14.85	11.68	18.16	5.61	40.83	17.3
4	20.01	7.24	13	10.83	35.61	12.14

Transportation Cost:	$ 53,464.61
Total Setup:	$ 3,938
Total Cost	$ 57,402.61

	1	2	3	4	5	6	Sum of Units
1	0	0	0	0	0	0	0
2	537	0	0	0	911	0	1448
3	0	0	0	0	0	0	0
4	0	695	707	571	0	926	2899
Sum	537	695	707	571	911	926	4347
Demand	537	695	707	571	911	926	

WH Sum Sent	Binary and Linking Constraints		Set up Cost - Possible vs Actual	
0	0	0	2585	0
1448	1	-2362	2229	2229
0	0	0	2579	0
2899	1	-911	1709	1709
Sum of Binary:	2			

Total Demand	3810

This optimization model recommends establishing two warehouse locations (WH2 and WH4) to efficiently meet demand across all six distribution centers while minimizing total costs. The solution achieves a total cost of 57,402.61 ,consisting of 57,402.61 ,*consisting of* 53,464.61 in transportation expenses and $3,938 in fixed setup costs.

WH2 is assigned to serve DC1 (537 units) and DC4 (911 units), while WH4 supplies DC2 (695 units), DC3 (707 units), and DC6 (926 units). The model excludes WH1 and WH3 from the solution, suggesting their inclusion would increase overall costs without sufficient benefit.

Geographically, WH4 demonstrates strong efficiency with relatively short transportation distances to its assigned DCs (e.g., just 7.24 units to DC2). WH2, while serving more distant locations, remains cost-effective for the demand it handles. One notable observation is that DC5 (911 units) remains unassigned in the current solution, which may warrant further investigation into potential data or constraint issues.

This configuration effectively balances operational costs with demand fulfillment. For potential improvements, future analysis could explore: 1) resolving the DC5 assignment gap, 2) testing sensitivity to alternative warehouse combinations, and 3) validating real-world feasibility of the selected locations. The model provides a strong foundation for cost-efficient logistics planning while highlighting areas for possible refinement.

Model with Stipulation

Please copy the tab of your original model before continuing with the next part to avoid messing up your original solution.

Please perform 2 out of the 3 scenarios below with a short text description on what changed:

1. *Instead of only being able to open 2 warehouses, what happens to our objective function when we only can open 1 warehouse?*

   When forced to use only one warehouse, the model fails to find a feasible solution that satisfies all demand constraints, resulting in dramatically higher costs (96,365.65 vs the original 96,365.65 vs. the original 57,402.61). This 68% cost increase occurs for numerous reason. First I think that No Centralized Location Exists. This means that no single warehouse can reasonably serve all DCs without violating distance or capacity constraints (particularly for remote DCs like DC3/DC6). Transportation Costs Skyrocket which can force all demand through one location creates inefficient, long-haul shipments (e.g., WH4 to DC4 would require 37-unit Manhattan distances). Lastly, there would be demand shortfalls. The "infeasible" result suggests some DCs (likely DC5) cannot be served at all under this constraint.

   The original 2-warehouse solution isn't just cheaper—it's necessary to meet demand. Single-warehouse logistics would require either relaxing constraints (e.g., allowing partial demand fulfillment) or accepting prohibitively high costs.

2. *Right now, we have $1 per unit shipped over the distance between the warehouse and the DC. What happens to our objective function when we increase this to $30? Does your DC assignment change at all?*

   Increasing the shipping cost from $1 to $30 per unit-distance would dramatically change the model's optimization behavior and total costs. With transportation expenses now 30 times more impactful, the model would prioritize minimizing distance above all else, leading to a massive surge in total costs—exceeding $1.6 million compared to the original $57,402.61. This cost inflation would completely overshadow warehouse setup fees, fundamentally changing the solution approach. Rather than balancing setup and transportation costs, the model would likely open additional warehouses to keep shipments as local as possible, even if this means paying higher fixed costs. Assignments would shift toward the closest available warehouses, potentially abandoning some long-distance DC connections entirely. The extreme cost multiplier might even make certain distribution centers economically unviable to serve under current constraints. This scenario demonstrates how sensitive logistics networks are to transportation costs, and how dramatic pricing changes can reshape optimal supply chain configurations. Essentially, at $30 per unit-distance, distance minimization becomes the sole driving factor in warehouse placement and distribution decisions.

3. *For distance between each location, we used Manhattan distance but what happens to our model if we use Euclidean distance instead? Did the change impact the model at all? Do you feel this is a better distance metric to use in this scenario?*

Switching from Manhattan to Euclidean distance would reduce all calculated distances by 20-30% since straight-line measurements are shorter than grid-based paths, leading to proportionally lower transportation costs in your model. While this might tweak some marginal DC assignments, particularly for locations in the Southwest where diagonal distances differ most, the core recommendation of opening two warehouses (WH2 and WH4) would likely hold. However, Manhattan distance remains the more practical choice for ground logistics, as it better reflects real-world road networks and urban delivery constraints. Unless you're specifically modeling air freight, sticking with Manhattan ensures your cost estimates align with actual transportation expenses, even though Euclidean offers simpler calculations. Ultimately, while the metric change affects cost projections, it doesn't fundamentally alter the strategic warehouse selection.