

WEC 2025 Programming Presentation

Team: Round Lake

Scott Kenning, Christian Bookout, Julian
France, Arun Alex



The Problem:
Optimize Fire Hall Placement
Over a Map of Calgary-
Cow-gary

What is Linear Programming (LP)?

- Optimization technique that achieves an optimal value for a function with linear relationships
- 0 - 1 value
- Objective Function, Constraints, Variables

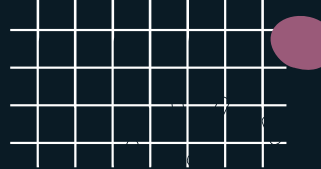
What is Integer Linear Programming (ILP)?

- Boolean values only
- Restricted to 0 or 1 results (can't have half of a fire hall!)

How to Solve LP / ILP problems

- Common to use solvers (COIN-OR CLP / CBC)
- Simplex
- “Divide and conquer” strategy
- Branch pruning
- Relaxation (ILP)

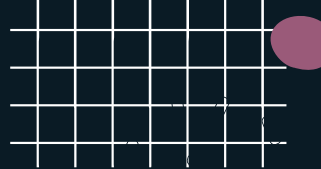
Our Use of ILP



- 1st constraint to solve for min # of halls
 - Discretize area of city by creating polygon boundary and defining the set of points inside of the city.
 - Ensure the hall bounds cover the entire city by including a sampling of the city's perimeter coordinates in the list of points.

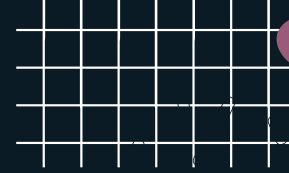


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 - Ensure the hall bounds cover the entire city by including a sampling of the city's perimeter coordinates in the list of points.
- 2nd constraint to maximize distance between halls
 - Ensure future developments have the max amount of pre-existing hall coverage.

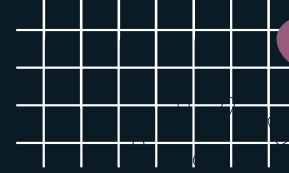




What Makes ILP Slow

- So why does ILP take so long to compute?
 - Candidate grid size of 1 to 2 km and a discretization grid size of 0.5 to 1 km

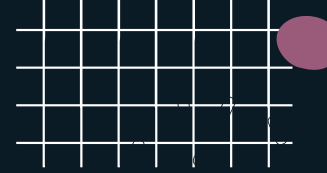




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 - Grid of 1000+ points that need to be enclosed within a fire hall's reach, with a grid of 250+ points that are possible fire hall locations
 - That is a lot of possible permutations (even with a lot of possible optimizations)



Technology

- Python
 - PuLP
 - Numpy
 - Pandas
 - Matplotlib



[1]

Design Decisions

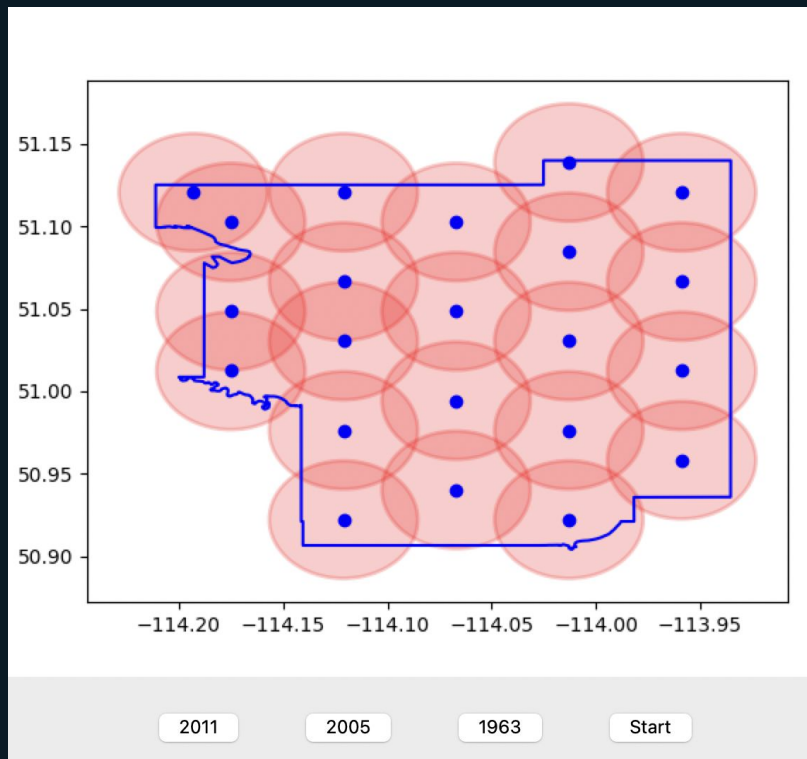
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 - Easily show polygon, circles, and points using subplots

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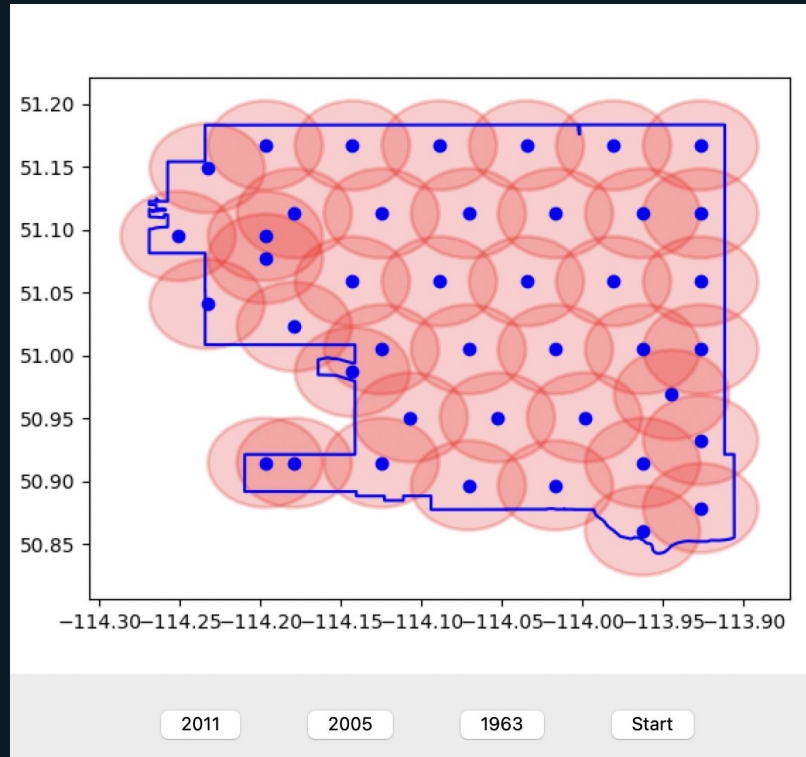
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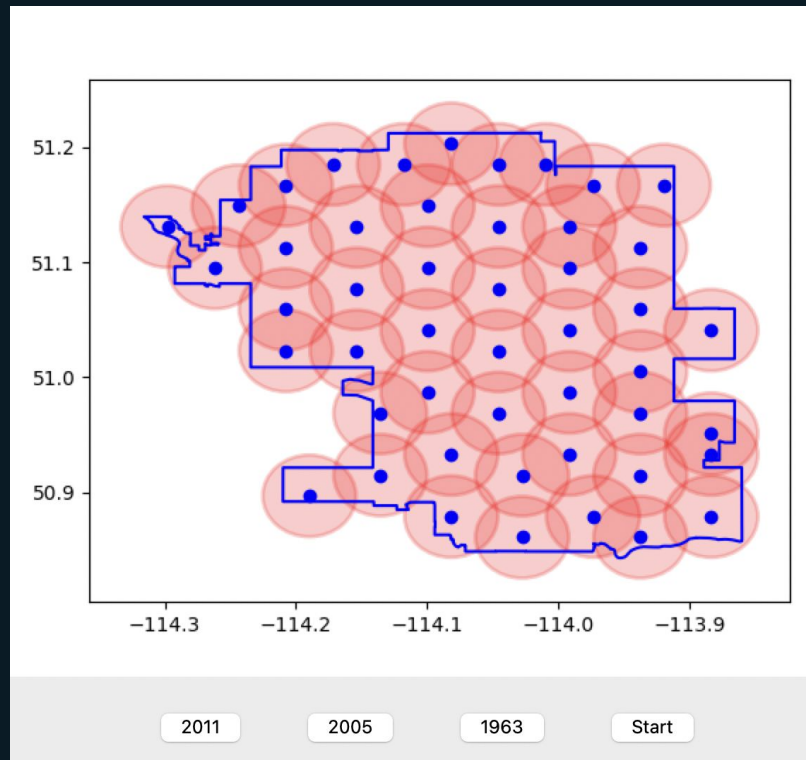
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- ILP using PuLP
 - Picked over greedy algorithm or other solutions due to reliability of ILP in finding the minimum.
As compared to a greedy algorithm:
 - Pros: More reliably finds minimum fire halls needed for complete coverage
 - Cons: Takes a long time (especially with a high number of constraints)



1963



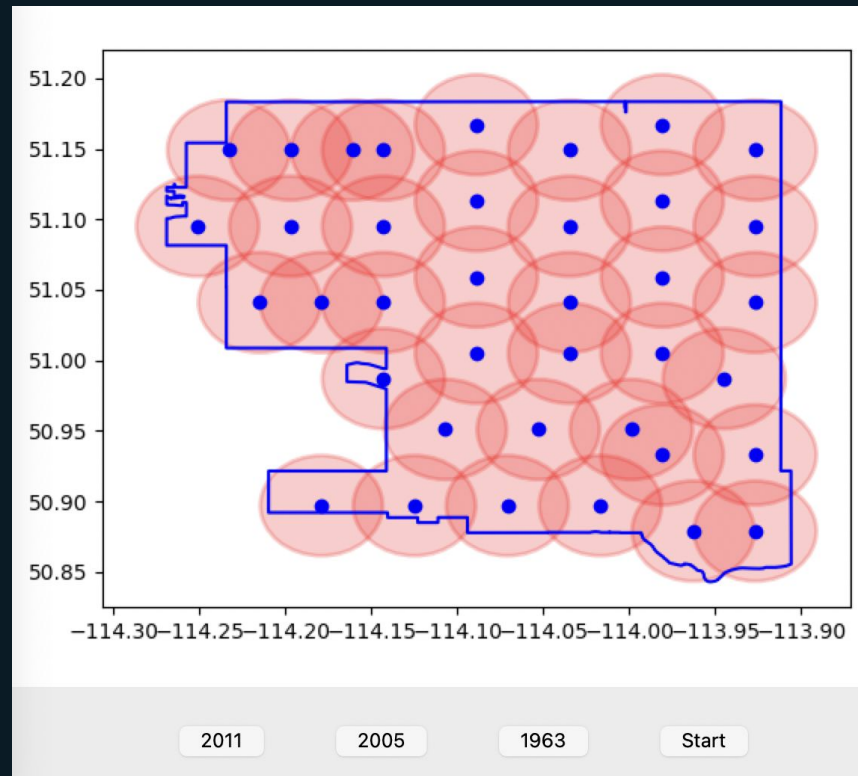
2005



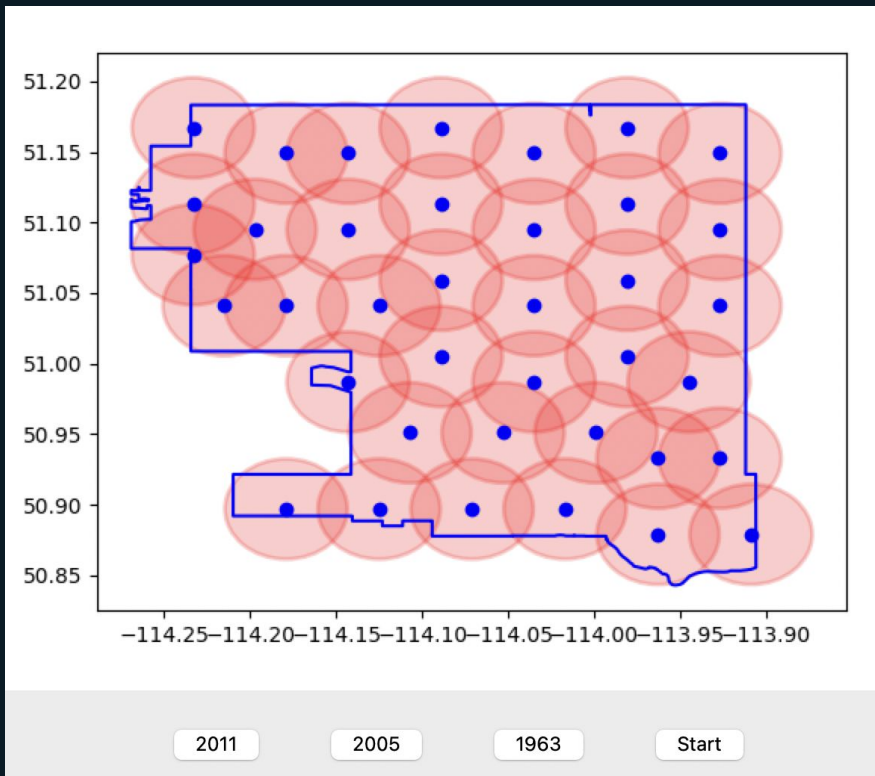
2011

Engineering Decisions

- Minimize overlap of fire hall radiuses.
- Don't use future city bounds to develop past fire hall locations, since that doesn't replicate real world
 - Instead optimize current for future fire halls assuming the future city bounds aren't known



Unoptimized Hall Spacing

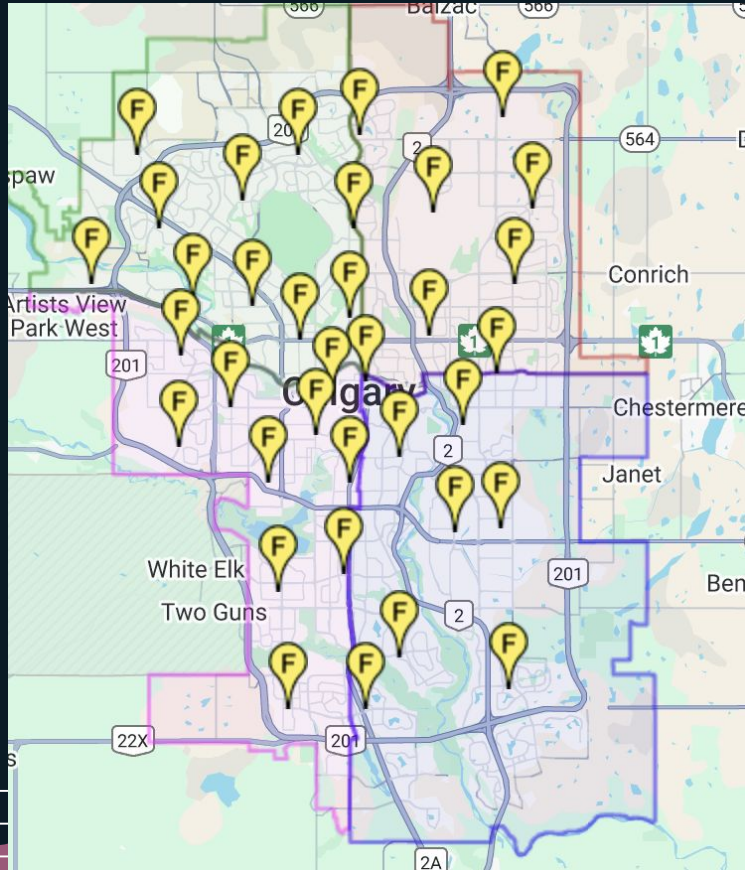


Optimized Hall Spacing

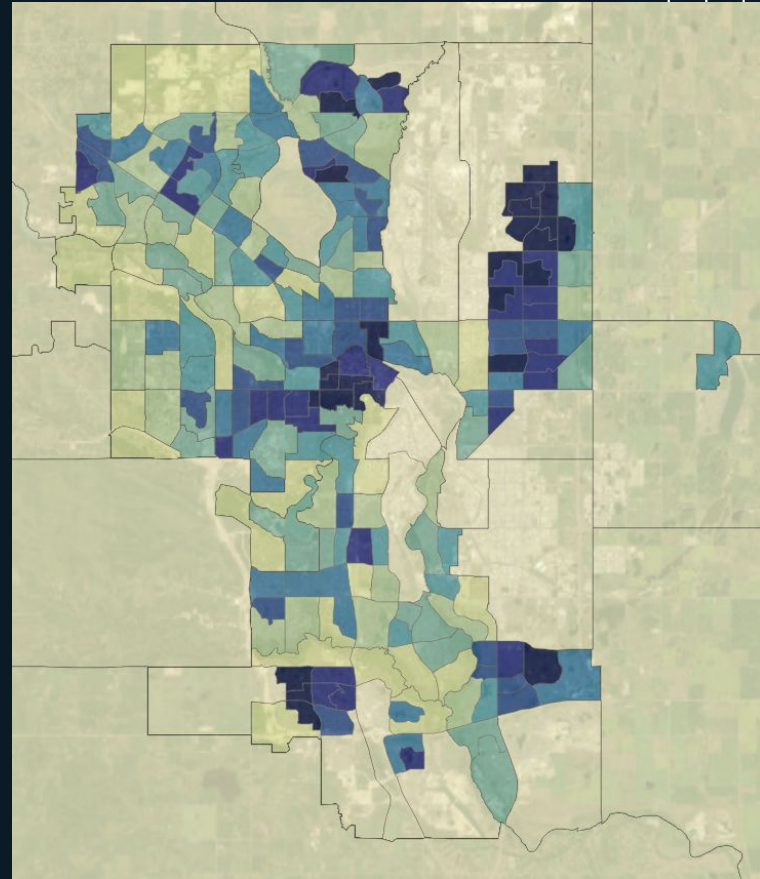
Future Optimizations

- Sampling of grid points to minimize checks necessary while solving
- Code smell
- Investigate reliability sacrifices with greedy algorithm
- Hall distance constraint optimization

Calgary Fire Halls vs Population Density

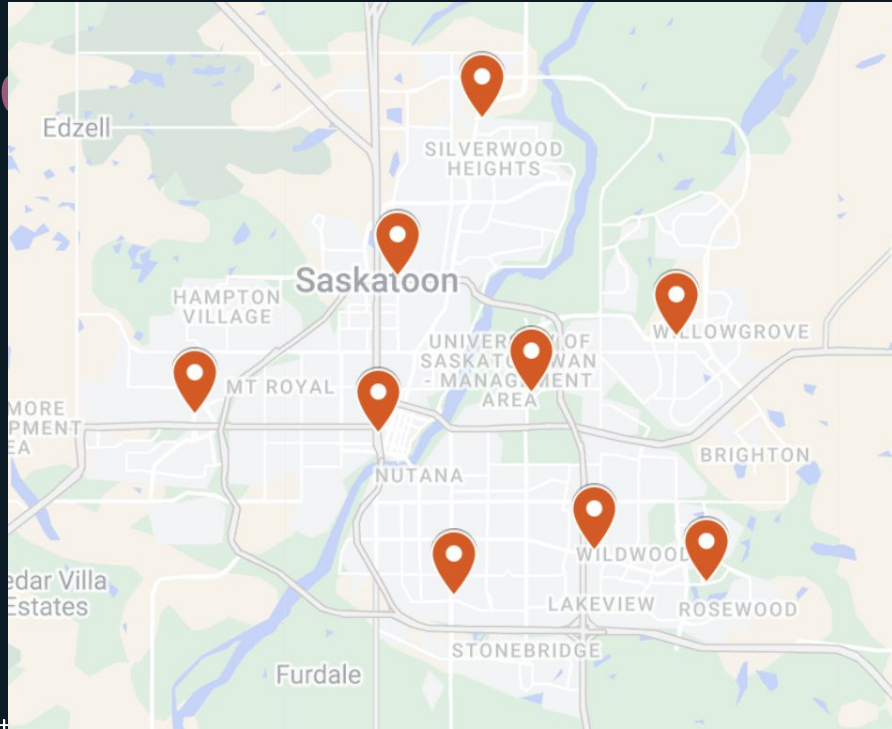


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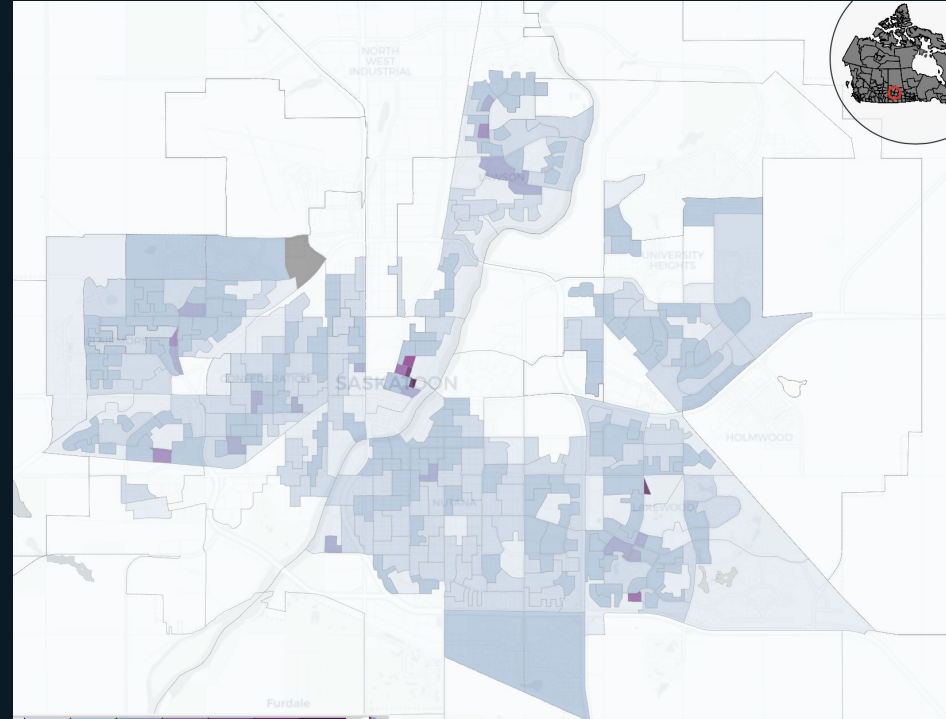


[3]

Comparison with Saskatoon (Fire Halls vs Population Density)

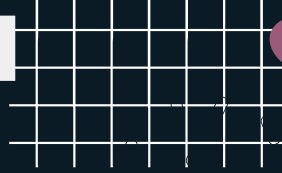


[4]



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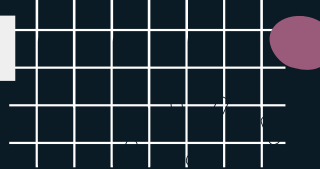
Key Takeaways from Real-World Comparisons



- Fire hall count is primarily a function of population, not area.



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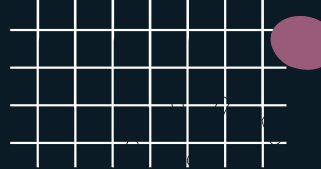


Key Takeaways from Real-World Comparisons

- Fire hall count is primarily a function of population, not area.
- Population density is a more important metric in fire hall placement than area coverage.
- Existing infrastructure impacts where fire halls can / can't be built.



How we used ChatGPT



- Used in most areas - but not much AI code made the final cut.
- Used for “templating” code - save time not reading docs.
- Not used directly for program logic.
- Exception was understanding ILP implementation.
- Minimal use of existing code snippets - only for solved, trivial problems



References

- [1] "The Python Logo", Python, 2025, <https://www.python.org/community/logos/>
- [2] "Calgary Map of Places - The Interactive Map of Calgary", Calgary mapped, 2025, <https://calgarymapped.com/index.html?map-of=fire-stations>
- [3] "Calgary population density," Census Mapper, 2016, <https://censusmapper.ca/maps/2327#10/>
- [4] "Google Maps", Google, 2025, <https://www.google.ca/maps/>
- [5] "Saskatoon population density", Census Mapper, 2021, <https://censusmapper.ca/#11/52.1390/-106.6405>
- [6] Myrabella, "Lac Gentau in the Ossau Valley of the Pyrenees, France", Wikimedia commons, 2010, https://en.wikipedia.org/wiki/Lake#/media/File:Gentau_Pic_du_Midi_Ossau.jpg
- [7] "HD Flat Fire Station Illustration Icon Transparent PNG", CityPNG, 2024 <https://www.citypng.com/photo/16898/hd-flat-fire-station-illustration-icon-transparent-png>

Bibliography

- COIN-OR LP Solvers (<https://github.com/coin-or>)
- PuLP Mixed LP Solver (<https://github.com/coin-or/pulp>)