Multi-Period Facility Location Optimization

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Motivation

- Having thousands of options to locating new facilities in a city, where can strategic planners plan to build new facilities, in order to optimize the network, while maximizing equity across dwellers?
- Factoring parameters including population growth, mobilization of populations, zoning change, travel distance, budget constraints, capacity limitation, and differences in costs to build in different areas makes the problem very hard to solve, requiring extensive analysis, and specific models and software.

Objectives

- Build an optimization Model to optimize the public-school network in Sydney's metropolitan area, to maximize social welfare.
- The model to factor in the possibility of opening new schools, close, expend and reduce the size of existing ones.
- Include practical factors specific to Sydney, providing a scientific tool for decision makers in the NSW government, to make more informed decisions in locating schools.

Applications

- The direct application of this research is on Sydney's public-school network. The Model is Build to include the specifics related to this network and will use real data provided by the NSW government as a case study.
- This research can also be applied to other school network in Australia, and around the world.
- The principals of this research can be applied to networks beyond schools, including other public facilities, hospitals, and emergency centers.

Benefits

- The benefits of this research are split into two different aspects:
  - Humanitarian: i) this research brings more equity and fairness across all students living in a city, and ii) enhances the overall quality of education provided by schools, by reducing allocations to over-capacitated schools.
  - Economic: this research focuses on reducing the total travel distance of users, saving on travel time, fuel, and road usage, and ii) minimize the total capital costs needed to satisfy the demands.

Abstract

With the expansion of cities around the world and the growth of their populations, rises the need for new public facilities to serve the increase in demand. Along the importance of satisfying this need, comes the complexity of selecting where and when to open new facilities, among thousands of possible options, in a way that optimizes the network and brings equity across the dwellers of a city. One of the most critical public facilities is schools, as the demand for these facilities is massive, the cost to open new facilities is substantial, the obligation to serve every demand at each time-period is mandatory, and the need to be as equitable as possible across the whole population is fundamental.

Methodology

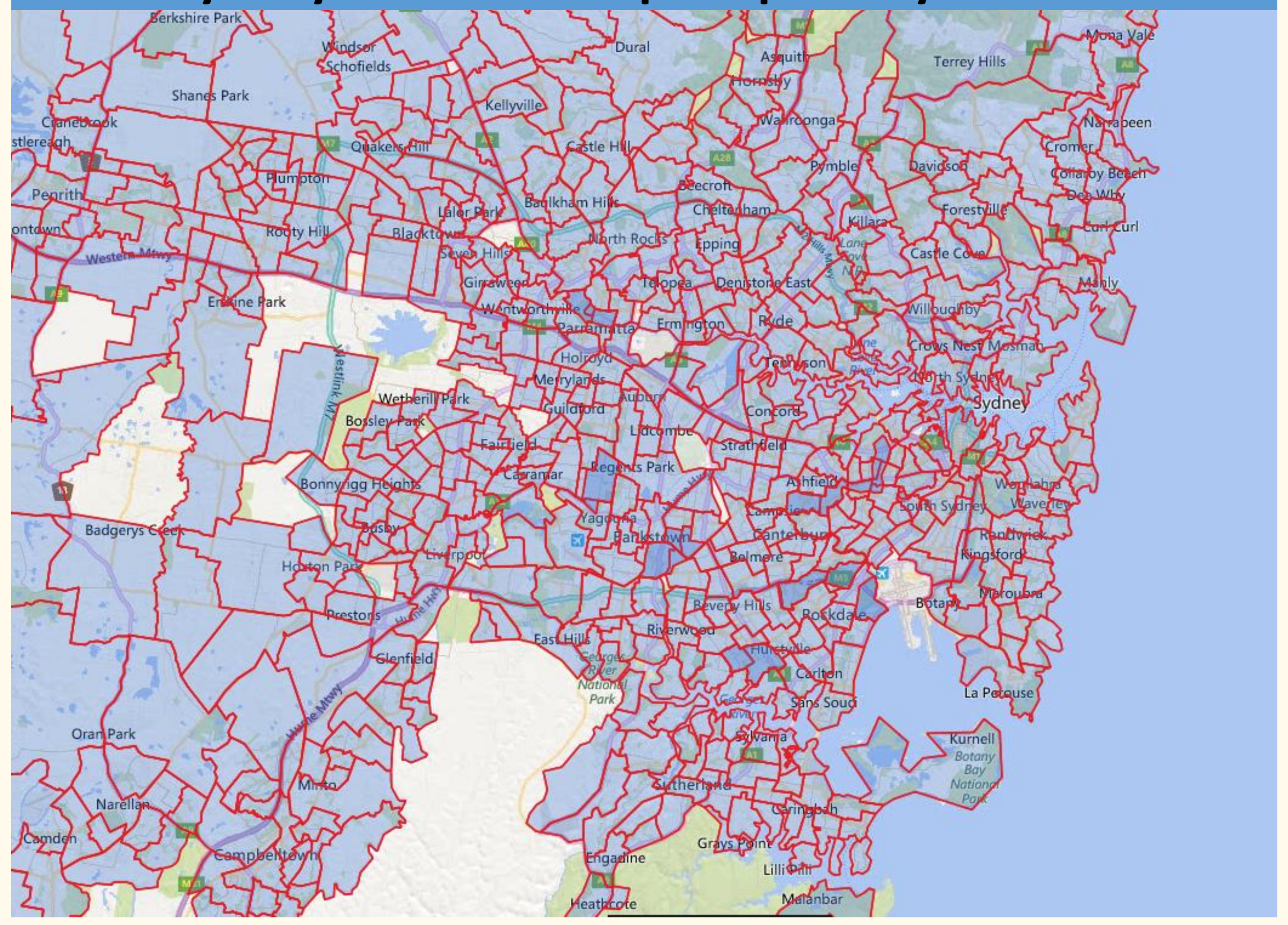
- Framing the problem by investigating a multi-period facility location problem, where the objective is to determine the location of new public schools in a way that maximizes equity across all users.
- Incorporating all parameters affecting the problem, including parameters to cater for the availability of land in different areas around a city, the fluctuation of land prices from one location to another, and the possibility to build different sizes of facilities in a certain location.
- Estimating the values of all uncertainties deterministically, in each time-period, across the entirety of the planning horizon, including the demand in each zone, the construction cost of new schools, the available budgets, the cost of land, and the inflation rate of costs.
- Building a Model in AMPL to formulate the problem and then solve it in CPLEX to generate the optimum solution.

Problem Illustration

Variables

- Allocating the demand from each cluster "demand nodes" to an open school "supply node".
- Selecting the size of new schools
- Locating where to build the new schools

Sydney's clusters map for primary schools



Constraints

- Budget
- Catchment Areas
- Travel distance
- Capacity of schools
- Supply all demand
- Availability of the right size of land

Where will you build new schools in the next 10 to 20 years, across these hundreds of clusters?

- *Main Constraint*: Satisfying all the demand
- *Objective*: Maximizing Social Welfare
- *Main Constraint*: Abiding by the budget

Model

- A mathematical formulation is created to represent the problem. This formulation would include all the parameters and variables of the problem. The objective function and all constraints functions are as well formulated.
- After that, a model is created in AMPL, converting the mathematical formulation developed into syntaxes.
- Using a CPLEX solver, the generated model on AMPL is run to produce the sought optimum solution

Data

- Data constitute a very important and time-consuming part of the process. It is of a substantial size and would require meticulous refinement and tabularization to be usable.
- For the school network optimization problem studied, data include demand forecast, forecast of land prices, current demand, supply, capacities, construction costs forecasts, potential site characteristics, etc.
- In New South Wales, the government has been collecting all school related data for the past years. Forecasts are as well available through government and private entities.
- After the collection of the data, tabularization and cleaning is completed to bring the data to an exportable form to AMPL, following the format of the Model's formulation.
- CPLEX uses the data to generate the optimum solution.

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