Project I: Eliminating Child Care Deserts in New York State through Optimization

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Child care, commonly referred to as day care, involves the supervision and care of children, typically ranging from two weeks to 12 years of age[1]. This service is particularly vital for working parents, offering a professional environment for children while their caregivers are engaged in employment[2].

An ongoing challenge in the United States (US) is the prevalence of "child care deserts"—regions where the demand for licensed child care far exceeds available slots. Over half of American children live in such areas[3]. For instance, due to the limited availability of child care services, many regions in New York State are designated as "child care deserts." This classification is determined by several factors, including:

- The total number of available child care slots;
- The population of children requiring care;
- The percentage of employed parents;
- The average income in the area.

Specifically, in high-demand areas—defined as regions where at least 60% of parents are employed or the average income is $60,000 or less per year—an area is considered a child care desert if the number of available slots is less than or equal to half the population of children aged two weeks to 12 years. In normal-demand areas, where employment and income levels do not meet the high-demand criteria, the threshold is lower: an area is classified as a child care desert if the available slots are less than or equal to one-third of the population of children within the same age range.

In this project, we will focus on the issue of child care deserts in New York State (NYS). It is important to consider specific policies that apply to NYS, such as the increased capacity requirements for children aged 0-5. Babies and toddlers, in particular, tend to need child care more than older children, which is expected to be reflected in the state's policy. Beyond addressing overall demand, the NYS government ensures that children under the age of 5 have sufficient access to care. This means that the number of available slots for children in this age group must be at least two-thirds of the population of children aged 0-5.

[1] Bradley, R. H., & Vandell, D. L. (2007). Child care and the well-being of children. *Archives of pediatrics & adolescent medicine*, *161(7)*, 669-676.

[2] Adams, G., & Henly, J. R. (2020). Child care subsidies: Supporting work and child development for healthy families.

[3] `https://www.americanprogress.org/series/child-care-deserts/`

The Problem of Budgeting

The New York State (NYS) government aims to eliminate child care deserts across the state by increasing the number of child care slots in all areas, ensuring that no region is classified as a child care desert. To achieve this goal, the government plans to allocate funding for either building new child care facilities *or* expanding existing ones. Note that, building new facilities can cost more than 1 year to be completed, hence expanding based on the newly-built facilities are not considered in the current plan.

As a first step, NYS envisions an ideal scenario where new facilities can be built anywhere in the state.[4] There are three facility sizes available for construction, each with specific capacities and associated costs, as outlined in the provided data.

When expanding existing facilities, the maximum increase in capacity is 1.2 times the current size, up to a maximum of 500 slots per facility[5]. Because expanding capacity at larger facilities is often easier and less costly on a per-slot basis compared to smaller facilities, the cost of expanding child care capacity should depend on the *scale of the expansion*[6]. In particular, the expansion cost is influenced by the facility's current capacity and the scale of the expansion:

- The expansion cost is proportional to the proportion of the increase in capacity;
- To double the capacity (+100%), the government needs to pay a baseline cost ($20,000), and the capacity based cost for ($200 per each existing slot).

Additionally, any newly created slots for children under the age of 5 require an extra cost of $100 per slot for specialized equipment.

Your task as consultants is to assist the NYS government in determining the **minimum amount of funding** (in total) needed to meet their target for each area, categorized by zip code.

The Problem of Realistic Capacity Expansion and Distance

After reviewing the idealistic scenario, NYS officials provided additional recommendations to better reflect the complexity of expanding child care facilities and choosing appropriate locations for new ones.

Recommendations on costs. Officials recognized that, due to space limitations, the marginal cost of expanding slots in existing facilities should depend on the scale of the expansion. In other words, the larger the expansion, the higher the marginal cost per scale of the expansion. Motivated by this, instead of providing a fixed cost function, the officials propose a more realistic approach where the cost of adding slots follows a model where higher the expansion, higher the increase in the cost of adding more slots [7].

To break it down:

- For small expansions (up to 10% more than the current capacity), the expansion cost is lower. As before, it's calculated based on a baseline cost ($20,000), and the capacity based cost for ($200 per each existing slot).

[4] This means that any number of new facilities can be built in any area within NYS.

[5] Note that this constraint only applies to the expanded facilities. It is possible that the capacity of some of existing facilities excess this limit.

[6] Proportion of the increase in capacity.

[7] Think of it this way: when you only increase the number of slots by a small amount, it's relatively cheap. However, as you add more and more slots, the cost to add additional slots becomes higher, reflecting the increased difficulty of expansion.

- Once you start expanding beyond 10% but stay under 15%, the expansion costs rise more steeply. Now, for more expansion, the cost is higher than it was for the initial 10%. To double the capacity (+100%), there is a baseline cost ($20,000), and the capacity based cost ($400 per each existing slot).
- Finally, if you're expanding between 15% and 20%, the costs rise significantly. Here, the capacity based cost increases to $1000 per each existing slot. This reflects the reality that very large expansions are the most costly due to space constraints and other logistical issues.

In essence, the more slots you try to add, especially beyond certain thresholds, the more expensive it becomes to add each additional slot. The cost grows in stages, so recognize that the larger the expansion, the harder and more costly it becomes. The restriction on the scale of expansion is equivalent to say: it costs arbitrarily large to expand a facility to more than 20% of its current capacity, thus no one wants do that.

Recommendations on locations. At the same time, NYS officials have been evaluating potential locations for new facilities. To avoid an over-concentration of child care centers in specific regions, they recommend imposing a distance limitation between facilities, within each area. This means that, within each area, no two facilities, whether new or existing, can be located too close to one another. The minimum distance is 0.06 mile.

Your task is to help the NYS government determine the **minimum amount of funding** needed to achieve their goals, considering both the more complex cost structure and the distance limitation for new and existing facilities.

The Problem of Fairness

To address the issue of child care deserts, governments have introduced significant funding to help child care providers maintain and expand their services. In New York State (NYS), the government has received a total of $ 1 billion to improve the availability of child care services statewide[8] . However, beyond simply eliminating child care deserts, the government also wants to ensure that access to child care is distributed fairly across all regions, while maximizing overall social coverage.

One key fairness measure officials recommend is to minimize the gap in child care availability between different areas. Specifically, they want to ensure that the difference in the ratio of available child care slots to the total population of children between any two areas does not exceed 0.1. This means that no region should be significantly better or worse off than another in terms of child care access.

Under this fairness constraint, the government's goal is to maximize a social coverage index. This index is based on the weighted sum of child care coverage for two groups: children under 5 and all children, with a 2:1 weighting in favor of younger children (under 5). The higher weight reflects the greater importance of child care coverage for younger children in promoting overall social well-being.

Your task is to help the NYS government determine the best strategy to maximize this social coverage index while ensuring that no area is classified as a child care desert and staying within the $100 million budget. If it is impossible to satisfy the fairness requirement under the given budget, report this issue.

[8] `https://ocfs.ny.gov/programs/childcare/deserts/#overview`

Appendix

Available Data

- `child_care_regulated.csv`: This dataset contains the information of (existing) child care facilities in New York State.
- `population.csv`: This dataset contains the population of children in different ranges of ages (e.g., 0-5, 5-10, 10-14, etc.) in each zipcode region in New York State.
- `avg_individual_income.csv`: This dataset contains the average individual income in each zipcode region in New York State.
- `employment_rate.csv`: This dataset contains the employment rate in each zipcode region in New York State.
- `potential_locations.csv`: This dataset contains the potential locations available for building a facility in New York State.
- We estimate the cost of building a new facility based on this article. To build a new facility, you can assume the government needs to spend a fixed (one-time) amount of money based on the capacity of the facility:

Facility Size	# of Slots (Ages 0-5)	Cost of New Facility ($)
100 slots (Small)	50 slots	65,000
200 slots (Medium)	100 slots	95,000
400 slots (Large)	200 slots	115,000

Table 1: Construction cost estimates for different sizes of child care facilities