Location Selection of Cell Sites for Major US Telecom Company

Final Project Report – Spring 2021

Submitted by: Balani Vinay, Faubion Findlay, Sharda Ilesh

BIA 650 – PROCESS ANALYTICS AND OPTIMIZATION

Prof. Edward A. Stohr

Table of Contents

Abstract

Deployment of cellular networks involves substantial capital investment. Competition motivates service providers to minimize these costs while maintaining service quality. The selection of a cell site is one such important aspect in maintaining service quality and reach as many consumers as possible while keeping the total cost of running the network low. Based on the technical and business information available for each Cellular Market Areas (CMA), We develop a cost-minimizing planning model that simultaneously determines two critical variables – Total revenue opportunity and Point of Presence covered for the entire country. The Non-Linear Programming method of maximizing the objective cell is used in our problem. We also note the appropriate role of such optimization models in the overall planning process.

Introduction

The wireless industry is an integral part of the U.S. economy, with $188 billion in 2019[1]. Wireless service provides significant benefits to society from direct consumption, but it also improves the productivity of other economic activities by reducing information frictions. Cell towers are an integral part of our critical telecommunication infrastructure. In the past, we were limited by where we could communicate from and how. Now dispatchers can use the software on a cell phone to send and immediately receive communications, thanks to cell towers.

In 2019, there were 395,562 mobile wireless cell sites in the United States[2]. These numbers will only go up with the significant investment made by major US telecom companies in the 5G network building. Thus, for telecom companies, it becomes imperative to plan and select each cell site location carefully. Each accurately selected location gives them a competitive edge over their rivals and helps them penetrate their consumer base better and broader.

Business Questions

1. In which geographic areas should the Major US Telecom deploy its sites?
2. How many sites per Cellular Market Area (CMA) are required to be built to achieve maximum profitability?
3. What is the total revenue opportunity generated by executing the current plan?
4. How many Point of Presences (POPs) are being covered with this project?

Data Collection

The data consists of geographic locations, aka Cellular Market Areas (CMAs), that are considered to build cell sites.

For each location, we have the following data available:

- Area (sq. miles): This is the area in Sq. Miles for each CMA. The FCC either uses these areas for administrative convenience in the licensing of the cellular systems. These areas can be either of the two, Metropolitical Statistical Areas or Rural Service Areas.

- POPs covered: POP covered broadly refers to the population of the people captured under each CMA, if all the sites needed for a particular CMA are built. This metric helps the telecom companies establish the target population captured and the market share acquired.

- Sites Needed: A cell site or cell tower station is a cellular-enabled mobile device site where antennas and electronic communications equipment are placed—typically on a radio mast, tower, or other raised structure—to create a cell in a cellular network. The raised structure typically supports an antenna and one or more sets of transmitter/receiver transceivers, digital signal processors, control electronics, a GPS receiver for timing, primary and backup electrical power sources, and shelter[3]. In our problem, each CMA has been assigned the number of sites that can be built to it.

- Average Cost Per Site: Average cost to set up a cell site or cell tower. This cost includes the cost of all the equipment mentioned above as well cost of land acquisition and labor hours.

- Average Revenue per Customer per Year: This is the average annual revenue generated from each customer. Here we have used each POP as a customer.

- Market Share: This represents our company's market share in the wireless telecom market in each CMA. As our company is a major telecom company, its market share in each CMA ranges from 25% to 40%.

- Total Revenue Opportunity per Year: This is the total revenue generated by the telecom in the year from the respective CMA. It is obtained by multiplying Average Revenue per customer per Year with POPs and the percentage market share in the respective market share.

Research Method

The method used to solve this study is Nonlinear Programming (NLP). This method involves solving a system of equalities and inequalities, collectively termed constraints, over a set of actual unknown variables, along with an objective function to be maximized or minimized. Some of the constraints or the objective function are non-linear.

The problem is a non-linear programming problem (NLP) if the objective function is non-linear and/or the feasible region is determined by non-linear constraints. Thus, in maximization form, the general non-linear program is stated as:

Maximize $f(x_1, x_2, \ldots, x_n)$,

subject to:

$$g_1(x_1, x_2, \ldots, x_n) \leq b_1,$$

$$\vdots \qquad \vdots$$

$$g_m(x_1, x_2, \ldots, x_n) \leq b_m,$$

where each of the constraint functions g_1 through g_m is given[4].

For our problem,

Input Variables:

- Average Cost per Site
- Total Revenue Opportunity per Year for Each Location

Decision Variables:

- **Select CMA**: This is a binary variable that is used to determine whether to select the CMA location or not. 1 value represents CMA is selected, and 0 value represents CMA is not selected.
- **Percent of sites to do**: Once we have selected a CMA for building our network, we decide how many percentages of sites we build in that CMA.

Objective Cell:

- **Sum of Total Revenue Opportunity**: We maximize this objective variable. It is the sum product of the Total Revenue Opportunity per Year for Each Location and the Percentage of Sites to do.

Other Calculated Variables:

- **POPs Covered**: This is the multiplication of POPs covered in each CMA and the percentage of sites built in that CMA.
- **Total POPs Covered**: This is the sum of the POPs Covered for all CMA. It gives us the total number of POPs we can reach.

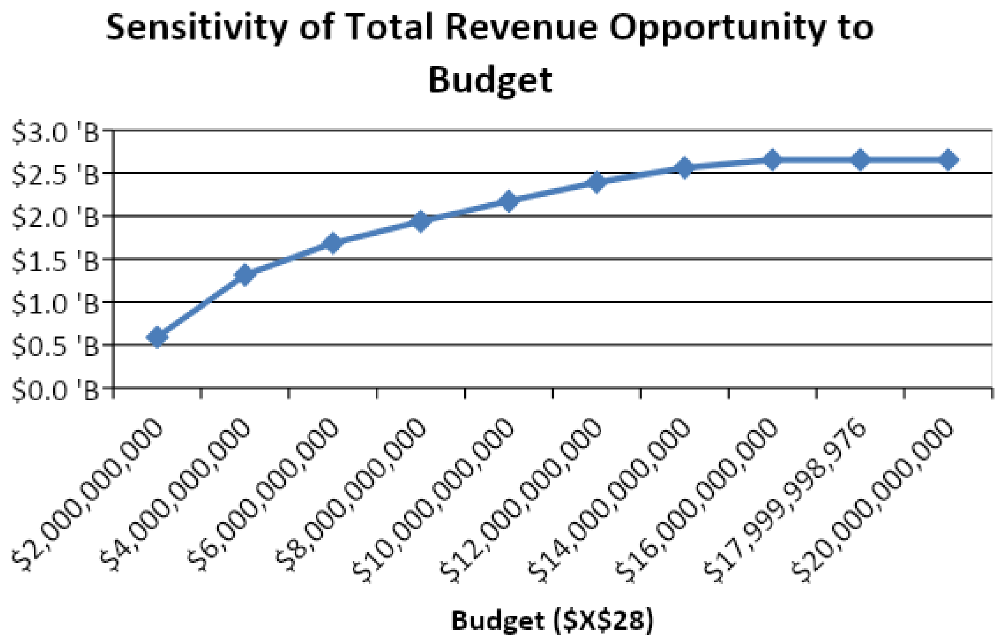
Constraints:

- If a CMA is selected, we need to build at least 15% of the total site requirements of that CMA.
- The Total Cost of building all the sites in all the CMAs should be less than the Total Budget allocated for this project. In our problem, the budget is $ 10 Bn.
- The Total Point of Presences (POPs) Covered should exceed 30 million.

Results

- Once we run our model in Microsoft Excel Solver tool, we get optimised selection of sites to be selected for maximising our objective site after taking into consideration the constraints.
- The Total Revenue Opportunity that was maximized is $2.18 Bn. This means that a $10 Bn investment would break-even in its 5th year and the company would make operational profits from there on.

  Of the 49 CMAs that were present in our dataset 32 CMAs are selected for building all the 100% sites whereas 1 CMA is selected to be built for limited percentage of sites and 16 CMAs are not selected and hence no sites would be built in those sites.
- The Total POPs Covered under this model are 132 million which is much higher than 30 million requirements. This extensive coverage of network will help the telecom network to improve significantly its market share.
- If we prepare a sensitivity analysis graph of total revenue opportunity vs revenue it tells us that till a certain point increase in budget leads to increase in revenue but beyond a certain number the increase in budget does not lead to any revenue growth.



Limitations & Future Scope

- Microsoft Excel though being an excellent tool to solve complex optimization problems, can only take up to 49 constraints for each problem. This is why we could only run our optimization problem on 49 CMAs and adjust our Total Budget and POPs expectations accordingly. Several industrial computational tools can handle a large amount of data and constraints. Using that in the future, we can solve our problem, which would cover all the USA's CMAs, and we can also use other variables to the original scale.
- The CMAs are divided by the Federal Communications Commission (FCC). There is no further granular geographical division available right now which can help us optimize our model even more precisely. That would otherwise enable us to select only a few sites with maximum impact in terms of POP reach in that particular CMA and discard those sites with minimum impact. Thus, the budget saved from those sites would help us reach even those CMAs discarded by the model earlier for being less profitable.

Conclusion

The Non-Linear Programming method was used to determine the location and number of Cell Sites to be built for a major US telecom. Our objective was to maximize the total revenue opportunity for the company, subject to several businesses and technical constraints. The NLP method was used in this problem as it helps us maximize a function subject to many linear and non-linear constraints. This computational exercise helped us to answer the following business problems:

i) In which CMA should we build our cell sites
ii) The percentage of sites to be built in selected CMA
iii) The total revenue opportunity by the cell site selection
iv) The POPs coverage with the cell site selection.

Using appropriate computing tools, the same business problem and its solving methodology can be expanded to more extensive and closer to real-life datasets and get optimized solutions that the company can execute to achieve their business goals.

References

Sun, P (2015) The Economics of Quality Investment in Mobile Telecommunications.

Dutta, A and Hsu, V (2001) Cellular Network Design Site Selection and Frequency Planning, Annals of Operations Research.

Heath, T (1999) Telecom Infrastructure: The New Facility Backbone, Site Selection magazine.

1. https://www.statista.com/statistics/293490/revenue-of-wireless-telecommunication-carriers-in-the-us/
2. https://www.statista.com/statistics/185854/monthly-number-of-cell-sites-in-the-united-states-since-june-1986/
3. https://en.wikipedia.org/wiki/Cell_site/

4. https://web.mit.edu/15.053/www/AMP-Chapter-13.pdf