OPTIMIZATION CASE STUDY-1

The cement depot location optimization problem

Introduction

Client is a leading cement company with 3 plants located in Rajasthan, M.P. & Karnataka, supplying three types of cements to more than 1000 sub-districts in India. Client currently has 100 depots supplying cements to dealers in the sub-districts through a combination of rail & road network. Due to inorganic expansion, the company is now facing these issues.

- High logistics cost
  - Sub-optimal depot locations
- Inventory management
  - Stock-outs / Excess inventory at depots

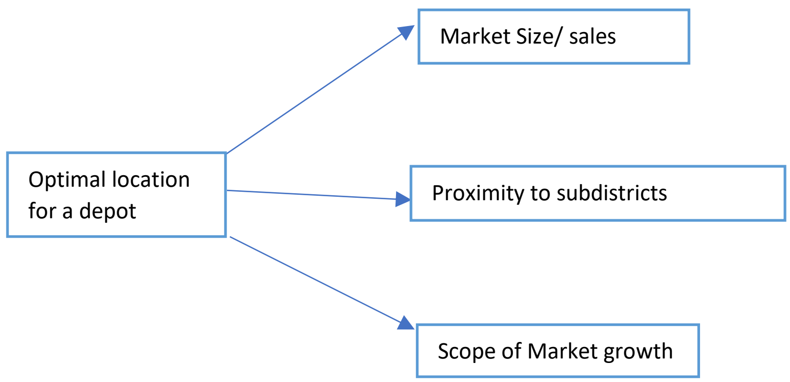
And therefore, needs to optimized its supply chain & identify cost saving opportunities. A mathematical network optimizer formula is developed to help identify optimal new depot locations for operations at the minimum logistics costs possible.

Key Assumptions

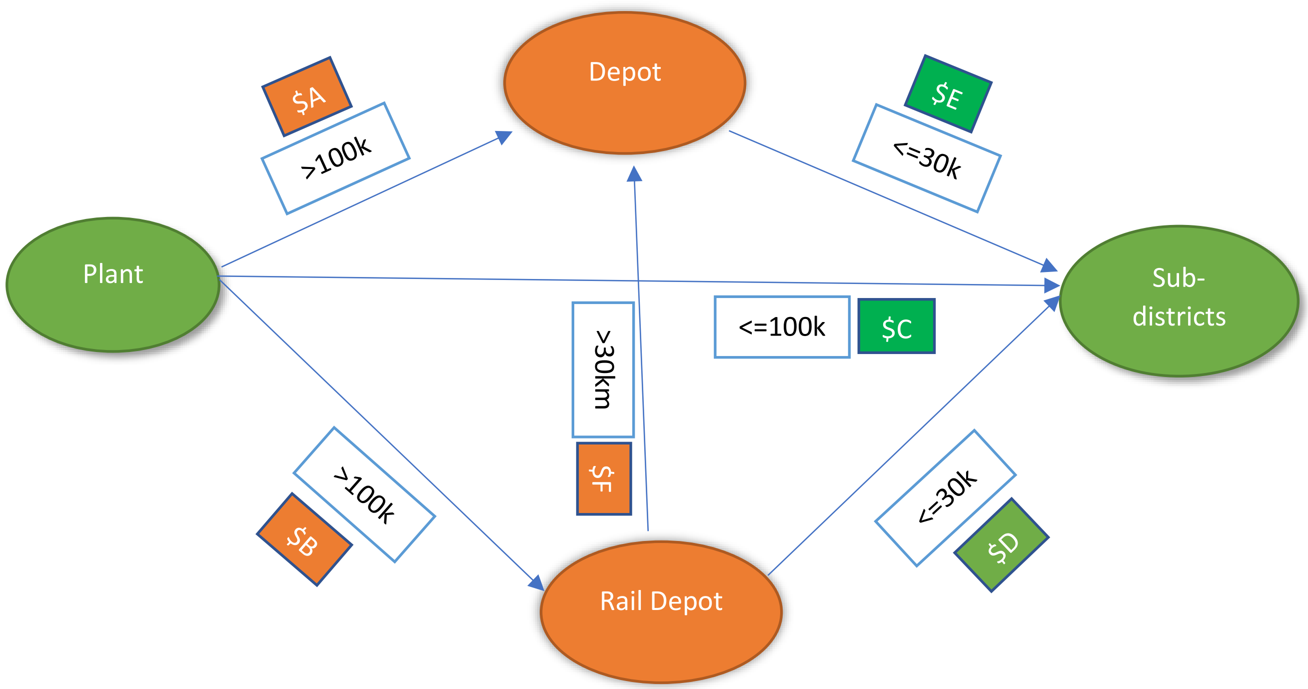
1. Each state has one plant
2. Each plant produces all 3 types of cement.
3. Building cost of new depots and operational cost of depots are constant
4. Traffic flow and route quality are constant
5. There is a linear relationship between distance covered and cost of transportation.
6. Further distance in kilometer assumptions are made in the table below. Given that the serviceability limit of a depot is 30km and a direct dispatch radius of a 100km from a plant. Cement moving from plant to sub-districts should satisfy these distance limitations else attracts a penalty cost unit α for any extra kilometer.

To / From	Depot	Rail depot	Sub-districts
Plant	> 100 km	> 100km	<= 100km
Depot	X	X	<= 30km
Rail Depot	>= 30km	X	<= 30km

7. we further assume the optimal location for a depot is influenced only by Market factors and any other influence such as varying infrastructure cost, government taxes etc. are constant across sub-districts. The diagram below illustrates this idea.



Distribution network



Mathematical Formulation

To create a mathematical formula for this problem we represent some key indicators below.

plant = p

Depot = d

Rail Head = rh

Sub-district = c

Product = pd

As shown in the previous diagram we assume a specific cost when each the route is used within the distance constraints. With any extra distance covered resulting to a penalty cost. I begin by examining the scenario where all transportations are within the specified the distance limitations as case 1.

Case 1

I first examine the case where the transportation of products is well within the specific limits implying no further cost results due to distance penalties. Therefore, I sum only the specified transportation cost on each route the product used before arriving at the sub-district.

cost of product(pd) transported = X

cost of transport from *p* to *d* = A

cost of transporting from p to rh = B

cost of transporting from p to c = C

cost of transporting from rh to c = D

cost of transporting from d to c = E

cost of transporting from rh to d = F

Objective function

Min $(X^*A_{p\text{-}d} + X^*B_{p\text{-}rh} + X^*C_{p\text{-}c} + X^*D_{rh\text{-}c} + X^*E_{d\text{-}c} + X^*F_{rh\text{-}d})$

Subject to:

At p, $X_{p\text{-}d} + X_{p\text{-}rh} + X_{p\text{-}c = 1}$

At c, $X_{p\text{-}c} + X_{d\text{-}c} + X_{rh\text{-}c = 1}$

At d, $X_{p\text{-}d} + X_{p\text{-}rh} + X_{p\text{-}c = 0}$

At rh, $X_{p\text{-}rh} + X_{rh\text{-}d} + X_{rh\text{-}c = 0}$

Case 2

In case 2, I examine the scenario where due to demand in certain regions transportation distances of products exceed the serviceability limits there by resulting extra cost. In this case I consider whether building an extra depot in this location will be cost effect or using the existing network is more cost efficient. The formula considers the sum of the fixed costs from operating within the distance limits plus a penalty unit cost α for every extra kilometer in distance covered multiplied by an Indicator whether a new depot is needed or not. Plus, the cost β for building a new depot multiplied by an Indicator whether a new depot is needed or not.

The binary Indicator for whether a new depot is needed is $I_{\beta<\sum\alpha*PI}$. Which takes a value of 1 when the cost of a new depot β is less than the the sum of the penalty costs inccured due to operating in the location and 0 otherwise.

A binary indicator PI takes a value of 1 for each extra kilometer covered outside the distance limits and zero if no further kilometer is covered. The total summation $(\sum_{n=1}^{\infty} a_n * PI_n)$ represents the total penalty costs.

Objective Function

- MIN (Sum (fixed costs) + Sum (penalty cost*penalty indicator) *new depot indicator+ (new depot cost) *new depot indicator)

  Let,
  X be the cost of cement transported
  Set R represent of all possible routes from plant to sub-district
  Variable W represent the transportation cost of using a route
  β the cost of building a new depot
  α the unit penalty cost for any extra kilometer travelled

  $$\text{Min}\left(X + \sum_{i\in R}^{j}\left(W_{ij}\right) + \left(\sum_{n=1}^{\infty} a_n * PI_n\right)^* I_{\beta>\sum\alpha*PI} + \beta^* I_{\beta<\sum\alpha*PI}\right)$$

  Subject to

  $$\sum_{i\in R}^{j}\left(W_{ij}\right) = A_{p\text{-}d} + B_{p\text{-}rh} + C_{p\text{-}c} + D_{rh\text{-}c} + E_{d\text{-}c} + F_{rh\text{-}d}\ , \forall i, j \in R$$

  PI_n , $I \in \{0,1\}$

  At p, $X_{p\text{-}d} + X_{p\text{-}rh} + X_{p\text{-}c} = 1$

  At c, $X_{p\text{-}c} + X_{d\text{-}c} + X_{rh\text{-}c} = 1$

  At d, $X_{p\text{-}d} + X_{p\text{-}rh} + X_{p\text{-}c} = 0$

  At rh, $X_{p\text{-}rh} + X_{rh\text{-}d} + X_{rh\text{-}c} = 0$

How S&OP adherence can be improved

There are number of ways S&OP adherence can be improved. To help optimize business procedure. I would improve S&OP adherence by

1. Capacity Plan Adherence

   Measuring the planned quantity of tons cement expected to move through a depot within a period vs the actual quantity that moves will be an effective measure to ensure S&OP adherence. This can be expressed as a ration of (Planned quantity of cement – Actual quantity of cement)/ Plan quantity of cement. This ratio can help create a base line by which future planning is estimated.

2. Percentage On-time Delivery to Sub-district

   Percentage On-time delivery is a good metric in measuring the overall efficiency of the cement supply chain. It will help track the rate of supplies that arrive to sub-districts on time. It is expressed as (planned tons expected in time t – actual tons in time t)/ planned tons expected in time t. This ratio measured within specified windows provided a good measure for our S&OP adherence.

3. Production Plan Adherence

   Measuring how well production is able to meet plan output is key to main tight delivery windows. This can be expressed as a ratio of (planned production – actual production)/ planned production. This can help create a base line by which we measure future output to ensure S&OP adherence.