617 Project Report

- The entire project can be described in one line as follows: “Finding an optimal transportation cost and finding corresponding savings by relaxing constraints”. Before diving into the project, we would like to mention all the assumptions we have made for this project.

Assumptions:

1. Our first assumption is “Historic Demand = Future Demand”. The logic behind this is there is no clear trend or seasonality in the data. Adding to that, we just have one year of data. This is the reason, we have gone with this assumption.
2. We have assumed equal wear and tear, which implies all the production lines have to be used proportionally (Useful for second What-If analysis).
3. We have used “per unit cost” and “Shipping Distances” to solve the Transportation Problem. As all the metrics are interconvertible it doesn’t make any difference.
4. Trucks can be moved from facility to retail store with partial capacity. There is no need to have 100% capacity. Also, no “Pooling” has been done.
5. Aggregate Planning has not been performed at there is no enough data to model it. Hence our only model is a “Transportation Problem”, with varying numbers.

Introduction:

- The entire project is divided into 2 parts.
  - Part-1: Finding an optimal route between facilities and retail stores which minimizes per unit cost, as we have mentioned metric doesn’t matter as long as the assumptions holds good.
  - Part-2: Finding the cost savings by implementing the new production line instead of old production lines for 3 years.

Given Data:

- The historical demand of each region (Pittsburgh, Cleveland, Buffalo, Philadelphia, Boston, New York, Providence, Hartford) where retail outlets are located, for each month (January till December).
- Shipping distances from the three production facilities located in Troy NY, Newark NJ and Harrisburg PA to each of the retail outlets in Pittsburgh, Cleveland, Buffalo, Philadelphia, Boston, New York, Providence, Hartford. Other metrics like cost/truck and unit cost are given. As mentioned in the previous paragraph, these metrics doesn’t matter. However, I have modelled using Shipping Distance and per unit cost.
- Production Line Characteristics like Units per hour, Energy (kWh) per hour, Emissions per product, Energy (kWh) per unit, Energy Cost per kWh and Energy Cost per unit of each of the three lines in each of the three production facilities

- Fast production Characteristics like Units per hour, Energy (kWh) per hour, Emissions per product, Energy (kWh) per unit, Energy Cost per kWh and Energy Cost per unit, common for each line.

Given Facts:

- Currently, DinoBall operates under the policy that each facility will, monthly, produce the same number of toys.
- MCS Corporation currently implements the requirement that every production line at a facility runs for the same length of time during a month.
- Each production line has the required salaried staff to operate the production lines who all work 40 hours per week.
- MCS Corporation contracts with LM Trucking to transport DinoBall from their facilities to their retail stores.
- LM Trucking is then to charge a premium of 20% to MCS Corporation in billing them for the logistics services.
- MCS is charged for the energy they use to run their production lines. Due to their age, each production line requires different amounts of energy (kWh) and each production facility have negotiated a set price per kWh with the power company.

MODEL

Data:

- Unit Cost table from facility to retail store.

	PB	CL	BF	PH	B	NY	PD	HF
Tr	1.07	1.02	0.63	0.5	0.37	0.33	0.36	0.25
NW	0.77	1.06	0.61	0.19	0.48	0.03	0.41	0.27
HB	0.43	0.7	0.63	0.23	0.82	0.36	0.74	0.61

- Production table for all the facilities in all the months.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Tr	475	492	508	525	483	493	477	500	433	492	625	767
NW	475	492	508	525	483	493	477	500	433	492	625	767
HB	475	492	508	525	483	493	477	500	433	492	625	767

- Demand in all the retail stores from January through December.

	PB	CL	BF	PH	B	NY	PD	HF
Jan	200	100	125	250	225	400	50	75
Feb	150	125	100	300	200	425	75	100
Mar	225	150	75	250	225	375	100	125
Apr	250	200	100	200	200	350	125	150
May	250	175	75	200	250	300	75	125
Jun	180	175	100	300	175	400	50	100
Jul	180	200	125	250	200	250	100	125
Aug	200	150	200	300	150	200	150	150
Sep	150	100	150	300	200	125	25	100
Oct	150	100	100	350	250	400	50	75
Nov	200	75	150	400	300	500	150	100
Dec	300	200	175	450	400	475	150	150

Decision Variable:

- We just have one decision variable, for part – 1.
- $\boldsymbol{x_{ij}}$ - Number of goods shipped from a facility to a retail store. Note that "i" corresponds to facilities and "j" corresponds to retail stores.

Objective Function:

- Minimizing Cost which is sum of all the costs required to produce in each line of each factory and then transport it from each factory to each retail store, for each of the 12 months.
- The objective function is given below:
  1.07*x_{14} + 1.02*x_{15} + 0.63*x_{16} + 0.5*x_{17} + 037*x_{18} + 0.33*x_{19} + 0.36*x_{110} + 0.25*x_{111} + 0.77*x_{24} + 1.06*x_{25} + 0.61*x_{26} + 0.19*x_{27} + 0.48* x_{28} + 0.03*x_{29} + 0.41*x_{210} + 0.27*x_{211} + 0.43*x_{34} + 0.7*x_{35} + 0.63*x_{36} + 0.23*x_{37} + 0.82*x_{38} + 0.36*x_{39} + 0.74*x_{310} + 0.61*x_{311}.

Constraints:

- Monthly demand should meet and the capacity constraints should be satisfied. We can divide the constraints into 2 parts.
- Part – 1: Balanced Production, which implies each facility should produce same quantity, proportionally.
- Part – 2: Imbalanced Production, which implies each facility can produce as much as they can to satisfy the demand.
- Note than part -2 is just a part of part-1. If we remove the equality constraint then we can convert the problem to imbalanced from balanced.

- $x_{14} + x_{15} + x_{16} + x_{17} + x_{18} + x_{19} + x_{110} + x_{111} = Troy_{Prod}$
- $x_{24} + x_{25} + x_{26} + x_{27} + x_{28} + x_{29} + x_{210} + x_{211} = Newark_{Prod}$
- $x_{34} + x_{35} + x_{36} + x_{37} + x_{38} + x_{39} + x_{310} + x_{311} = Harrisburg_{Prod}$
- $x_{14} + x_{24} + x_{34} = Pittsburg_{Demand}$
- $x_{15} + x_{25} + x_{35} = Cleveland_{Demand}$
- $x_{16} + x_{26} + x_{36} = Buffalo_{Demand}$
- $x_{17} + x_{27} + x_{37} = Philadelphia_{Demand}$
- $x_{18} + x_{28} + x_{38} = Boston_{Demand}$
- $x_{19} + x_{29} + x_{39} = New\ York_{Demand}$
- $x_{110} + x_{210} + x_{310} = Providence_{Demand}$
- $x_{111} + x_{211} + x_{311} = Hartford_{Demand}$

- **The next constraint is to make all the variables greater than zero and integer constraint**.

- If you remove first 3 constraints then it will become imbalanced problem.

Results:

- We have implemented this model in multiple software (Excel, AMPL, Python, and R). We got same results in all those software. There are two parts in the results as well. The only adjustment made for the first what if analysis is removal of the production constraint. Second what if is pretty much a mathematical manipulation.
- Part – 1 (**What If -1**): The total cost with balanced production is $5854 and the total cost with imbalanced production is $ 5733. Hence the total amount (***transportation cost***) saved by changing from balanced to im-balanced is **$121/year**. Note that this is considering even wear and tear in place.
- Part -2 (**What If – 2**): In this we have calculated the total energy cost with old production line using their proportions of usage. The subtracted the total energy cost by using the new production line. Note that it has been mentioned in the project problem statement that assume two what if conditions independently. Hence, while calculating the savings I am keeping the balanced production constraint in-tact. The total amount (***energy cost***) saved is **$138,731/year**. For three years total savings would be **$416,193**. This is the reserve price MCS Corporation can determine if they want to change to the new production line.

Conclusion:

- We would like to conclude by recommending MCS Corporation to scrape the balanced production. If you observe the old lines are very inefficient and costly. Hence, the first thing they should do is to remove the "Equal Wear and Tear" policy or implement new production lines instead of the old ones. It will save a tonne of money for them.
- Holistically speaking, this is a very basic problem. We would have made a complete project if we had a bit more data. For instance, the historic demand is pretty small. We cannot do much with that historic data except for assuming Future Data = Historic Data. We would have preferred more data.

- Also, the information pertaining to the production lines is very small. Had we provided with data about cost of firing, cost of hiring, cost of incremental production, aggregate number of units produced by worker, initial inventory, etc we could have made more accurate decisions.
- We can incorporate practical truck capacity constraints into the model. That would have been really interesting.
- Finally, the bottom line is, in order for MCS Corporation to remain profitable they have to take some bold decisions and provide the consultants with more data to make comprehensive "data driven decisions".

Note: We have built the model in four different software and ended up with same results. I will be attaching all our references and materials in this section.

References:

Same model in different software.

- Project in Excel, Part -1 {Excel}
- Project in Excel, Part – 2 {Excel}
- Project in Python {Python}
- Project in R {R Studio}
- Project Mod in AMPL {AMPL}
- Project Data in AMPL {AMPL}
- Project What in AMPL {AMPL}

Actual References:

- The Transportation Problem
- Transportation and Assortment in R
- Using lpSolve in R
- 615 Textbook