Project Report on

NUCLEAR WASTE DISPOASAL

Final group project for

Quantitative Management Modelling

Submitted by:

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Problem Formulation

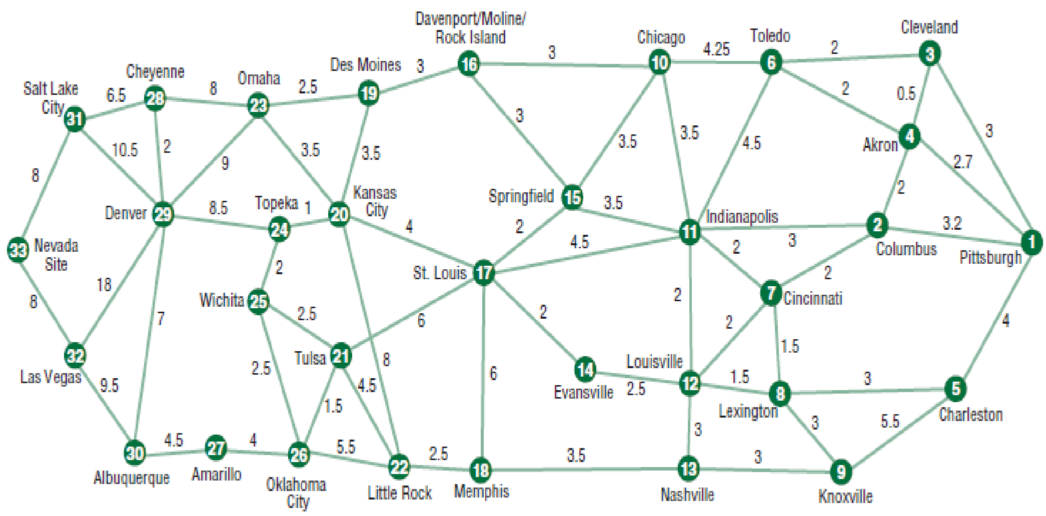
Case overview

Our project is based on a case selected from the textbook Introduction to Management Science, (10th edition) by Anderson, Sweeney and Williams. The case is described as follows:

Nuclear waste is very radioactive and very hazardous to living beings. Due to the hazardous nature of the nuclear waste, the waste should be transported very carefully to specific government regulated sites from Pittsburgh to Nevada.

PAWV power and light company has contracted with a waste disposal firm to dispose their nuclear waste at government disposal sites in Nevada. There is only one waste disposal site across the country. The nuclear waste must be travelled in reinforced container trucks across the country, the travel must be confined to the interstate highway system.

There are 29 cities between Pittsburgh to Nevada to dispose the nuclear waste. The truck must travel between the route listed between the 29 cities to dispose the nuclear waste.



Current problem

The government insisted that the truck should travel between Pittsburgh to Nevada in 42 hours to reduce the effects of the radiation by the nuclear waste.

The truck should be travelled between the cities such that the least population must be affected by the hazardous nuclear waste.

The population between the cities in (Millions)

- Akron – 0.5
- Albuquerque – 1.00
- Amarillo – 0.30
- Charleston – 1.30
- Cheyenne -0.16
- Chicago – 10.00
- Cincinnati – 1.20
- Cleveland – 1.80
- Columbus – 0.75
- Rock island - 1.00
- Denver – 2.00
- Des Moines – 0.56
- Evansville – 0.30
- Indiana polis – 1.60
- Kansas City – 2.10
- Knoxville – 0.54
- Las Vegas – 1.60
- Lexington – 0.50
- Little rock – 0.60
- Louisville - 0.93
- Memphis – 1.47
- Nashville – 1.00
- Oklahoma City – 1.30
- Omaha – 1.40
- Salt Lake City – 1.20
- Springfield – 0.36
- St. Louis – 2.00
- Toledo – 0.76
- Topeka – 0.30
- Tulsa – 1.00
- Wichita – 0.73

Model Description

We are using network model and integer programming to solve our problem.

In our network model each node represents a city, each arc represents the route and the time required by trucks to travel from source to the destination.

The library we are using to solve the problem is lpsolveApi.

In our problem formulation we have two important steps:

1) Objective function – In our problem we are minimising the objective function, as we must expose the nuclear waste to least population possible.

2) Constraints – we have four main constraints for time travel constraint, starting node constraint, intermediate node constraint, and ending node constraint.

Objective function

The main objective of our problem is to dispose the nuclear waste with the least amount of the population exposed during the journey because of the toxic nature of the nuclear waste.

We must build network model such that minimising the objective function such that the least population us exposed.

Decision variables:

- Xij defines the travel of Waste Disposal Truck from Source (i) to destination (j) Cities.
- Cij defines the Population of the Cities.
- Dij defines the time taken to travel between cities.

$$\text{Minimize} \sum_{\text{Truck Path}} Cij\ Xij$$

Min: 0.75 X12 + 1.80 X13 + 0.50 X14 + 1.30 X15 + 0.50 X24 + 1.2 X27 + 1.6 X211 + 0.5 X34 + 0.76 X36 + 0.76 X46 + 0.5 X58 + 0.54 X59 + 10 X610 + 1.6 X611 + 0.5 X78 + 1.6 X711 + 0.93 X712 + 0.54 X89 + 0.93 X812 + X913 + 1.6 X1011 + 0.36 X1015 + X1016 + 0.93 X1112 + 0.36 X1115 + 2 X1117 + X1213 + 0.3 X1214 + 1.47 X1318 + 2 X1417 + X1516 + 2 X1517 + 0.56 X1619 + 1.47 X1718 + 2.1 X1720 + X1721 + 0.6 X1822 +2.1 X1920 + 1.4 X1923 + 0.6 X2022 + 1.4 X2023 + 0.3 X2024 + 0.6 X2122 + 0.73 X2125 + 1.3 X2126 + 1.3 X2226 + 0.16 X2328 + 2.2 X2329 + 1.3 X2526 + 0.3 X2627 + X2730 + 2.2 X2829 + 1.2 X2831 + X2930 + 1.2 X2931 + 1.6 X2932 + 1.6 X3032;

Constraints:

Time constraints:

The truck must travel within 24 hours because of the government regulation of minimising the radiation exposed by the nuclear waste. So, the constraint would be <= 42 hours.

$$\sum_{\text{Truck out}} D_{ij} X_{ij} <= 42$$

3.2 X12 + 3 X13 + 2.7 X14 + 4 X15 + 2 X24 + 2 X27 + 3 X211 + 0.5 X34 + 2 X36 + 2 X46 + 3 X58 + 5.5 X59 + 4.25 X610 + 4.5 X611 + 1.5 X78 + 2 X711 + 2 X712 + 3 X89 + 1.5 X812 + 3 X913 + 3.5 X1011 +3.5 X1015 + 3 X1016 + 2 X1112 + 3.5 X1115 + 4.5 X1117 + 3 X1213 + 2.5 X1214 + 3.5 X1318 + 2 X1417 + 3 X1516 + 2 X1517 + 3 X1619 + 6 X1718 + 4 X1720 + 6 X1721 + 2.5 X1822 + 3.5 X1920 + 2.5 X1923 + 8 X2022 + 3.5 X2023 + X2024 + 4.5 X2122 + 2.5 X2125 +1.5 X2126 + 5.5 X2226 + 8 X2328 + 9 X2329 + 2.5 X2526 + 4 X2627 + 4.5 X2730 + 2 X2829 + 6.5 X2831 + 7 X2930 + 10.5 X2931 + 18 X2932 + 9.5 X3032 + 8 X3133 + 8 X3233 <=42;

Starting node constraint:

Starting point of the truck from Source location and can enter anyone neighbouring City.

$$\sum_{\text{Truck out}} X_{ij} = 1$$

X12 + X13 + X14 + X15 = 1;

Intermediate node constraints:

Equality Constraints for each City, the truck entered to a city should leave the city as well.

$$\sum_{\text{Truck in}} X_{ij} - \sum_{\text{Truck out}} X_{ij} = 0$$

$X12 - X24 - X27 - X211 = 0;$

$X13 - X34 - X36 = 0;$

$X14 + X34 + X24 - X46 = 0;$

$X15 - X58 - X59 = 0;$

$X36 + X46 - X610 - X611 = 0;$

$X27 - X78 - X711 - X712 = 0;$

$X58 + X78 - X89 - X812 = 0;$

$X59 + X89 - X913 = 0;$

$X610 - X1011- X1015 - X1016 = 0;$

$X211 + X611 + X711 + X1011 - X1112 - X1115 - X1117 = 0;$

$X712 + X812 + X1112 - X1213 - X1214 = 0;$

$X913 + X1213 - X1318 = 0;$

$X1214 - X1417 = 0;$

$X1015 + X1115 - X1516 - X1517 = 0;$

$X1016 + X1516 - X1619 = 0;$

$X1117 + X1417 + X1517 - X1718 - X1720 - X1721 = 0;$

$X1318 + X1718 - X1822 = 0;$

$X1619 - X1920 - X1923 = 0;$

$X1720 + X1920 - X2022 - X2023 - X2024 = 0;$

$X1721 - X2122 - X2125 - X2126 = 0;$

$X1822 + X2022 + X2122 - X2226 = 0;$

$X1923 + X2023 - X2328 - X2329 = 0;$

$X2024 - X2425 + X2429 = 0;$

$X2125 + X2425 - X2526 = 0;$

$X2126 + X2226 + X2526 - X2627 = 0;$

$X2627 - X2730 = 0;$

$X2328 - X2829 - X2831 = 0;$

$X2329 + X2429 + X2829- X2930 - X2931 - X2932 = 0;$

$X2730 + X2930 - X3032 = 0;$

$X2831 + X2931 - X3133 = 0;$

$X2932 + X3032 - X3233 = 0;$

Ending node constraints:

The Truck shall reach the destination city from only one city.

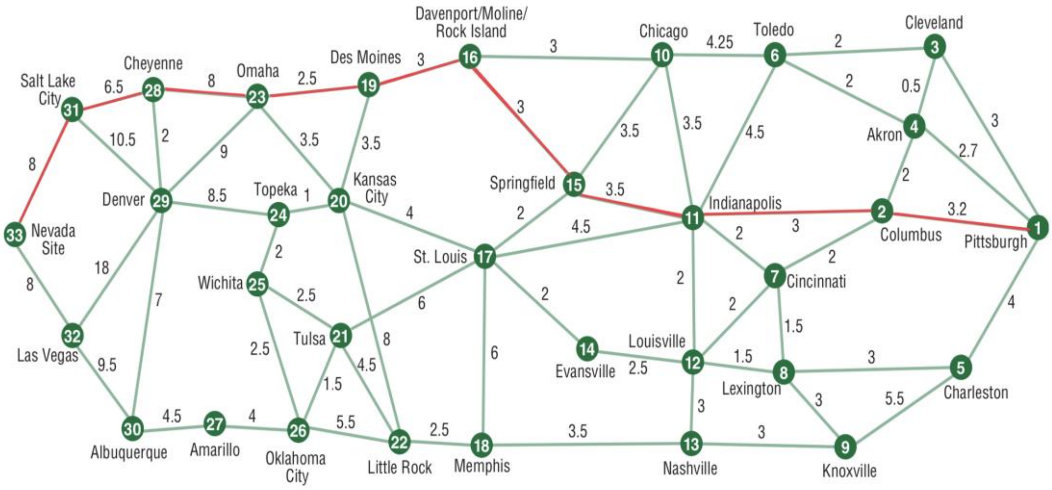
$$\sum_{\text{Truck in}} Xij = 1$$

X3133 + X3233 = 1;

Results:

- By solving the above objective function, we get the result as 7.03. This represents the population (in millions) that have been exposed to nuclear radiation from the truck. Therefore, 7.03 million will be the least possible population exposed to the truck possible.
- By solving the above constraints, we get the time constraint as 40 hours and 42 minutes. This constraint represents the travel time of Nuclear waste disposal truck from Pittsburgh to Nevada waste site.

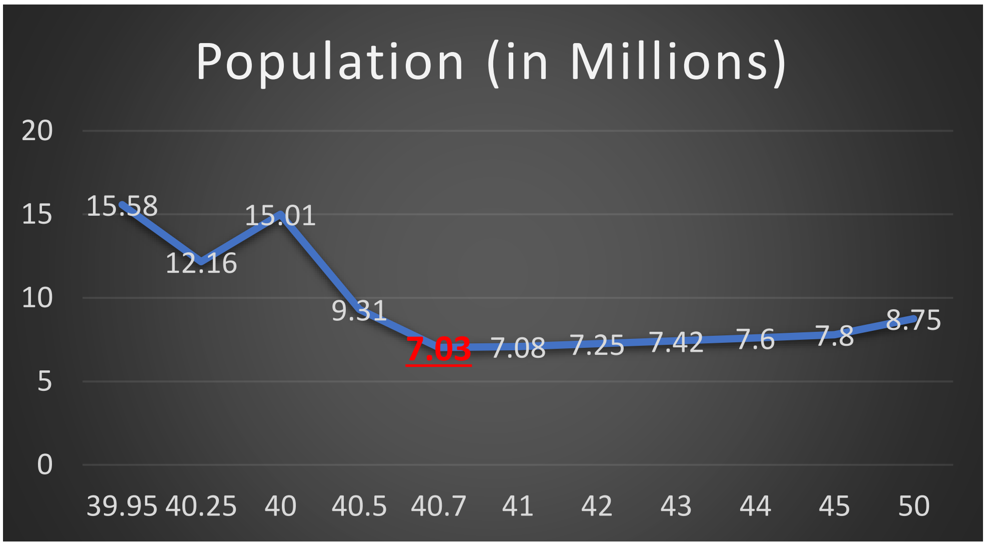
The following highlighted lines are the optimal route for the trucks to travel,



Experimental Results:

We have tried to put forth few alterations in the constraints. So, that we can observe some variations in our goal. Initially we have considered the time constraint regulated by the government that the nuclear waste must be disposed within 42 hours from its source to waste disposal site.

However, by manipulating the time variable we can gain some further insights. Below is the graph showing the time variations and the number of populations that will be affected by Nuclear radiations from the waste carrying truck.



From the above graph we can see that,

- There is infeasible solution for travel time less than 39.95 hours.
- When travel time increases even the number of people affected by radiation also increases.

Thus, it is necessary to consider travel time above 39.95 hours, the optimal time would be 40.7 hours and anything more or less than 40.7 would affect more population.

Conclusion and Future Scope

We can conclude that with optimal travel time of **40 hours 42 minutes**, we are affecting a smaller number of populations (7.03 Million). There can be even better solution in hypothetical situation like when there are

- Dedicated interstate highways to disposal sites from Nuclear Power Plants.
- More than one government operated high level nuclear waste disposal sites.
- Railroad connectivity for faster transportation

In practical world these hypothetical situations aren't possible, but we can improve by considering few things like

- By doing R&D to improve the designs of Casks, Buffer. So, there is less radiations from the Nuclear waste while transporting.
- Stakeholder Tool for Assessing Radioactive Transport (START) is a tool that can perform geospatial data visualization and transportation routing analysis. This is tool is restricted to only for government use. If provided to nuclear power plant companies, they can improve their waste transportation.
- Government need to revise the Nuclear Act Policy of 1982 for current situations.

References:

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