Application Project GB730

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Introduction

The USA government plans to allocate Covid-19 vaccines at various distribution centers among cities with the highest populations through which the vaccines will be distributed to other cities within the State.

We found this problem interesting because of unbalanced distribution of Covid-19 vaccines that we observed in India. Having a generalized optimization model for vaccine distribution would assist any country in fighting the Covid epidemic more efficiently.

Problem Statement

Build a linear optimization model which identifies potential vaccine distribution center locations among the cities within each state in the US and allocates each city to a distribution center in its vicinity.

Objectives and Decision Variables

Objective

- Minimize the total distance traveled in shipping vaccine vials through all the cities under consideration in the state.

Decision Variables

- Assign cities where distribution centers are to be located
- Assign each city to its respective distribution center.

Constraints

- All decision variables are binary in nature.
- Number of distribution centers in a state should be equal to the number of centers allocated to it by the government.
- Assign distribution center to a city only if a distribution center exists there.
- Each city needs to get assigned to a distribution center.

Optimization Model

Model Platform

- Generalized model is built on python and an instance of the model for Wisconsin state is illustrated in Excel.
- Python is used to build the model because of its ability to scale in order to include all cities, towns and villages in the state if we have population census data.
- Python library pyomo is used to formulate, solve, and analyze the optimization model.
- Google maps API is employed to construct the distance matrix for all the cities, towns and villages with population data.

Optimization Model

Input Parameters

- Cities and their population for the State under consideration.
- Number of distribution centers allocated to state by the government.
- Number of vaccine vials per shipment.
- Google maps API key to access and create distance matrix for the cities

Optimization Model

Sample Inputs (Python Model)

City	Population
Milwaukee	577,222
Madison	269,840
Green Bay	107,395
Kenosha	99,986
Racine	77,816
Appleton	75,644
Waukesha	71,158
Eau Claire	69,421
Oshkosh, Oshkosh	66,816
Janesville	65,615

```
# Number of vials per shipment
vials_per_shipment = 2000
# Number of DCs required in State
DC_num = 4
#Maps url and google API key
maps_url = "https://maps.googleapis.com/maps/api/distancematrix/json?"
API_key = "AIzaSyBxHhp-sHroFA0kEpa7OFuzCit2UdaTEm0"
```

Optimization Model

Sample Output (Python Model)

```
Minimized distance to be traveled to deliver vaccine shipments = 11699.5


Vaccine distribution centers are to be located in the following locations:


Milwaukee
Madison
Appleton
Eau Claire


Distribution center allocation:
Distribution centre in Milwaukee allocated to Milwaukee
Distribution centre in Milwaukee allocated to Kenosha
Distribution centre in Milwaukee allocated to Racine
Distribution centre in Milwaukee allocated to Waukesha
Distribution centre in Madison allocated to Madison
Distribution centre in Madison allocated to Janesville
Distribution centre in Appleton allocated to Green Bay
Distribution centre in Appleton allocated to Appleton
Distribution centre in Appleton allocated to Oshkosh, Oshkosh
Distribution centre in Eau Claire allocated to Eau Claire
```

Optimization Model

Single Instance for Wisconsin State Excel model

Distances between cities

	Milwaukee	Madison	Green Bay	Kenosha	Racine	Appleton	Waukesha	Eau Claire	Oshkosh	Janesville
Milwaukee	0	128	188	65	39	172	31	395	142	123
Madison	128	0	224	185	169	175	105	287	145	69
Green Bay	191	218	0	251	236	49	218	313	81	274
Kenosha	64	184	248	0	17	229	84	451	199	116
Racine	39	169	233	17	0	214	69	436	184	106
Appleton	172	169	49	229	214	0	158	293	32	225
Waukesha	31	103	214	88	72	161	0	370	131	99
Eau Claire	396	286	309	452	437	320	372	0	319	344
Oshkosh	143	140	81	200	184	32	128	294	0	196
Janesville	122	65	270	115	106	221	81	339	191	0

DVs: Locate a service center? (Constraint: Binary)

1	1	0	0	0	1	0	1	0	0

DVs: Assign cities to the DC?

Milwaukee	1	0	0	0	0	0	0	0	0	0
Madison	0	1	0	0	0	0	0	0	0	0
Green Bay	0	0	0	0	0	1	0	0	0	0
Kenosha	1	0	0	0	0	0	0	0	0	0
Racine	1	0	0	0	0	0	0	0	0	0
Appleton	0	0	0	0	0	1	0	0	0	0
Waukesha	1	0	0	0	0	0	0	0	0	0
Eau Claire	0	0	0	0	0	0	0	1	0	0
Oshkosh	0	0	0	0	0	1	0	0	0	0
Janesville	0	1	0	0	0	0	0	0	0	0

Constraint: Only can assign DC to a city if an DC exists there

4	2	0	0	0	3	0	1	0	0
<=	<=	<=	<=	<=	<=	<=	<=	<=	<=
10000	10000	0	0	0	10000	0	10000	0	0

Numbers of trips needed to deliver vaccines quantity needed in each city

	Total Trips required	Dist. Traveled	City Population
Milwaukee	289	-	577,222
Madison	135	-	269,840
Green Bay	54	2,657	107,395
Kenosha	50	3,190	99,986
Racine	39	1,529	77,816
Appleton	38	-	75,644
Waukesha	36	1,120	71,158
Eau Claire	35	-	69,421
Oshkosh	33	1,056	66,816
Janesville	33	2,148	65,615

Number of vials shipped per trip: 2,000

Objective: Minimize the total distance traveled in KM

11,700

Constraint: Building exactly 4 distribution centers

4	=	4

Constraint: Each city needs to get assigned to an DC

1	=	1
1	=	1
1	=	1
1	=	1
1	=	1
1	=	1
1	=	1
1	=	1
1	=	1
1	=	1

DC Total Vaccine vials to be allocated to DC by Government

Milwaukee	826,182
Madison	335,455
Appleton	249,855
Eau Claire	69,421
Total Vaccine allocated to Wisconsin	1,480,913

Optimization Model

How the model works

- The python model reads the state population data by city (excel file) and creates the distance matrix using Google maps API.
- Model calculates the number of trips required to meet vaccine requirement for each city based on its population and vials per shipment.
- Pyomo utilizes the distance matrix and number of trips required, applies constraints and minimizes the objective and gives the potential distribution centers and cities assigned to them.

Benefits and Limitations

Benefits

- The model can be scaled to be used for any state in any country as long as they have the latest census data and google map coordinates (i.e., latitude and longitude)

Limitation

- The population data by city should be structured in a way that Google maps recognizes the city names.
- Population data by city needs to be collated and inputted by user.
- User should have access to Goggle Maps API which is a paid service.

Challenges and Inspirations

Challenges:

- Structuring the API link to extract distance matrix for cities under consideration.

Inspirations:

- GB760 Business Data Technologies course helped in understanding the usage of APIs to extract information from websites.
- We are proud of how we incorporated Google maps API to construct distance matrix as a way to remove user dependencies.

Extensions and Clients

Extension of project:

- The model could be further enhanced such that the city and population data is extracted directly from either Wikipedia or population census website based on the state the user inputs.

Clients:

- Democratic Central or State Governments.
- Supply chain and Logistics companies.

References

References

- The population data of top 10 cities in Wisconsin state is taken from Wikipedia. (link: https://en.wikipedia.org/wiki/List_of_cities_in_Wisconsin)
- Google Maps distance matrix documentation (Link: https://developers.google.com/maps/documentation/distance-matrix/overview)

Supporting Files

Wisonsin
Population Data

Model Instance
or Wisconsin State

Python Model

Team Contribution

The team members equally contributed towards all aspects of the project

Thank you

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