Bachelor of Technology Project (MCD411)
Mid-Term Report

Efficient Foodgrain supply chain for Uttarakhand

Project No. I-10

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Abstract

The state of Uttarakhand is a hilly state with more than 60% area covered with forests. Difficult terrain, limited availability of transporters, restricted windows for transportation and the disintegrated storage spaces have led to the state government incurring very high costs for transportation of TPDS commodities. During monsoon and winter seasons some high-altitude areas get cut off from the main supply hubs, causing reduced access and limited availability of food grains. In addition to this, some other challenges like Slow delivery of grains, international borders, extreme terrain conditions, natural calamities, harsh weather, and disintegrated storage spaces have to be addressed.

A GUI based executable application was developed, which enables users to select from several working scenarios, and input grain allocations through various government schemes (AAY, PHH, SFY etc). In output, a detailed tagging data is generated giving the amount to be transported through each arc to meet demand at minimal associated cost; Google map plots are generated for quick visualization.

Introduction

United Nations World Food Programme (WFP) is the world's largest humanitarian organization fighting hunger worldwide through delivering food assistance in emergencies and working with communities to improve nutrition and build resilience. WFP in India through its Country Strategic Plan (2019-2023) aims to support India in achieving the targets of Sustainable Development Goals 2 and 17, by enhancing the efficiency, targeting, service delivery and supply chain of government programmes for improving access to food. This project is part of an agreement between WFP, FCI and the Govt. of Uttarakhand to support them to make their supply chain systems more efficient and cost-effective overcoming.

Some of the challenges that the State of Uttarakhand has to address on a regular basis - like earthquakes, fires, etc. are not predictable and frequently result in considerable costs due to emergency solutions that need to be quickly planned and implemented. However, there are also more predictable challenges that tend to happen around the same periods in the year (e.g. seasonal access constraints and monsoons). To reduce cost of transportation and ensure pre-prepositioning of adequate safety stocks in the areas where access is affected by these seasonal and predictable hazards, WFP India shall support the state of Uttarakhand by undertaking a supply chain optimization of the end-to-end TPDS operations including procurement in the state.

The TPDS supply chain of Uttarakhand has never been optimised before now. The taggings in it's network exist in chronological manner i.e in the order they were added with time and demand, hence, were not optimised. Uttarakhand procures Rice for itself and relies on FCI for supply of wheat. The stages of grain flow -

Rice: Procurement Centre, Mill, Base Godown, Interior Godown, Fair price shops
Wheat: FCI godown, Base/ Internal godown, Fair price shops

A similar project was executed for the state of Odisha, where a savings of around 30% was observed just by changing allocation (tagging) of different nodes. It was not required to physically relocate any node to yield the optimal solution and stakeholders (farmers and beneficiaries) were not affected.

Literature Survey

Network Flow Models

Flow Network is a special case of the more general linear program. It is an important class since many aspects of actual situations are readily recognized as networks and the representation of the model is much more compact. A directed graph with vertices and edges, denoted by G(N,A), where N is the set of n nodes and A is the set of m directed arcs Two distinguished nodes, Source (s) and Sink (t) to supply and receive flow. Flows will come out of s and need to obey a few constraints with capacities of arcs in order to reach t. Each arc, (i,j) ∈ A also has an associated cost per unit flow.

TPDS Supply Chain Optimisation in Odisha

Government of Odisha (GoO) has made remarkable progress and enhancements to the Targeted Public Distribution System (TPDS) of the state since the adoption of the National Food Security Act' 2013 (NFSA) and the implementation of End-to-End (EtE) computerisation of the TPDS. As part of this process, the procurement and distribution systems for TPDS have been digitised and automated. In an endeavor to make these systems even more efficient, accountable and transparent at the request of GoO, World Food Programme (WFP) undertook an assessment of the entire procurement and distribution operations as well as the deployed software systems i.e. Paddy Procurement Automation System (P-PAS) and the Supply Chain Management System (SCMS), during April, 2017.

Uttarakhand TPDS

Uttarakhand PDS is taken by the Department of Food, Civil Supplies and Consumer Affairs. Supply to consumers a)Rice and Wheat b)Sugar and Kerosene. Schemes covered a)NFSA (AAY and PHH) b)State Food Scheme (SFY) c)Mid day Meal. FCI godowns in Uttarakhand:174Internal Godowns and 22 Base Godowns, 913 FPSs in the state. Food grains movement in Uttarakhand is mostly via railways and roads, areas with difficult terrain are supplied via roads and extension of helicopter services in areas such as Pitthorgarh. F.E.A.S.T. (Food & Essential Commodities Assurance & Security Target) is a project which evaluates the online allocation quantity of digitized ration card and also maintains the supply chain management of food grains. e-Khareed is an e-governance initiative portal to usher in transparency at all levels in the food grains procurement process.RCMS(Ration Card Management System) is used to digitize the

existing Ration card and allow users to enter a new ration card and manage the old ration cards.

COIN-OR

Computational Infrastructure for Operations Research (COIN-OR), is a project that aims to create for mathematical software what the open literature is for mathematical theory. The open literature (e.g., a research journal) provides the operations research (OR) community with a peer-review process and an archive. Papers in operations research journals on mathematical theory often contain supporting numerical results from computational studies. The software implementations, models, and data used to produce the numerical results are typically not published. The status quo impeded researchers needing to reproduce computational results, make fair comparisons, and extend the state of the art.

PuLP

PuLP is a free open source software written in Python. It is used to describe optimisation problems as mathematical models. PuLP can then call any of numerous external LP solvers (CBC, GLPK, CPLEX, Gurobi etc) to solve this model and then use python commands to manipulate and display the solution. PuLP allows the free interchange of solvers without much change in the program, only a parameter for the LpProblem.solve function is changed.PuLP nicely bridges the gap between the OR practitioner and the python programmer. This allows the OR practitioner to use python to quickly develop and solve LP and IP models while having access to all of the tools available in the python standard library. The python programmer can now embed LP models in complex programs written in python.

Tkinter

Tkinter is the standard GUI library for Python. Python when combined with Tkinter provides a fast and easy way to create GUI applications. Tkinter provides a powerful object-oriented interface to the Tk GUI toolkit. Tkinter is included with standard Linux, Microsoft Windows and Mac OS X installs of Python.Tkinter is free software released under a Python license.

Project Objectives and Work Plan

Project Definition and Motivation

Over the time, the TPDS of Uttarakhand has observed very few upgrades in terms of efficiency improvement, resulting in higher cost to be incurred by the government. This project tries to enhance the efficiency and effectiveness of Govt.'s food safety network for Uttarakhand state TPDS using Computational Infrastructure for Operations Research(COIN-OR). Also, Reduce the cost of transportation and ensure pre-prepositioning of adequate safety stocks in the areas where access is affected by seasonal and predictable hazards.

Adopting a more strategic and long-term approach to plan the allocation of food grains inside the state, supply chain issues can be anticipated, and optimization techniques can be leveraged to evaluate different implementation scenarios that are cost-efficient solutions yet practical and implementable.

To deliver a software tool, which provides features like scenario selection and freedom to the operator to update input and allocation data according to situational need. Ultimately providing the end-user with an yearly supply plan to be followed.

Objectives of the work

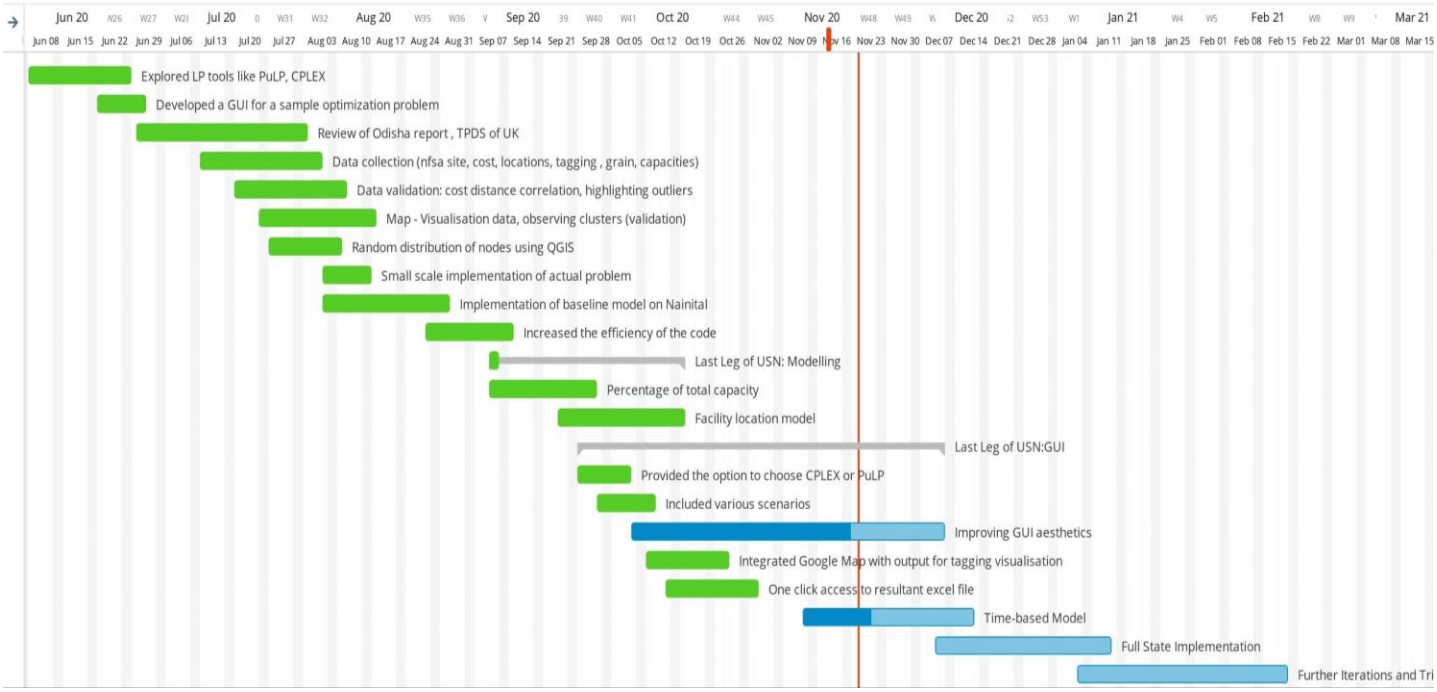
1. Mapping of Supply Chain systems landscape (such as F.E.A.S.T. and e-Khareed) and analysis of the available data and quality to ensure data coverage and quality are appropriate for optimization purposes.
2. Data analysis and mapping to ensure a thorough understanding of the network complexity and key supply chain considerations.
3. Supply chain network mapping, at the end of the phase submit a visual representation of Uttarakhand’s supply chain network.
4. Design and develop prototype of optimization algorithm to optimize TPDS supply chain operations for all districts of Uttarakhand
5. Creating a user friendly GUI which on hitting the solve button returns all the taggings in an excel file along with their visualisation on a map
6. Finalisation of Tool, handover of product and training the concerned officials about the real-time usage of tool.

Methodology

The goal of the project is to reduce the total transportation cost and find the resulting node taggings for Uttarakhand. A network flow model is formulated and is modelled using PuLP library in Python. PuLP is an open-source linear programming (LP) package which largely uses Python syntax and comes packaged with many industry-standard solvers. It also integrates nicely with a range of open source and commercial LP solvers. Using PuLP, the minimum cost is obtained along with the taggings.

A user friendly GUI is created using Tkinter using Python which takes some input values and on hitting the solve button runs the optimization engine in the background and returns the optimal cost, taggings in an excel sheet and visualisation of the obtained taggings on a map. Below is the Gannt chart representing some of the objectives that have been achieved and also the future work plan.

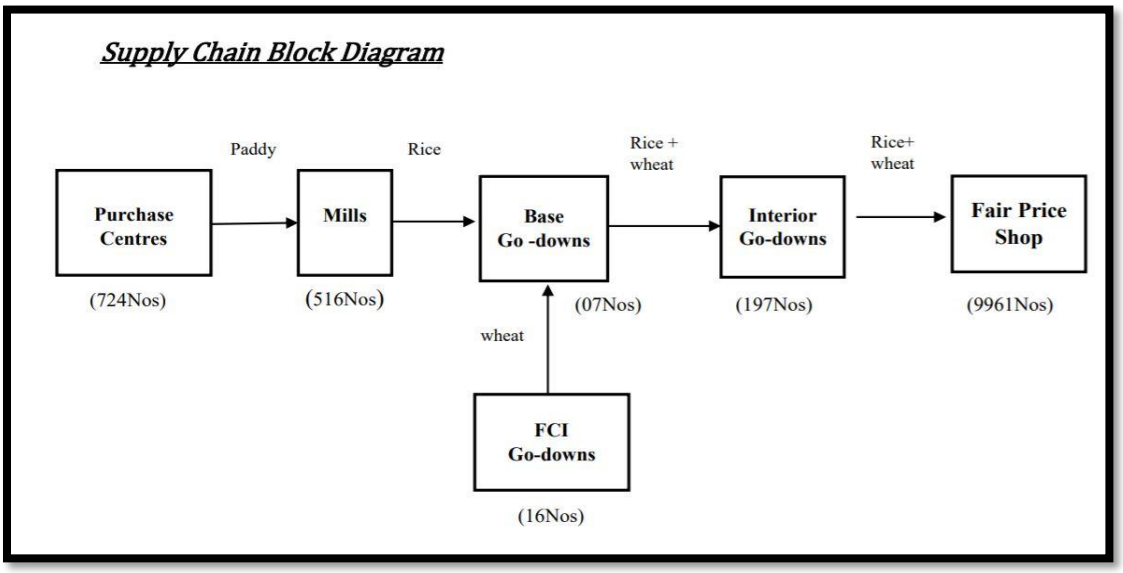
Gantt Chart



Work Progress

Theoretical Model

Baseline Scenario:



C_{ij}^k = Cost of transportation from i^{th} node to j^{th} for k^{th} commodity (Rs/Quintal).
X_{ij}^k = Volume of food grains transported from i^{th} to j^{th} node for k^{th} commodities (Qtl).

Objective function:

$$\text{Min} \ \sum_k \sum_i \sum_j C_{ij}^k X_{ij}^k \quad \forall (i,j) \in \text{Script\_S}$$

Subject to constraints,

- **Mass – balance (capacity) constraints.**

  $$\sum_j X_{ji}^k - \sum_j X_{ij}^k \leq C_i \ , \ \text{Where } C_i = \text{Capacity of } i^{th} \text{ node}$$

  Also, we have assumed that the grain flow is uni-directional and a node only supplies to its succeeding node. This is part of pre-processing for this problem
  Note: The capacity of Fair price shop is ∞ or large valued number “L”.

- **Non -Negatively restriction:**

  $$X_{ij}^k \geq 0, C_{ij}^k \geq 0$$

- **Demand at FPS:**

$D(f)_j^k$=Demand of j^{th} fair price shop for K^{th} commodity.

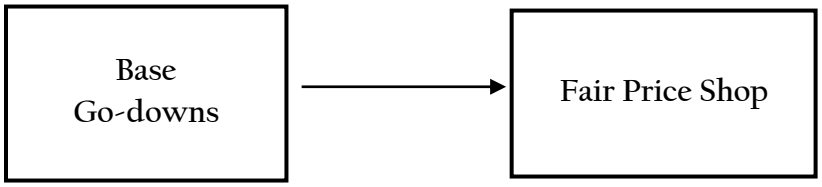
$$\sum_{i=1}^{i=i} X_{ij}^{K} \geq \alpha_j D(f)_j^k$$

i.e. we have to supply at least the amount required at FPS.

Uttarakhand TPDS Problem – USN Last Leg Model:

Let B be the set of base godowns, F_c be the set of FCI godowns each containing 7 warehouses and 409 FPSs respectively. This was gathered from the available data for the district. This is a multi-commodity flow problem having K commodities, where K=1 or 2 for rice and wheat respectively. S is the set of taggings/arcs between nodes i and j or $(i,j) \in S$. Let C_{ij}^k be the cost of transportation from the i^{th} base godown to j^{th} FPS for the k^{th} commodity.

USN LAST LEG _MODEL



(07 Nos) (409 Nos)

$$\min \sum_k \sum_i \sum_j C_{ij}^k x_{ij}^k$$

subject to

$$\sum_j^n \sum_{k=1}^2 x_{ij}^k \leq C_i$$

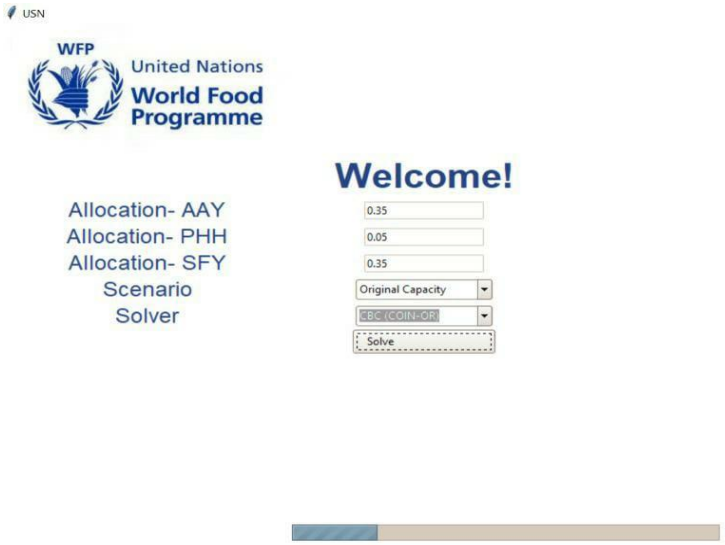
$$\sum_i^m x_{ij}^k \geq D_j^k$$

$$x_{ij}^k \geq 0$$

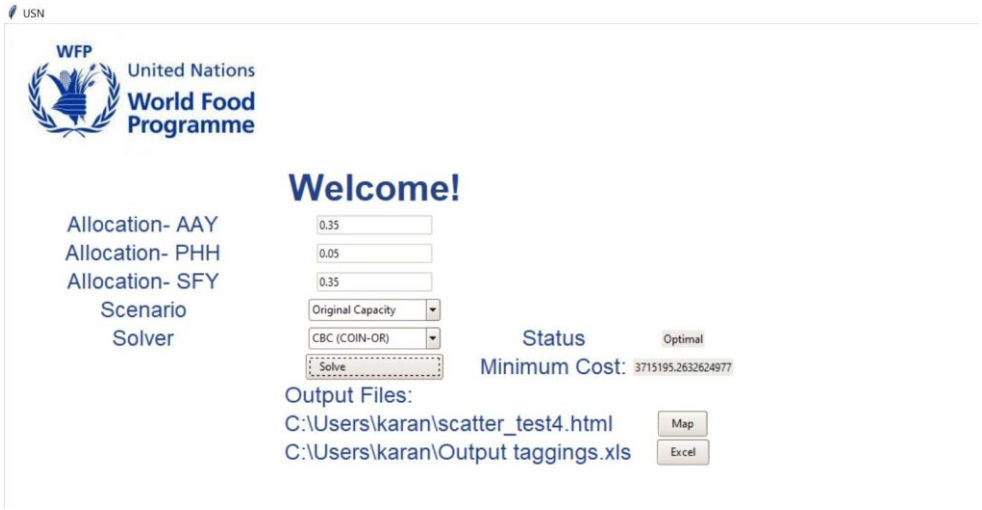
where C_i is the capacity of the i^{th} base warehouse, D_j^k is the demand of the j^{th} FPS for the k^{th} commodity.

Working of Software Tool

This is how the main screen looks like on running the executable file. Here we type the values of AAY, PHH, SFY and in the drop down lists we have various options for scenarios and two options for solver (COIN-OR and CPLEX). After entering the values and choosing the desired options, we hit the solve button. The progress bar below indicates the progress of the optimization engine running in the background



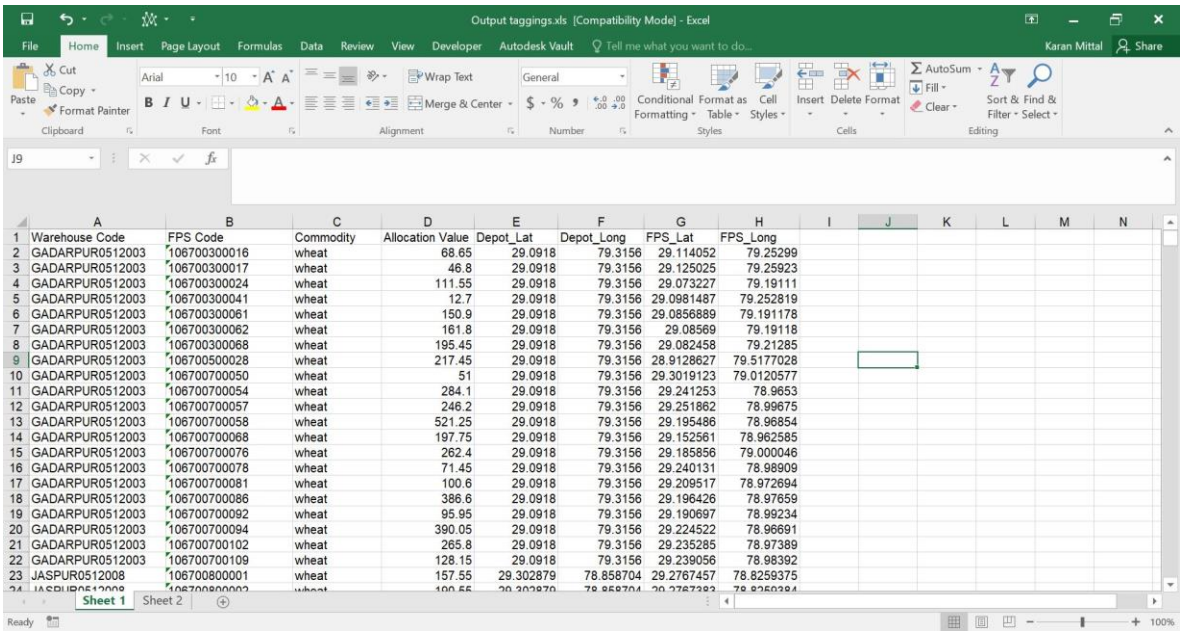
On hitting the solve button, we get the minimum cost and two output files which can be accessed directly by clicking the respective buttons. On clicking the map button, a visualization of the obtained taggings can be seen on a map. Further, on clicking the excel button, we obtain the taggings corresponding to the optimal cost in an excel file



Results and Discussion

Taggings

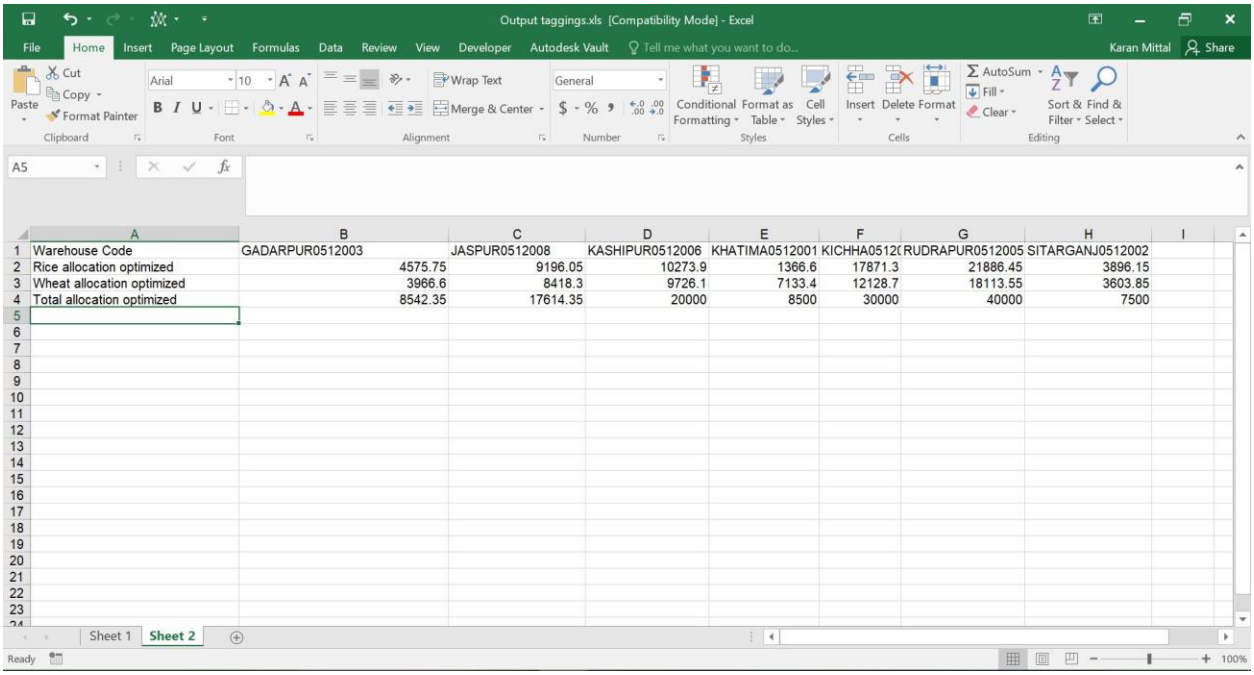
Excel file containing all the obtained taggings along with their respective coordinates and allocation value



	A	B	C	D	E	F	G	H
1	Warehouse Code	FPS Code	Commodity	Allocation Value	Depot_Lat	Depot_Long	FPS_Lat	FPS_Long
2	GADARPUR0512003	106700300016	wheat	68.65	29.0918	79.3156	29.114052	79.25299
3	GADARPUR0512003	106700300017	wheat	46.8	29.0918	79.3156	29.125025	79.25923
4	GADARPUR0512003	106700300024	wheat	111.55	29.0918	79.3156	29.073227	79.19111
5	GADARPUR0512003	106700300041	wheat	12.7	29.0918	79.3156	29.0981487	79.252819
6	GADARPUR0512003	106700300061	wheat	150.9	29.0918	79.3156	29.0856889	79.191178
7	GADARPUR0512003	106700300062	wheat	161.8	29.0918	79.3156	29.08569	79.19118
8	GADARPUR0512003	106700300068	wheat	195.45	29.0918	79.3156	29.082458	79.21285
9	GADARPUR0512003	106700500028	wheat	217.45	29.0918	79.3156	28.9128627	79.5177028
10	GADARPUR0512003	106700700050	wheat	51	29.0918	79.3156	29.3019123	79.0120577
11	GADARPUR0512003	106700700054	wheat	284.1	29.0918	79.3156	29.241253	78.9653
12	GADARPUR0512003	106700700057	wheat	246.2	29.0918	79.3156	29.251862	78.99675
13	GADARPUR0512003	106700700058	wheat	521.25	29.0918	79.3156	29.195486	78.96854
14	GADARPUR0512003	106700700068	wheat	197.75	29.0918	79.3156	29.152561	78.962585
15	GADARPUR0512003	106700700076	wheat	262.4	29.0918	79.3156	29.185856	79.000046
16	GADARPUR0512003	106700700078	wheat	71.45	29.0918	79.3156	29.240131	78.98909
17	GADARPUR0512003	106700700081	wheat	100.6	29.0918	79.3156	29.209517	78.972694
18	GADARPUR0512003	106700700086	wheat	386.6	29.0918	79.3156	29.196426	78.97659
19	GADARPUR0512003	106700700092	wheat	95.95	29.0918	79.3156	29.190697	78.99234
20	GADARPUR0512003	106700700094	wheat	390.05	29.0918	79.3156	29.224522	78.96691
21	GADARPUR0512003	106700700102	wheat	265.8	29.0918	79.3156	29.235285	78.97389
22	GADARPUR0512003	106700700109	wheat	128.15	29.0918	79.3156	29.239056	78.98392
23	JASPUR0512008	106700800001	wheat	157.55	29.302879	78.858704	29.2767457	78.8259375

Sheet 1 | Sheet 2

Sheet 2 contains the rice, wheat and total allocation corresponding to each warehouse in Udham Singh Nagar

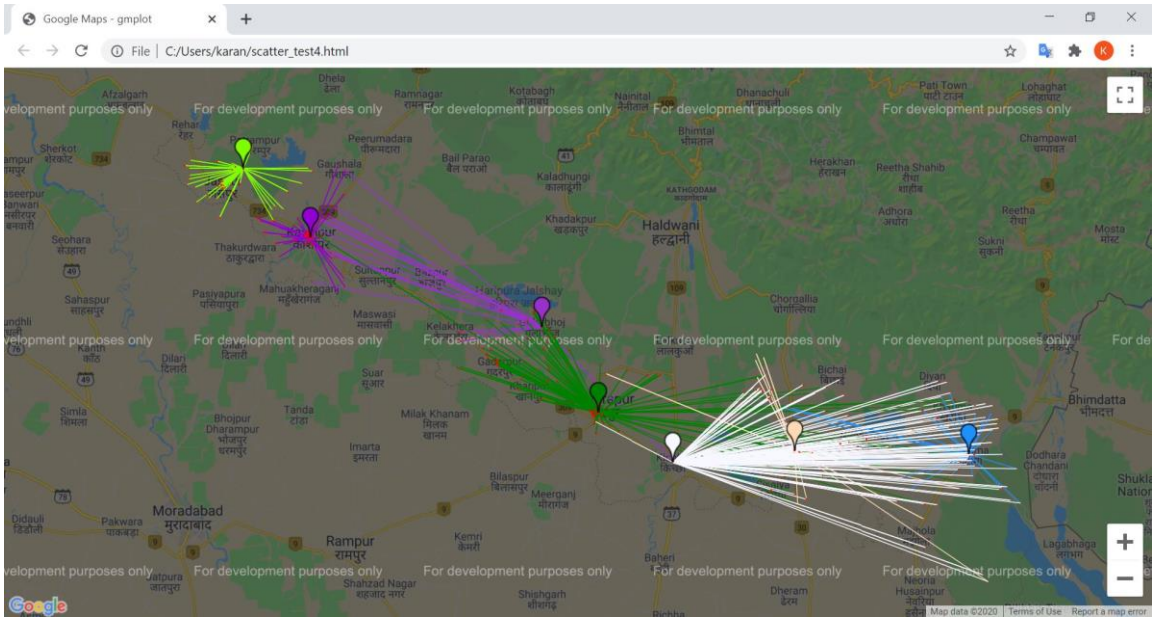


	A	B	C	D	E	F	G	H
1	Warehouse Code	GADARPUR0512003	JASPUR0512008	KASHIPUR0512006	KHATIMA0512001	KICHHA0512(	RUDRAPUR0512005	SITARGANJ0512002
2	Rice allocation optimized	4575.75	9196.05	10273.9	1366.6	17871.3	21886.45	3896.15
3	Wheat allocation optimized	3966.6	8418.3	9726.1	7133.4	12128.7	18113.55	3603.85
4	Total allocation optimized	8542.35	17614.35	20000	8500	30000	40000	7500

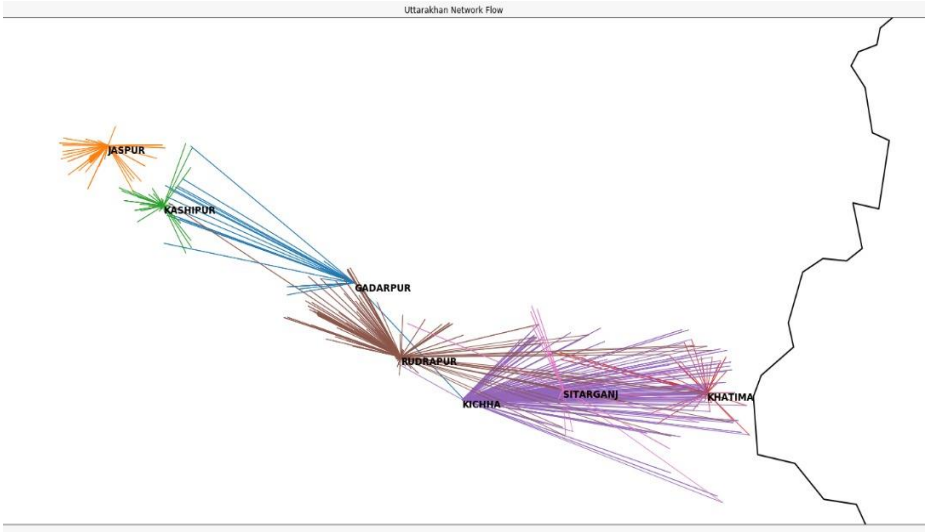
Sheet 1 | Sheet 2

Map

Used gmplot library to plot the obtained taggings on the map. Below is the plot for taggings of the last leg of Udham Singh Nagar



Similar Plot obtained using Tableau



Conclusions and Further Work

Conclusions

Using Linear Programming techniques, minimum transportation cost for the last leg of Udham Singh Nagar was obtained. Optimal routes from Warehouses to Fair Price Shops were also obtained indicating drastic reduction in the total transportation cost compared to the original taggings. The obtained taggings were visualised on a map for a better understanding.
A user-friendly GUI was created that can be used by any government official to get the optimal taggings. The official simply needs to input the grain allocation values through various government schemes (AAY, PHH, SFY etc) and select the scenario and solver from the dropdown list. Now the official needs to click on the solve button and in a few seconds, he/she will get the optimal taggings.

Further Work

The future work will aim at extending the model to all legs of the supply chain and further extend it to all the districts of Uttarakhand. In order to accomplish this, following are the future goals:

- Formulating a time - based model as wheat and rice are grown and transportation is possible only in certain months of the year
- Implementing the time - based model on all districts of Uttarakhand
- Further improvement of the GUI by making it more user-friendly and easier to use for a government official

References

1. S.Mitchell, ‘An Introduction to pulp for Python Programmers’,The Python Papers Monograph, Vol. 1 (2009)

2. D G Mogale, Mukesh Kumar, et al., ’Grain silo location-allocation problem with dwell time for optimization of food grain supply chain network’, Transportation Research Part E: Lo- gistics and Transportation Review, Volume 111, March 2018, Pages 40-69

3. D G Mogale, Sri Krishna Kumar, Manoj Kumar Tiwari, ’An MINLP model to support the movement and storage decisions of the Indian food grain supply chain’, Control Engineering Practice, Volume 70, January 2018, Pages 98-113

4. Alexandre Dolgui, D.G.Mogale, Rishabh Kandhway, Sri Krishna Kumar, Manoj Kumar Tiwari, ’A multi-period inventory transportation model for tactical planning of food grain supply chain’, Computers and Industrial Engineering, Volume110, August2017, Pages 379-304
5. Nasrin Asgari, Reza Zanjirani Farahani, Hannaneh Rashidi-Bajgan, Mohsen S Sajadieh, ’Developing model-based software to optimise wheat storage and transportation:A real-world application’, Applied Soft Computing Journal, 13 (2) (2013), pp. 1074-1084

6. L.M. Maiyar, J.J. Thakkar, ’A combined tactical and operational deterministic food grain transportation model: Particle swarm based optimization approach’, Computers & Industrial Engineering, 110 (2017), pp. 30-42