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SOLVING TRANSPORTATION PROBLEM OF A CAPSULE MANUFACTURER USING PHEROMONE OPTIMIZER AND A HYBRID OF KRUSKAL'S METHOD AND THE NORTHWEST CORNER METHOD

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ABSTRACT

Associated Capsules is a well known manufacturer of capsules, which provides the same to many pharmaceutical companies based in India. They use the help of Swift Transportation Pvt. Ltd., a transportation company, to transport these capsules to different parts of Western India. They use one truck, a large one at that, to transport this. Transportation is a very costly affair.

The transportation model is a special class of the linear programming problem. It deals with the situation in which a commodity is shipped from sources to destinations. The objective is to be determined the amounts shipped from each source to each destination that minimize the total shipping cost while satisfying both the supply limit and the demand requirements. The model assumes that the shipping cost on a given route is directly proportional to the number of units shipped on that route. In general, the transportation model can be extended to areas other than the direct transportation of a commodity, including among others, inventory control, employment scheduling and personnel assignment. So it is very competitive and difficult situation to make a vital decision.

This situation can be represented numerically in the form of a Linear Programming Model. Linear Programming is used worldwide for optimizing profit problem. It is a method to achieve the best outcome (Max profit at low cost) whose requirement is represented by linear relationships.

We have used novel techniques named the Pheromone optimizer and a hybrid of Kruskal's Method and Northwest Corner Method to solve this problem. In the former method, every neighbouring node is given a scent value and a fade value and the path so chosen is one with the most scent value. In the hybrid method, a minimum spanning tree is constructed and then the Northwest corner method is used

Results obtained were positive, with savings of rupees 45,000 in transportation costs and fuel amount for the pheromone optimizer and ____________ for the hybrid method.

1. INTRODUCTION

1.1 Theoretical Background: Transportation problems have been widely studied in Computer Science and Operations Research. Business and Industries are practically faced with both economic optimization such as cost minimization of non-economic items that are vital to the existence of their firms. It is one of the fundamental problems of network flow problem which is usually use to minimize the transportation cost for industries with number of sources and number of destination while satisfying the supply limit and demand requirement.

Transportation models play an important role in logistics and supply-chain management for reducing cost and improving service. Some previous studies have devised solution procedure for the transportation problem with precise supply and demand parameters. Efficient algorithms have been developed for solving the transportation problem when the cost coefficients and the supply and demand quantities are known exactly. In real world applications, the supply and demand quantities in the transportation problem are sometimes hardly specified precisely because of changing economic conditions.

Transportation problem deals with the problem of how to plan production and transportation in such an industry given several plants at different location and larger number of customers of their products.

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Because of its major application in solving problems which involving several products sources and several destinations of products, this type of problem is frequently called "The Transportation Problem". The classical transportation problem is referred to as special case of Linear Programming (LP) problem and its model is applied to determine an optimal solution of delivery available amount of satisfied demand in which the total transportation cost is minimized The transportation problem can be described using linear programming mathematical model and usually it appears in a transportation tableau.

One possibility to solve the optimal problem would be optimization method. The problem is however, formulated so that objective function and all constraints are linear and thus the problem can be solved.

1.2 Motivation: I have always been more inclined towards applying the concepts we learn in computer science in real life. The theory we learn in classrooms counts for nothing if we don't have a practical usage for it. That's why, we decided to use the knowledge we have gained through subjects like Operations Research and coding subjects to use it in a real life problem. we earlier wanted to increase the profits of a restaurant through optimization of transportation, but failure to get authenticated data meant we had to change my plans. we instead managed to get data from a pharmaceutical company and used that to complete this project.

1.3 Aim of the Project: In simple words, the aim of the project is to reduce the transportation costs of a pharmaceutical company by optimizing it, by using LPP. More specifically, I'm using the pheromone method to solve this problem.

1.4Objectives of the proposed work: While the work has been done for a pharmaceutical company, the potential for usage of this method is far and wide. This can be generalized to be used for any industry which requires a high amount of transportation. wet not only considers the big cities, but also small towns like Chiplun and the distances covered.

Apart from this, the other objectives are:
Reduce the consumption of fuel while transporting the shipments.
Reduce the distance travelled in total by the trucks.
Make use of proper type of vehicle wherever necessary.
Make in use of constraints in a proper manner to eliminate overheads and unnecessary extra costs.

1.5: Report Organization: The most ideal approach to discover and test a streamlined route is to utilize the calculation, all things considered. So as to do that an organization called Associated Capsules based in Kandivali, Mumbai, Maharashtra has given information to be utilized to locate an ideal method to decrease transportation costs. The organization has offered contract to a strategic partner called Swift Logistics Private Limited.

Associated Capsules are positioned number two on the planet for manufacturing of capsules. These capsules are void containers. They are transported to different pharmaceutical organizations which fill the containers with the medicines or the materials which make up the medicines. The organization has real customers like Pfizer, Ranbaxy, Fortis, Apollo and so forth. The organization is humongous with branches abroad as well. The Kandivali branch is the most established one and is the principle branch of the organization. The provisions are conveyed to Nepal, Sri Lanka, US, UK, Europe and Australia. While for India, Himachal Pradesh is the real customer state. The contracted organization Swift Logistics handles the national transportation of the manufactured capsules. The abroad transportation is taken care of by some other contracted organization. In this paper the strategies utilized by Swift Logistics will be the real issue articulation for the proposed calculation.

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2. LITERATURE SURVEY

2.1: Survey of existing models

Table 2.1

AUTHOR	*DATE*	*DESCRIPTION*
Ali Mahrous, A.M. And Sik, Yang Hyung	15 Apr. 2012	Solution of the transportation problem using LPP in the real life area of mining engineering. Conditions like environmental and climatic change are also taken into consideration.
S. Datta	1 Feb 2000	Evaluation of the current literature on the use of Operational Research (OR) in solving the transportation problems in the developing countries. The review is a result of several months of searching through a wide range of journals and publications. The studies are classified into three broad groups: (a) Planning and Evaluation; (b) Distribution and Location; and (c) Scheduling and Routing.
Kasana, H.S. And Kumar, K.D.	2005	Introduction to the basic concepts of Operations Research and their examples.
Marco Dorigo	1992	Development of ant colony optimization by the author. Theory and possible usage of the method for future optimization purposes
Yaseen, S.G. And Al-Slamy N.M.	Jun 2008	Ant Colony Optimization (ACO) is model for bio-simulation due to their relative individual simplicity and their complex group behaviors. This paper introduces ACO as a distributed algorithm that is applied to solve Traveling Salesman Problem (TSP). The case study is Jordan's Seaport Motion, ACO principles are applied to find best route for goods propagation from Al-Aqaba Seaport to inside Amman.
		Using simple test cases of three variables to show how LPP can be used to solve the transportation problem.

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Sengamelaselvi, J.	Jan. 2017	Northwest corner, Vogel Approximation and MODI method have been used and their results have been compared. No real life data has been taken and all the data shown is assumed one.
Rao, S.S. and Rao, S.S.	2009	Engineering optimization: theory and practice. Publisher John Wiley & Sons.
Gaurav Sharma, Abbas S.H., And Gupta V.K.	Jan. 2012	Solving the transportation problem using a zero point method, steering away from the traditional solution of MOBI problems. Data set is assumed and not based on real life industries.
Kazharov, A.A. And Kureichik, V.K.	May 2017	Using Ant Colony Optimization to solve the travelling salesman problem. The data considered is assumed and the model is done more for research purposes rather than real life applications.
Rami Musa, Jean-Paul Arnaout And Hosang Jung	August 2010	This paper addresses the transportation problem of cross-docking network where the loads are transferred from origins (suppliers) to destinations (retailers) through cross-docking facilities, without storing them in a distribution center (DC). The paper is based on minimizing the transportation cost in a network by loading trucks in the supplier locations and then route them either directly to the customers or indirectly to cross-docking facilities so the loads can be consolidated. For generating a truck operating plan in this type of distribution network, the problem was formulated using an integer programming (IP) model and solved using a novel ant colony optimization (ACO) algorithm.
Konstantinos Paparizzos	February 2017	Using a non improving

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		simplex method to solve transportation problems in order to understand the different parameters the problem is based on.
Robert Vanderbei	2014	This book is about constrained optimization. It begins with a thorough treatment of linear programming and proceeds to convex analysis, network flows, integer programming, quadratic programming, and convex optimization. Along the way, dynamic programming and the linear complementarity problem are touched on as well. The book aims to be a first introduction to the subject. Specific examples and concrete algorithms precede more abstract topics. Nevertheless, topics covered are developed in some depth, a large number of numerical examples are worked out in detail, and many recent topics are included, most notably interior-point methods. The exercises at the end of each chapter both illustrate the theory and, in some cases, extend it.
Zulkipli Ghazali, M. Amin Abd Majid And Mohd Shazwani	2012	Managers regularly make decisions pertaining to the effective and efficient allocation of resources to various activities in meeting organizational objective. The task of deciding the optimum plan for distributing goods at the lowest cost possible is a case in point. Minimizing cost of transportation is fundamental for companies in the midst of highly competitive business environment. This study highlights the application of linear programming and

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		spreadsheet that facilitate managers in a Malaysian Trading Company in determining the optimum transportation plan that leads to the lowest transportation cost of polymer from four plants to four demand destinations. It also discusses sensitivity technique in analyzing the impact of uncertainty of unit shipping cost to the total shipping cost of the trading company.

2.2: Gaps in the survey:

The literature that we used for the project was quite noteworthy. The papers were full of insightful details which helped me model my method for pheromone optimization a lot. There were however some areas where there was a significant lack of expertise.

Transportation problems have never been seriously tackled in developing countries as suggested by Datta (2000). This is down to the inadequacy of funds available for research in these topics. When there is a significant amount of research available, the solutions provided are often too niche, as seen in the work done by Ali Mahrous and Sik (2012). While the work they have done is exemplary in the field of transportation for mining industry, it is impossible to generalize it for using it in other fields.

Most of the generalized solutions given by other authors are done using dummy data. This data is not real life data and hence its application cannot be verified. The model has never been tried in the business side of things and as a result remains an academic infatuation. This is seen in Sengamelaselvi (2017) and Kazharov and Kureichik (2017). While the work done by these researchers is commendable, their usage in real life applications is questionable.

In short, a real life solution of the transportation problem which can be general enough for all kinds of businesses was missing. Here, we decided to step in to try to make a solution available.

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3. OVERVIEW OF THE PROPOSED SYSTEM

3.1: Introduction:
Pheromone Optimizer
The algorithm being used is the ant colony optimization, a well known optimization algorithm first suggested by Dorigo in 1992.
The first step is to take in input. The information can be taken in type of .csv files.
There are two sources of information that ought to be taken in order for the calculation to work.

The first is the request of provisions. The request can be from different locations. The locations can be places from which the provisions are to be transported. In our case, the locations are different urban areas where the pharmaceutical companies are based. They are the customers of Associated Capsules organization.

The second input is for mapping the transportation network. The second information is likewise in type of .csv files. The information in this document is the distance between the locationswhere the items must be transported. The distances are in kilometers.

The following stage is to recognize the starting location. Once the location has been identified, we use pheromone optimization to understand the best solution we can get.

A MST is an undirected tree that interfaces every one of the edges in a chart with no cycles and least conceivable edge weight. Pheromone optimization is then used here.
Pheromone optimization:

- Initialize the edges and nodes
- Identify the starting location
- Initialize scent values and scent fade values
- Identify the neighbor with the largest scent value
- Proceed to that node and repeat the process until all nodes are reached
- The diagram is a base traversing tree

As a real life application was promised, these nodes actually signify the locations where the offices of the company are. The distances between the nodes are the real life distances between the towns.

The pheromone optimizer takes into consideration the following aspects.

- The distance between every node and the starting point
- The utilization of fuel to every mode and back to starting point
- The kind of truck to be utilized to transport the provisions

In view of the quantity of supplies to be given to these spots, the sort of truck is utilized

The truck is chosen on the basis of distance and the amount of provisions required by a particular location. For instance, if the destination is close, like to Pune being just 149 km from the initial location, and the request being 20, it is well inside the limit of a small truck. As a result, a small truck is chosen.

If the order is from places like Ahmedabad and Gandhinagar, it is trickier. Both of these locations lie on an indistinguishable path and the between them is only 26 km. Yet the order states Ahmedabad requires 60 boxes while Gandhinagar requires just 25. Summing the request deferrals to add up to request of 85, yet the big truck has a limit of just 70 boxes per visit. In this way, the visit is split into two where:

1)	Ahmedabad : 45 Gandhinagar: 35	(Large Truck)	1136 km
2)	Ahmedabad: 15	(Small Truck)	1136 km

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Hybrid Method
The algorithm that this project proposes is an hybrid of NorthWest Corner algorithm and Kruskal's algorithm.

The foremost step is to take in input. The input can be taken in form of .csv files.
There are two inputs that should be taken inorder the algorithm to work.

The first one is the demand of supplies. The demand can be from various places. The places can be areas from which the supplies are to be delivered. In this case the places are various cities where the pharmasuetical companies a are located. They are the clients of Associated Capsules companies.

The second type of input is for mapping the transportation network. The second input is also in form of .csv format. The input in this file is distance between the places where the products have to be delivered. The distances are in kilometres and the places represent the real places in India.

Here the next step is to identify the start location. Once the location has been established, then is to apply the Krushkals algorithm to find the minimum spanning tree.

An MST is a undirected tree that connects all the edges in a graph without any cycles and minimum possible edge weight. Kruskal's algorithm is a greedy algorithm that constructs a minimum spanning tree based on minimum edge weight each node. Also it makes sure that the edge does not build a cycle.

Kruskal's algorithm
- Intialise the edges and nodes
- find the start node
- find the node with minimum increased edge weight.
- Check if the selected edge forms a cycle
- If no keep on selecting edges based on increasing edge weight till all nodes are covered
- The graph is a minimum spanning tree

For this project purpose, we use the real places instead of nodes. The places where the shipments are to be delivered are identified, and we apply the kruskal's algorithm to those places.
Thus, a minimum spanning tree is created by using those places as nodes and no we can know the minimum distance between any node and the start place.

Now, this is where the northwest corner algorithm comes.

The northwest corner algorithm calculates following parameters,
- The distance to each node and back to source
- The consumption of fuel to each node and back to source
- The type of truck to be used to transport the supplies
- The total consumption of fuel and total distance travelled by truck.

The distance between each node is calculated by the already formulated minimum spanning tree drawn by kruskal's algorithm.

The places that are near to the start node are delivered first.
Based on the number of supplies to be provided to these places, the type of truck is used

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3.2: Model Framework and Architecture

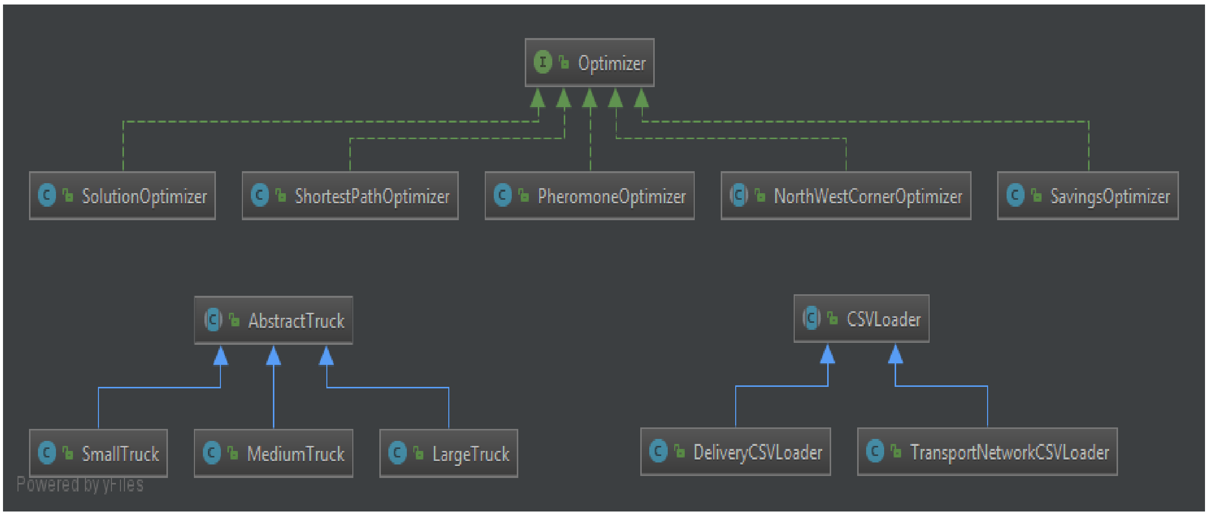

Fig 1.Model Framework

The above diagram portrays the proposed algorithm used in this project.

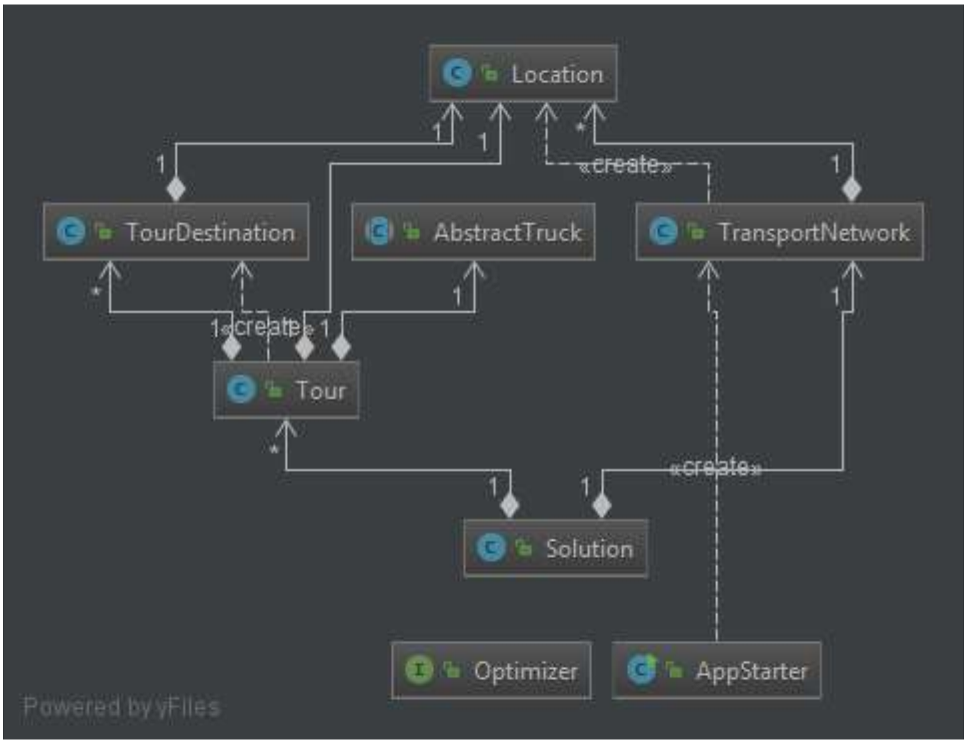

Fig 2. Model Architecture

Here are all the components, explained:
Abstract Truck: This class contains the framework required for construction of trucks and their components. The components include the description the capacity of the truck and the mileage of the truck.
The trucks have been divided into 3 classes.
The small trucks have capacity of about 40 boxes. The mileage of these trucks is around 7 km per liter.

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These can be used for places where the demand is less or where the demand is distributed whenever the amount left for transportation is less than 40 boxes.
The medium trucks are used for places where the demand is more than 40 but less than 50. Medium have less mileage than the small trucks.
The large trucks are for places where the demand is less than 70. The program has a capacity limit of 70 boxes and cannot be used for more than 70 per trip. They have the least mileage.

Transport Network: This is the component which maps out all the nodes for us. The map is then used as the blackboard for the pheromone optimization

Tour Destination: This component calculates the amount the truck should travel to reach the destination. It also gives the number of boxes to carry to that particular destination. Based on the demand the type of truck is chosen by this component and is released for the tour. The truck reaches the destination and then comes back to original start place. Also it also stores the amount of boxes left to be delivered if the demand is not fulfilled in one tour, and another tour is needed to complete the transportation.

App Starter: The AppStarter is the initial class that takes in input and the trigger call from the command prompt. This is where the java jdk is called. The CSV files are read in this and fed into the Transport Network. If there is an error in the reading of the files the app does not start and a Failure error is shown. As CSVs have specific format of representation, the app started only accepts values that are separated by semicolon.

Tour: This component carries out the actual tour and checks for any cycles happening along the tour. It creates a single tour of one truck on the map with multiple destinations. Create Tour without specific Truck (chosen automatically). Get the specified type of truck or an automatic truck type if not specified. Add a destination to this tour. Remove a destination from this tour. Get all of this tours destinations.

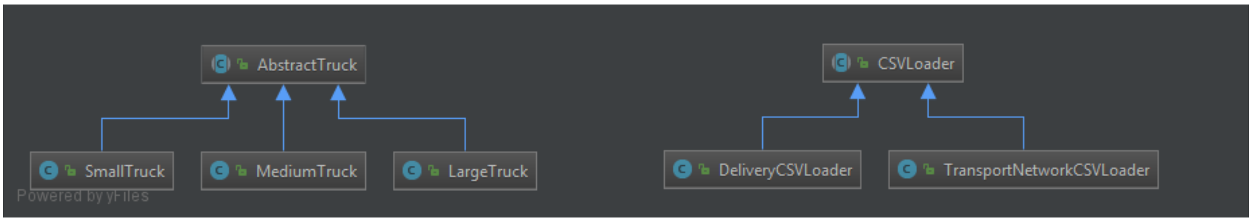

Fig 3: Loaders

There are two CSV loaders as you can see. The first one the Delivery CSV Loader takes in the demand from the destination. Here the demand in mentioned in the name of cities. Thus, Delivery CSV Loader contains the data of number of names of cities with their corresponding demands. Each is separated by semicolons.

The other java component, Transport Network CSV Loader takes in data from another CSV file that contains the map data. This contains the distances between the nodes which are then used for our map.

4. PROPOSED SYSTEM ANALYSIS AND DESIGN

4.1: Introduction

The transportation model is an exceptional class of the direct programming issue. It manages the circumstance in which an item is delivered from sources to goals. The goal is to be resolved the sums dispatched from each source to every goal that limit the aggregate delivery cost while fulfilling both as far as possible and the request prerequisites. The model expects that the transportation cost on a given course is specifically relative to the quantity of units dispatched on that course. All in all, the transportation model can be stretched out to regions other than the immediate transportation of an item, including among others, stock control, work planning and faculty task. So it is exceptionally aggressive and troublesome circumstance to settle on a key choice.

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4.2: Requirement Analysis

4.2.1: Functional Requirements

4.2.1.1: Product Perspective

The product here is itself a minimization of cost of logistics. With respect to achieving the end result the requirements that the needed with product perspective are as follows:

Input files

Two CSVs one satisfying the demand and the other the distance between the places where the demand is to be achieved.

Some rules to be kept in mind are:

The start position of the tour should be fixed thoroughtout the program

The start node should be present in the distance CSV. Otherwise the program will go in an endless loop.

If shortest path is to be found ignoring the kruskal's algorithm, the input data should be limited and be precise. Otherwise the program may get in an endless loop.

It is not required to give the distance from each and every place to other places, meaning it is not necessary to create a mesh topology while constructing a map. If there is at least one node connecting the other node respectively it is enough to trigger a solution.

The best way to do this is to observe the path followed by the truck in real time scenario. If a place A lies between place X and place Y, the distance between A-X and A-Y is sufficient to construct a path from X-Y. Additional distance factor between X-Y is not required.

Java JDK:

For this program to run Java JDK must be install in the local system as the whole program is based on JAVA. JDKJava Development Kit(JDK) allows you to code and run Java programs.

Maven:

Apache maven is a comprehensive tool for software project management. Its is based on project object model (POM). It's a complete build that manages documentation, reporting, build with a central piece of information.

Command prompt:

Command prompt is a command line interpreter program used to handle commands entered inside it. It is an inbuilt application in Windows Operating System.

Excel:

Microsoft Excel is an office Suite Application that is able to run macros, prepare charts, or in this case it can open .csv files which provides the input for the algorithm. The CSVs can also be created and edited in text file editor like notepad but excel provides much more features.

4.2.1.2: Product Features

The functional requirements for product features are actual data to compare with. In this case the data is from the Swift Logistics Company that operates from Mumbai. The logistics company handles the transportation of capsules boxes for Associated Capsules. Being so, the company was gracious enough to provide me data for the places the Swift Logistics trucks operated. The provided me a data for year 2014 where the excel workbook provided the distance the trucks travelled to places where the clients were located. Also the workbook also mentioned the amount of cost the logistic company charged to the manufacturing company. With that data I was able to compare the results the proposed algorithm could produce against the costs of transportation of goods by Swift Logistics.

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Another main feature requirement is Sublime software. Sublime is an editor with a numerous helpful packages inside. I used sublime as my default code editor with which I was able to include the packages helpful to create vertex, nodes, and graphs. The code is also tweaked in such a way that a custom made data set can be also inputted into the appStarter. The appstarter will trigger the algorithm and will give a comprehensive and systematic solution to the proposed problem with the hybrid algorithm proposed in this paper.

4.2.1.3: User Characteristics

The intended people who want to use this algorithm must be equipped with a thorough knowledge of

- Java Environment and Core Java concepts
- Graph Theory
- Linear Programming Problems (Transportation Problem)
- Apache Maven Architecture
- Command prompt commands
- Excel manipulations and conversions
- Actual data for input
- Worksheet handling

4.2.1.4: Assumption & Dependencies

Assumptions taken in this project are as follows

First assumption is that the distance between the cities in the input CSVs is about approximate. It is only the distance required to reach a city from another city. Since a city can be big or small depending on the size, it might be possible that the destined place might even not be in a city. The whole scenario depends on the location of factory in the area. So a plus minus of about 10- 60 km can be the flexible margin in this case.

The second assumption is that the mileages of trucks are:

Large: 3km per litre

Medium: 4 km per litre

Small: 7 km per litre

This is a general approximation of taking all the types of truck with all the practical statistics. The actual mileage of the trucks can be different. They may differ in the size too. Also it is very much possible that the vehicles might not be truck or tractors or commercial vans. Trucks are been used in this project because Swift Logistics use large trucks for the transportation of shipments.

The third assumption is the demand in the cities by the factories. The data provided by the Associated Capsules in limited to the number of tucks in use and the distance travelled by the trucks. The amount of capsules delivered in not been disclosed by the company as it is confidential. Here we can assume the data to be different for each city. We can also tweak the data to our own benefit to test the algorithm and its efficiency to prove its effectiveness in the transportation problem.

The fourth assumption is also related to trucks. We have defined the capacities of the trucks according to our own benefit. The small trucks can carry about 40 boxes of capsules. The medium trucks can carry about 60 boxed of capsules and the large trucks can carry about 70 boxes of capsules. The data can differ from company to company. But in this case the capsules boxes are big and heavy. Also they need to be refrigerated. Thus, one box occupies a large volume inside the truck.

4.2.1.5: Domain requirements

The domain requirements are:

- Java Development kit and Java Runtime environment
- Apache Maven
- Sunrise
- Sublime

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4.2.1.6: User Requirements:
The user requirements are:
- Demand data for the amount of boxes that need to be deliver to the cities (factories).
- The capacity of trucks that they require to be evaluated with
- The distance between the cities that require the boxes to be transported to.

4.2.2: Non-Functional Requirements
4.2.2.1: Product requirements*:*
- The capacity of the truck should not be greater than 70. 70 is the limit for this algorithm.

4.2.2.1.1: Efficiency:
- The distances provided by the input CSV file should have the distance between citis that lie on the route from one place to another. A reference should be provided for better optimization and which actually benefit the algorithm.
- Another requirement is that no unnecessary distances should be provided in the input. The number of inputs or the number of distances between two cities increases, the probability of the algorithm going into an infinite loop is a greater chance. This is only for the shortest Path algorithm.

4.2.2.1.2: Reliability:
The algorithm is very much reliable in real life scenarios. But the algorithm doesn't account for the traffic, closed routes optimization or any other factors that may lead to more fuel cost than already mentioned. The algorithm is merely a theoretical concept and can be tweaked with real time scenarios like Google maps and traffic data to operate more effectively.

4.2.2.1.3: Portability
Portability of the algorithm is not a major problem. The algorithm can be easily downloaded and incorporated in various systems as long as they support java and have JDK and maven installed. The data can be customized and easily provided for input with output obtaining in the same command line interpreter.

4.2.2.1.4: Usability of this algorithm:
Since the algorithm can be only used in JAVA runtime environment, this decreases the reach of the algorithm. But the algorithm can also be coded and implemented in other languages as necessary. Since the logic is not Java specific, the logic can also be modified and improved over the time when new constraints and inputs are available to make this algorithm go live and actually implement this in some company for their logistic division.

4.2.3: Engineering Standard Requirements
4.2.3.1: Economic
This whole project is based on cost. To be fair, the main purpose is to decrease the cost required. Thus, with respect to economy it is necessary for the organization to invest in the logistics fairly. Like the purchase of small and medium trucks along with the long trucks. At first the investment may seem hefty but one algorithm goes live, the company would greatly benefit on the cost and expenditure.

4.2.3.2:Environmental:
The objective of this algorithm is to reduce the fuel requirement. For environment requirement, it is necessary that the trucks run on CNG whenever possible and avoid use of petrol and diesel. Also they must be maintained properly and regular servicing is to be taken care of along the year.

4.2.3.3: Social:
Since the project is totally based on machines and the constraints of supply and demand, social requirement are not needed.

4.2.3.4: Political:
No political requirement is required for this project

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4.2.3.5: Ethical

In terms of ethics it is necessary that the distances mentioned are approximate and not precise. Also the algorithm cannot provide which route to apply for based on real time scenario. Thus it is ethical responsibility is to adhere to traffic norms and deliver the product safely to the concerned factories

4.2.3.6: Health and Safety

There is no health and safety requirement apart from road safety and health checkup of driver of the trucks.

4.2.3.7: Legality

No legal requirement required in this project

4.2.3.8: Inspectability

No Inspectability required in this project

4.2.4: System Requirements

4.2.4.1: Hardware Requirements

The main hardware requirements are as follows:

- A local system with a widely used operating system. The system can be a laptop, server, VM or any system having capability of running a JAVA program
- RAM: 128 MB
- Disk space: 124 MB for JRE; 2 MB for Java Update
- Processor: Minimum Pentium 2 266 MHz processor

4.2.4.2: Software Requirements

Windows

- Windows 10 (8u51 and above)
- Windows 8.x (Desktop)
- Windows 7 SP1
- Windows Vista SP2
- Windows Server 2008 R2 SP1 (64-bit)
- Windows Server 2012 and 2012 R2 (64-bit)
- Mac OS X
- Intel-based Mac running Mac OS X 10.8.3+, 10.9+
- Administrator privileges for installation
- 64-bit browser
- A 64-bit browser (Safari, for example) is required to run Oracle Java on Mac.
- Linux
- Oracle Linux 5.5+1
- Oracle Linux 6.x (32-bit), 6.x (64-bit)2
- Oracle Linux 7.x (64-bit)2 (8u20 and above)
- Red Hat Enterprise Linux 5.5+1, 6.x (32-bit), 6.x (64-bit)2
- Red Hat Enterprise Linux 7.x (64-bit)2 (8u20 and above)
- Suse Linux Enterprise Server 10 SP2+, 11.x
- Suse Linux Enterprise Server 12.x (64-bit)2 (8u31 and above)
- Ubuntu Linux 12.04 LTS, 13.x
- Ubuntu Linux 14.x (8u25 and above)
- Ubuntu Linux 15.04 (8u45 and above)
- Ubuntu Linux 15.10 (8u65 and above)
- Browsers: Firefox
- Code Editors: Sublime (Build 3125 and above)
- Apache Maven Continuum (3.3 and above)
- Office Suites: Excel, Calc, Worksheet analyzers.

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5. RESULTS AND DISCUSSIONS

5.1: Sample Test Cases
The results achieved by the pheromone algorithm are obtained in the same command prompt where the trigger to execute the input file and algorithm is told.

Based on the parameters given to the system along with constraints of demands, the algorithm will create a graph based on the distances provided by the input excel file.

The distances will help is constructing a minimum spanning tree and will define the shortest path from one node to another. Here the nodes are the places where the products are to be delivered.

Table 2.1

Places	Distance	Consumption	Cost
Roha	320	106.67	6166.4
Chiplun	534	178.00	10290.18
Belgaum	1060	353.33	20426.2
Daman	708	236.00	13643.16
Ankleshwar	980	326.67	18884.6
Goa	1210	403.33	23316.7
Gandhinagar	1230	410.00	23702.1
Nashik	370	123.33	7129.9
Pune	370	123.33	7129.9
Indore	1270	423.33	24472.9
Baroda	870	290.00	16764.9
Kolhapur	840	280.00	16186.8
Halol	1250	416.67	24087.5
Ahemdabad	1296	432.00	24973.92
Total	12308	4102.67	237175.16

The Table above represents the data from the Swift Logistics Pvt. Ltd. Currently Swift Logistics uses only one truck type for transportation purposes.

The truck is refrigerated and contained because that is the requirement for transportation.

The rate per kilometer of this truck is equivalent to the rate of large truck that is about ₹ 19.27. For example
For, Roha cost will be equal to: ₹320 * 19.27 = ₹6166.4
For , Chiplun cost will be equal to: ₹ 534 * 19.27 = ₹10290.18
For, Belgaum cost will be equal to: **₹1060*** 19.27 = ₹20426.2
For, Daman cost will be equal to: ₹708 * 19.27 = ₹13643.16
For, Ankleshwar cost will be equal to: ₹980 * 19.27 = ₹18884.6
For, Goa cost will be equal to: ₹1210 * 19.27 = ₹23316.7
For, Gandhinagar cost will be equal to: ₹1230 * 19.27 = ₹23702.1
For, Nashik cost will be equal to: ₹370 * 19.27 = ₹7129.9
For, Pune cost will be equal to: ₹370 * 19.27 = ₹7129.9
For, Indore cost will be equal to: ₹1270 * 19.27 = ₹24472.9
For, Baroda cost will be equal to: ₹870 * 19.27 = ₹16764.9
For, Kolhapur cost will be equal to: ₹840 * 19.27 = ₹16186.8

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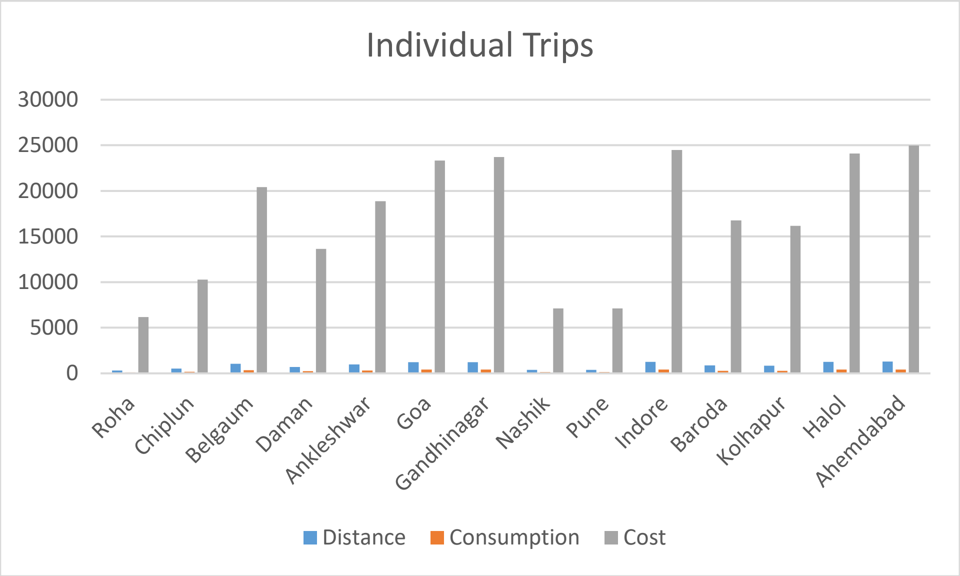
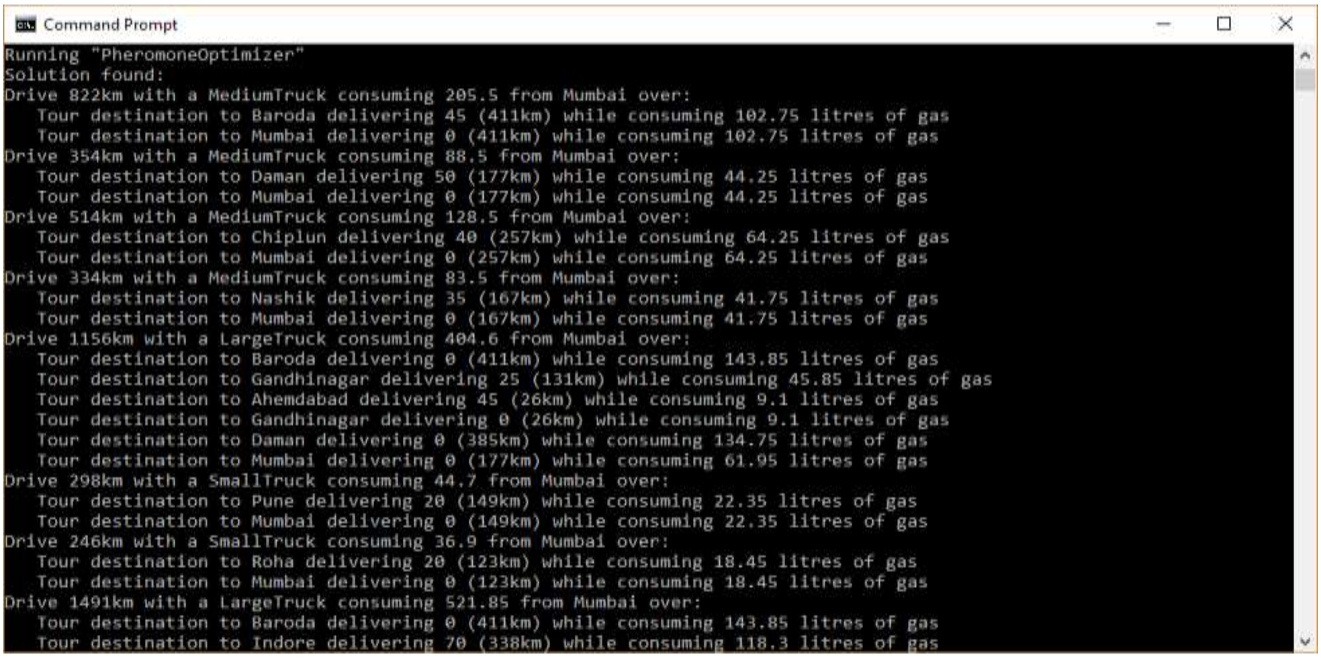
For, Halol cost will be equal to: 1250 * 19.27 = 24087.5
For, Ahemdabad cost will be equal to: 1296 * 19.27 = 24973.92

Similarly for all places the cost will be correspondingly calculated. In the end if we calculate the total cost of transportation that would amount to
6166.4 + 10290.18 + 20426.2 + 13643.16 + 18884.6 + 23316.7 + 23702.1 + 7129.9 + 7129.9 + 24472.9 + 16764.9 + 16186.8 + 24087.5 + 24973.92 = 237175.16
Thus, the total cost will be around ₹237175.16

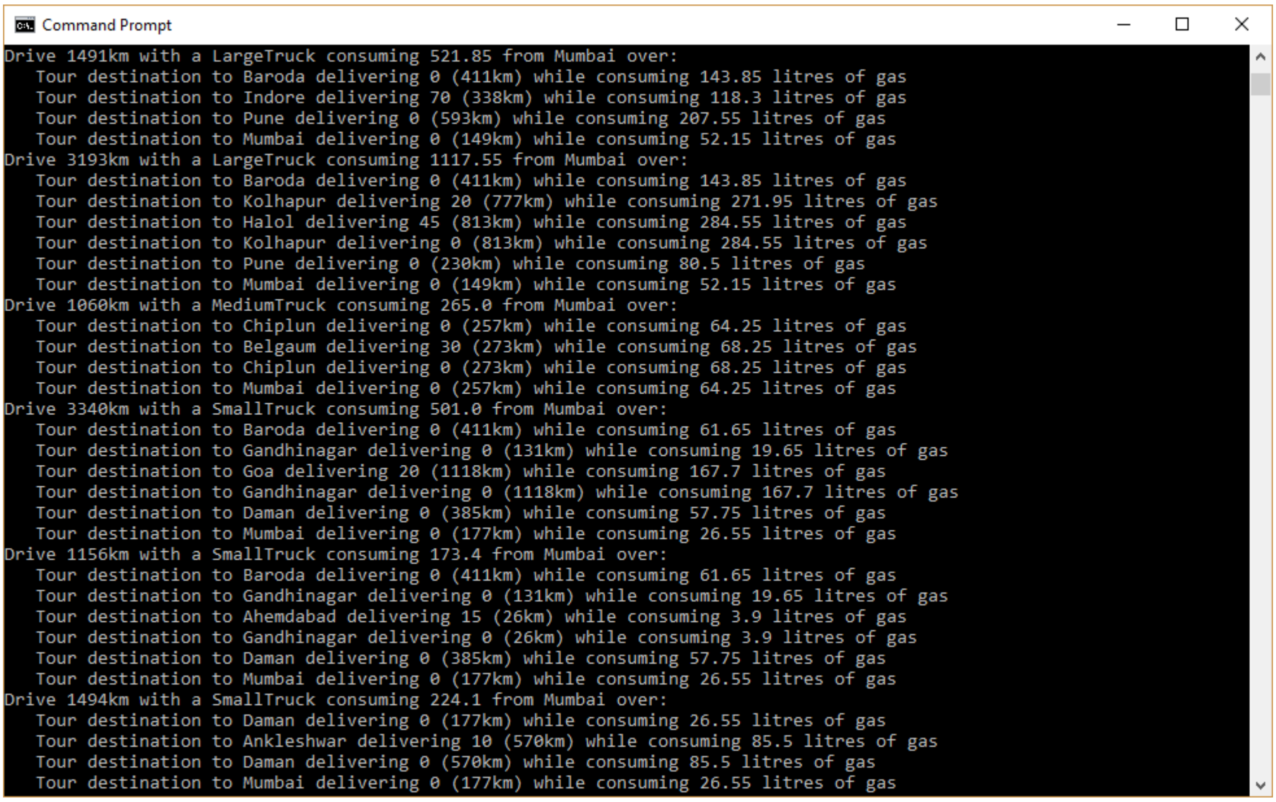


Pheromone optimizer results:



```
Command Prompt
Running "PheromoneOptimizer"
Solution found:
Drive 822km with a MediumTruck consuming 205.5 from Mumbai over:
   Tour destination to Baroda delivering 45 (411km) while consuming 102.75 litres of gas
   Tour destination to Mumbai delivering 0 (411km) while consuming 102.75 litres of gas
Drive 354km with a MediumTruck consuming 88.5 from Mumbai over:
   Tour destination to Daman delivering 50 (177km) while consuming 44.25 litres of gas
   Tour destination to Mumbai delivering 0 (177km) while consuming 44.25 litres of gas
Drive 514km with a MediumTruck consuming 128.5 from Mumbai over:
   Tour destination to Chiplun delivering 40 (257km) while consuming 64.25 litres of gas
   Tour destination to Mumbai delivering 0 (257km) while consuming 64.25 litres of gas
Drive 334km with a MediumTruck consuming 83.5 from Mumbai over:
   Tour destination to Nashik delivering 35 (167km) while consuming 41.75 litres of gas
   Tour destination to Mumbai delivering 0 (167km) while consuming 41.75 litres of gas
Drive 1156km with a LargeTruck consuming 404.6 from Mumbai over:
   Tour destination to Baroda delivering 0 (411km) while consuming 143.85 litres of gas
   Tour destination to Gandhinagar delivering 25 (131km) while consuming 45.85 litres of gas
   Tour destination to Ahemdabad delivering 45 (26km) while consuming 9.1 litres of gas
   Tour destination to Gandhinagar delivering 0 (26km) while consuming 9.1 litres of gas
   Tour destination to Daman delivering 0 (385km) while consuming 134.75 litres of gas
   Tour destination to Mumbai delivering 0 (177km) while consuming 61.95 litres of gas
Drive 298km with a SmallTruck consuming 44.7 from Mumbai over:
   Tour destination to Pune delivering 20 (149km) while consuming 22.35 litres of gas
   Tour destination to Mumbai delivering 0 (149km) while consuming 22.35 litres of gas
Drive 246km with a SmallTruck consuming 36.9 from Mumbai over:
   Tour destination to Roha delivering 20 (123km) while consuming 18.45 litres of gas
   Tour destination to Mumbai delivering 0 (123km) while consuming 18.45 litres of gas
Drive 1491km with a LargeTruck consuming 521.85 from Mumbai over:
   Tour destination to Baroda delivering 0 (411km) while consuming 143.85 litres of gas
   Tour destination to Indore delivering 70 (338km) while consuming 118.3 litres of gas
```

Fig 4 screenshot 1



```
Command Prompt
Drive 1491km with a LargeTruck consuming 521.85 from Mumbai over:
   Tour destination to Baroda delivering 0 (411km) while consuming 143.85 litres of gas
   Tour destination to Indore delivering 70 (338km) while consuming 118.3 litres of gas
   Tour destination to Pune delivering 0 (593km) while consuming 207.55 litres of gas
   Tour destination to Mumbai delivering 0 (149km) while consuming 52.15 litres of gas
Drive 3193km with a LargeTruck consuming 1117.55 from Mumbai over:
   Tour destination to Baroda delivering 0 (411km) while consuming 143.85 litres of gas
   Tour destination to Kolhapur delivering 20 (777km) while consuming 271.95 litres of gas
   Tour destination to Halol delivering 45 (813km) while consuming 284.55 litres of gas
   Tour destination to Kolhapur delivering 0 (813km) while consuming 284.55 litres of gas
   Tour destination to Pune delivering 0 (230km) while consuming 80.5 litres of gas
   Tour destination to Mumbai delivering 0 (149km) while consuming 52.15 litres of gas
Drive 1060km with a MediumTruck consuming 265.0 from Mumbai over:
   Tour destination to Chiplun delivering 0 (257km) while consuming 64.25 litres of gas
   Tour destination to Belgaum delivering 30 (273km) while consuming 68.25 litres of gas
   Tour destination to Chiplun delivering 0 (273km) while consuming 68.25 litres of gas
   Tour destination to Mumbai delivering 0 (257km) while consuming 64.25 litres of gas
Drive 3340km with a SmallTruck consuming 501.0 from Mumbai over:
   Tour destination to Baroda delivering 0 (411km) while consuming 61.65 litres of gas
   Tour destination to Gandhinagar delivering 0 (131km) while consuming 19.65 litres of gas
   Tour destination to Goa delivering 20 (1118km) while consuming 167.7 litres of gas
   Tour destination to Gandhinagar delivering 0 (1118km) while consuming 167.7 litres of gas
   Tour destination to Daman delivering 0 (385km) while consuming 57.75 litres of gas
   Tour destination to Mumbai delivering 0 (177km) while consuming 26.55 litres of gas
Drive 1156km with a SmallTruck consuming 173.4 from Mumbai over:
   Tour destination to Baroda delivering 0 (411km) while consuming 61.65 litres of gas
   Tour destination to Gandhinagar delivering 0 (131km) while consuming 19.65 litres of gas
   Tour destination to Ahemdabad delivering 15 (26km) while consuming 3.9 litres of gas
   Tour destination to Gandhinagar delivering 0 (26km) while consuming 3.9 litres of gas
   Tour destination to Daman delivering 0 (385km) while consuming 57.75 litres of gas
   Tour destination to Mumbai delivering 0 (177km) while consuming 26.55 litres of gas
Drive 1494km with a SmallTruck consuming 224.1 from Mumbai over:
   Tour destination to Daman delivering 0 (177km) while consuming 26.55 litres of gas
   Tour destination to Ankleshwar delivering 10 (570km) while consuming 85.5 litres of gas
   Tour destination to Daman delivering 0 (570km) while consuming 85.5 litres of gas
   Tour destination to Mumbai delivering 0 (177km) while consuming 26.55 litres of gas
```

Fig 5 Screenshot 2

Table 3.1

Tours	**Distance**	**Gas Consumed**	**Truck Type**	**Cost**
Tour 1	**822**	**205.5**	**Medium**	**13858.92**
Tour 2	**354**	**88.5**	**Medium**	**5968.44**
Tour 3	**334**	**83.5**	**Medium**	**5631.24**
Tour 4	**1156**	**404.6**	**Medium**	**19490.16**
Tour 5	**298**	**44.7**	**Large**	**5742.46**
Tour 6	**246**	**36.9**	**Small**	**3798.24**
Tour 7	**1491**	**521.85**	**Small**	**23021.04**
Tour 8	**3193**	**1117.55**	**Large**	**61529.11**
Tour 9	**1060**	**265**	**Large**	**20426.2**
Tour 10	**1494**	**224**	**Small**	**23067.36**
Tour 11	**3340**	**501**	**Small**	**51569.6**
Total	**13788**	**3493.1**		**234102.77**

For the 11 tours the cost is calculated according to different operating cost of type of vehicle used. The rates for large differ from medium and small, accordingly the small truck has different rate than large and medium. The following rates can be considered to calculate the cost based on the vehicle used in transportation of the boxes to various locations.

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Table 4.1

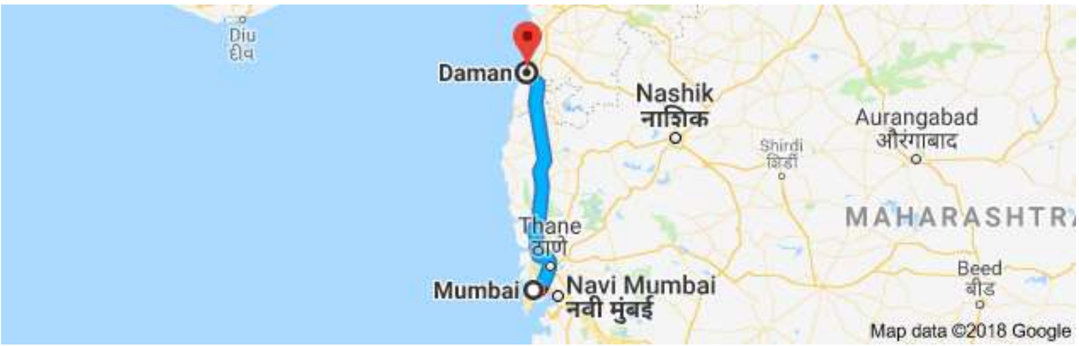
Type	Rate
Small	15.44
Medium	17.23
Large	19.27

The values we got in the table are as follows:
Thus, to calculate the cost of Tour 1, the truck used here was medium sized for which the rate is ₹17.23.
822 * ₹17.23 = ₹13858.92
For, Tour 2, the truck used was medium, for which the rate is ₹17.23
354* ₹17.23 = ₹5968.44
For, Tour 3, the truck used was medium, for which the rate is ₹17.23

334 * ₹17.23 = ₹5631.24
For Tour 5, the truck used was large, the rate for which is 19.27
298* 19.27= 5742.66
For Tour 6, the truck used was small, the rate for which is 15.44
246*15.44 = 3798.24

6. MAPS OF THE TOURS SUGGESTED

Route 1: Mumbai to Baroda



Route 2: Mumbai to Daman

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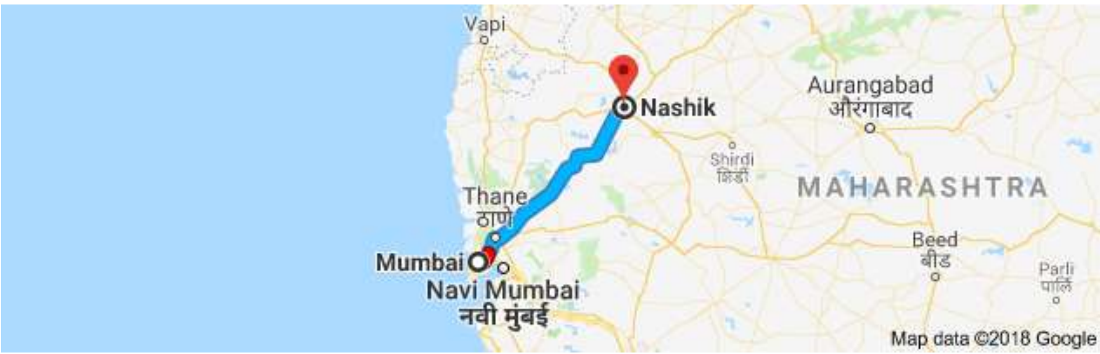
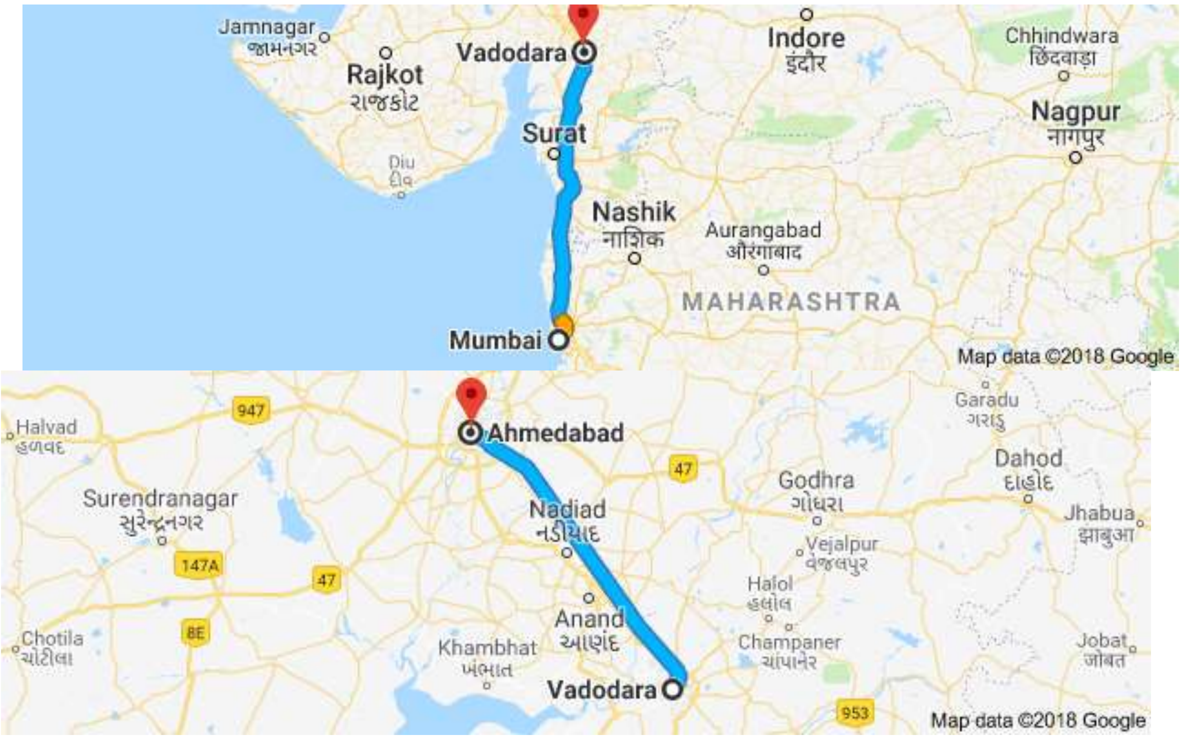
Route 3: Mumbai to Chiplun



Route 4: Mumbai to Nashik



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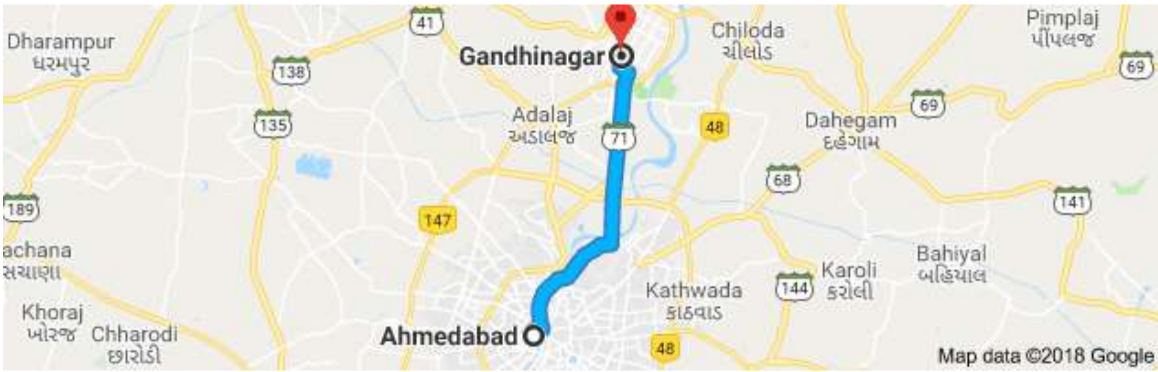
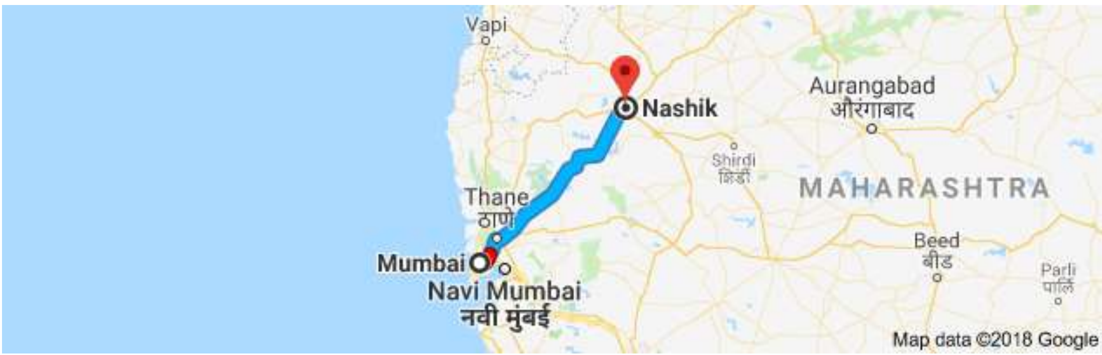


Route 5: Mumbai to Ahmedabad is a mixture of all the images as mentioned in the screenshot

Route 6: Mumbai to Pune

Route 7: Mumbai to Roha



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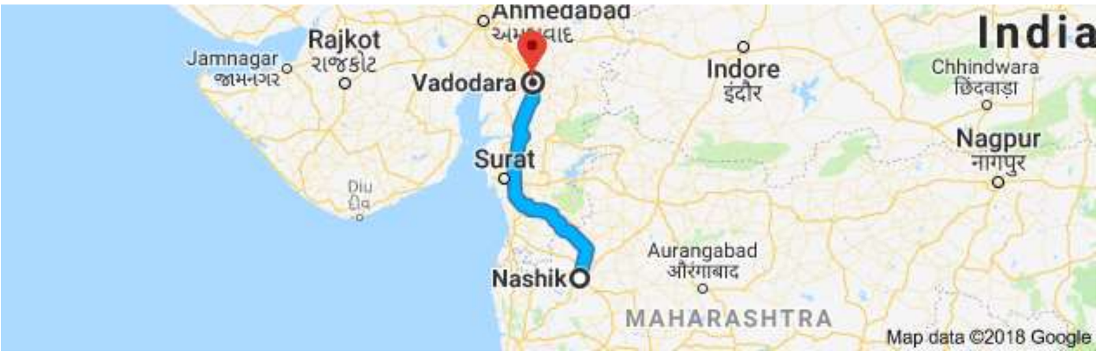
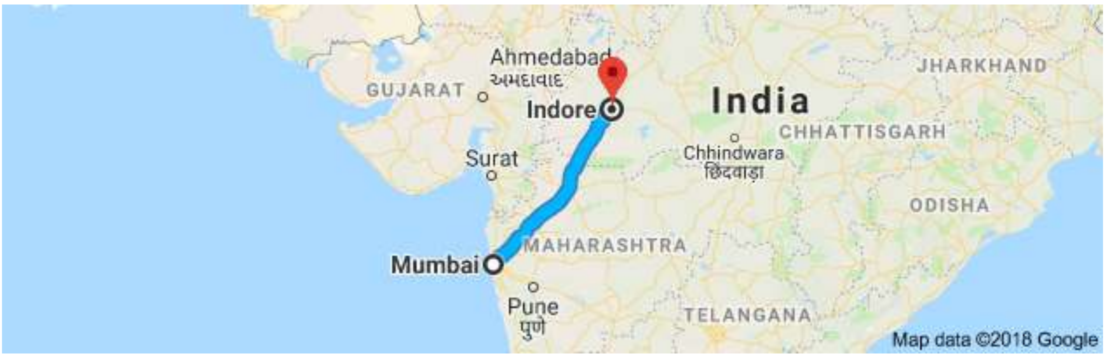
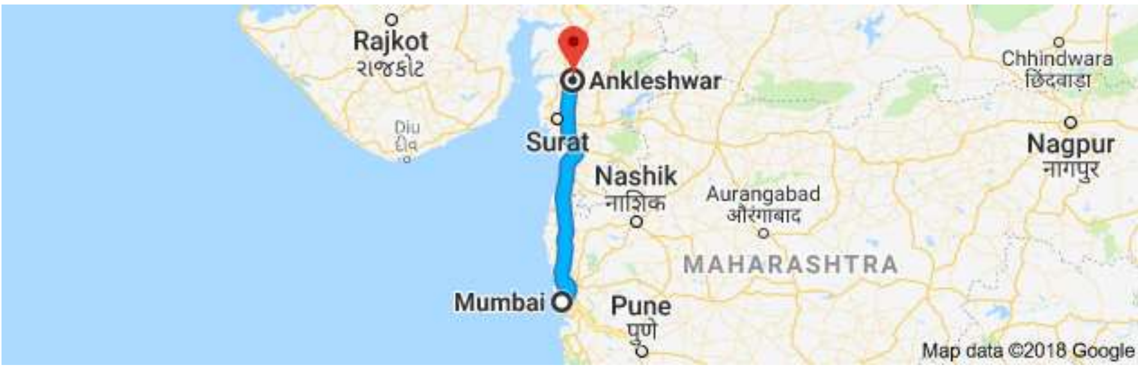


Route 8: Mumbai to Baroda, second route



Route 9: Mumbai to Indore

Route 10: Mum to Halol



Route 11: Mumbai to Ankleshwar

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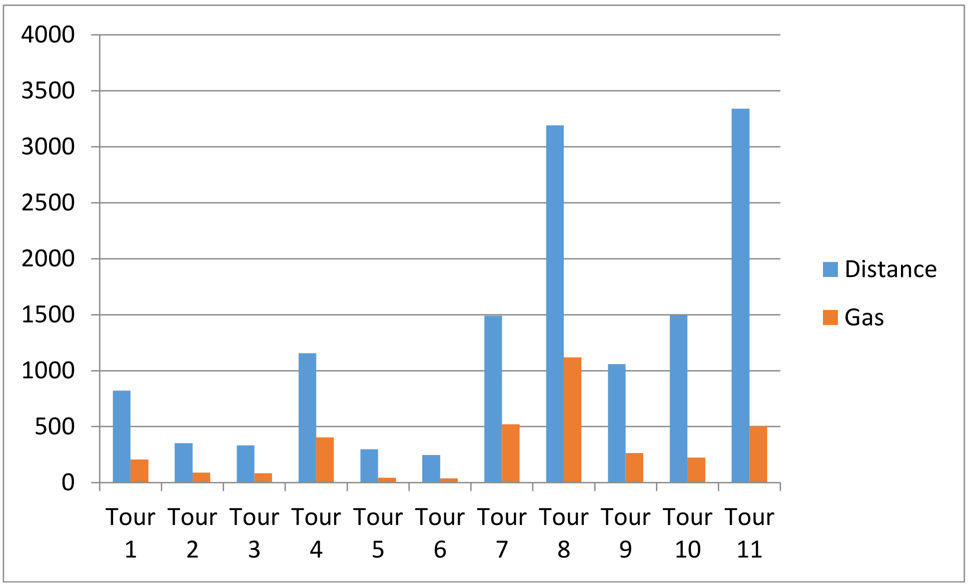
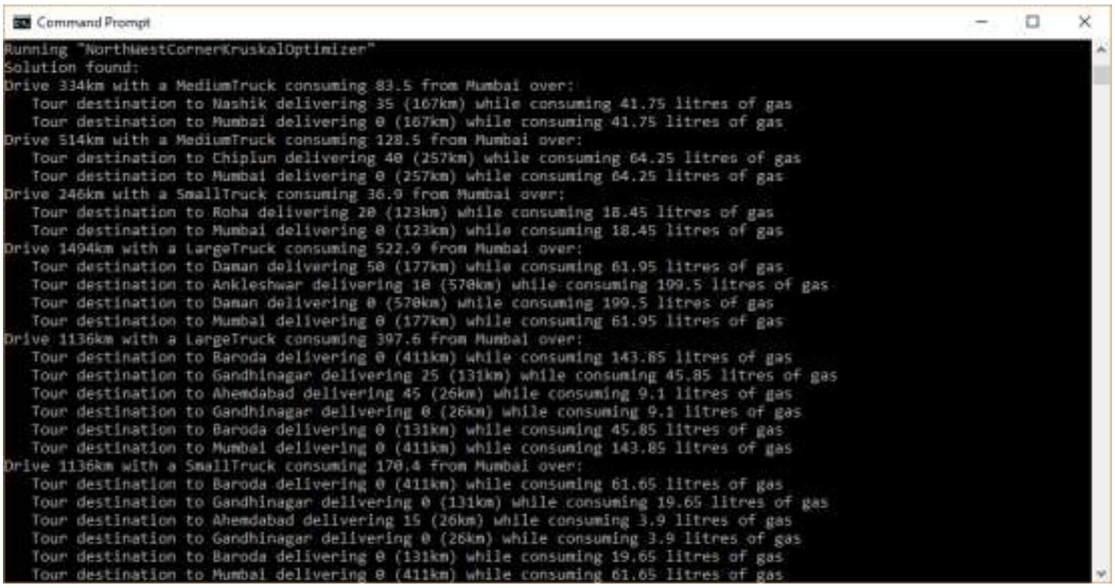


The total cost saved is 237175.16 – 234102.77 = 3072.39

Now 3072.39 rupees might not seem much, but this is before we take into consideration the fuel costs. Assuming the cost of diesel at 67.43 rupees, the total fuel consumed by the truck in individual journey is 4102.67 liters. We have used 3493.1 liters of fuel.

Therefore, we have saved 4102.67-3493.1 = 609.57 liters of fuel. Multiplying this by the diesel price, we save 609.57*67.43 = 41103.30 rupees in fuel.
Approximately, we are saving close to 50,000 rupees by using this optimization.

6.1 Hybrid method results:



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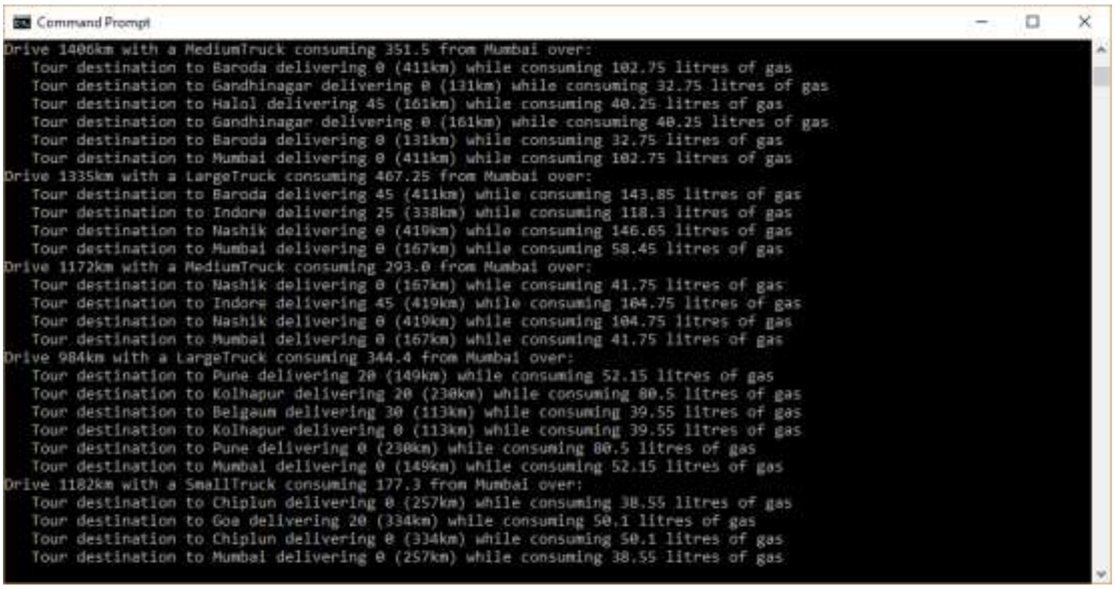

```
Command Prompt
Drive 1406km with a MediumTruck consuming 351.5 from Mumbai over:
   Tour destination to Baroda delivering 0 (411km) while consuming 102.75 litres of gas
   Tour destination to Gandhinagar delivering 0 (131km) while consuming 32.75 litres of gas
   Tour destination to Halol delivering 45 (161km) while consuming 40.25 litres of gas
   Tour destination to Gandhinagar delivering 0 (161km) while consuming 40.25 litres of gas
   Tour destination to Baroda delivering 0 (131km) while consuming 32.75 litres of gas
   Tour destination to Mumbai delivering 0 (411km) while consuming 102.75 litres of gas
Drive 1335km with a LargeTruck consuming 467.25 from Mumbai over:
   Tour destination to Baroda delivering 45 (411km) while consuming 143.85 litres of gas
   Tour destination to Indore delivering 25 (338km) while consuming 118.3 litres of gas
   Tour destination to Nashik delivering 0 (419km) while consuming 146.65 litres of gas
   Tour destination to Mumbai delivering 0 (167km) while consuming 58.45 litres of gas
Drive 1172km with a MediumTruck consuming 293.0 from Mumbai over:
   Tour destination to Nashik delivering 0 (167km) while consuming 41.75 litres of gas
   Tour destination to Indore delivering 45 (419km) while consuming 104.75 litres of gas
   Tour destination to Nashik delivering 0 (419km) while consuming 104.75 litres of gas
   Tour destination to Mumbai delivering 0 (167km) while consuming 41.75 litres of gas
Drive 984km with a LargeTruck consuming 344.4 from Mumbai over:
   Tour destination to Pune delivering 20 (149km) while consuming 52.15 litres of gas
   Tour destination to Kolhapur delivering 20 (230km) while consuming 80.5 litres of gas
   Tour destination to Belgaum delivering 30 (113km) while consuming 39.55 litres of gas
   Tour destination to Kolhapur delivering 0 (113km) while consuming 39.55 litres of gas
   Tour destination to Pune delivering 0 (230km) while consuming 80.5 litres of gas
   Tour destination to Mumbai delivering 0 (149km) while consuming 52.15 litres of gas
Drive 1182km with a SmallTruck consuming 177.3 from Mumbai over:
   Tour destination to Chiplun delivering 0 (257km) while consuming 38.55 litres of gas
   Tour destination to Goa delivering 20 (334km) while consuming 50.1 litres of gas
   Tour destination to Chiplun delivering 0 (334km) while consuming 50.1 litres of gas
   Tour destination to Mumbai delivering 0 (257km) while consuming 38.55 litres of gas
```

Tour	Distance	Consumption	Truck Type	Cost
Tour 1	**334**	**83.5**	**Medium**	**6309.26**
Tour 2	**514**	**128**	**Medium**	**9709.46**
Tour 3	**246**	**35.4**	**Small**	**4044.24**
Tour 4	**1494**	**522.9**	**Large**	**28789.38**
Tour 5	**1136**	**397.6**	**Large**	**21890.72**
Tour 6	**1136**	**170.4**	**Small**	**18675.84**
Tour 7	**1406**	**351.5**	**Medium**	**26559.34**
Tour 8	**1335**	**467.25**	**Large**	**25725.45**
Tour 9	**1172**	**293**	**Medium**	**22139.08**
Tour 10	**984**	**344**	**Large**	**18961.68**
Tour 11	**1182**	**177**	**Small**	**19432.08**
Total	**10939**	**2970.55**		**202236.53**

This table represents the cost calculated by the above hybrid algorithm. For the 11 tours the cost is calculated according to different operating cost of type of vehicle used. The rates for large differ from medium and small, accordingly the small truck has different rate than large and medium. The following rates can be considered to calculate the cost based on the vehicle used in transportation of the boxes to various locations.

Type	Rate
Small	16.44
Medium	18.89
Large	19.27

Thus, to calculate the cost of Tour 1, the truck used here was medium sized for which the rate is ₹18.89.
334 * ₹18.89 = ₹6309.26

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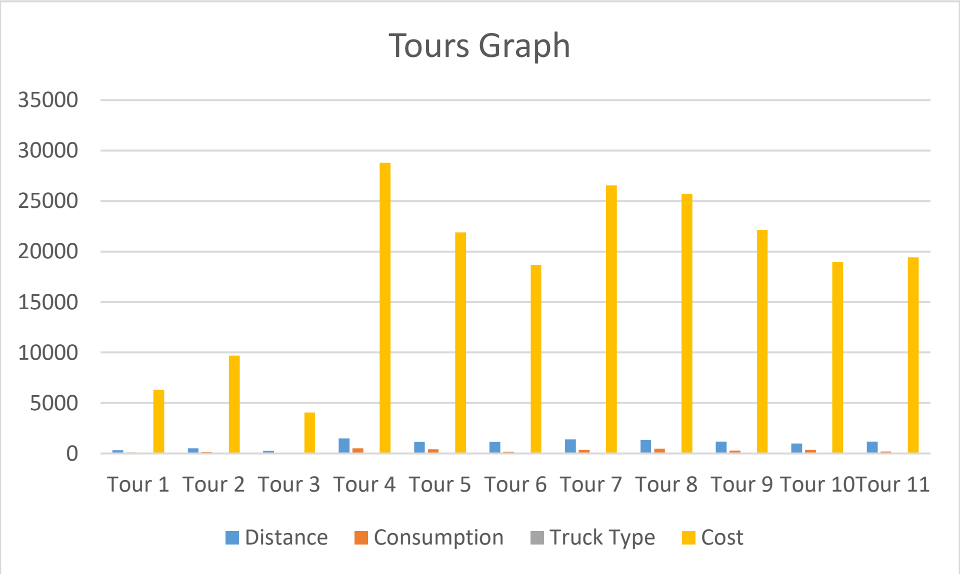
For, Tour 2, the truck used was medium, for which the rate is ₹18.89
514 * ₹18.89 = ₹9709.46
For, Tour 3, the truck used was small, for which the rate is ₹16.44.
246 * ₹16.44 = ₹4044.24
For, Tour 4, the truck used was large, for which the rate is ₹19.27.
1494 * ₹19.27 = ₹28789.38
For, Tour 5, the truck used was large, for which the rate is ₹19.27.
1136 * ₹19.27 = ₹21890.72
For, Tour 6, the truck used was small, for which the rate is ₹16.44.
1136 * ₹16.4.= ₹18675.84
For, Tour 7, the truck used was medium, for which the rate is ₹18.89
1406 * ₹18.89 = ₹26559.34
For, Tour 8, the truck used was large, for which the rate is ₹19.27.
1335 * ₹19.27 = ₹25725.45
For, Tour 9, the truck used was medium, for which the rate is ₹18.89
1172 * ₹18.89 = ₹22139.08
For, Tour 10, the truck used was large, for which the rate is ₹19.27.
984 * ₹19.27 = ₹18961.68
For, Tour 11, the truck used was small, for which the rate is ₹16.44.
1182 * ₹16.44 = ₹19432.08

Similarly the corresponding costs can be calculated. For the total cost occurred by these tour,
The total cost = 6309.26 + 9709.46 + 4044.24 + 28789.38 + 21890.72 + 18675.84 + 26559.34 + 25725.45 + 22139.08 + 18961.68 + 19432.08 = 202236.53
The total cost is around ₹202236.53.



To calculate savings: ₹237175.16 - ₹202236.53 = ₹34938.63

With the above calculations we can conclude that a total savings of ₹34938.63 (approx. 3.5 lakhs) can be possible for the company.

For the basis of fuel consumption, the consumption occurred in solo trips is around **4102.67 litres**
While by above proposed algorithm the consumption is around **2970.55 litres.**
This is a total savings of 1132.12 litres of gas.

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6.2: Summary of the Result
To summarize the result we found above, the result consist of three parts

- The individual costs of tours or trips from one place to another and back to start destination
- The cost of fuel required to complete the trips or tours.
- The distance travelled by the trucks in total.

We can see that the trips that Swift Logistic Pvt Ltd covers only one city at a time. Also it uses a large truck for all its logistics purposes. Dividing the truck used in these trips by based on demand and remaining boxes to be delivered, a lot of fuel and cost can be saved at the end of the day.

The tours that are prepared by the algorithm also cover more than one city at one instance. This may not be the case in every tour but if the demand of a city is less and the truck is able to satisfy the demand while transporting the shipment to another city, this may benefit the current city's needs. This majorly works in cutting costs and avoiding unnecessary trips to places that lie in the middle of a long route.

In the above data values given to the algorithm, the algorithm concluded to save around ₹45,702 of transportation costs than the solo trips it is conducting to supply shipments.

The Hybrid method helps us save₹34938.63amount in transportation costs

We can thus say that both the pheromone optimizer and the hybrid method help in cutting down costs and fuel consumption.

7. CONCLUSION, LIMITATIONS AND SCOPE FOR FUTURE WORK

Conclusion
From the above observations we can conclude that pheromone optimization and the hybrid method can be used can be used to optimize the transportation problem. It can be used in practical real world scenarios and is destined to cut costs and fuel consumption. The graphical method of reducing costs works very well as minimum spanning tree uses the least cost to reach from a source to destination. The scent and fade basis of the optimizer gives a new direction to the previously solved problem and makes it easier for us to apply this in a real life problem.

The division of truck fleet into 3 parts is the major factor for which it is able to achieve this difference. Constructing a minimum spanning tree helps in finding a direct route from source to destination when enough parameters are given and can be surely used in solving transportation problems in real world scenarios.

Future Work
Future work would be to optimize the algorithm even further and add more constraints and factors to evaluate the optimum solution. Constraints like route change or 'must stops' in order to make the algorithm more realistic and practical so that it can be incorporated in applications and companies.

This algorithm can be used in any industry where ERP and supply chain management is necessary. Be it mining, manufacturing, restaurants or even pure transportation businesses. The algorithm can also be used in the financial business and for optimization of non transportation problems as well.

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