FEASIBILITY STUDY AND SUPPLY CHAIN OPTIMIZATION OF LPG DISTRIBUTION SYSTEM USING ELECTRIC VEHICLE

M.Tech. Thesis

By

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INDIAN INSTITUTE OF TECHNOLOGY INDORE

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A THESIS

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DEPARTMENT OF MECHANICAL ENGINEERING

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CANDIDATE'S DECLARATION

I hereby certify that the work which is being presented in the thesis entitled **FEASIBILITY STUDY AND SUPPLY CHAIN OPTIMIZATION OF LPG DISTRIBUTION SYSTEM USING ELECTRIC VEHICLE** in the partial fulfilment of the requirements for the award of the degree of **MASTER OF TECHNOLOGY** and submitted in the **DEPARTMENT OF MECHANICAL ENGINEERING, Indian Institute of Technology Indore**, is an authentic record of my own work carried out during the time period from July 2019 to June 2021 under the supervision of **Dr. Bhupesh Kumar Lad**, Associate Professor.

The matter presented in this thesis has not been submitted by me for the award of any other degree of this or any other institute.

03-06-2021

PRIYANSHU UPADHYAY

This is to certify that the above statement made by the candidate is correct to the best of my/our knowledge.

4/6/21

(Dr. Bhupesh Kumar Lad)

PRIYANSHU UPADHYAY has successfully given his/her M.Tech. Oral Examination held on **04/06/2021**.

4/6/21

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DEDICATION

Abstract

With the growth of environmental awareness in environmental pollution and energy dearth, electric vehicle comes out as the emerging replacement for Internal combustion engine vehicles (ICEVs). There is an increase in the market share of EVs worldwide due to them being environment friendly in aspects of carbon emission and minimal noise production. There are proven environmental benefits of use of EVs over ICEVs on environmental aspects. To study EVs benefits in light commercial sector, this research studies a comparison between an EV and an ICEV for LPG distribution in Indore city based on environmental and economic aspects, LPG distribution uses light commercial vehicles on frequent and regular basis. It further calculates the Total Cost of Ownership (TCO) for both types of vehicles for ten years. It also deals with studying the supply chain of the LPG distribution system in Indore city from warehouses to end customers. The data of around 2.25 lakh customers was created to develop this model. The delivery route was optimized using the constrained vehicle routing problem (CVRP), which was solved using the Simulated Annealing algorithm. The routes were optimized for EVs, and charging points were considered in the warehouses.

Further ICEV and EV were compared on the optimized route based on the carbon footprints generated. The optimized route was also compared with a random clustering approach considering it as a present scenario.

There are various approaches which traces the vehicle's location on a predefined path or tracing of a vehicle on an instantaneous generated path. This thesis also consists of s novel approach which combines both predefined path and the path of instantaneous generated demands and traces the vehicle's position on a constantly changing new path. This method helps in delivering the instantaneous generated demands and also connects inter-agency and intra-agency distributors.

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ABBREVIATIONS

BEV - Battery Electric Vehicle

PHEV - Plugin Hybrid Electric Vehicle

EV - Electric Vehicle

HEV - Hybrid Electric Vehicle.

ICEV - Internal Combustion Engine Vehicle.

KM - kilometre

GHG - Greenhouse Gases

GoI - Government of India

FAME – Faster Adoption and Manufacturing of Hybrid Electric Vehicles in India

LPG – Liquified Petroleum Gas.

LCS – Light Commercial Sector.

MTOE - Million Tonnes of Oil Equivalent.

kWh - Kilowatt Hour

LCV - Light Commercial Vehicle

CO_2 - Carbon dioxide

CVRP - Constrained vehicle Routing Problem

TSP - Traveling Salesman Problem

LPG - Liquified Petroleum Gas

TCO – Total Cost of Ownership

IOCL – Indian Oil Corporation Limited

RTTS – Real Time Tracking System

Chapter 1 Introduction

Air pollution and the depletion of fossil fuels are among significant concerns in this evolving world. The use of ICEVs is a common threat to both air pollution and the depletion of fossil fuels. The transportation sector consumes about 17% of the energy (crude oil), and approximately 88% of the greenhouse gas (GHG) emission in the transportation sector accounts from road transportation [1] [2]. Since CO_2 is the second-largest contributor to GHG emissions, reducing it will have a positive environmental impact [3] [4]. US-based study shows the quantifying benefits of EVs over ICEVs on parameters which includes both societal and economic benefits [5]. Thus, to minimise the adverse effects of ICEVs, the entire world is heading towards the use of EVs.

Transportation in supply chain operations is one of the essential elements and it has greatly contributed to raising the level of air pollution. It is not only environmentally infeasible but also puts extra economic burden. A UK based case study shows that electric light commercial vehicle (eLCV) is beneficial over LCV in different sectors. It may decrease CO_2 emission from LCVs by 30% by 2030 if a proper electrification strategy is made [6].

The LCV used in supply chains are among the sources of CO_2 emission and one of its examples is LPG distribution system. It uses ICEVs on a frequent basis for delivery of cylinders. India is the 3rd largest consumer of LPG cylinders after China and USA where around 4.2 million cylinders are delivered on a daily basis. Thus, it contributes a lot in generation of CO_2. Further, a case study on the Indonesian LPG Distribution system shows that on optimising the existing supply chain, the cost associated with the supply chain decreases. A study says that an optimised heterogenous fleet system is more suitable for dairy industry as it is more economical and environmentally friendly [supply chain routing, downloads]. Different studies show that optimising the distribution system in the supply chain reduces the total cost of transportation. [10][11][12].

Presently users are more interested in using EVs, but there is no such concrete study which shows the feasibility of EVs in light commercial sector. Thus, this paper fills this gap. This paper shows the introduction of EVs in light commercial sector through a case study in LPG distribution system. Most of the countries still uses cylinders for LPG distribution system instead of gas pipelines. Thus, CO_2 emission due to use of ICEVs in this supply chain is a global problem. Thus, it proves the viability of EVs over ICEVs on economic and environmental fronts. The results also reflect the reduction in generation of carbon footprints. Further it also optimises the routes using Constrained vehicle routing problem (CVRP) algorithm considering the location of charging stations and compares the optimised supply chain with existing supply chain. The study takes 1 lakh customers into consideration for this study.

The Constraint Vehicle Routing Problem (CVRP), one of the Traveling Salesman Problem (TSP) advancements, optimises the route. As easy to define the TSP, it is equally difficult to solve it and becomes even more complicated once the nodes increase [13] [14]. This problem is known to be NP-hard. There are many exact and heuristic algorithms to solve this problem [15].The vehicle routing problem (VRP) aims to find a set of routes at a minimal cost, beginning and ending the route at the depot to fulfil the known demand of all nodes. Each node is visited only once, by only one vehicle, and each vehicle has a defined capacity [16]. Mathematical and a heuristic approach can be used to solve a CVRP. The mathematical approach gives the exact solution but takes considerable computational time means it is not suitable for large-scale problems. There are many approaches like genetic algorithm, Tabu search, Simulated Annealing in metaheuristic.SA was successfully used to solve VRP previously [18][19][20][21][22].

The further sections in this part gives the brief introduction about the frequently used terminologies and overview of the entire work.

1.1. Electric Vehicle

An EV uses one or more electric motor for propulsion. It may be powered through a collector system by electricity from off-vehicle sources or self-contained with a battery, solar panels, fuel cells or an electric generator to convert fuel to electricity. EVs are mainly categorized in three categories

Types of e- vehicles:

1.1.1. Battery e- vehicles: BEV entirely runs on an electric battery with a fully rechargeable battery with no gasoline engine parts. Depending on the type of battery used, it can be fast-charged. These vehicles are zero-emission vehicles as they do not generate any air pollution hazard or tailpipe emission.

1.1.2. Plug-in Hybrid Electric Vehicles: PHEVs have both an electric motor and an engine to drive the vehicle. Regenerative braking is used to recharge the battery like regular hybrid cars. Unlike hybrid vehicles, they have a massive battery and can be recharged using plugin into the grid. PHEV can travel anywhere around 10-50 km before the gasoline engine provides assistant. Once the battery is exhausted, PHEV behaves as a regular hybrid car and can travel several hundred km on gasoline.

1.1.3. Hybrid Electric Vehicles: HEVs have a gas-powered engine and an electric motor to drive the vehicle. The battery's energy is gained through regenerative braking, which recoups otherwise lost energy in braking to assist the gasoline engine during acceleration. In traditional ICEVs this energy is usually lost in the form of heat.

1.2. Necessity of EVs

ICEVs are the second largest source of CO_2 emission. It contributes to about 20% of GHG emission globally. About 70% of the total energy i.e. crude oil produced is consumed by transportation sector. Considering the Indian scenario, it consumes about 17% of the total energy. This translates to an estimated 94 MTOE energy. If India were to follow the current trends of energy consumption, it would require an estimated 200 MTOE of energy supply annually, by the year 2030 to meet the demand of this sector. The road transportation accounts for 88% of GHGs emission in the transportation sector which means the entire sector contributes an estimated 142 Million Tonnes of CO_2 emissions annually, out of which 123 million tonnes is contributed by the road transport segment alone. Keeping in view the climate change commitments made by Government of India during the COP21 Summit held at Paris to reduce emission intensity by 33- 35% by 2030 from 2005 levels, it is pertinent to introduce alternative means in the transport sector which can be coupled with India's rapid economic growth, rising urbanization, travel demand and country's energy security. Electric mobility presents a viable alternative in addressing these challenges, when packaged with innovative pricing solutions, appropriate technology and support infrastructure and thus, has been on the radar of Government of India

Electric mobility will also contribute to balancing energy demand, energy storage and environmental sustainability. Electric vehicles could help diversify the energy needed to move people and goods thanks to their reliance on the wide mix of primary energy sources used in power generation, greatly improving energy security. Thanks to their storage capacity, they could help support the uptake of clean electricity, enabling greater use of variable renewable in electricity production. If coupled with the decarburization of the power sector, electric vehicles would also provide major contributions to keep the world on track to meet its shared climate goals. The use of EVs is also cost effective and saves around 75 – 80% of the operational cost. The use of EVs has a positive environmental impact and their use may discuss the operational cost of a vehicle by 75-80 %.

Electric mobility comes with zero or ultra-low tailpipe emissions of local air pollutants and much lower noise, and, by being one of the most innovative clusters for the automotive sector, can provide a major boost to the economic and industrial competitiveness, attracting investments, especially in countries.

The government of India have undertaken multiple initiatives to promote manufacturing and adoption of electric vehicles in India. With support of the government, electric vehicles have started penetrating in the Indian market. However, availability of adequate Charging Infrastructure is one of the key requirements for accelerated adoption of electric vehicles in India.
Availability of adequate Charging Infrastructure is one of the key requirements for accelerating the adoption of electric vehicles in India. In this regard, Ministry of Power has issued "Charging Infrastructure for Electric Vehicles – Guidelines and Standards" mentioning the roles and responsibilities of various stakeholders at Central & State level, for expediting the development of public EV charging infrastructure across the country. Ministry of Power has designated Bureau of Energy Efficiency (BEE) as the Central Nodal Agency (CNA) for the National-level rollout of charging infrastructure in the country.

1.3. Benefits of EVs.

Benefits of choosing an EV over ICEV are broadly classified on the basis of economic, environmental backgrounds

1.3.1. Economical:

EVs have fewer moving parts as compared to ICE, thus EVs need less maintenance. Higher efficiency, lower fuel cost and lower operational cost makes EVs economical than ICE vehicles.

1.3.2. Improved Air quality:

EVs have no tailpipe emission as compared to ICE vehicles. Adopting EVs will help in reducing local air pollution. Shifting to EVs will reduce Greenhouse Gas (GHG) emissions that gets emitted from running an ICE vehicle.

1.3.3. Convenience:

EVs have no gears and are much easier to drive than ICE vehicles. The lack of combustion and mechanical drivetrain makes EVs much quieter

1.3.4. Other Benefits:

- Comfortably charge at home.
- Upfront incentives from Government to EV owners.
- Incentive for scrapping ICE vehicles.
- EV owners can claim income tax deduction up to Rs 150,000 under Section 80EEB.
- Reduced dependence of imported fossil fuel for the country.

1.4. Challenges in using EVs

A dream that is turning into reality with many companies boldly launching their EVs in market and most of them getting success. But there are many problems on which it needs to be worked in order to make EVs success to next level in India. Challenges which are faced are:

1.4.1. High Purchasing Cost: It is one of the major problems if Indian scenario is considered. There is a huge price difference in electric model and internal combustion engine model of a car. The price variation of electric cars in India varied from INR. 9.5 lakh to INR. 24 lakhs, which is par the average vehicle price as per the Indian scenario.

1.4.2. Service and Maintenance: Since there is enough market for EVs, it is difficult to get the parts of a vehicle, if required. Still the repair and accessories availability of the electric vehicle is in the initial stage and only when the market scales up, such system will be well developed.

1.4.3. **Battery Manufacturing Capabilities:** As per the report of International Energy Agency, the battery manufacturing capacity of around 1,000-Gigawatt hour (GWh) is required by the year 2025. The price of lithium-ion battery is decreasing tremendously as government is providing subsidies in battery manufacturing sectors. Market experts estimate that the EV battery industry in India has a potential of $300 billion by 2030. Currently, there are a few manufacturers (ISRO-BHEL joint effort, Amara Raja, HBL, Eon Electric and Exide), but battery manufacturers worldwide are eying the Indian market.

1.4.4. **Power Management:** India produces just sufficient power to fulfil the electricity demands of the country. In this situation surplus demand for EVs will be a challenging situation. Thus, India should focus on increasing the production capacity of the electricity. Increasing renewable sources to fulfil the energy demands is must be considered. Discussing about the mathematical part, for 1 Mn EVs, assuming an average battery capacity of 30 kWh, India requires around 15Mn units (kWh) of electricity per day.

1.4.5. **Lack of charging Infrastructure:** The number of EVs on road is projected to increase rapidly in this decade. In 2019, 1% of the automobile market was captured by EVs. However, the cumulative number of EVs on road will increase tremendously in upcoming 10-15 years. Thus, sufficient charging infrastructure is required in order to fulfil the charging demand of the vehicles. As of now there are very less charging stations in India. And hardly any fast-charging infrastructure available. Local regulatory issues and electric grid upgrades will also play major role in developing the infrastructure. There are at present 250 public charging stations in India. For a million EV per city in India, an estimated number of 2 million charging stations (mix of both fast and slow) will be required.

1.4.6. The charging challenge: This challenge discusses about the charging time taken by the vehicle to charge a vehicle. In case of ICEV, hardly it takes few minutes to refuel the vehicle. But in case of EV, it may take up to several hours to charge a vehicle depending upon the charging infrastructure available and type of battery used. The below figure depicts the problem faced, which needs to be resolved.

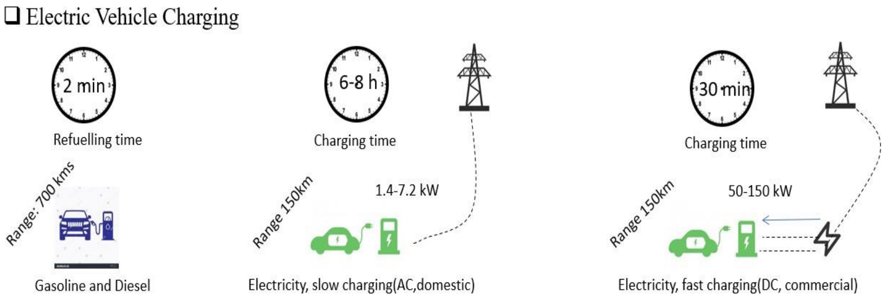


Figure 1 Electric Vehicle Charging

1.5. FAME I and FAME II

With advancements in the use of EVs due to their benefits of ICEVs, the GoI is also launching different schemes and projects in order to promote the sale of EVs and to develop confidence among the customers to increase the use of EVs. This section briefly describes the schemes FAME I and FAME II launched by GoI to promote the use of EVs.

The National Electric Mobility Mission Plan (NEMMP) 2020 is a National Mission document providing the vision and the roadmap for the faster adoption of electric vehicles and their manufacturing in the country. As part of the NEMMP 2020, Department of Heavy Industry formulated a Scheme viz. Faster Adoption and

Manufacturing of (Hybrid &) Electric Vehicles in India (FAME India) Scheme in the year 2015 to promote manufacturing of electric and hybrid vehicle technology and to ensure sustainable growth of the same.

The Phase-I of this Scheme was initially launched for a period of 2 years, commencing from 1st April 2015, which was subsequently extended from time to time and the last extension was allowed up to 31st March 2019. The 1st Phase of FAME India Scheme was implemented through four focus areas namely (i) Demand Creation, (ii) Technology Platform, (iii) Pilot Project and (iv) Charging Infrastructure. Market creation through demand incentives was aimed at incentivizing all vehicle segments i.e. 2-Wheelers, 3-Wheelers Auto, Passenger 4-Wheeler vehicles, Light Commercial Vehicles and Buses.

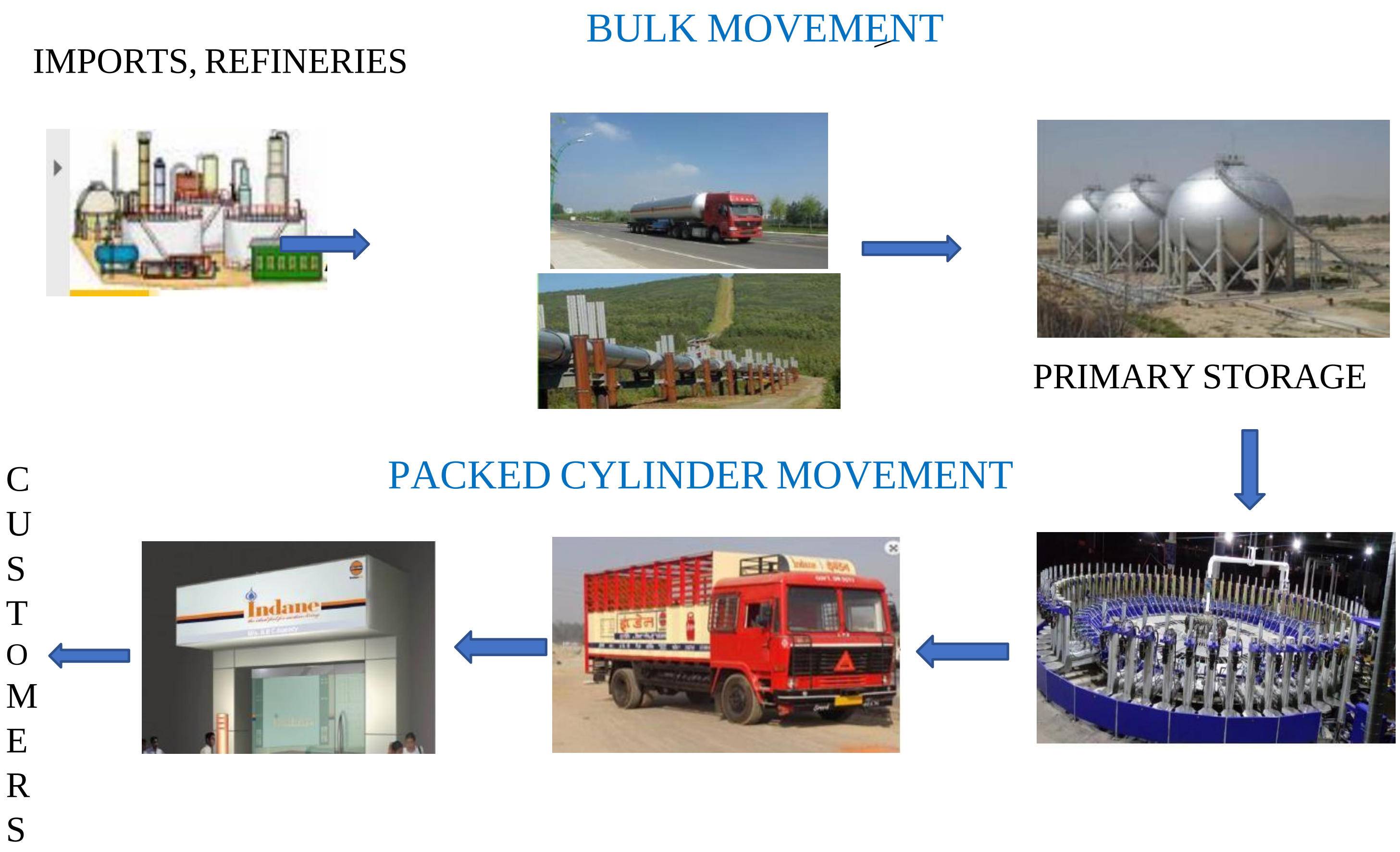
Government has approved Phase-II of FAME Scheme with an outlay of Rs. 10,000 Crore for a period of 3 years commencing from 1st April 2019. Out of total budgetary support, about 86 percent of fund has been allocated for Demand Incentive so as to create demand for xEVs in the country. This phase aims to generate demand by way of supporting 7000 e-Buses, 5 lakh e-3 Wheelers, 55000 e-4 Wheeler Passenger Cars (including Strong Hybrid) and 10 lakh e-2 Wheelers. However, depending upon off-take of different category of xEVs, these numbers may vary as the provision has been made for inter as well as intra segment wise fungibility.

Only advanced battery and registered vehicles will be incentivized under the scheme. With greater emphasis on providing affordable & environment friendly public transportation options for the masses, scheme will be applicable mainly to vehicles used for public transport or those registered for commercial purposes in e-3W, e-4W and e-bus segments. However, privately owned registered e-2Ws are also covered under the scheme as a mass segment.

1.6. Supply Chain Network

A supply chain consists of all parties (manufacturers, suppliers, transporters, warehouses, retailers, and customers) and, within each organization, all the functions involved, directly or indirectly, in fulfilling a customer request. Considering the LPG distribution supply chain, it mainly consists of two types of movement of LPG: the first one is the bulk movement and the second one is the packed cylinder movement.

The bulk movement of the LPG starts from ports or refineries depending on weather the LPG is imported or extracted. From refineries / ports it is carried to the primary storage plant with the help of rails, large capacity trucks or the pipelines; from there onwards it is packed in the different capacity cylinders in the bottling plants as per the requirements. From here the cylinders are delivered to the warehouses in the trucks and then distributed to the end users with the help of mini trucks or autos. The given figure shows the supply chain network of LPG distribution system.



Source: www.iocl.com

Figure 2 Supply Chain Network of LPG Distribution System

1.7. Carbon Footprints

"A carbon footprint is the total greenhouse gas (GHG) emissions caused directly and indirectly by an individual, organization, event or product."- It is calculated by summing the emissions resulting from every stage of a product or service's lifetime (material production, manufacturing, use, and end-of-life). Throughout a product's lifetime or lifecycle, different greenhouse gases GHGs may be emitted, such as carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O), each with a greater or lesser ability to trap heat in the atmosphere. These differences are accounted for by calculating each gas's global warming potential (GWP) in units of carbon dioxide equivalents (CO_2e), giving carbon footprints a single unit for easy comparison.

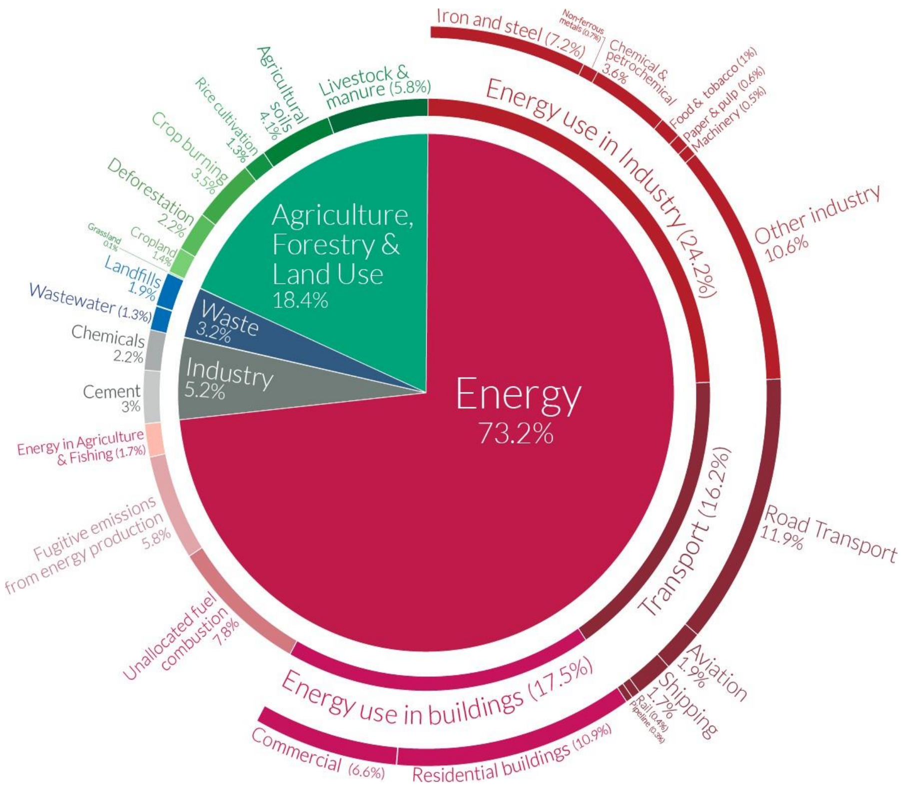


Figure 3 Sector-wise Global GHG Emission

The figure shows the global greenhouse gases emission by different sectors. It shows that 73.2% of the total emission accounts from energy and transportation alone accounts for 16.2% of the total emission. Thus reduction in carbon footprints in this sector will have a positive impact on the environment. The LCS accounts for around 32% of the transportation sector. Thus, the main aim of the study is to reduce the carbon footprints generated in the LCS.

1.8. Organisation of Thesis

The thesis is basically divided into 7 chapters. The first chapter is the introductory part, which gives the overall outline of the entire work part by part. It also comprises defining of few basic terms. The second chapter comprises of the literature review of the work done and it also consists of the problem statement and objectives required to fulfil the project. The third chapter comprises of a case study which proves the economic and environmental viability of the EVs in the LPG distribution system. The fourth chapter of the thesis comprises of another case study, which introduces EVs in the LPG distribution system and it also involves the optimization of the routes for more efficient output. The fifth chapter of the thesis consists of the detailing of the model made for the real time tracking of the vehicles. The sixth and seventh chapter consists of results and its conclusions respectively. The last chapter of the thesis comprises of the future scope of the work done. The author tried to formulate the thesis in such a way that each chapter is linked smoothly with the previous and upcoming chapter.

Chapter 2 Literature Review and Problem Formulation

2.1. Literature Review

Transportation is an essential sector in connecting one location to another for the delivery or pickup of freight and/or passengers. However, it comes with hazardous and fatal emissions that severely impact global health. Therefore, "greening" road transportation has become a top-ranking necessity [24]. Transportation with a low negative impact on human health and the environment is defined as green transportation [25], and through realizing the importance and the capability of transportation to promote improvements in a company, the number of companies that are considering "greening" as a strategy is growing [26]. Reducing emissions can be initiated by an efficiently designed VRP. In recent years, the GVRP has considered special issues related to the VRP and the environment. Lin et al. [27] defined that the objective of GVRP is to be able to harmonize the economic and environmental costs by applying effective routes to meet financial indices and environmental concerns. Therefore, the vehicle route should be designed to satisfy green transportation requirements by reducing consumption levels and consequently reducingCO_2 emissions fromroad transportation tominimize the total cost [24].The GVRP research stream is divided into two groups. One group considers minimizing the fuel consumption [14, 22] and another considers the use of AFVs & alternative fuel stations (AFSs) [12]. According to [27], other notable research streams sharing the concept of the GVRP on minimizing the negative impact on the environment are the Pollution-Routing Problem (PRP) and the VRP in reverse logistics. Kara et al. [22] began studies on energy (i.e., fuel consumption) minimization by considering that transportation cost is affected by load and distance. They formulated the problem as an integer linear program and solved it exactly using CPLEX 8.0. Kuo [14] considered the minimization of total fuel consumption for

the time-dependent vehicle routing problem (TDVRP). The transportation speed was used to calculate the fuel consumption in this model. Xiao et al. [18] also focused on minimizing fuel consumption but used a load-dependent function where the fuel consumption rate (FCR) is linearly associated with the vehicle's load. A simulated annealing heuristic was used to solve the problem. Erdo˘gan andMiller-Hooks [12] considered the use of alternative fuel in the problem of recharging or refueling of the vehicle, the alternative fuel powered vehicle (AFV) in particular. They used a Modified Clarke and Wright Savings (MCWS) heuristic and the Density-Based Clustering Algorithm (DBCA) to solve the problem. Schneider et al. [23] examined the VRP time window when employing an electrical vehicle. They presented a hybrid heuristic that combines a variable neighborhood search (VNS) algorithm with a tabu search (TS) heuristic to solve their problem. The GVRP is one benchmark instance that demonstrates the performance of the VNS/TS heuristic. The VNS/TS heuristic outperforms both heuristic methods proposed by [12]. Fuel oil being used as the primary source of energy has, in fact, a side effect on the environment. Therefore, the use of alternative energy is intended to reduce the adverse effects of fossil fuels. In fact, there are many AFVs that are marketed and sold to consumers around the world. USA has 13,776 alternative fuel stations. Due to environmental concerns, an increasing oil demand, and rising oil production
costs, efforts for cleaner alternative fuels and advanced propulsion technologies are the driving factors for developing AFVs. Furthermore, AFVs hold the potential to solve many environmental challenges that relate to emissions caused by transportation [28–30]. Table 1 lists the comparative research related to the GVRP from [12, 14, 18, 22, 23]. Due to the capacity limitation in each vehicle, some studies look at capacity as an extension of the VRP. Lin et al. [15] defined the CVRP as a variant of the VRP in which the vehicles have the maximal loading capacity to serve a set of customers with known demands in order to minimize the total cost. As defined by Breedan [17], the demand of the standard VRP is deterministic and known. In light of the properties of

cost in the matrix distance, the CVRP can be further partitioned into the symmetric CVRP (SCVRP) and asymmetric CVRP (ACVRP) [31].

2.2. Problem Statement

With the advancing world, the use of the ICEVs have increased exponentially, which has drastic impact on environment. There are many studies done in past which shows the positive impact of EVs over ICEVs on environmental basis. Literatures show that the use of EVs is beneficial. Thus this study focuses on the implementation of EVs in light commercial sector, as there is no study found which shows the benefits of use of EVs in LCS. The study further shows the economic benefits of use of EVs. Thus, to show the benefits of EVs in LCS, a case study on LPG distribution system is done, which is among a major industry using LCVs on a frequent and regular basis. Further studies shows the optimization of routes reduces the operational costs, thus this study also focuses on the optimization of the travelled routes which further optimises the distance travelled as the major focus is on to reduce the carbon footprints generated, which eventually decreases the environmental pollution. Further the optimization of the routes will also have the economical benefits. Thus, to perform the desired study, few objectives need to be fulfilled as described in the next section.

2.3. Objectives

In order to solve the problem, the following objectives were to be fulfilled.

1. ***Feasibility of e vehicles in Light Commercial Sector. :*** this objective deals with the study of EVs feasibility in LCS. It shows the viability of EV in LCS through a case study of LPG distribution in a Tier II city of India on the basis of economic and environmental aspects.

2. ***Study of supply chain of LPG distribution system.:*** This objective involves the study of the supply chain of LPG distribution from the warehouses to the end-users.
3. ***Optimization of Supply Chain of LPG distribution system using EVs:*** This deals with the optimization of supply chain of LPG distribution system of the given city. It involves the use of advanced version of TSP i.e. CVRP to optimize the problem. It considers the location of the charging points during optimization the locations, which is noble concepts in its own.
4. ***Development of real time tracking system :*** This involves the development of a system that considers the instantaneous demand of cylinders. This system optimizes the routes considering both the already generated demands and instantaneously generated demands, finding the optimal path for the vehicle.

Chapter 3 Economic Viability of EVs

This section discusses the economic and environmental viability of EV in light commercial sector. For this, a case study of LPG distribution is considered

3.1. Environmental Aspect

To study EVs' environmental aspect in the LPG distribution system, we considered a one-day distribution of LPG cylinders throughout the country. In India, on average, one day sale of LPG cylinders is approximately 4.5millions. Out of this, 88 % of cylinders are distributed for domestic purpose. Thus, to analyse EV's feasibility, the distribution of 3.96 million cylinders was considered with both ICEV and EV. To deliver a cylinder average distance covered is 4kms. Therefore, the average daily distance involved in the cylinders' delivery is 18 million kilometres.

In ICEV, TATA ACE (base variant) was considered. It has a fuel capacity of 30L with an average mileage of 21-22Km/l as claimed.[23] Thus, a mileage of 20Km/l was taken in this study.

In the case EV, Etrio TATA Ace was considered, which gives a mileage of around 120 km on a single charge of 16 kW battery.

3.1.1. Calculation of generation of CO_2 in diesel fuel.

The generation of CO2 is calculated based on lightweight diesel (LWD)as a fuel.

Molecular formula of LWD = $C_{12.3}H_{22.2}$

Molecular weight = 170g / mole.[24]

The percentage of carbon in LWD is 86.82% and the density of LWD lies between 820 – 845kg/$m^{3.}$ Thus, taking an average of 832.5kg/m^3 for calculation.

Thus, amount of carbon in one litre of diesel = (0.8682*832.5) = 724.9 grams.

Therefore, the amount of CO_2 produced = (1933.18 + 724.9) grams = 2.658 kg per litre of diesel.

3.1.2. Calculation of CO_2 generation in electricity production.

The calculation of the generation of CO_2 is based on the thermal powerplants. Different powerplants produce different amount of CO_2 depending on the carbon content of coal used. Thus, the average of all is taken in this study for calculation from the literature.[25]. Thus, CO_2 produced in the generation of electricity equals 0.9525kg/kWh.

The below table shows the comparison study of ICEV and EV on the one-day distribution of LPG cylinders, and it shows that on using EVs instead of ICEVs, CO_2 generation can be reduced by 563.4 tons daily.

ICEV (TATA Ace)	EV (Etrio's TATA Ace)
Mileage = 20km/litre	Battery used = 16kW
1 litre of diesel consumes = 2.658 kg of CO_2	1 unit (per kWh) of electricity produces = 0.9525 kg/kWh
Total CO_2 produced = $18*10^6*2.658/20$ = 2392.2 tons of CO_2 per day.	Total CO_2 produced = 18*106*0.9525*16/150 =1828.8 tons of CO_2 per day.
Difference in CO_2 generated = (2392.2-1828.8) tons = 563.4 tons	

Table 1 CO_2 generation in EV and ICEV

3.2. Economic Aspect

To study the economic feasibility of EV over ICEV, distribution of LPG cylinders for one year was considered. Cosidering the capacity constraint, assuming an ICEV and EV deliver 20 LPG cylinders per day, travelling 80kms each. As of 22/02/2021, the average diesel price in Indore was Rs. 88. Since the mileage of the ICEV is 20km/litre, the amount spent on diesel per day is equals 88 * 4 = Rs. 352. Therefore, the amount spent in a year = Rs. 352*12*30 = Rs. 1,26,720.An EV consumes approximately nine units of electricity to travel 80 km. Assuming commercialised charge per kWh of electricity equals Rs. 5.[27] Therefore, the amount spent on electricity per day equals Rs. 45 and the amount spent in one-year equals Rs. 45*30*12 = Rs. 16,200. Therefore, one year saving on using EV instead of ICEV is Rs. (1,26,720- Rs.16,200) = Rs. 1,10,520. Thus, it concludes that the amount spent on the fuel of ICEV is four times that of EV. Also, TATA Ace's on-road price is Rs.4.5 lakh, whereas that of EV is Rs.7.75 lakh. The GoI also provides a subsidy to promote the use of EVs. For the given category of vehicle, GoI provides the maximum subsidy of Rs. 1.5 lakh under the National Electric Mobility Mission Plan. As per the above analysis, the extra initial cost of EVs can be covered in approximately 1.6 years, and after which Rs. 1,10,520 can be saved annually on using EV over ICEV.

The TCO was calculated considering the running cost, ex-showroom price, the subsidy given on vehicle, insurance cost, battery cost and maintenance cost. The below table also shows the Total Cost of Ownership [TCO] comparison of ICEV and EV over ten years of cylinder distribution.

	ICEV	EV
Running Cost (INR)	1267200	125337
Ex- Showroom (INR)	450000	775000
Subsidy (INR)	0	150000
Insurance (INR)	18000	15300
Battery (INR)	0	230400
Maintenance (INR)	198864	76570
Total (INR)	1934064	1072607

Table 2 TCO Comparison of ICEV and EV

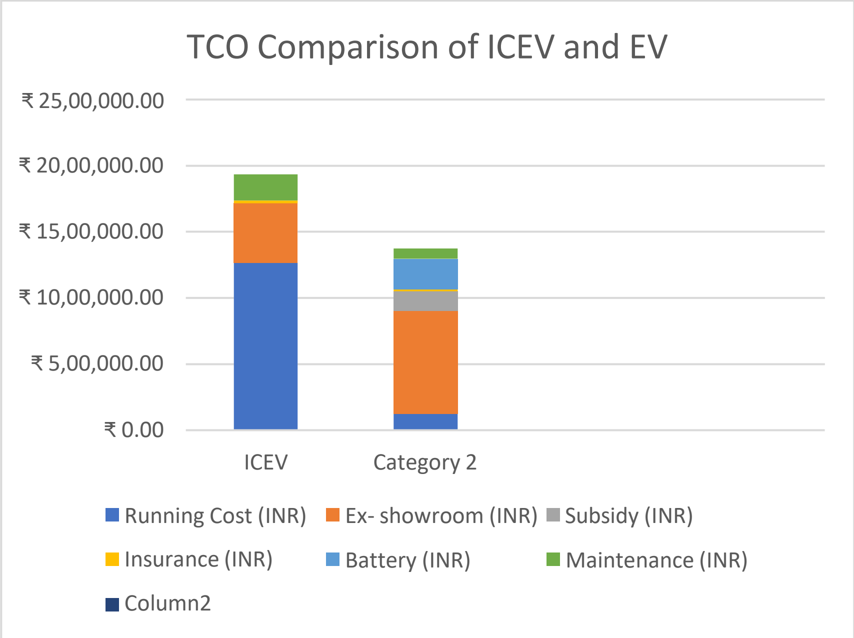


Figure 4 TCO Comparison of ICEV and EV

The above table and graph show that the per km cost in driving an ICEV for 10 years is Rs. 6.71, whereas that in EV is Rs. 3.72 and use of EV will boost also up the economy as more money will stay local on the decrease in consumption of crude oil.

3.3. Health Aspect

17.8 % of total deaths in 2019 in our country were attributed to air pollution. About 9.8 lakh deaths of those 16.7 lakh deaths due to air pollution resulted from ambient particulate matter pollution. The total number of deaths due to ambient particulate matter pollution has increased by 115.3 % between the years 1990 to 2019. Studies have indicated an increased risk in cardiovascular and respiratory diseases due to the close residential contiguity to air pollution caused by vehicular traffic.[28][29] Particulate matter (PM) causes respiratory and cardiovascular diseases, reproductive and central nervous system dysfunctions, and even cancer [32].

Prolonged exposure of human beings to pollutants in the air causes irregularities during gametogenesis, which deteriorates reproduction capabilities. Low birth weight of infants have been linked with fossil fuel emissions [30][31][32]

Chapter 4 A case study: LPG Distribution System

This case study was done on the Tier II city of India. The main aim of the study was to analyse the feasibility of EVs in light commercial sector on economic and environmental aspects. This for the same, scenario of LPG distribution was considered.

4.1. Data Acquired and assumptions.

To perform this case study, a Tier II in India was considered with a population of around 19 lakhs. The following parameters were calculated to get the the near optimal data for the study. The first aim was to determine the number of families holing LPG connections.

4.1.1. ***Number of customers:*** An Average Indian family contains 5.2 members [33]. Thus, for this study, a family of 5 members was considered. Thus, the approximate number of families in Indore city is around six lakhs. As per the National Statistical Office Report, around 86.6% of Indian urban households use LPG cylinders. Thus, the total number of families using LPG cylinders in the urban area is = 0.89*6 = 5.196 lakhs.

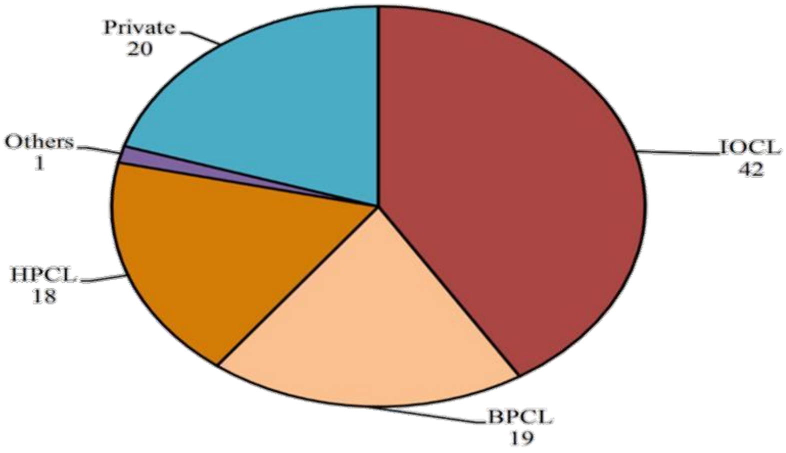


Figure 5 Market share of different companies (in %)

The market share of IOCL is 42%. Therefore, the total number of customers of IOC can be around 218232.Thus, for this study, 225000 customers were considered.

4.1.2. ***Distribution of customers:*** In this city there are total 22 distributors [34]. These locations were plotted on the Google Map, and the customers were distributed so that more customers were in the nearby periphery of the distributor and rest were distributed between the city's geographical coordinates. This distribution was done keeping in mind that sometimes few customers may transfer from one place to another but the distributor remains the same thus keeping this is in mind, 20% to 40% of customers of each agency was distributed randomly in the city. The demographic land of Indore city lies between 22.63333°N - 22.80416°N and 75.805°E - 75.93333°E. Thus, customers were distributed in this range as per the distributors' location.

4.1.3. ***Details of customers and distributors:*** Details of each customer include its name, latitude, longitude, radial latitude and radial longitude. A sample table of customer details is shown below.

Customer Name	Longitude	Latitude	Radial longitude	Radial latitude
Customer 1	75.881645	22.76509	1.324345488	0.397314057

Customer 2	75.833259	22.676997	1.323501017	0.395776589
Customer 3	75.878409	22.744695	1.32428901	0.396958107
Customer 4	75.806888	22.784819	1.32304077	0.397658383
Customer 5	75.910176	22.799759	1.324843433	0.397919127

Table 3 Geographical location of customers

Each gas agency was assigned a random number of customers between 8000 to 10,000. The details of the number of customers assigned to each agency are shown below.

Distribution Agencies	***Number of customers allocated***	***Density Distribution***
Distributor 1	10967	0.61
Distributor 2	9223	0.71
Distributor 3	10559	0.72
Distributor 4	9305	0.65
Distributor 5	10314	0.73
Distributor 6	9615	0.7
Distributor 7	10634	0.63
Distributor 8	9920	0.76
Distributor 9	10267	0.78
Distributor 10	9514	0.62
Distributor 11	10407	0.63
Distributor 12	9344	0.6
Distributor 13	10556	0.73
Distributor 14	9834	0.78
Distributor 15	9798	0.8
Distributor 16	9659	0.61
Distributor 17	10588	0.74
Distributor 18	10154	0.68

Distributor 19	10176	0.66
Distributor 20	9935	0.79
Distributor 21	10135	0.65
Distributor 22	9121	0.62
Total customers	220025	

Table 4 Customer allocations to gas agencies

Here density distribution refers to the percentage of customers in the nearby periphery of the distributor.

4.1.4. ***Daily demand of customers:*** After allocation of customers to agencies, next is to create daily demand for each agency. The demand sheet for all the customers was created. Parameters assigned for creation of demand sheet:

a. ***Mean demand time:*** It is the average time between two consecutive orders of the customer. Its value is distributed randomly between 21 and 60. The minimum value is taken as 21 because in India, between two consecutive orders minimum time duration is 21 days, and the maximum value is taken as 60 considering the variation in the number of family members.

b. ***First demand:*** It is the day on which the first order to the customer is delivered. The value of first-order is taken randomly between 1 and 60. This range is taken because it is not that all the customer will demand the cylinder on the first day. Some may have recently ordered, or some will order after few days depending on the consumption.

c. ***Second demand onwards:*** This show the day on which the given order will be delivered. From second order onwards normal distribution for customers was considered taking mean as mean demand time and standard deviation equals 3. Normal distribution was considered so that customers demand shall dwell around mean demand time. Demand was calculated such that each demand must be a positive integer value, and it must be constrained to 365 days as data was limited to one-year calculation.

The sample datasheet of 5 customers of Chauhan Indane is shown below. Exactly, the order details of all other customers were created.

CUSTOMER	MDT	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
C 1 W17	32	23	56	87	118	148	185	221	250	284	319	349				
C 2 W17	57	40	94	150	202	260	317									
C 3 W17	51	52	102	158	211	260	309	360								
C 4 W17	23	45	71	94	121	149	177	198	221	252	280	298	326	351		
C 5 W17	28	22	48	82	111	136	162	187	212	239	265	293	316	343		

Table 5 Customers daily demand details

In the 1st column, the customer's name is mentioned, the 2nd column consists of mean demand time, the 3rd column states the day on which the first order for a particular customer is delivered. Similarly, 4th column shows the day on which the second order is delivered and so on. For customer C1 W 17, the total number of order equals eleven.

After creating the demand datasheet of a distributor (Chouhan Indane), the number of orders per day was calculated, which shows the number of orders to be delivered per day. Given below simulated chart shows the per day distribution of cylinders of Chauhan indane for 365 days.

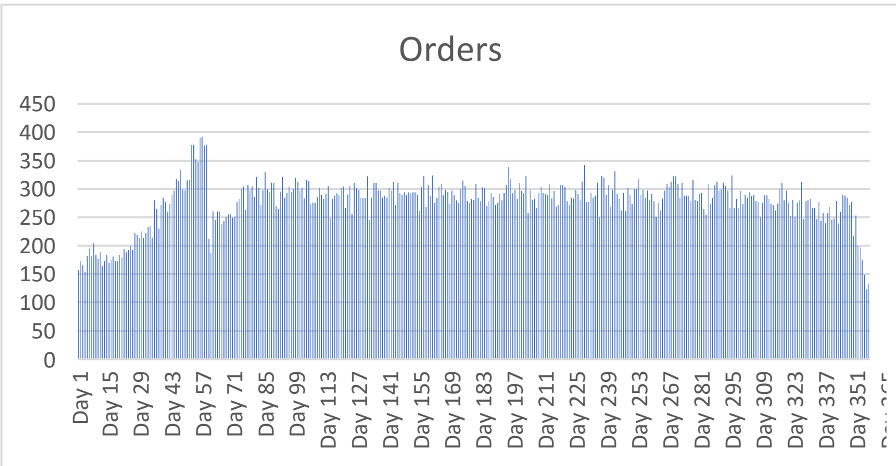


Figure 6 Daily demand of a distributor for the entire year

d. ***Warehouse Locations:*** After calculating the per-day demand of all the 22 distributors, the customer's distance matrix is formed whose cylinders have to be delivered. Generally, cylinders are delivered from warehouses instead of gas agencies; thus, it is assumed that delivery of cylinders will start from the warehouse. Thus, for this location of all 22 warehouses were located. The given below table shows the coordinates of warehouses. These coordinates were determined by the actual location of the warehouses.

Warehouse	Longitude	Latitude	Radial longitudes	Radial latitudes
warehouse 1	75.76862	22.7	1.322372887	0.396177183
warehouse 2	75.80975	22.6347	1.32309072	0.395038564
warehouse 3	75.92795	22.6326	1.325153638	0.395000866
warehouse 4	75.87814	22.6472	1.324284316	0.395256025
warehouse 5	75.90216	22.6781	1.324703531	0.395796189
warehouse 6	75.8895	22.6822	1.324482579	0.395866523
warehouse 7	75.92795	22.6325	1.325153638	0.395000691
warehouse 8	75.90293	22.6754	1.32471697	0.395748543
warehouse 9	75.8763	22.7209	1.324252203	0.396543342
warehouse 10	75.88999	22.68	1.324491131	0.395829698
warehouse 11	75.88945	22.7473	1.324481707	0.397003048
warehouse 12	75.92141	22.764	1.325039497	0.397295731
warehouse 13	75.89906	22.7873	1.324649428	0.39770081
warehouse 14	75.87391	22.7743	1.32421049	0.397474797
warehouse 15	75.83161	22.7925	1.323472238	0.397792787
warehouse 16	75.84411	22.818	1.323690398	0.398236785
warehouse 17	75.85247	22.82	1.323836303	0.39827204
warehouse 18	75.85116	22.8199	1.32381344	0.398271342
warehouse 19	75.78158	22.7431	1.322599075	0.396929747
warehouse 20	75.81483	22.6712	1.32317938	0.395675416
warehouse 21	75.93452	22.7166	1.325268303	0.396467074

warehouse 22	75.90154	22.7843	1.324692711	0.397648976

Table 6 Geographical location of warehouses

4.2. Route Optimisation

The Traveling Salesman Problem (TSP) is one of the most famous combinatorial optimisation problems used to find the shortest distance travelled between the given nodes. The advances version of TSP i.e. CVRP is used here. To optimise the route using EVs, charging points were assumed in warehouses themselves, and the charging capacity of each charging station is sufficient to charge all vehicles to 100% battery status before the start of the delivery schedule. The location of charging stations and warehouses are as shown below:

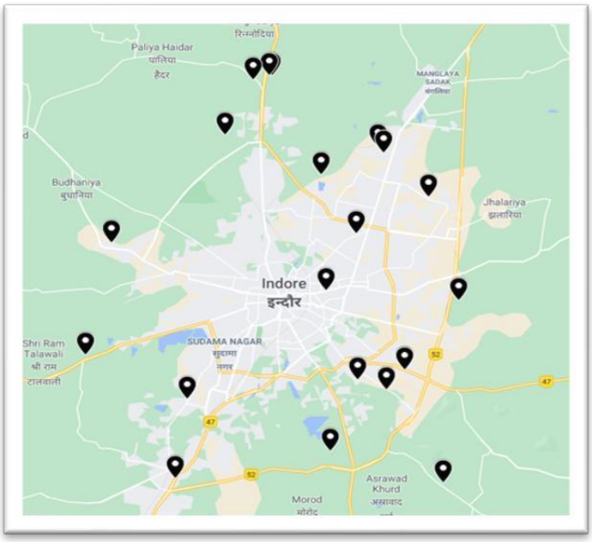


Figure 7 Location of warehouses. (Source: https://cx.indianoil.in/webcenter/portal/Customer/distributorsearchpage)

Figure 8 Location of charging points

Now to find the optimised route, we have to select the agency and the day. For instance, in this article, it is calculated for Distributor 4 for the 59th day. Since, daily demand is already calculated, a distance matrix is now formed for the given day. In order to calculated the distances, the Haversine formula was used. Haversine Equation gives the least distance between any two focuses on the spherical body by utilising latitude and longitude. [35][36][37]. Thus, it can be used to calculate the distance between two coordinates on the Earth's surface.

$$= 2r \sin^{-1}\left(\sqrt{\sin^2\left(\frac{\emptyset_2-\emptyset_1}{2}\right)+\cos(\emptyset_1)\cos(\emptyset_2)\sin^2\left(\frac{\varphi_2-\varphi_1}{2}\right)}\right)$$

Where,

d = distance between two points with latitude and longitude (Ø, φ)

r = radius of the Earth.

Since, the distance calculated using the Haversine formula does not consider the actual route followed on the map, a multiplying factor was calculated, which resembles the distance calculated closer to the actual distance. The difference between the actual distance and distance calculated using Haversine formula was calculated and was approximately equal to 1.5 times of 'd'. Thus, the distances were multiplied with this factor. A Simulated Annealing approach was used to optimise the path. To optimise the route following parameters and constraints were kept into account. Single-cylinder per customer is delivered. Each vehicle is constrained to maximum delivery capacity of 20 cylinders. Accordingly, the number of vehicles used per day per gas agency was calculated.

Chapter 5 Real-time tracking System

Real-time tracking system is used to automatically identify and track the location of objects or people in real time. Wireless RTTS tags are attached to objects or worn by people, and in most RTTS, fixed reference points receive wireless signals from tags to determine their location. Examples of real-time locating systems include tracking automobiles through an assembly line, locating pallets of merchandise in a warehouse, or finding medical equipment in a hospital. The proposed RTTS in this thesis is different from of actually a RTTS means. The proposed RTTS can be defined as the simulation model of the real-time tracking of the interagency and intra-agency vehicles, which tracks the vehicle in given interval of time and tries to deliver the instantaneous demand generated optimally. This system is simply a simulation model without considering the actual vehicles used.

5.1. Problem Statement

In this era, though the LPG cylinder's delivery is booked at least a day before, there may be some cases that instantaneous demand of cylinders is required by the customers. Thus, to benefit the customers, a simulated model is proposed that involves inter-agency and intra agency communication between the delivery agents and tracking of the vehicles to fulfil the instantaneous delivery. This system can benefit both the customers and the distributors as formal can get instantaneous delivery and later may get extra revenue, as instantaneous delivery will charge some extra penny from the beneficiary.

There are models which either traces predefined demands path or instantaneously generated demands, but this is a noble approach in itself which combines both and fulfils the previously generated demands and real time demands and also traces the position of vehicles.

5.2. Development of RTTS

A small-scale model is developed in order to examine it. This model consists of a total of 81 customers in which around 20 customers will be delivered cylinders as per the previous delivery schedule.

5.1.1. Generation of Demand: The demand was generated considering the assumption that the customer who had received a cylinder in the last 15 days will not require the cylinder instantaneously. Thus demand will be generated among the remaining customers. The demand will be generated in the interval of 10 minutes.

5.1.2. Optimization of the Route: the route will be optimized for the already generated demand using previously defined methods. After instantaneous demand generation, re-optimization of the route is done, considering the generated demand.

5.3. Assumptions and Constraints.

1. The capacity of each vehicle is limited. Thus, each vehicle can fulfil a maximum of two instantaneous demands.
2. Extra demand generated is fulfilled in the next working day.
3. The speed of vehicle is constant.
4. Demand was generated using the previous model and the route was optimized using the TSP algorithm.
5. The battery of the vehicles is sufficient to complete all the deliveries.
6. There is a route from every customer to every customer.
7. Service time at every customer was taken as 5 minutes.
8. The grid resembles the square of size 1km x 1km.
9. The entire model is scaled down by the factor of 3.

5.4. Creation of Model

To create this model, 81 customers were considered, and each of them was located on the intersection of the grid lines, resembling the coordinates of the customers as the customer's geographical location.

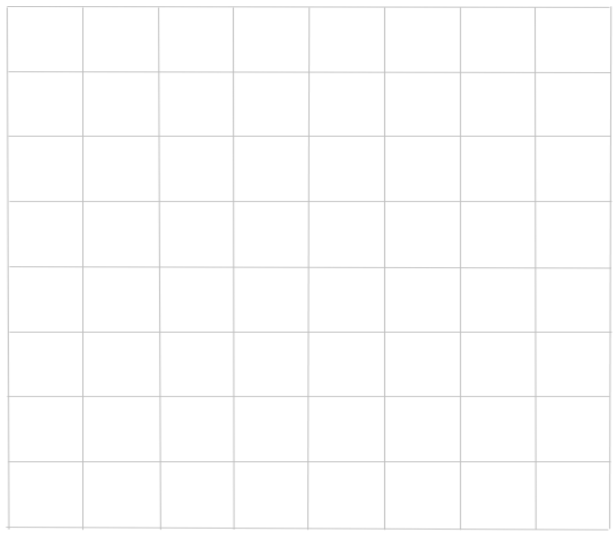


Figure 9 Intersection of lines resembles customers location

Each intersection point in the above grid shows the location of the customers. In the below figure, blue dots resemble the customer's locations where cylinders are to be delivered. The red dot shows the location of a warehouse.

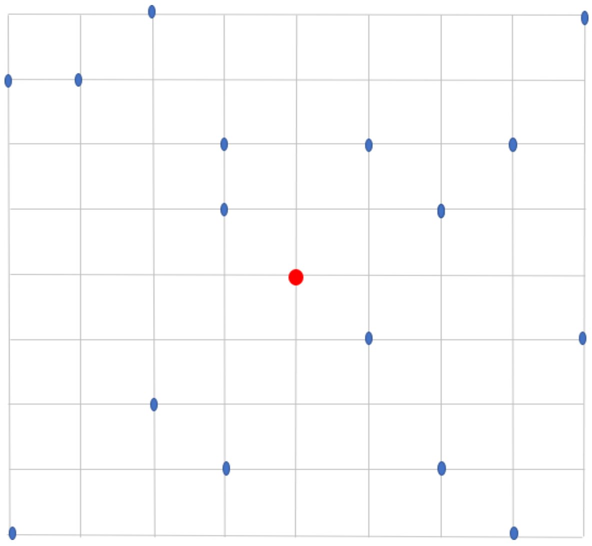


Figure 10 Customers for which daily demand is generated

The routes of the above customers are optimized using the Travelling Salesman Algorithm, as shown in figure 11.

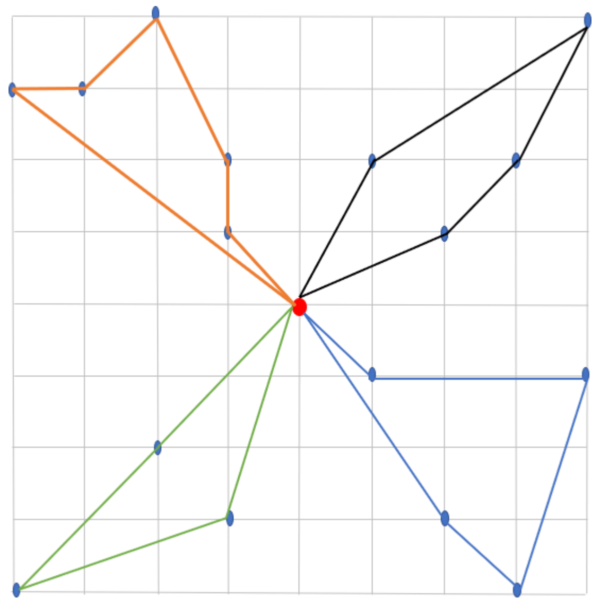


Figure 11 Optimized route for the given day

After optimising the route, instantaneous demand is generated among the customers where cylinders were not delivered in the last 15 days. The figure 12 shows the points where no cylinders were delivered in last 15 days. (Data was collected from previously defined model).

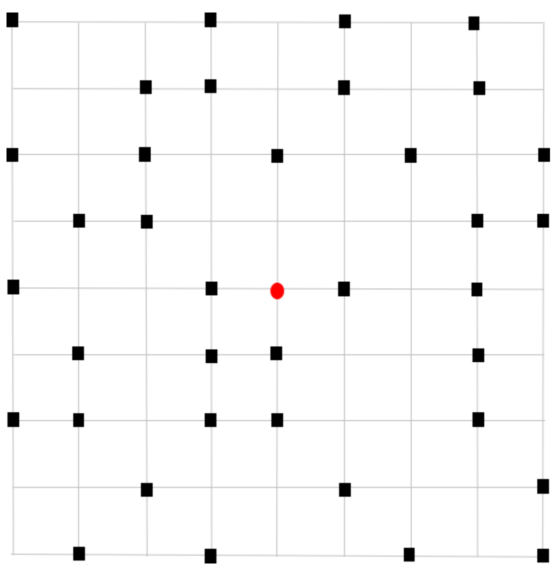


Figure 12 Potential customers for instantaneous demand generation

The delivery is scheduled from 1000 hour onwards, and the first instantaneous demand was generated at 1000 hours. The black squares in figure 14 onwards shows the location of customers where instantaneous demand is generated. Considering these demands, routes will be optimized for all the vehicles, and one which has minimum difference in distance travelled in the previously optimized route and currently optimized route will be given the instantaneous demand assuring the vehicle has not exceeded its maximum capacity.

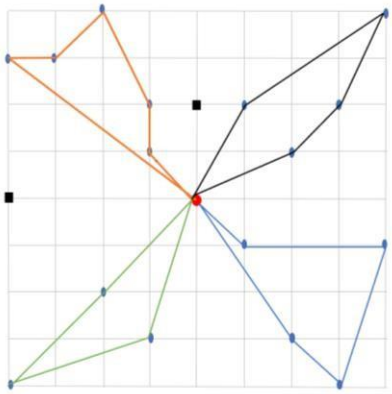


Figure 14 Optimized route

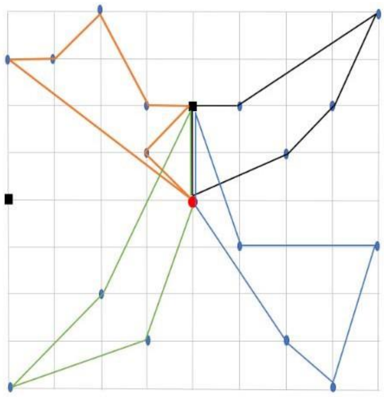


Figure 13 TSP applied on all possible route.

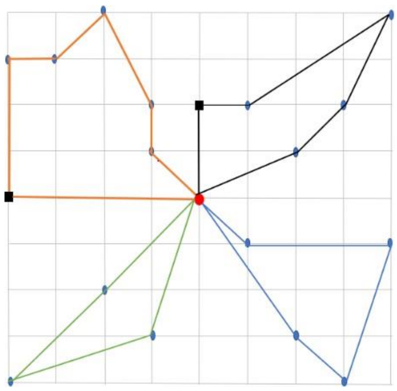


Figure 15 Best routes obtained

After finalising the route as shown in figure 15, the delivery of the cylinders begin and the vehicles are tracked after every ten minutes interval and new demands are generated accordingly. It is not necessary that the demand will be generated in all the intervals. The entire model is simulated for the time period of 2 hours 20 minutes including the lunch time of 20 minutes from 1100 hours to 1120 hours. The given figures show the position of vehicles in the interval of ten minutes, new demands generated and the optimised route accordingly.

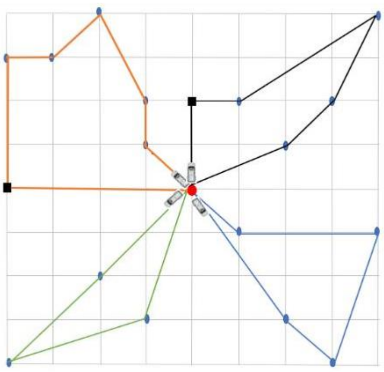


Figure 16 Situation at 1000 hours

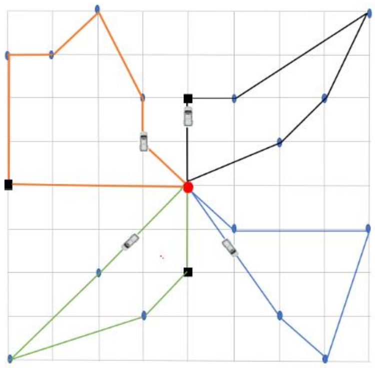


Figure 17 Situation at 1010 hours

The figure 16 shows the position of vehicles and demand generated at 1000 hours. According to the demand generated, the route is further optimised for the new demands. After generation of demands at 1000 hours, the vehicles started the delivery and further the position of vehicles is examined after 10 minutes and the figure 17 shows the position of vehicles at 1010 hours. It also shows the new demands generated in this interval and accordingly, new routes are

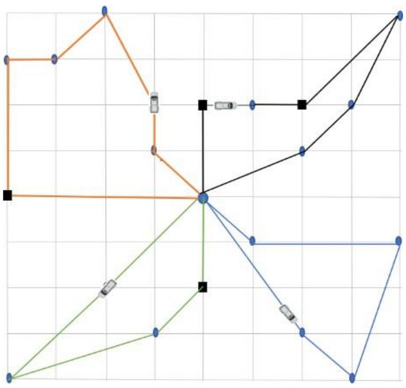


Figure 18

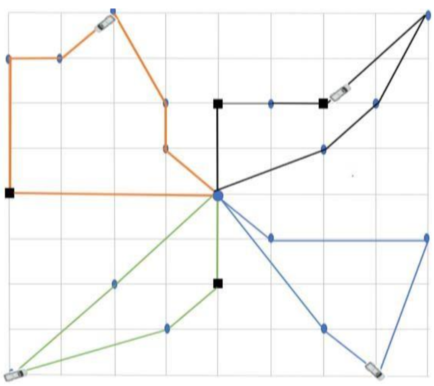


Figure 19

Figure 18 & 19 shows the situation of instantaneous demands and current position of vehicles at 1020 hours and 1030 hours respectively.

The figure 18 shows the situation at 1020 hours. It can be seen that a new demand is generated during this interval, thus, there is alteration in the routes and vehicles continues on the new generated path. The next figure shows the positions of the vehicles at 1040 hours. There is one new demand generated and again the new route is decided and optimized

The below figure shows the position of vehicles and demand generated at 1030 hours. Again, no new demands are generated and vehicles continues on the same path.

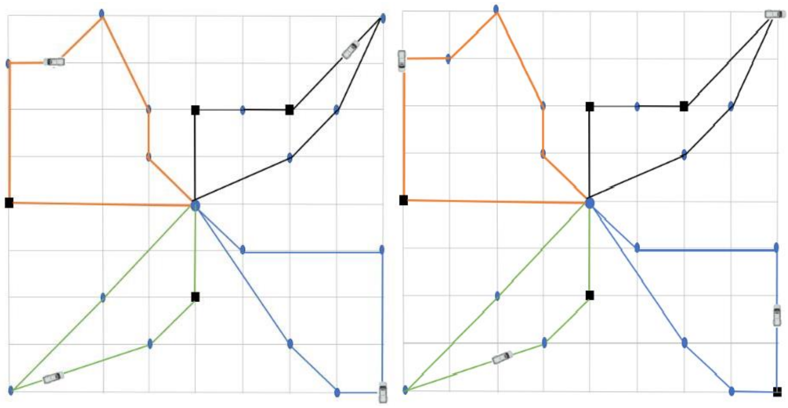


Figure 20 (a) & (b) Situations at 1040 and 1050 hours respectively

The figure 20(b) shows the position of vehicles and demand generated at 1050 hours. According to the demand generated, the route is further optimised for the new demands. Now in this interval no new demands were generated, thus, vehicle continues in the previously defined routes.

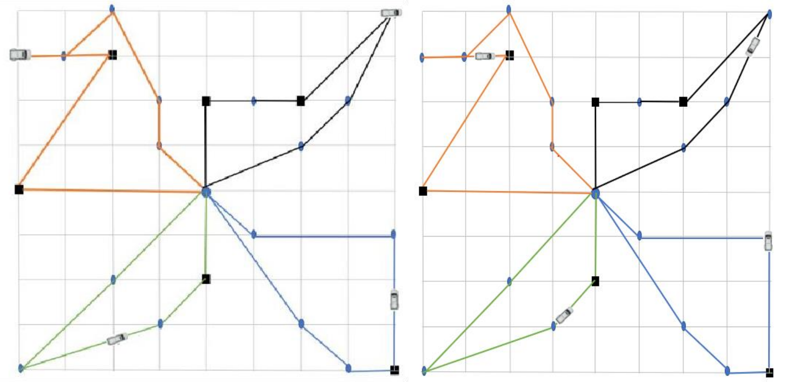


Figure 21 (a) & (b) Situations at 1100 and 1120 hours respectively.

The above figure 21 (a) and (b) shows the position of vehicles and demands at 1100 hours and 1120 hours respectively. It is visible that a demand is generated at 1100 hours while no demand is generated at 1120 hours.

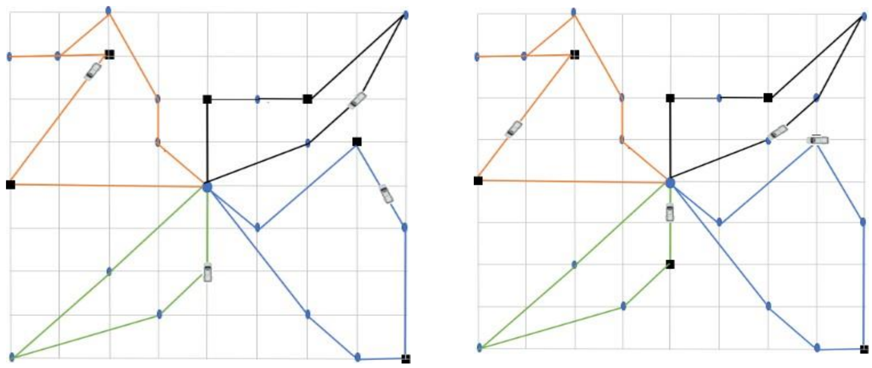


Figure 22 (a) & (b) Situations at 1130 and 1140 hours respectively

At 1130 hours, a demand is generated which is closer to vehicle following black path. So a best optimized route will be obtained if vehicle on black path covers he demand. But it had already exhausted its limit. Thus, it will be covered in the route which will cover second minimum extra difference only if its limit is not exhausted. Again if its limit is exhausted, until it will get the result fulfilling all the constraints.

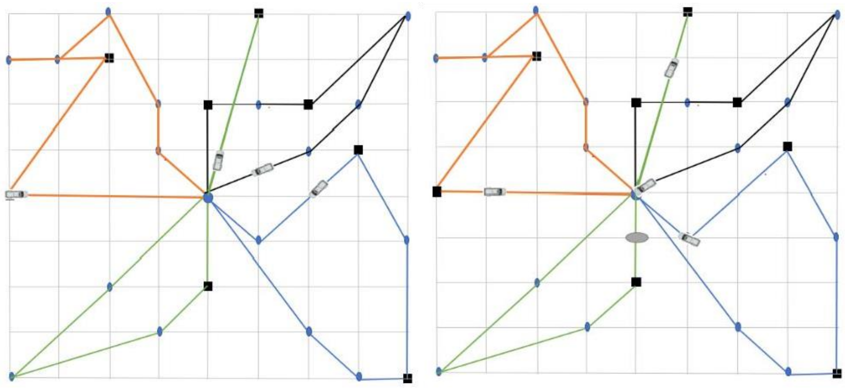


Figure 23(a) & (b) Situations at 1150 and 1200 hours respectively

The model runs in a similar way, until a demand is generated at 1200 hours, which is generated after the daily limit to fulfil instantaneous demand of all the vehicles was exhausted. Thus, that demand cannot be fulfilled by any of the vehicle. So the model is designed in such a way that this particular demand will be considered in the first slot of the next working day.

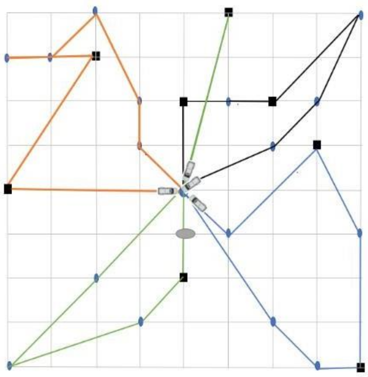


Figure 24 Final position at the end of the day

The figure 24 shows the final position at the end of the day, when all the demands were fulfilled and the vehicles returned back to their respective starting points.

This model can be implemented in the real-world situation, as it is benefitting both customers and distributors. It is providing instantaneous delivery to the end users or customers fulfilling their urgent requirement and extra amount for this service can be charged by distributors, which is again a profitable deal for the distributors.

Chapter 6 Results

The path was optimised for a particular gas agency, for a given day, and the results are shown below which shows the optimised number of the vehicles used, cylinders distributed by each vehicle and battery consumed by each vehicle. The results are shown in the way the route followed by the vehicles and battery left after each customer visited.

The path was optimized using metaheuristic, in which Simulated Annealing approach was used. The optimized for Pagare Indane for 59th day is:

Route for vehicle 1:

WAREHOUSE Load(0) -> C 6513 W1 Load(1) -> C 8264 W1 Load(2) -> C 7501 W1 Load(3) -> C 8983 W1 Load(4) -> C 6532 W1 Load(5) -> C 6545 W1 Load(6) -> C 8326 W1 Load(7) -> C 7058 W1 Load(8) -> C 7247 W1 Load(9) -> C 8228 W1 Load(10) -> C 8487 W1 Load(11) -> C 7869 W1 Load(12) -> C 8419 W1 Load(13) -> C 8630 W1 Load(14) -> C 8675 W1 Load(15) -> C 8100 W1 Load(16) -> C 7397 W1 Load(17) -> C 7683 W1 Load(18) -> C 8925 W1 Load(19) -> C 6946 W1 Load(20) -> WAREHOUSE Load(20)

Distance of the route: 76.3935km

Load of the route: 20

Battery of the vehicle 1:

WAREHOUSE Charge left(100) -> C 6513 W1 Charge left(82.432) -> C 8264 W1 Charge left(76.9675) -> C 7501 W1 Charge left(75.0775) -> C 8983 W1 Charge left(73.102) -> C 6532 W1 Charge left(72.8815) -> C 6545 W1 Charge left(72.0085) -> C 8326 W1 Charge left(68.4235) -> C 7058 W1 Charge left(64.351) -> C 7247 W1 Charge left(63.9265) -> C 8228 W1 Charge left(61.28) -> C 8487 W1 Charge left(59.373) -> C 7869 W1 Charge left(53.9695) -> C 8419 W1 Charge left(53.12) -> C 8630 W1 Charge left(49.70) -> C 8675 W1 Charge left(49.50) -> C 8100 W1 Charge left(47.87) -> C 7397 W1 Charge left(46.928) -> C 7683 W1 Charge left(46.6344) -> C 8925 W1 Charge left(45.885) -> C 6946 W1 Charge left(41.9695) -> WAREHOUSE Charge left(23.606)

Route for vehicle 2:

WAREHOUSE Load(0) -> C 9118 W1 Load(1) -> C 6985 W1 Load(2) -> C 7283 W1 Load(3) -> C 7530 W1 Load(4) -> C 6444 W1 Load(5) -> C 7191 W1 Load(6) -> C 9348 W1 Load(7) -> C 8307 W1 Load(8) -> C 9334 W1 Load(9) -> C 6967 W1 Load(10) -> C 9826 W1 Load(11) -> C 7643 W1 Load(12) -> C 8465 W1 Load(13) -> C 7715 W1 Load(14) -> C 8685 W1 Load(15) -> C 7838 W1 Load(16) -> C 9890 W1 Load(17) -> C 8479 W1 Load(18) -> C 475 W1 Load(19) -> C 1130 W1 Load(20) -> WAREHOUSE Load(20)

Distance of the route: 54.411km

Load of the route: 20

Battery of the vehicle 2:

WAREHOUSE Charge left(100) -> C 9118 W1 Charge left(85.7245) -> C 6985 W1 Charge left(85.129) -> C 7283 W1 Charge left(83.8285) -> C 7530 W1 Charge left(78.4675) -> C 6444 W1 Charge left(78.259) -> C 7191 W1 Charge left(74.3875) -> C 9348 W1 Charge left(73.645) -> C 8307 W1 Charge left(71.3305) -> C 9334 W1 Charge left(70.7485) -> C 6967 W1 Charge left(70.29)-> C 9826 W1 Charge left(68.95) -> C 7643 W1 Charge left(67.39) -> C 8465 W1 Charge left(66.96) -> C 7715 W1 Charge left(63.91) -> C 8685 W1 Charge left(62.61) -> C 7838 W1 Charge left(61.46) -> C 9890 W1 Charge left(58.23) -> C 8479 W1 Charge left(57.98) -> C 475 W1 Charge left(56.26) -> C 1130 W1 Charge left(55.99) -> WAREHOUSE Charge left(45.589)

Route for vehicle 3:

WAREHOUSE Load(0) -> C 9061 W1 Load(1) -> C 4893 W1 Load(2) -> C 3854 W1 Load(3) -> C 5346 W1 Load(4) -> C 5545 W1 Load(5) -> C 5689 W1 Load(6) -> C 3926 W1 Load(7) -> C 135 W1 Load(8) -> C 4279 W1 Load(9) -> C 189 W1 Load(10) -> C 9434 W1 Load(11) -> C 8870 W1 Load(12) -> C 9926 W1 Load(13) -> C 8349 W1 Load(14) -> C 7433 W1 Load(15) -> C 1632 W1 Load(16) -> C 4626 W1 Load(17) -> C 1060 W1 Load(18) -> C 3250 W1 Load(19) -> C 1323 W1 Load(20) -> WAREHOUSE Load(20)

Distance of the route: 32.87km

Load of the route: 20

Battery of the vehicle 3:

WAREHOUSE Charge left(100) -> C 9061 W1 Charge left(90.316) -> C 4893 W1 Charge left(89.995) -> C 3854 W1 Charge left(89.815) -> C 5346 W1 Charge left(89.395) -> C 5545 W1 Charge left(89.26) -> C 5689 W1 Charge left(88.7995) -> C 3926 W1 Charge left(88.594) -> C 135 W1 Charge left(88.249) -> C 4279 W1 Charge left(87.8095) -> C 189 W1 Charge left(87.6475) -> C 9434 W1 Charge left(86.098) -> C 8870 W1 Charge left(83.6485) -> C 9926 W1 Charge left(83.347) -> C 8349 W1 Charge left(80.7145) -> C 7433 W1 Charge left(79.291) -> C 1632 W1 Charge left(78.109) -> C 4626 W1 Charge left(77.011) -> C 1060 W1 Charge left(76.9315) -> C 3250 W1 Charge left(76.303) -> C 1323 W1 Charge left(75.973) -> WAREHOUSE Charge left(67.12)

Route for vehicle 4:

WAREHOUSE Load(0) -> C 5693 W1 Load(1) -> C 1053 W1 Load(2) -> C 9394 W1 Load(3) -> C 4648 W1 Load(4) -> C 2111 W1 Load(5) -> C 4326 W1 Load(6) -> C 2560 W1 Load(7) -> C 1393 W1 Load(8) -> C 2438 W1 Load(9) -> C 2446 W1 Load(10) -> C 220 W1 Load(11) -> C 1059 W1 Load(12) -> C 6050 W1 Load(13) -> C 5387 W1 Load(14) -> C 4714 W1 Load(15) -> C 3542 W1 Load(16) -> C 5177 W1 Load(17) -> C 4484 W1 Load(18) -> C 4194 W1 Load(19) -> C 1439 W1 Load(20) -> WAREHOUSE Load(20)

Distance of the route: 23.496km

Load of the route: 20

Battery of the vehicle 4:

WAREHOUSE Charge left(100) -> C 5693 W1 Charge left(91.489) -> C 1053 W1 Charge left(90.259) -> C 9394 W1 Charge left(89.71) -> C 4648 W1 Charge left(89.46) -> C 2111 W1 Charge left(89.01) -> C 4326 W1 Charge left(88.7965) -> C 2560 W1 Charge left(88.5655) -> C 1393 W1 Charge left(88.198) -> C 2438 W1 Charge left(87.92) -> C 2446 W1 Charge left(87.64) -> C 220 W1 Charge left(87.37) -> C 1059 W1 Charge left(87.24) -> C 6050 W1 Charge left(86.30) -> C 5387 W1 Charge left(86.059) -> C 4714 W1 Charge left(85.954) -> C 3542 W1 Charge left(85.83) -> C 5177 W1 Charge left(84.92) -> C 4484 W1 Charge left(84.549) -> C 4194 W1 Charge left(83.86) -> C 1439 W1 Charge left(81.933) -> WAREHOUSE Charge left(76.50)

Route for the vehicle 5:

WAREHOUSE Load(0) -> C 6379 W1 Load(1) -> C 8117 W1 Load(2) -> C 9314 W1 Load(3) -> C 8508 W1 Load(4) -> C 7504 W1 Load(5) -> C 8950 W1 Load(6) -> C 8547 W1 Load(7) -> C 8565 W1

Load(8) -> C 7456 W1 Load(9) -> C 7837 W1 Load(10) -> C 6163 W1 Load(11) -> C 3047 W1 Load(12) -> C 4959 W1 Load(13) -> C 4019 W1 Load(14) -> C 225 W1 Load(15) -> C 1801 W1 Load(16) -> C 9594 W1 Load(17) -> C 4795 W1 Load(18) -> C 5142 W1 Load(19) -> C 714 W1 Load(20) -> WAREHOUSE Load(20)

Distance of the route: 39.621km

Load of the route: 20

Battery of the vehicle 5:

WAREHOUSE Charge left(100) -> C 6379 W1 Charge left(91.951) -> C 8117 W1 Charge left(89.5315) -> C 9314 W1 Charge left(88.4275) -> C 8508 W1 Charge left(86.728) -> C 7504 W1 Charge left(85.06) -> C 8950 W1 Charge left(82.13) -> C 8547 W1 Charge left(81.7105) -> C 8565 W1 Charge left(81.18) -> C 7456 W1 Charge left(74.97) -> C 7837 W1 Charge left(74.3184) -> C 6163 W1 Charge left(73.43) -> C 3047 W1 Charge left(72.2845) -> C 4959 W1 Charge left(71.9485) -> C 4019 W1 Charge left(71.61) -> C 225 W1 Charge left(71.051) -> C 1801 W1 Charge left(70.80) -> C 9594 W1 Charge left(69.53) -> C 4795 W1 Charge left(69.2965) -> C 5142 W1 Charge left(68.85) -> C 714 W1 Charge left(68.66) -> WAREHOUSE Charge left(60.37)

Route for vehicle 6:

WAREHOUSE Load(0) -> C 3790 W1 Load(1) -> C 1058 W1 Load(2) -> C 4280 W1 Load(3) -> C 2512 W1 Load(4) -> C 4763 W1 Load(5) -> C 843 W1 Load(6) -> C 4920 W1 Load(7) -> C 1201 W1 Load(8) -> C 2908 W1 Load(9) -> C 3045 W1 Load(10) -> C 1082 W1 Load(11) -> C 2402 W1 Load(12) -> C 4200 W1 Load(13) -> C 2960 W1 Load(14) -> C 2752 W1 Load(15) -> C 686 W1 Load(16) -

> C 382 W1 Load(17) -> C 5748 W1 Load(18) -> C 2570 W1 Load(19) -> C 5401 W1 Load(20) -> WAREHOUSE Load(20)

Distance of the route: 24.4305km

Load of the route: 20

Battery of the vehicle 6:

WAREHOUSE Charge left(100) -> C 3790 W1 Charge left(91.58) -> C 1058 W1 Charge left(91.40) -> C 4280 W1 Charge left(90.98) -> C 2512 W1 Charge left(90.86) -> C 4763 W1 Charge left(90.77) -> C 843 W1 Charge left(89.91) -> C 4920 W1 Charge left(89.32) -> C 1201 W1 Charge left(88.87) -> C 2908 W1 Charge left(88.486) -> C 3045 W1 Charge left(88.253) -> C 1082 W1 Charge left(88.03) -> C 2402 W1 Charge left(87.776) -> C 4200 W1 Charge left(87.608) -> C 2960 W1 Charge left(87.448) -> C 2752 W1 Charge left(87.250) -> C 686 W1 Charge left(86.79) -> C 382 W1 Charge left(85.594) -> C 5748 W1 Charge left(85.453) -> C 2570 W1 Charge left(85.150) -> C 5401 W1 Charge left(85.0165) -> WAREHOUSE Charge left(75.569)

Route for vehicle 7:

WAREHOUSE Load(0) -> C 5317 W1 Load(1) -> C 3565 W1 Load(2) -> C 4917 W1 Load(3) -> C 29 W1 Load(4) -> C 4825 W1 Load(5) -> C 2618 W1 Load(6) -> C 742 W1 Load(7) -> C 1644 W1 Load(8) -> C 1003 W1 Load(9) -> C 3486 W1 Load(10) -> C 2365 W1 Load(11) -> C 3969 W1 Load(12) -> C 494 W1 Load(13) -> C 2118 W1 Load(14) -> C 3705 W1 Load(15) -> C 4104 W1 Load(16) -> C 2214 W1 Load(17) -> C 5611 W1 Load(18) -> C 3277 W1 Load(19) -> C 4520 W1 Load(20) -> WAREHOUSE Load(20)

Distance of the route: 23.21km

Load of the route: 20

Battery of the vehicle 7:

WAREHOUSE Charge left(100) -> C 5317 W1 Charge left(92.098) -> C 3565 W1 Charge left(91.8175) -> C 4917 W1 Charge left(91.5415) -> C 29 W1 Charge left(91.351) -> C 4825 W1 Charge left(90.9295) -> C 2618 W1 Charge left(90.82) -> C 742 W1 Charge left(90.632) -> C 1644 W1 Charge left(90.457) -> C 1003 W1 Charge left(90.10) -> C 3486 W1 Charge left(89.959) -> C 2365 W1 Charge left(89.74) -> C 3969 W1 Charge left(89.245) -> C 494 W1 Charge left(88.9195) -> C 2118 W1 Charge left(88.5745) -> C 3705 W1 Charge left(87.916) -> C 4104 W1 Charge left(87.658) -> C 2214 W1 Charge left(87.436) -> C 5611 W1 Charge left(86.522) -> C 3277 W1 Charge left(86.3725) -> C 4520 W1 Charge left(85.888) -> WAREHOUSE Charge left(76.787)

Route for vehicle 8:

WAREHOUSE Load(0) -> C 1715 W1 Load(1) -> C 1697 W1 Load(2) -> C 1160 W1 Load(3) -> C 4474 W1 Load(4) -> C 2842 W1 Load(5) -> C 4082 W1 Load(6) -> C 3679 W1 Load(7) -> C 1690 W1 Load(8) -> C 638 W1 Load(9) -> C 5675 W1 Load(10) -> C 1243 W1 Load(11) -> C 4882 W1 Load(12) -> C 2889 W1 Load(13) -> C 2070 W1 Load(14) -> C 1680 W1 Load(15) -> C 3105 W1 Load(16) -> C 2083 W1 Load(17) -> C 1118 W1 Load(18) -> C 1995 W1 Load(19) -> C 1575 W1 Load(20) -> WAREHOUSE Load(20)

Distance of the route: 22.518km

Load of the route: 20

Battery of the vehicle 8:

WAREHOUSE Charge left(100) -> C 1715 W1 Charge left(95.029) -> C 1697 W1 Charge left(92.1865) -> C 1160 W1 Charge left(91.729)

-> C 4474 W1 Charge left(91.515) -> C 2842 W1 Charge left(90.824) -> C 4082 W1 Charge left(90.785) -> C 3679 W1 Charge left(89.696) -> C 1690 W1 Charge left(89.57) -> C 638 W1 Charge left(89.17) -> C 5675 W1 Charge left(89.01) -> C 1243 W1 Charge left(88.90) -> C 4882 W1 Charge left(88.725) -> C 2889 W1 Charge left(88.49) -> C 2070 W1 Charge left(88.097) -> C 1680 W1 Charge left(87.87) -> C 3105 W1 Charge left(87.74) -> C 2083 W1 Charge left(87.52) -> C 1118 W1 Charge left(87.03) -> C 1995 W1 Charge left(86.59) -> C 1575 W1 Charge left(84.18) -> WAREHOUSE Charge left(77.48)

Route for vehicle 9:

WAREHOUSE Load(0) -> C 8841 W1 Load(1) -> C 9226 W1 Load(2) -> C 8056 W1 Load(3) -> C 7925 W1 Load(4) -> C 9927 W1 Load(5) -> C 7223 W1 Load(6) -> C 8096 W1 Load(7) -> C 9819 W1 Load(8) -> C 8713 W1 Load(9) -> C 5470 W1 Load(10) -> C 5153 W1 Load(11) -> C 4343 W1 Load(12) -> C 5638 W1 Load(13) -> C 290 W1 Load(14) -> C 1586 W1 Load(15) -> C 2211 W1 Load(16) -> C 4931 W1 Load(17) -> C 4071 W1 Load(18) -> C 1555 W1 Load(19) -> C 2352 W1 Load(20) -> WAREHOUSE Load(20)

Distance of the route: 30.65km

Load of the route: 20

Battery of the vehicle 9:

WAREHOUSE Charge left(100) -> C 8841 W1 Charge left(95.2405) -> C 9226 W1 Charge left(94.039) -> C 8056 W1 Charge left(90.9115) -> C 7925 W1 Charge left(88.669) -> C 9927 W1 Charge left(87.928) -> C 7223 W1 Charge left(87.8065) -> C 8096 W1 Charge left(86.473) -> C 9819 W1 Charge left(85.8085) -> C 8713 W1 Charge left(84.8065) -> C 5470 W1 Charge left(80.989) -> C 5153 W1 Charge left(80.812) -> C 4343 W1 Charge left(80.62) -> C 5638 W1 Charge left(80.347) -> C 290 W1 Charge left(80.083) -> C 1586 W1 Charge left(79.8985) -> C 2211 W1 Charge left(79.489) -> C 4931 W1 Charge left(79.1905) -> C 4071 W1 Charge left(78.8665) -> C 1555 W1 Charge left(78.496) -> C 2352 W1 Charge left(78.2875) -> WAREHOUSE Charge left(69.3415)

Route for vehicle 10:

WAREHOUSE Load (0) -> C 5959 W1 Load(1) -> C 4996 W1 Load(2) -> C 4437 W1 Load(3) -> C 6031 W1 Load(4) -> C 5687 W1 Load(5) -> C 5336 W1 Load(6) -> C 2965 W1 Load(7) -> C 1511 W1 Load(8) -> C 2394 W1 Load(9) -> C 5222 W1 Load(10) -> C 4963 W1 Load(11) -> C 2110 W1 Load(12) -> C 4553 W1 Load(13) -> C 3395 W1 Load(14) -> C 5708 W1 Load(15) -> C 5826 W1 Load(16) -> C 2094 W1 Load(17) -> C 5603 W1 Load(18) -> WAREHOUSE Load(18)

Distance of the route: 18.744km

Load of the route: 18

Battery of the vehicle 10:

WAREHOUSE Charge left(100) -> C 5959 W1 Charge left(94.3285) -> C 4996 W1 Charge left(93.682) -> C 4437 W1 Charge left(93.4855) -> C 6031 W1 Charge left(93.016) -> C 5687 W1 Charge left(92.8255) -> C 5336 W1 Charge left(92.158) -> C 2965 W1 Charge left(92.0095) -> C 1511 W1 Charge left(91.1155) -> C 2394 W1 Charge left(90.74) -> C 5222 W1 Charge left(90.57) -> C 4963 W1 Charge left(90.47) -> C 2110 W1 Charge left(90.38) -> C 4553 W1 Charge left(89.60) -> C 3395 W1 Charge left(89.50) -> C 5708 W1 Charge left(88.87) -> C 5826 W1 Charge left(87.96) -> C 2094 W1 Charge left(87.41) -> C 5603 W1 Charge left(86.95) -> WAREHOUSE Charge left(81.25)

Route for vehicle 11:

WAREHOUSE Load(0) -> C 4539 W1 Load(1) -> C 3721 W1 Load(2) -> C 2723 W1 Load(3) -> C 852 W1 Load(4) -> C 1759 W1 Load(5) -> C 8058 W1 Load(6) -> C 1062 W1 Load(7) -> C 1734 W1 Load(8) -> C 2176 W1 Load(9) -> C 5343 W1 Load(10) -> C 5593 W1 Load(11) -> C 4115 W1 Load(12) -> C 4308 W1 Load(13) -> C 3361 W1 Load(14) -> C 4616 W1 Load(15) -> C 1682 W1 Load(16) -> C 1556 W1 Load(17) -> C 3600 W1 Load(18) -> C 2263 W1 Load(19) -> C 1012 W1 Load(20) -> WAREHOUSE Load(20)

Distance of the route: 18.41km

Load of the route: 20

Battery of the vehicle 11:

WAREHOUSE Charge left(100) -> C 4539 W1 Charge left(94.339) -> C 3721 W1 Charge left(94.195) -> C 2723 W1 Charge left(94.0765) -> C 852 W1 Charge left(93.661) -> C 1759 W1 Charge left(92.638) -> C 8058 W1 Charge left(92.05) -> C 1062 W1 Charge left(91.7455) -> C 1734 W1 Charge left(91.10) -> C 2176 W1 Charge left(90.452) -> C 5343 W1 Charge left(90.127) -> C 5593 W1 Charge left(90.019) -> C 4115 W1 Charge left(89.839) -> C 4308 W1 Charge left(89.635) -> C 3361 W1 Charge left(89.506) -> C 4616 W1 Charge left(88.9405) -> C 1682 W1 Charge left(88.7665) -> C 1556 W1 Charge left(88.1935) -> C 3600 W1 Charge left(88.0435) -> C 2263 W1 Charge left(87.59) -> C 1012 W1 Charge left(86.90) -> WAREHOUSE Charge left(81.58)

Route for vehicle 12:

WAREHOUSE Load(0) -> C 7122 W1 Load(1) -> C 10000 W1 Load(2) -> C 2765 W1 Load(3) -> C 2955 W1 Load(4) -> C 4651 W1 Load(5) -> C 3578 W1 Load(6) -> C 3482 W1 Load(7) -> C 5164 W1

Load(8) -> C 5460 W1 Load(9) -> C 3638 W1 Load(10) -> C 5252 W1 Load(11) -> C 4171 W1 Load(12) -> C 5225 W1 Load(13) -> C 2011 W1 Load(14) -> C 7697 W1 Load(15) -> C 3570 W1 Load(16) -> C 620 W1 Load(17) -> C 505 W1 Load(18) -> C 1621 W1 Load(19) -> C 766 W1 Load(20) -> WAREHOUSE Load(20)

Distance of the route: 19.0005km

Load of the route: 20

Battery of the vehicle 12:

WAREHOUSE Charge left(100) -> C 7122 W1 Charge left(97.081) -> C 10000 W1 Charge left(94.41) -> C 2765 W1 Charge left(92.95) -> C 2955 W1 Charge left(92.56) -> C 4651 W1 Charge left(92.14) -> C 3578 W1 Charge left(91.760) -> C 3482 W1 Charge left(90.96) -> C 5164 W1 Charge left(90.61) -> C 5460 W1 Charge left(90.46) -> C 3638 W1 Charge left(90.23) -> C 5252 W1 Charge left(90.067) -> C 4171 W1 Charge left(89.93) -> C 5225 W1 Charge left(89.59) -> C 2011 W1 Charge left(89.56) -> C 7697 W1 Charge left(89.33) -> C 3570 W1 Charge left(89.074) -> C 620 W1 Charge left(88.68) -> C 505 W1 Charge left(88.28) -> C 1621 W1 Charge left(87.95) -> C 766 W1 Charge left(87.69) -> WAREHOUSE Charge left(80.99)

Route for vehicle 13:

WAREHOUSE Load(0) -> C 3877 W1 Load(1) -> C 513 W1 Load(2) -> C 5018 W1 Load(3) -> C 4 W1 Load(4) -> C 4339 W1 Load(5) -> C 3315 W1 Load(6) -> C 4799 W1 Load(7) -> C 4198 W1 Load(8) -> C 948 W1 Load(9) -> C 1049 W1 Load(10) -> C 8230 W1 Load(11) -> C 2556 W1 Load(12) -> C 4600 W1 Load(13) -> C 3610 W1 Load(14) -> C 6519 W1 Load(15) -> C 6069 W1 Load(16) -> C 3173 W1 Load(17) -> C 6403 W1 Load(18) -> C 9427 W1 Load(19) -> C 8884 W1 Load(20) -> WAREHOUSE Load(20)

Distance of the route: 18.489km

Load of the route: 20

Battery of the vehicle 13:

WAREHOUSE Charge left(100) -> C 3877 W1 Charge left(94.537) -> C 513 W1 Charge left(94.036) -> C 5018 W1 Charge left(93.895) -> C 4 W1 Charge left(93.826) -> C 4339 W1 Charge left(93.6595) -> C 3315 W1 Charge left(93.0025) -> C 4799 W1 Charge left(92.002) -> C 4198 W1 Charge left(91.8235) -> C 948 W1 Charge left(91.324) -> C 1049 W1 Charge left(91.1665) -> C 8230 W1 Charge left(90.3325) -> C 2556 W1 Charge left(90.1315) -> C 4600 W1 Charge left(89.8465) -> C 3610 W1 Charge left(89.4115) -> C 6519 W1 Charge left(88.888) -> C 6069 W1 Charge left(88.58) -> C 3173 W1 Charge left(88.52) -> C 6403 W1 Charge left(88.32) -> C 9427 W1 Charge left(83.23) -> C 8884 W1 Charge left(81.778) -> WAREHOUSE Charge left(81.51)

Route for vehicle 14:

WAREHOUSE Load(0) -> C 7426 W1 Load(1) -> C 8009 W1 Load(2) -> C 9109 W1 Load(3) -> C 6252 W1 Load(4) -> C 8107 W1 Load(5) -> C 7531 W1 Load(6) -> C 6941 W1 Load(7) -> C 6557 W1 Load(8) -> C 9518 W1 Load(9) -> C 7021 W1 Load(10) -> C 6338 W1 Load(11) -> C 8149 W1 Load(12) -> C 8592 W1 Load(13) -> C 9000 W1 Load(14) -> C 6315 W1 Load(15) -> C 7381 W1 Load(16) -> C 8802 W1 Load(17) -> C 8309 W1 Load(18) -> C 8753 W1 Load(19) -> C 6759 W1 Load(20) -> WAREHOUSE Load(20)

Distance of the route: 51.65km

Load of the route: 20

Battery of the vehicle 14:

WAREHOUSE Charge left(100) -> C 7426 W1 Charge left(92.764) -> C 8009 W1 Charge left(92.6845) -> C 9109 W1 Charge left(85.39) -> C 6252 W1 Charge left(84.07) -> C 8107 W1 Charge left(82.507) -> C 7531 W1 Charge left(81.1525) -> C 6941 W1 Charge left(78.97) -> C 6557 W1 Charge left(77.956) -> C 9518 W1 Charge left(75.6055) -> C 7021 W1 Charge left(72.481) -> C 6338 W1 Charge left(69.94) -> C 8149 W1 Charge left(67.3495) -> C 8592 W1 Charge left(64.75) -> C 9000 W1 Charge left(62.06) -> C 6315 W1 Charge left(59.69) -> C 7381 W1 Charge left(59.44) -> C 8802 W1 Charge left(57.5125) -> C 8309 W1 Charge left(56.08) -> C 8753 W1 Charge left(55.853) -> C 6759 W1 Charge left(54.00) -> WAREHOUSE Charge left(48.34)

Route for vehicle 15:

WAREHOUSE Load(0) -> C 4038 W1 Load(1) -> C 7843 W1 Load(2) -> C 9530 W1 Load(3) -> C 9845 W1 Load(4) -> C 1516 W1 Load(5) -> C 7685 W1 Load(6) -> C 3509 W1 Load(7) -> C 4091 W1 Load(8) -> C 4897 W1 Load(9) -> C 1584 W1 Load(10) -> C 9876 W1 Load(11) -> C 3253 W1 Load(12) -> C 2933 W1 Load(13) -> C 8721 W1 Load(14) -> C 4462 W1 Load(15) -> C 848 W1 Load(16) -> C 731 W1 Load(17) -> C 2361 W1 Load(18) -> C 2626 W1 Load(19) -> C 2509 W1 Load(20) -> WAREHOUSE Load(20)

Distance of the route: 16.401km

Load of the route: 20

Battery of the vehicle 15:

WAREHOUSE Charge left(100) -> C 4038 W1 Charge left(94.846) -> C 7843 W1 Charge left(94.747) -> C 9530 W1 Charge left(94.312) -> C 9845 W1 Charge left(94.0255) -> C 1516 W1 Charge left(93.0685) -> C 7685 W1 Charge left(92.3365) -> C 3509 W1

Charge left(92.32) -> C 4091 W1 Charge left(92.0065) -> C 4897 W1 Charge left(91.6195) -> C 1584 W1 Charge left(91.318) -> C 9876 W1 Charge left(91.222) -> C 3253 W1 Charge left(90.73) -> C 2933 W1 Charge left(90.52) -> C 8721 W1 Charge left(90.178) -> C 4462 W1 Charge left(90.0235) -> C 848 W1 Charge left(89.6035) -> C 731 W1 Charge left(89.5075) -> C 2361 W1 Charge left(88.714) -> C 2626 W1 Charge left(88.4125) -> C 2509 W1 Charge left(88.354) -> WAREHOUSE Charge left(83.599)

Route for vehicle 16:

WAREHOUSE Load(0) -> C 9934 W1 Load(1) -> C 6369 W1 Load(2) -> C 6316 W1 Load(3) -> C 9733 W1 Load(4) -> C 8684 W1 Load(5) -> C 7219 W1 Load(6) -> C 6892 W1 Load(7) -> C 8869 W1 Load(8) -> C 6809 W1 Load(9) -> C 6649 W1 Load(10) -> C 9983 W1 Load(11) -> C 7254 W1 Load(12) -> C 8787 W1 Load(13) -> C 8842 W1 Load(14) -> C 7003 W1 Load(15) -> C 9868 W1 Load(16) -> C 7596 W1 Load(17) -> C 906 W1 Load(18) -> C 2882 W1 Load(19) -> C 5296 W1 Load(20) -> WAREHOUSE Load(20)

Distance of the route: 32.09km

Load of the route: 20

Battery of the vehicle 16:

WAREHOUSE Charge left(100) -> C 9934 W1 Charge left(96.1495) -> C 6369 W1 Charge left(95.144) -> C 6316 W1 Charge left(94.471) -> C 9733 W1 Charge left(94.25) -> C 8684 W1 Charge left(93. -> C 7219 W1 Charge left(91.99) -> C 6892 W1 Charge left(91.042) -> C 8869 W1 Charge left(89.79) -> C 6809 W1 Charge left(88.946) -> C 6649 W1 Charge left(88.21) -> C 9983 W1 Charge left(87.46) -> C 7254 W1 Charge left(85.031) -> C 8787 W1 Charge left(83.54) -> C 8842 W1 Charge left(82.04) -> C 7003 W1 Charge left(80.245) -> C

9868 W1 Charge left(78.013) -> C 7596 W1 Charge left(76.66) -> C 906 W1 Charge left(75.9175) -> C 2882 W1 Charge left(75.4795) -> C 5296 W1 Charge left(75.2215) -> WAREHOUSE Charge left(67.909)

Route for vehicle 17:

WAREHOUSE Load(0) -> C 6192 W1 Load(1) -> C 330 W1 Load(2) -> C 2623 W1 Load(3) -> C 1994 W1 Load(4) -> C 146 W1 Load(5) -> C 2939 W1 Load(6) -> C 4252 W1 Load(7) -> C 2667 W1 Load(8) -> C 3655 W1 Load(9) -> C 4250 W1 Load(10) -> C 2171 W1 Load(11) -> C 184 W1 Load(12) -> C 2169 W1 Load(13) -> C 3324 W1 Load(14) -> C 5783 W1 Load(15) -> C 5499 W1 Load(16) -> C 5192 W1 Load(17) -> C 13 W1 Load(18) -> C 6888 W1 Load(19) -> C 7601 W1 Load(20) -> WAREHOUSE Load(20)

Distance of the route: 16.953km

Load of the route: 20

Battery of the vehicle 17:

WAREHOUSE Charge left(100) -> C 6192 W1 Charge left(96.175) -> C 330 W1 Charge left(94.697) -> C 2623 W1 Charge left(94.46) -> C 1994 W1 Charge left(93.95) -> C 146 W1 Charge left(93.73) -> C 2939 W1 Charge left(93.61) -> C 4252 W1 Charge left(93.27) -> C 2667 W1 Charge left(93.09) -> C 3655 W1 Charge left(92.94) -> C 4250 W1 Charge left(92.80) -> C 2171 W1 Charge left(92.678) -> C 184 W1 Charge left(92.364) -> C 2169 W1 Charge left(91.506) -> C 3324 W1 Charge left(91.352) -> C 5783 W1 Charge left(90.932) -> C 5499 W1 Charge left(90.540) -> C 5192 W1 Charge left(90.425) -> C 13 W1 Charge left(89.690) -> C 6888 W1 Charge left(88.373) -> C 7601 W1 Charge left(85.235) -> WAREHOUSE Charge left(83.046)

Route for vehicle 18:

WAREHOUSE Load(0) -> C 8171 W1 Load(1) -> C 9017 W1 Load(2) -> C 7112 W1 Load(3) -> C 9498 W1 Load(4) -> C 6773 W1 Load(5) -> C 7269 W1 Load(6) -> C 9213 W1 Load(7) -> C 8604 W1 Load(8) -> C 7040 W1 Load(9) -> C 7694 W1 Load(10) -> C 7534 W1 Load(11) -> C 8472 W1 Load(12) -> C 1415 W1 Load(13) -> C 4182 W1 Load(14) -> C 5723 W1 Load(15) -> C 4309 W1 Load(16) -> C 2324 W1 Load(17) -> C 4243 W1 Load(18) -> WAREHOUSE Load(18)

Distance of the route: 20.241km

Load of the route: 18

Battery of the vehicle 18:

WAREHOUSE Charge left(100) -> C 8171 W1 Charge left(99.367) -> C 9017 W1 Charge left(97.6555) -> C 7112 W1 Charge left(97.426) -> C 9498 W1 Charge left(96.08) -> C 6773 W1 Charge left(95.4625) -> C 7269 W1 Charge left(94.769) -> C 9213 W1 Charge left(92.84) -> C 8604 W1 Charge left(92.35) -> C 7040 W1 Charge left(91.252) -> C 7694 W1 Charge left(90.505) -> C 7534 W1 Charge left(89.4235) -> C 8472 W1 Charge left(87.9595) -> C 1415 W1 Charge left(86.059) -> C 4182 W1 Charge left(85.747) -> C 5723 W1 Charge left(85.28) -> C 4309 W1 Charge left(85.184) -> C 2324 W1 Charge left(84.911) -> C 4243 W1 Charge left(84.53) -> WAREHOUSE Charge left(79.759)

Total distance of all routes: 539.604km

Total load of all routes: 356

Chapter 7 Conclusion

The optimised result shows that in order to fulfil the demand of a given day of the given distributor, 132.7785 km was travelled in order to deliver 152 cylinders. Now, the optimised path is compared with the currently used method where the agent distributes the cylinders to the nearby customers. This clustering distribution is shown on the Google Map, where all the customers were plotted on the map and the number of vehicles used were equals to that used in optimised results. Thus, total eight clusters were formed and distribution was made accordingly. The results were then compared with the optimised path. The given figure shows the customers distribution on Google Map and different colors shows different clusters formed according to the nearest neighbour rule and their distribution.

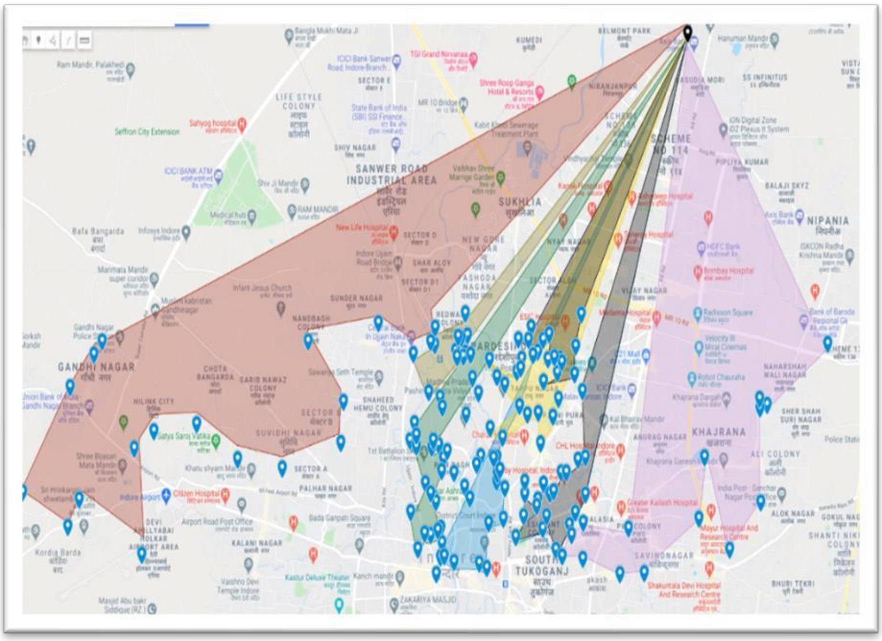


Figure 25 Cylinders distribution using clustering approach

Source: Google Maps

The comparison was made for both cases, and it was found that the distance covered in the optimised route was less than the c current working clustering approach. The comparison was also made on the grounds of generating carbon footprints when ICEV and EV followed the same routes.

Vehicle (Distance travelled/vehicle/day)	Optimised Approach (Distance travelled (in km))	Clustering Approach (Distance travelled (in kms))
Vehicle 1	18.93	32.7
Vehicle 2	5.2425	21.3
Vehicle 3	27.19	28.8
Vehicle 4	19.647	26.75
Vehicle 5	9.87	18.75
Vehicle 6	35.853	50.4
Vehicle 7	5.745	23.4
Vehicle 8	7.28	13.0
Total distance	132.78	215.1

Table 7 Comparison between optimized and random approach

The above comparison shows that if EV is used instead of ICEV, there can be a considerable reduction in carbon footprints and also, if the route is optimised, there will be more positive environmental, health and economic impacts.

	ICEV	EV
Distance travelled (in kms)	132.78	132.78
Fuel/ electricity consumed	6.639 litres	14.16kWh
CO_2 produced (in kg)	84.00	12.039
Difference in CO_2 generation = 84-12.039 = 71.96kg		

Table 8 CO_2 generation in ICEV and EV

Chapter 8 Future Scope

The work presented in this thesis is a novel work in itself. As there are lot of studies which discuss about the benefits of use of EVs over ICEVs. But none of the studies discuss about the benefits of using EVs in light commercial sector, this thesis does that. The case study discussed here is also a novel approach of implementation of EVs in LPG distribution system. If, implemented in a real-world situation, it can be a very initiative approach in reducing the use of ICEVs.

The real-time tracking system modelled here is unique in its type. As there is no model which not only discusses tracking of vehicles but also considers the real-time generated demand and modifies the path accordingly with already generated demands.

Thus, this project can be implemented as a pilot project which talks abou the replacement of ICEV, also gives the initial idea of placing of charging points, optimizes the routes according to the demand generated. The second model can also be implemented as it benefits both end users and the distributors.

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