GIS Framework for Taluka Bus Transportation Analysis and Provisioning

Master Thesis Project

submitted in partial fulfillment of the

requirements for the degree of

Master of Technology

by,

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Sudhanshu Kulkarni
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Contents

List of Figures

List of Tables

List of Abbreviations

QGIS	Quantum Geographic Information System
MRSAC	Maharashtra Remote Sensing Application Centre
NGO	Non-Governmental Organisation
SRTU	State Road Transport Undertaking
MSRTC	Maharashtra State Road Transport Corporation
GIS	Geographical Information System
NTDPR	National Transport Development Policy Report
PMGSY	Pradhan Mantri Gramin Sadak Yojana
JRY	Jawahar Rozgar Yojana
ICT	Information and Communication Technology
EPKM	Earning Per Kilometre
KPL	Kilometers per litre
ETIM	Electronic Ticket Issuing Machine
PWD	Public Works Department
VTS	Vehicle Tracking System

GM	General Manager
IT	Information Technology
DEM	Digital Elevation Model
ODK	Open Data Kollect
OSM	Open Street Maps
GGP	Group Gram Panchayat

Dedicated to Aai-Baba

Abstract

In this report we look at rural public transport as a development service and ways of representing it, analyzing it and social accounting. We propose an Information and Communication Technology (ICT) framework for the same. We begin with surveying the literature, surrounding public transport and specializing for the case of India and rural Maharashtra. Then we overview key service provider Maharashtra State Road Transportation Corporation (MSRTC) and its operations. Finally we look at the role of ICT in rural transport operations. Next we begin with *Shahapur taluka* as a case study and *Shahapur Taluka* bus depot. We outline the key data formats and the connections between the same. We used graph theory as a tool to represent the key data set which is form 4 and ABC data for profit and loss accounting. We call this digital geography. In digital geography, vertices corresponds to key locations and edges corresponds to roads and paths in this graph corresponds to route segments. We integrate digital geography with the census data. We show the utilization of digital geography for analytic as well as operational queries. We apply the same to the representation of *Shahapur Taluka*. Finally we finish with recommendations and scope for future improvements.

Keywords: Network, Graph Theory, Shahapur Taluka, Demographics, Operational data, Bus-Depot

Background

"Sadak, Bijli, Paani" are now the bare necessities for contemporary India, have replaced the previous notion of *"Roti, Kapda, Makaan"* which is a good sign. Now bigger challenge awaits because all the formerly mentioned requires infrastructure building. Planning, deployment, maintaining an infrastructure itself is a hefty task for the government and government agencies. To top it all if we see the rural planning is highly unplanned which transpires to the poor infrastructure, eventually widening the *"Bharat-India"* divide.

Transportation in itself is an indicator of development. When I got to experience that I realized its value first hand. for my 9 weeks summer field stay I went to a very small hamlet called *Devichapada* in *Javhar* Taluka of *Palghar* District, a hamlet of size of 51 households. In our village there was a *pucca* road from which bus plied. This bus acted as a school bus for the students going for +2 education in *Dengachimet* School. As a result of which almost all of the children were educated and all the girls were educated till class 10th. Some were graduate and were learning computers, vocational courses. Also because of the *pucca* road mobile health service plied to the village and gave free health check-up in the village, also every 3 months a healthcare van of some NGO came to check the health of the students studying in *Zila-Parishad* school. Not only this the access to Javhar market, Big hospital etc. were also enabled because of access of bus-service twice a day. Hence, I wanted to learn more about transportation in rural India and how social-welfare accounting can be done.

Chapter 1

Introduction

The current work aims to look at public transportation as a development service and ways of replicating, analysing and improvising the existing tools and practices used in a bus depot like form4, operational sheets, control charts, traffic data and related data analysis and incorporation of those in the implementation so that the work-load is reduced and higher efficiency, productivity can be achieved to deliver quality services. In the bigger picture the work is focused primarily in integrating census, geographical data and bus depot transportation in such a way that street level bureaucrat and administrators can take better and effective decisions. The fieldwork is focused on Shahapur Taluka of Thane district of Maharashtra, however the methodology will be generic for all the rural taluka of Maharashtra.

1.1 Scope of the Project

The scope of this project is limited to Bus Transportation in Shahapur Taluka only and related data formats used in bus depot. The Project covers the Shahapur taluka and nearby talukas if and only if there is a bus service plying to the other taluka.

1.2 Chapter Organization

The entire report is divided into 12 chapters. **Chapter 1** sets the premise of the report, posing the research question and broad societal concern. **Chapter 2** is about the social dimension

of transportation and visualising transportation system with planning approach. **Chapter 3** essentially takes us to the site of study Shahapur Taluka Bus Depot where elaborate description of Bus depot is done along with an in-depth understanding of functioning of traffic department in Depot. **Chapter 4** puts forward the mathematical definition of Data structure Digital Geography. **Chapter 5** highlights mostly the plan and execution of fieldwork to all the tiers of bureaucracy in transportation department. In **Chapter 6** we have tried to do social welfare appraisal of bus service provisioning in Shahapur taluka with various development indicators. **Chapter 7** identifies the gaps in demand-supply in an in-depth manner for transportation as a service, followed by conclusion in **Chapter 8**. **Chapter 9** consists of annexures of various algorithms, codes, queries, checklists, survey forms etc. All the content is suitably supported with the help of references in **Chapter 12**.

1.3 Broad Societal Concern

The following is the Broad Societal Concern (BSC):
"Poor Public transportation service provisioning at Shahapur Taluka"

1.4 Research Question(s)

The research questions are as follows:

i) DRQ.1 What data structures can be used to represent a rural public transportation system?

ii) DRQ. 2 What are the gaps in demand-supply of transportation in Shahapur Taluka?

1.5 Objective

The objectives of the project are as follows:

i) To define a mathematical model of Taluka Public transportation based on Graph theory

ii) To generate GIS data of transportation maps with points of importance, routes, quality of routes and locations

iii) To map Form4 and Operational data in GIS

iv) To standardise the analysis coverage and profit-loss of a bus depot

v) To identify points for social coverage

vi) To do social benefit accounting of services offered by Shahapur Taluka Bus depot

1.6 Methodology

The following methodology was undertaken:

i) Visits to Shahapur Taluka depot, Thane Division Office, MSRTC head office

ii) Meeting and interviewing various agents of service i.e. Bus-driver, conductor, cashier, traffic controller, clerks, depot manager, BDO, Division Traffic Controller, Dy General Manager IT, General Manager Traffic, Chief Statistical Officer and Vice-Chairman and Managing director MSRTC

iii) Meeting the outsourced managed service agency of MSRTC

iv) Surveying the Non-MSRTC service providers by structured and unstructured interviews

v) Working from Shahapur Depot for 3 days

vi) Visiting villages and surveying the villagers

vii) Passenger survey

viii) Attending the monthly Panchayat Samiti Meeting

ix) Development of Digital Geography

1.7 Proposed Outputs

The following are the proposed outputs:

1. An integrated system of GIS data, Operational data and Census data
2. A framework for social benefit accounting of Shahapur Taluka Bus depot
3. Ascertaining the gaps in standard formats used by that are leading to losses to Shahapur Taluka Depot

Chapter 2

Transportation as a Carrier of Social Development

2.1 What is development?

Development" can be defined roughly as "an event constituting a new stage in a changing situation" implicitly a positive/ desirable event(5). It is always expected that development of society leads to improvement and betterment of society as a whole. In this sense development is always holistic and caters to the last person standing in the society. Given this definition "development" per say is a multidimensional concept because of the interdisciplinary nature of the socio-economic systems. A socio-economic system cannot be categorized into one set of discipline, hence interdisciplinary study of society is needed to understand development as a whole and quantify it.

2.2 What is a Rural Transportation System?

All communities require access to supplies, facilities, services and opportunities. *Roti, Kapda, Makaan, Sadak, Bijli, Paani*, healthcare, education and employment being some of them. Apart from them they like to be involved in some kind of leisure activities like *jatra, haat*, participate in religious activities, attend weddings, sing songs of their culture and so on.

Accessibility can be measured in time, effort and cost, availability of infrastructure and intermediate means of transport. It depends on the mobility and proximity of infrastructure. People walk long distances because walking is cheap, simple and efficient for short distances, difficult terrain and small loads. Intermediate means of transport can be minidors, jeeps, auto-rickshaws, small trucks, tractors etc. that act as a means of transport for distances upto 20 kms. Since there is an intrinsic lack of concentrated demand coupled with poor ability to pay. Improving rural mobility to reduce poverty thus requires a combination of appropriate transport infrastructure and affordable means of transport. The report tries to explore the *Rural Transportation Infrastructure management and design in Shahapur Taluka* and *Appraisal of Rural Transportation in Shahapur Taluka*

2.3 Patterns of Rural Transport

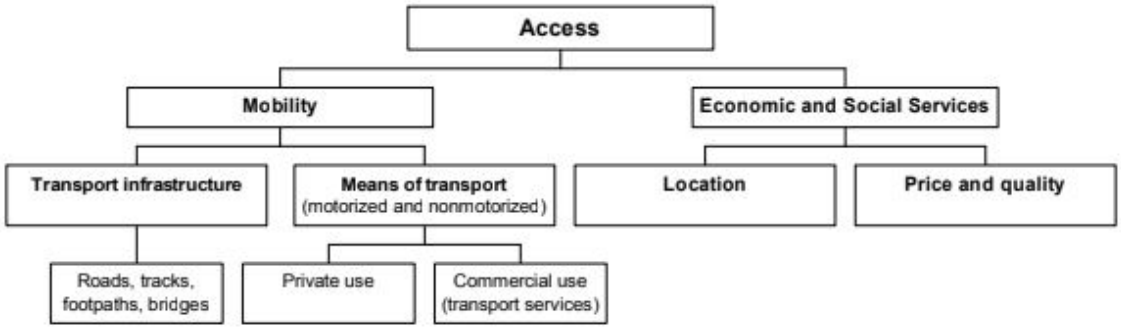


Figure 2.1: Hierarchy of Access(2)

Rural transportation involves movement of goods, people for a variety of purposes within or outside the village. Within a village majority of the movements are for fulfilling the basic necessities and household purposes, or a wide range of socio-economic activities like festivals, weekly markets, religious activities etc. Intermediate means of transport for the purpose of selling the produce, carrying small load are generally not tended by the rural planners. Out-of-village travel is less common but is of great economic and social importance. These trips

span longer distances hence access the best transportation service available, better infrastructure prevails and the urban connect is established.

2.4 Issues affecting Rural Mobility

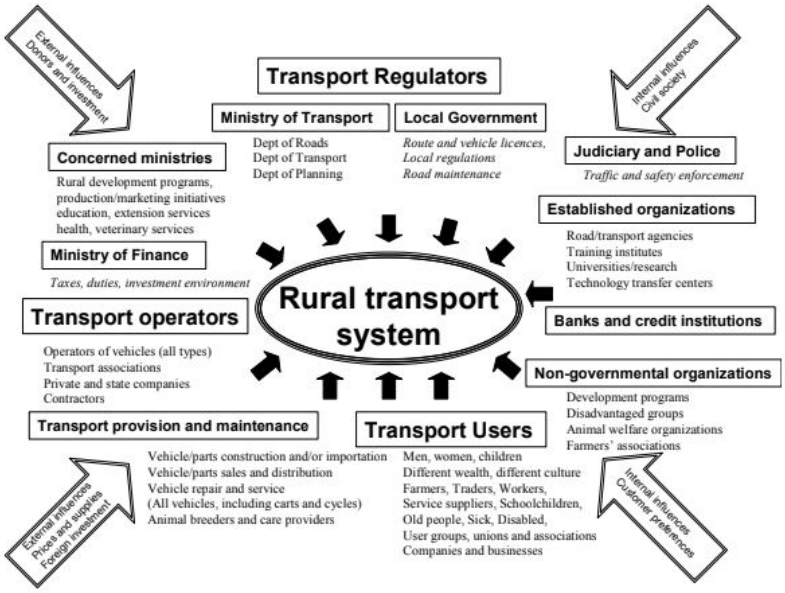


Figure 2.2: A typical Rural Transportation system(2)

Government is constantly focusing on the expansion of road networks in order to improve the access to rural transport but a little attention is paid towards sustainability, serviceability, development of means of transport, needs or views of the transport users, especially rural poor(2). As a result of which despite massive efforts being taken for developing the road infrastructure by government, rural interventions have not yet met their ultimate goal. Moreover areas with low demand, poorest of the poor and communities with low mobility remain neglected.

2.4.1 Wide range of Stakeholders

i) *Wide range of Stakeholders* There are many stakeholders in rural transport, with different priorities and agendas. These stakeholders influence the price, quantity and quality

of transport means and services. If we break the system down through planning approach, the key components of any such system will be the consumers, service providers and regulators. Other major institutional stakeholders can be local MLAs, *Vahatuk Samitis*, Vehicle suppliers, allied activities i.e. mechanic, fuel pumps etc., transport infrastructure contractors, local NGOs, worker unions and associations etc.

ii) *Users* Now if we see here the term users is very wide. Various attributes of a user can be age, gender, caste, income group, employment, education, purpose of travel(2). We'll look into each in brief. **Gender** is largely neglected when it comes to rural transportation planning for a very basic reason that the vehicles are operated and owned by men. Woman's transport is mostly localized compared to men. Also societal norms forbid a woman to travel alone citing safety, poor conduct etc. Hence women travel in closely knit clusters than men. *Women are tended invisible to the transportation planners* despite their dire need. Gender-sensitive design issues should be considered when accessing, addressing and promoting transportation services.(2) **People with special needs** Elderly, handicapped and ill people rely on public transportation and must be tended. **Occupation and task** sometimes transportation is seasonal, for example during sowing and harvest season, mobility of farmers and agro-based community is more compared to others. Similarly *Pandharpur yatra, Jejuri yatra* in *Aashad* month of Hindu calender have greater up trip load than the down load. In certain cases the transportation demand is almost constant throughout the year. These are the service class, employees at govt. offices, teachers, college students etc.

iii) *Operators* Operators form a major component of transportation scenario. Operators can be public, private. Public service provider is SRTU. The private players can be jeep, minidor, autorickshaw etc. Apart from this personal ownership of two-four wheelers etc. The pricing of the services in case of *public* players the motive is social-welfare than profit making so the prices are kept in affordable ranges. These public players also regulate the costs of their competitive service private players. One of the other factors influencing the costs are the *Vahatuk Associations*, these associations can be route based,

vehicle specific, political group specific, geographical area specific. Associations take responsibility for licensing, fare regulation and route allocation

iv) *Regulators* Regulating authorities are mostly government agencies like ministry of transport. In developing countries these tend to be weak. The legal framework for rural transport consists of traffic acts and ordinances. Apart from these revenue generation in the form of taxes is also one of the responsibilities. Traffic laws typically cover:

i) Vehicle construction and use

ii) Vehicle registration and licensing, including road worthiness inspection

iii) Licensing the drivers

iv) Patrol and policing

v) Penalties and insurances

2.4.2 Critical Mass of Users, Operators and Suppliers

For any transportation system to succeed a critical mass of niche users is required in order to sustain the service quality and serviceability. Once this critical mass of users is gained then all the other allied economic activities get boost. For example spare parts, repair shops etc.

2.4.3 Population Densities and Income levels

Patterns of demand and supply for rural transport services are often linked to population density and income levels in three broad categories:

i) *Low transport density in low income areas* Low population density translates to low demand, hence low transportation density. A vicious circle of insufficient transport, users and services impedes development. Choices are limited by high costs and low profitability. People have low income hence they use transportation only when needed like selling the harvest. They pool their produce and money and sell it in nearest market hub. Women are largely ignored in this.

ii) *Higher transport density in low to medium-income areas* Medium to high population density, irrigated agriculture (reducing seasonality), cash crops, efficient marketing systems, and non-agricultural employment is associated with higher transport density. In areas with these characteristics transport services have already achieved critical mass, making it easy to buy, sell, maintain a vehicle and a transportation system. Transportation system available at low to medium cost.

iii) *low to medium transport density in high-income rural areas* In this kind of scenario the dependency on public transportation is less. It is very likely the infrastructure is developed enough to support commutation by personal vehicle . There is availability of capital intensive agriculture, business activities.

2.4.4 Complementary and Supplementary Services

i) *Complementary Services* Complementary services are those which can work work together in such a way that demand of one is determined by the supply of the other. It is very common to use two or more than two transportation services for one journey.

ii) *Supplementary Services* These services are essentially substitutes of one another and user is typically indifferent to substitute one with another for exercising mobility. High economic activity leads to such scenarios where service providers catering different needs and penetration offer their services. High competition leads to regularization of prices and ultimately benefit the customer. One down point of this system is that the profit margins are less hence the service providers need to reinvent themselves in order to make profits.

2.4.5 Cost related issues

Cost forms the fuel to the transportation system. There is a trade-off between social-welfare and profit making. To achieve maximum coverage the earning per kilometer decreases. Whereas the routes that achieve maximum profits or that give the maximum choice those

become an obvious choice for administration and garner greater focus of authorities. The costs include fixed costs of obtaining a vehicle, repairs, fuel, maintenance, tires. Operating costs add to the total corpus. Volatility in price of any of these costs translate directly to the cost users pay.

2.5 SDGs and Rural Transportation

Transportation was not a part of Millennium Development Goals for 2000-2015[1]. There is a strong linkage between transportation and economic development, omission of which was viewed as a missed opportunity. In the Sustainable Development Goals adopted in September 2015, transportation was made a part of framework as a key contributor of development. SDGs have 169 targets, five of which are clearly linked with the transportation sector:

i) Target 3.6. By 2020, halve the number of global deaths and injuries from road traffic accidents

ii) Target 7.3. By 2030, double the global rate of improvement in energy efficiency

iii) Target 9.1. Develop quality, reliable, sustainable, and resilient infrastructure, including regional and trans-border infrastructure, to support economic development and human well-being, with a focus on affordable and equitable access for all

iv) Target 11.2. By 2030, provide access to safe, affordable, accessible, and sustainable transport systems for all, improving road safety, notably by expanding public transport, with special attention to the needs of those in vulnerable situations, women, children, persons with disabilities, and older persons

v) Target 12.c. Rationalize inefficient fossil-fuel subsidies that encourage wasteful consumption by removing market distortions, in accordance with national circumstances, including by restructuring taxation and phasing out those harmful subsidies, where they exist, to reflect their environmental impacts, taking fully into account the specific needs

[1] http://in.one.un.org/page/sustainabledevelopmentgoals/sdg11

and conditions of developing countries and minimizing the possible adverse impacts on their development in a manner that protects the poor and the affected communities

Transportation indirectly contributes towards the enabling of agricultural productivity (Target 2.1), air pollution (Target 3.9), and access to safe drinking water (Target 6.1), sustainable cities (11.6), and reduction for food loss (12.3) and lastly climate change adaption and mitigation (13.1). The same paper claims that the accessibility of an all-weather road within a reach of 2 kilometres can be seen as an indicator of attainment of the SDGs. In the Earth Summit of 1992 "Major Groups" [2] were identified as the focus of Agenda 21:

i) Women

ii) Children and Youth

iii) Indigenous Peoples

iv) Non-Governmental Organizations

v) Local Authorities

vi) Workers and Trade Unions

vii) Business and Industry

viii) Scientific and Technological Community

ix) Farmers

A better transportation system will not only contribute towards the mobility of the rural population but also provide better livelihood opportunities, access to better technologies and eventually escape poverty.

[2] https://sustainabledevelopment.un.org/mgos

2.6 Rural Transportation System in India

Transportation in rural India is more acute. Around a third of rural population continues to work at home/village and use no mode of transport to go to their workplace. This clearly shows the lack of opportunity. Due to lack of access to transport facilities, 18.5 million workers are forced to walk to work in rural areas. Around 48% of rural workers walk 2-10 km daily to reach at work. This is one of the reasons that large number of people remain at home. The same problem is faced by the young population who need to travel to schools and college(6). Owing to lack of facilities, most of the students could not pursue higher studies and learn necessary skills.

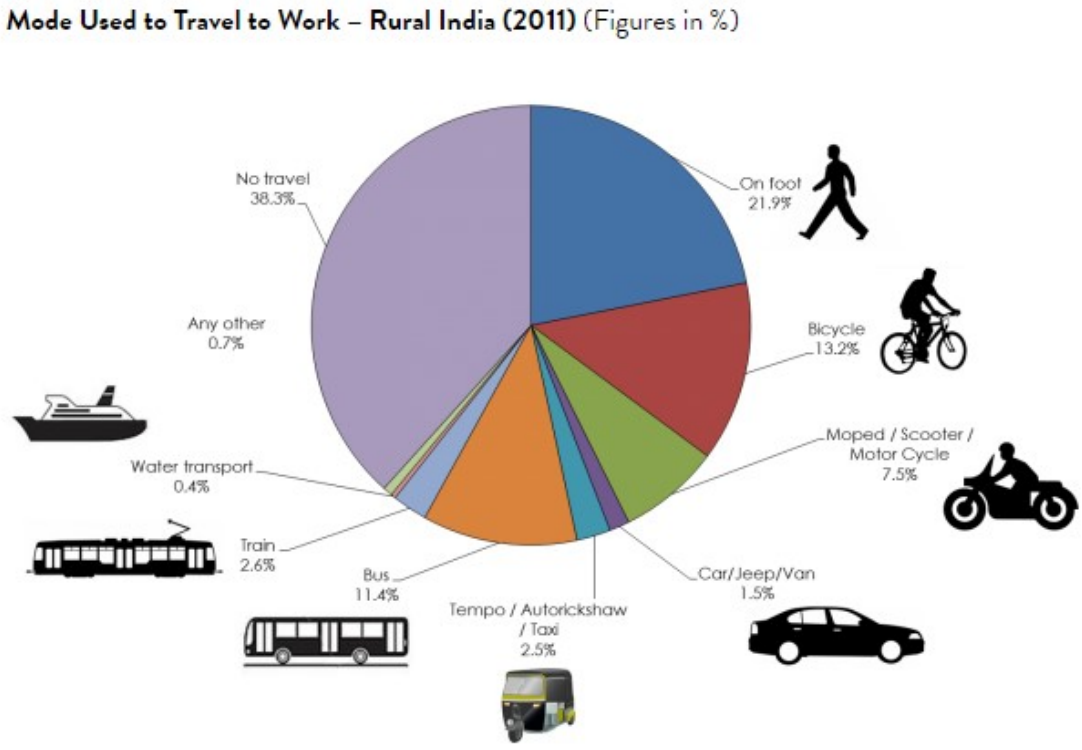


Figure 2.3: Rural Mobility Patterns in India [3]

As we can see in the figure above the most favoured form of transport is bicycle (11.2 million), followed by bus (9.6 million), moped, scooters and motorcycles (6.3 million), train (2.2 million), tempo, auto and taxi (2.1 million) and car, jeep and van (1.2 million) and water

transport (0.3 million).

The problem is more acute for women in rural India. The size of women workforce in rural India is one-third of men workforce, which clearly shows the lack of opportunities for women. Further, the data shows that more than 55% of women (11 million) continue to work at home and use no mode of transport to shuttle to their workplaces. Around 30% of women (6.5 million) reach to workplace on foot and 1.5 million rural women[4] use bus service.

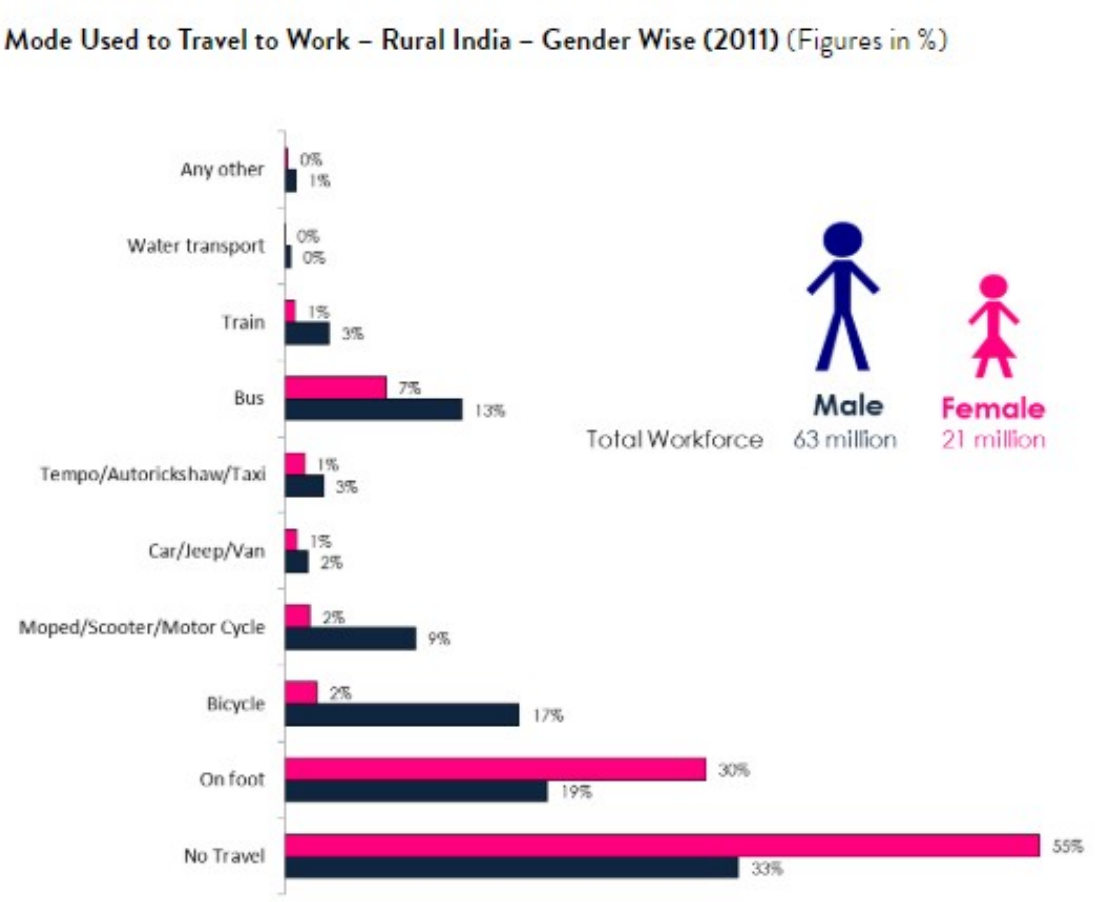


Figure 2.4: Mode of Transport in Rural India

As the asset ownership in rural India is low. Thus, if the family owns any private vehicle

[4][https://india.uitp.org/articles/mobility-in-rural-india]

(bicycle or two-wheelers or cars), men has the first right to use the transport. The women are largely dependent on buses to reach to workplace. As highlighted earlier, the same pattern should be followed by students who need to travel to school. Most of the girls are not able to go outside of their villages to pursue higher studies owing to lack of transport facilities. This is also one of the key reasons for the low participation of women in workforce.

2.7 National Transport Development Policy Report

The total road length in India increased from 400,000 km to 4.7 million km *(courtesy: NT-DPC report)*, surfaced roads increased from 157,000 km to 2.5 million km. The development of roads got a big boost by the PMGSY *(Pradhan Mantri Gramin Sadak Yojana)* to increase the connectivity of rural habitations. The highest Compound Annual Growth Rate of 4.4% was registered by rural roads under Panchayati Roads and *Jawahar Rozgar Yojana (JRY)* . The report ably identifies the lack of database for regional traffic and transportation surveys. The report also indicates higher investments in rural road network in upcoming 5 years' plan. NTDPC report also highlights the need of Information and Communication Technology (ICT) in the road transportation sector to mitigate with the following challenges:

i) *Good quality to support evidence-based policy making*

ii) *Increase in efficiency of the road transport system and satisfaction of its users*

iii) *Management of safety and care of the injured*

ICT will play a pivotal role in filling gaps due to data absence and pave way to detailed studies that involve collection of primary and secondary data about vehicles, number of passengers, accidents etc., transmitting them to the computer systems for storage, analysis and interpretation that enforce better drawing of conclusions, eventually better decision making. ICTs coupled with Geospatial Information Systems will provide real time monitoring of the vehicles, quick response to accidents and mishaps, route optimisation. GIS will not only enable the government in gathering important grass-root level data but also will help in

building better policies which will be more individualistic, holistic and community driven. The diagram obtained from the report highlights the implementation plan for tier 1-2 cities.

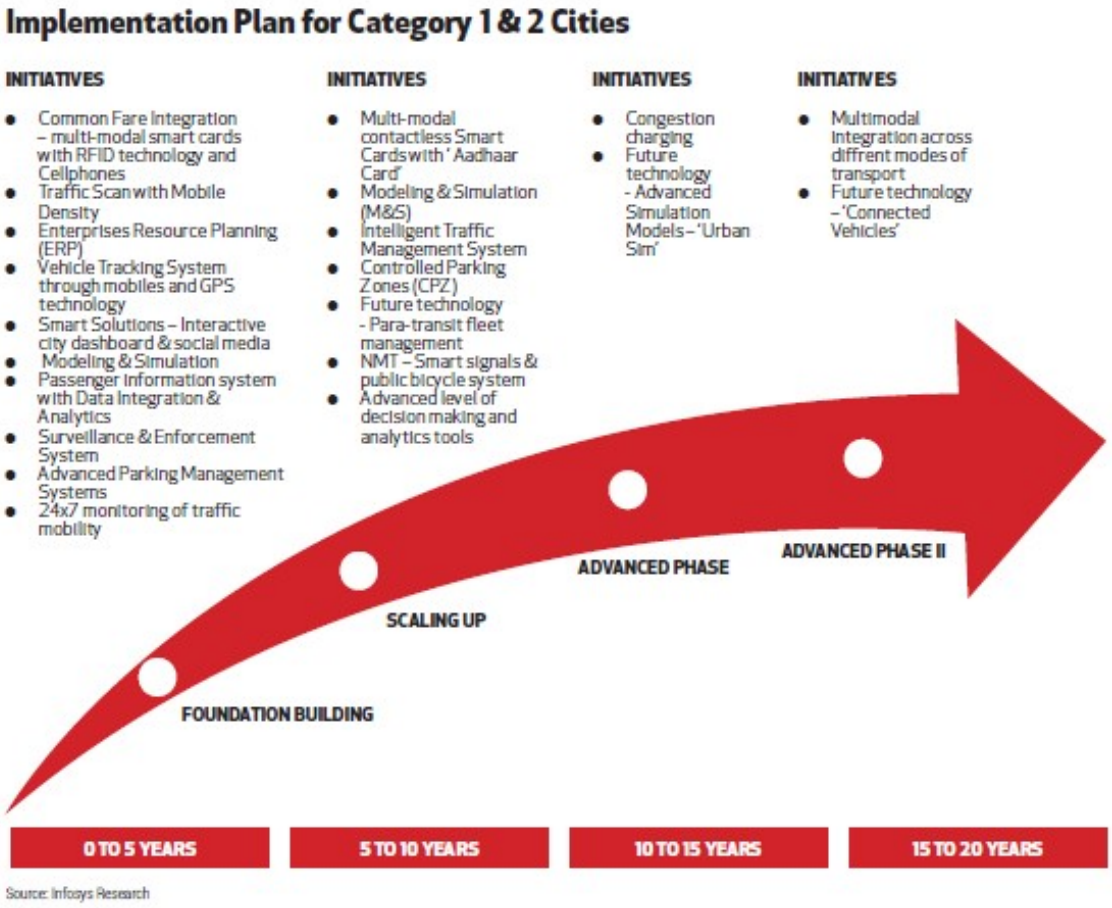


Figure 2.5: Plan for Transportation in tier 2 - tier 3 cities(3)

2.8 Maharashtra State Road Transport Corporation

Maharashtra State Road Transport Corporation is the State Transport Undertaking (STU) of Maharashtra. It serves routes to towns and cities within Maharashtra and adjoining states. MSRTC has divided the state into division i.e. 1 division per district and each division has certain depots which are located at taluka (7). Currently there are 18710 Buses, 609 Bus Stands and 250 Bus Depot pan Maharashtra. As per the annual report of 2017-18 the cor-

poration operated 206.61 crore km i.e. 56.61 lakh km daily. Corporation earned a revenue of Rs. 19.33 crore daily and carried 66.95 lakh passengers every day with a fleet of 18710 buses operating in 18765 routes[5] [6]. The corporation is now using GIS based website and monitoring system that is capable of generating reports and 20 point at division and depot level.

M.S.R.T.C. Buses

Total Buses	15500
Simple Buses 14022	14022
City Buses 651	651
Semi Comfortable	544
Mini Buses	199
Deluxe Buses	48
Air Conditioned	26
Midi	10

M.S.R.T.C. Offices

Central Office	1
Regional Offices	6
Central Workshops	3
Central Education Centre	1
Printing Press	1
Vibhagiya Karyalaya	30
Agaare	248
Bus Stands	570
Margastha Nivare	4000

Figure 2.6: MSRTC basic Information

At division level depot wise basic information is collected and based on these information various analytic reports are submitted to Divisional Management for improvement in performance.

At monitoring committee level Depot wise and Division wise various analytic report are submitted to 3 Committee Managements for improvement in performance. At the Central level depot wise, Division wise & Region wise information is collected, complied and submitted to Central Management for decision making. Depot wise, Division wise and Region wise information analysis is made available to each unit by way of MSRTC's (GIS) based website as under[7]:

i) *Geographical Information System*

ii) *Graphical Reports*

[5] https://www.msrtc.gov.in

[6] Administration Report 2016-17 Government of Maharashtra

[7] https://msrtc.maharashtra.gov.in/index.php/node/division/31

iii) *Vehicle Monitoring System*

iv) *20 Point and Budget*

v) *Daily Report*

This information is useful for decision making. This system is updated periodically by units. Despite all the efforts the corporation incurred a fiscal deficit of Rs. 522.78 crore (revenue Rs.7056.33 crore and expenditure of Rs. 7599.90 crore) which is 400 crore more than the 2016-17. The corporation is facing stiff competition from the 2-4 private motorised vehicles, private players as a result of which the load factor is dropping steadily. It is grappling with the revenues because of the rising fuel prices and steady dropout of passengers. Majority of the expenditure is on Staff 43% followed by Diesel and Engine Oil 33%. These two components form the major chunk of the expenditures incurred by the corporation. 12% of the expenditure goes into taxes if MSRTC is exempted or rebated from the taxes then the situation could be a little different and we may reach a break even. However currently efforts are being made to attract the customers back to STs.

The following are the paper cuttings from the leading Indian daily The Hindu, Hindustan Times[8]

[8]http://www.sify.com/finance/rising-fuel-costs-compels-corporation-to-increasing-msrtc-bus-fares-by-18-news-commodities-sghlOzdgghbei.html

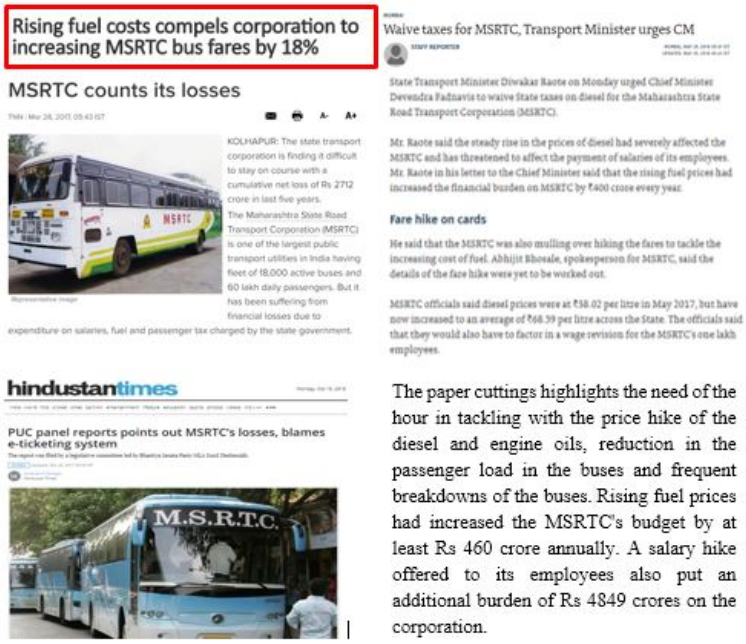


Figure 2.7: Some Paper cuttings

As evident from the table above obtained from the Annual Administration Report 2016-17 of MSRTC[9] that the Load factor and passengers are steadily reducing.

अ.क्र./ Sr. No.	तपशील / Particulars	वाहतूक सेवा उपलब्ध असलेल्या खेड्यांची टक्केवारी/ Percentage of Villlages served		वाहतूक सेवा उपलब्ध असलेल्या लोकसंख्येची टक्केवारी / Percentage of Population served	
		2015-16	2016-17	2015-16	2016-17
1	2	3	4	5	6
अ/ A	थेट / Direct	74.48 (30906)	75.53 (31341)	91.17 (1099.66)	91.66 (1119.86)
ब /B	३ कि.मी.पर्यंत/ Upto 3 Kms.	15.72 (6524)	15.11 (6269)	5.85 (70.52)	5.61 (68.49)
क /C	३ ते ५ कि.मी. दरम्यान/ Between 3 to 5 Kms.	5.61 (2328)	5.42 (2247)	1.68 (20.27)	1.59 (19.44)
ड /D	५ ते ८ कि.मी.दरम्यान/ Between 5 to 8 Kms.	2.57 (1067)	2.44 (1014)	0.86 (10.33)	0.74 (8.98)
इ /E	८ कि.मी.पलिकडे / Beyond 8 Kms.	1.61 (668)	1.50 (622)	0.45 (5.38)	0.40 (4.92)

Figure 2.8: Service coverage Information of MSRTC

In the above table we can see that MSRTC claims to have around 75.5% direct coverage

[9]Administration Report 2016-17 Government of Maharashtra

and 15.11% under 3 km of their serviceability. They also show that around 92% population comes under direct serviceability and 5.61% of population under upto 3km. The paper cuttings highlights the need of the hour in tackling with the price hike of the diesel and engine oils, reduction in the passenger load in the buses and frequent breakdowns of the buses. Rising fuel prices had increased the MSRTC's budget by at least Rs 460 crore annually. A salary hike offered to its employees also put an additional burden of Rs 4849 crores on the corporation.

Chapter 3

Shahapur Taluka Bus Depot

3.1 About

Figure 3.1: Google Street Maps image of Shahapur Depot

Shahapur[1] is one of the 7 talukas of Thane district. It operates around 65 buses on 270 routes for around 80 villages in Taluka. Being the rural taluka it has the lowest load factor among the other 7 other depots with a load factor of around 63% by June 17 reports. The taluka also houses three local train stops namely *Kasara, Asangaon, Vashind*. The nearest

[1]https://msrtc.maharashtra.gov.in/index.php/node/division/12

railway station is Asangaon and it often acts as a source of passengers to the depot. To measure operational efficiency of Traffic and Mechanical Engineering department, various performance indicators are taken into account and those are as under : **Traffic indicators:** Route, Schedule, Effective Kilometre, Traffic Receipt, Earning per km. % Load Factor, Vehicle Utilization, Crew Utilization etc. **Mechanical Engineering Indicators:** % Fleet Utilization, Rate of Breakdown, KPTL, KPL, Tyre consumption, Spring Consumption etc.

Figure 3.2: A typical scenario at Shahapur depot

3.2 Organisation of Bus-Depot

Each bus depot is headed by a **depot manager**. Depot manager is responsible for managing entire bus depot and its departments. For the external agencies he/she is the sole point of contact for all official purposes. A bus depot has two departments:

i) *Traffic*

Traffic department consists of various sections like *Cashier, Clerical section, Traffic control office, Announcement section, Ticket vending section, rest houses, waiting area*. Traffic department is responsible for crew shift scheduling, making sure that the depot follows the schedule issued by division office (Form 4). Storing various operational details and report generation. Apart from this traffic department is responsible to present the report in monthly *Panchayat Samiti* meeting.

ii) *Workshop*

Workshop department is responsible for scheduling the operational and maintenance of buses that are operational, scheduling shifts for the mechanics, generating reports of maintenance and inventory. They are also responsible for providing assistance to any bus in case of mishaps, tire bursting etc. events. They categorize their tires into category A, B and C. A tires after they loose their grip are sent to tire retreading units and then are degraded to B category, subsequently after retreading B ones we get category C tires. After C tires lose their groves then they are discarded. Mainly spring and tire are major components that are taken care at depot level workshop.

3.3 Plan of Bus-depot

Shahapur taluka depot's two departments are located at a distance of around 300-400 metres. Traffic department is located just adjacent to the road. On the road there are auto-rickshaw stands, minidor stands etc. The traffic department is located in the depot which houses offices of Announcer, cashier, trimax employee, ticket vendor, traffic controller and clerks. Rest houses for the crew is located just above that office. Traffic department is adjacent to the passenger waiting area and bus stand. There is also *Sulabh Shouchalaya* attached to the stand. The workshop is located in another ground to which ajoining is the cabin of Depot manager. The workshop consists of buses under repair,mobile van to help a bus in transit and other operations that fall beyond the scope of this project.

3.4 Existing System

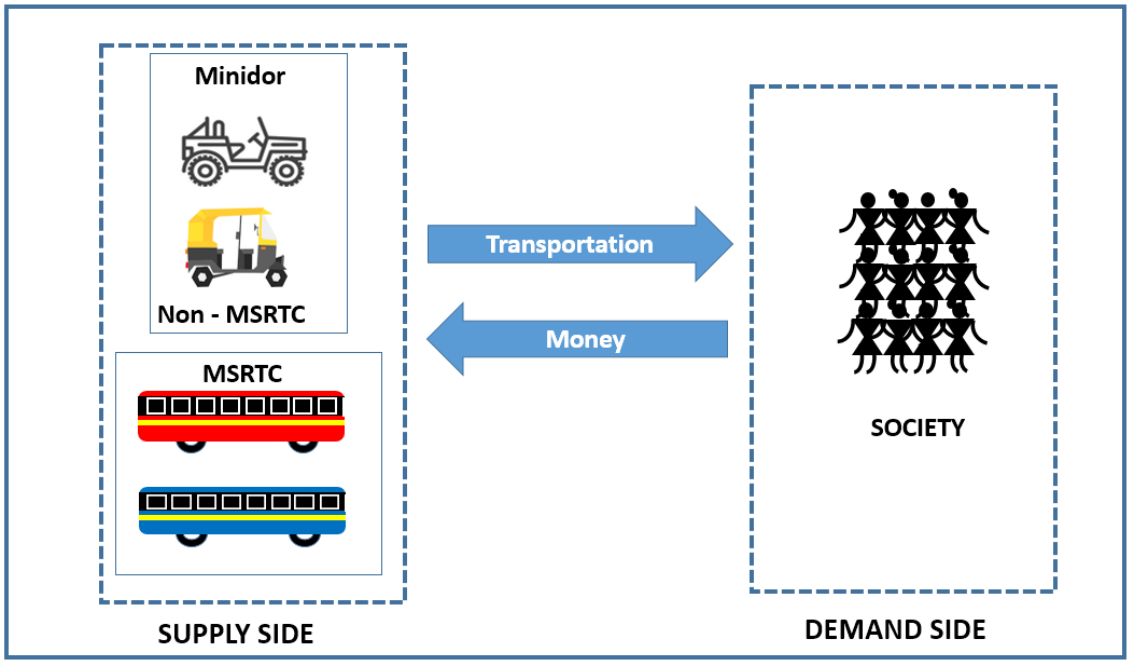


Figure 3.3: Illustration of Existing System

The following sub-sections highlight the existing scenario of transportation service provisioning in Shahapur taluka:

3.4.1 Public Transport service provisioning

Using planning approach we can simply reduce public transportation into a demand-supply problem. The *demand* side is created by society/institutions/marketplaces/ places to rendezvous/ religious activities and so on. On the other hand the *supply* of transportation is governed by various types of means of transport namely bus (ordinary and *Manav-vikas*), jeeps, minidors, auto-rickshaw and personal vehicles.

In case of Non-MSRTC transportation the service scheduling is mostly done by First-come-First-Serve basis, whilst MSRTC uses certain scheduling formats for scheduling their bus services. This format is ***Form 4***. A form 4 is essentially bus time-table that is prepared at the

Division level with the help of Depot manager of that particular taluka. It is updated upon request in 6 months. This format consists of the following fields:

i) ***Schedule id:*** A schedule is a group of bus services in such a way that the bus does not change.

ii) ***Service id:*** A service is a trip between termini at any given particular time of the day.

iii) ***Crew duty id:*** A crew duty is a group of bus services in such a way that the crew does not change

iv) ***Source terminal:*** Terminal of origin

v) ***Destination Terminal:*** Terminal of destination

vi) ***Distance:*** Total distance between the source and destination

vii) ***Arrival Time:*** Time of arrival at the terminal

viii) ***Departure time:*** Time to depart at the terminal

ix) ***Type of bus service:*** The category of bus service e.g. *Mofussil, obligatory, manav-vikas*

x) ***Remarks:*** Consists of remarks

xi) ***Op-Maint schedule:*** The timings when the bus maintenance is scheduled

xii) ***Waiting time:*** Waiting time for change of duty.

Apart from this there is an ABC operational data which essentially consists of tray earning during a bus service, earnings by various concessions, revenue earned by luggage, reservation, advanced booking and various passes. The ABC data also consists of EPKM and grade of the bus service. Currently if a bus service earns greater than 43.32 Rs. / km then it is considered as **category A**, else between 43.32 and 22.1 RS./km then it considered as **category B** else **category C**. Evidently A is the most profitable and C is the most lossy. In

case of *manav-vikas* services the money is subsidized by ministry as the focus is on human-development than on profit making. These manav-vikas buses act as school buses and connect the children (especially girls) to high schools and colleges thus bringing about human development. These both data formats are handled by the traffic controller at the depot.

शहापुर आगार

वेळापत्रक तक्ता क्र.4 सन :-2017 - 2018

नियत		कामगिरी	फेरीचा			वेळ				शेरा	थांबे
क्र.		क्र.	सांकेतिक क्र.			अंतर	सुटते	पोहचते			
			शटल सेवा								
1	0	C-1	S-S1452	SHAHAPUR	MURBAD	42.7	5.45	7.15	KINHAVALI	विश्रांती	
1		C-1	S-S1453	MURBAD	SHAHAPUR	42.7	7.45	9.15	KINHAVALI	मार्ग:- किन्हवली.	
1		C-1	S-S1454	SHAHAPUR	MURBAD	42.7	9.45	11.15	KINHAVALI	मार्ग:- किन्हवली.	
1	0	C-1	S-S1455	MURBAD	SHAHAPUR	42.7	11.45	13.15	KINHAVALI	मार्ग:- किन्हवली.	
1	0			चा/वा बदल							
1	0	C-2	S-S1456	SHAHAPUR	MURBAD	42.7	13.45	15.15	KINHAVALI	मार्ग:- किन्हवली.	
1		C-2	S-S1457	MURBAD	SHAHAPUR	42.7	15.45	17.15	KINHAVALI	विश्रांती	
1		C-2	S-S1458	SHAHAPUR	MURBAD	42.7	17.45	19.15	KINHAVALI	मार्ग:- किन्हवली.	
1	0	C-2	S-S1459	MURBAD	SHAHAPUR	42.7	19.45	21.15	KINHAVALI	मार्ग:- किन्हवली.	
	0					वाहन देखभाल वेळ21.15 ते 5.45 .					

Figure 3.4: Form 4

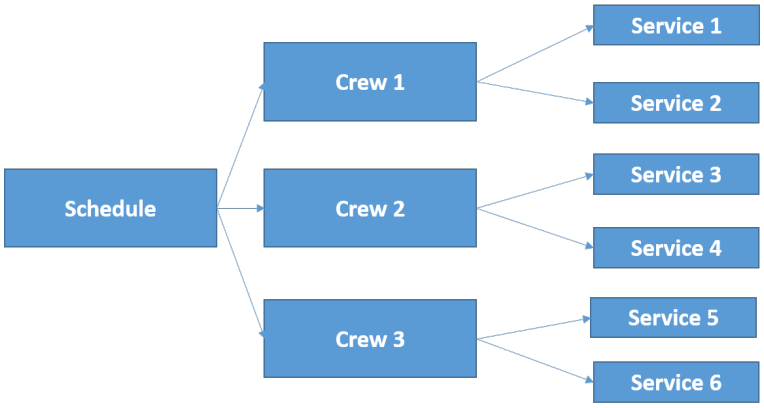


Figure 3.5: Schematic of Form 4

The following table summarizes the work of various designated employees at depot and their work.

	A	B	C	D	E	F	G
1	**Designation**	**Task**	**Input**	**Output**	**Used by**	**Stored at**	**Stores as**
2	**Announcer**	Announces arrival of Buses	**Bus Schedule from MSRTC Portal**	Announcement of arrival of Bus, Delay in bus service and inquiry	Announcer	MSRTC Server	Softcopy
3					Passenger	NA	NA
4		Updates the Control chart with the arrival time of the bus	**Control Chart**	Arrival Timings of Bus service	Depot Manager	T29 Office	Hardcopy
5	**Traffic Controller**	Assigning duties to the Crew as per Daily Shift Schedule	**Daily Attendance of Crew**	Daily Shift Allocation Schedule	Traffic Controller	Traffic Controller Office	Hardcopy
6			**Shift Schedule Roster**		Depot Manager		
7		Revenue Report	**Hard-copy of ETIM Daily Revenue data from TRIMAX**	Updated Current Month's Updated Table with ABC grading of the Bus Services	Traffic Controller	Traffic Controller Office	Softcopy
8			**Last month's ABC Table**		Division Traffic Controller	Thane Division Office	
9	**T29 Clerk**	Maintaining files (Control Chart)	**Last month's ABC Table (C8)**	Updates Daily Control chart (C4)	Announcer	T29 Office	Hardcopy
10	**TRIMAX Staff**	Printing reports, Technical Support of ETIM portal	**Credentials**	Hard-copy of ETIM daily revenue report (C7)	Traffic Controller	Traffic Controller Office	Hardcopy

Table 3.1: Duty allocation in Existing System

3.4.2 Generation and reporting of Form 4 and other ABC Operational data

Form 4 is generated at the division office located at the district by the Divisional Traffic Officer with the suggestion of Depot manager. Form 4 is essentially the ideal scenario or the service which is expected from a depot if it runs at full capacity.

The revenue earned by issuing tickets is stored in *TRIMAX* company's server. The revenue data also called as *Tray Earning* is printed and then entered in MS-Excel 2003 version spreadsheets along with the data of *Student pass*, *senior citizen pass*, *ahilyabai holkar pass*, *differently abled pass*, *luggage earning*, *reservation or advanced booking* and so on. There already pre-existing formulae on the sheet that do the grading and calculation of EPKM. The following are the steps followed to generate ABC operational data:

Step. 1 Obtain the daily revenue data from ETIM portal in hard-copy, provided by cash section to Traffic control office

Step. 2 Create a copy of previous month's ABC workbook and save as ABC_(current month)_(current year).xls

Step. 3 Update the daily data on **TRIPWISE_REG_** sheet of the ABC workbook

Step. 4 The summation of revenues of tickets sold in that month for that service reflects as tray earning in ABC table

Step. 5 This summation data along with schedule number are written manually in a notebook

Step. 6 A factor is updated on this notebook in red ink. This factor is calculated as follows:

Senior citizen multiplying factor = SCE ÷ (SCE + TE)
where, **SCE : Senior Citizen Earning**
TE : Tray Earning

Step. 7 This factor is then multiplied as an excel formula and dragged down

Step. 8 For each schedule the process is repeated in case of Shahapur Taluka the process is repeated around *55* times along with an update of data of around *15000* rows

The data is summarized and then sent to division office where for entire district data is collated and reported to higher officials. This entire process begins from the first of any month and continues till the seventh day of any given month.

Schedule No	Duty No	From	To	Deparute Time	service tax Of	Distanc	ABC Statu	TOTAL PASS EARNING (INCL VALUE OF	Luguad amin	eser vatio	Total Traffic Earning (INCL OF	Total EPKM (In Rs.)	Expected Earning	% Load Factor	sseng	remark (obligatri oprationl school
1	2	3	4	7	8	9	25	NCESSI	27	28	NCESSI	30	31	32	33	34
1	1	SHPR	murbad	5.30	7.00	42.7	C	27377	39		27416	20.71	73656	37	908	
	1	murbad	SHPR	7.30	9.00	42.7	B	52834	110		52945	40.00	73656	72	2260	
	1	SHPR	murbad	9.10	6.40	42.7	B	47855	135		47990	36.25	73656	65	2971	
	1	murbad	SHPR	11.00	12.30	42.7	B	45556	90		45644	34.48	73656	62	1948	
1	2	SHPR	murbad	13.00	14.30	42.7	B	61520	33		61552	46.50	73656	84	2640	
	2	murbad	SHPR	15.00	16.30	42.7	B	48166	33		48199	36.41	73656	65	2824	
	2	SHPR	murbad	17.00	18.30	42.7	B	56552	28		56580	42.74	73656	77	2306	
	2	murbad	SHPR	19.00	20.30	42.7	C	21313	14		21327	16.11	73656	29	1179	

Sub - A-B-C Summary of Trips for the month of AUGUST 2018 — shahapur — DEPOT

PART (I) :- Moffusial Operation

Type of Trips	No. of Trips	Effective Kms.	Passenger Earning (Tray + Adv Booking)	Net Passenger Earning (Excl Passenger Tax	Value of Concessio	et Passeng Earning + Value of Concession	Net EPKM (In Rs.)	Lugua ge	eserva	Total Traffic Earning	Total EPKM (In Rs.)	Expected Earning	% Load FActor	No. Of Passenger
1	2	3	4	5	6	7=	8 = (7/3)	9	10	11=(4+6+9+10)	12=(11/3)	13	14=(7/13*100)	15
A	27	21009	1061166	875462	191227	1066689	50.77	1159	990	1254542	59.71	932169	114.43	37701
B	296	314450	9295559	7668836	2470213	10139049	32.24	17406	1125	11784303	37.48	13952147	72.67	399248
C	107	61874	672983	555211	140131	695342	11.24	1339	0	814453	13.16	2745349	25.33	37651
TOTAL	430	397333	11029708	9099509	2801571	11901080	29.95	19904	2115	13853298	34.87	17629665	67.51	474600
Manav Vikas	72	26743	378636	312375	690453	1002828	37.50	1449	0	1070538	40.03	1186587	84.51	43409
Pure Extra	120	14776	515258	425088	38623	463711	31.38	303	0	554184	37.51	656611	70.73	13083
TOTAL	622	438852	11923602	9837972	3530847	13367819	30.46	21656	2115	15478026	35.27	19471863	68.65	531092

Figure 3.6: ABC data development

senior citizen

ABC Operational Form

=(M12*0.07053)

18	From	To	Seating Capacity	Deparute Time	service tax Of	Distance	Fare	Trips Optd.	Effective Kms.	Trag Earning + Advance Booking
951										
2416	3	4	6	7	8	9	10	11	12.0	13
3529										
2433	SHPR	murbad	44	5.30	7.00	42.7	54	31	1324	13486
	urbad	SHPR	44	7.30	9.00	42.7	54	31	1324	34255
	SHPR	murbad	44	9.10	6.40	42.7	54	29	1238	50034
3086	urbad	SHPR	44	11.00	12.30	42.7	54	29	1238	34491
4242	SHPR	murbad	44	13.00	14.30	42.7	54	31	1324	44580
2562	urbad	SHPR	44	15.00	16.30	42.7	54	31	1324	61280
1692	SHPR	murbad	44	17.00	18.30	42.7	54	31	1324	37019
	urbad	SHPR	44	19.00	20.30	42.7	54	31	1324	24438

Date	RIP	Time passenger earnig
19	1	474
20	1	508
21	1	770
22	1	573
23	1	522
24	1	501
25	1	212
26	1	696
27	1	297
28	1	1511
29	1	253
30	1	733
31	1	243
	31	13486

Figure 3.7: ABC data development

3.4.3 Bus schedule management

Any bus schedule under operation is used to generate the *control chart*. It is an everyday activity where the clerk will update the control chart containing bus-services with their previous month's grade. Arrival-departure of any bus on bus stand is announced by Announcer. The actual arrival time is updated daily on the control chart by the Announcer. After the shift the control chart is stored as hard-copy in the designated department. Any clashes between late arrival of the bus services for same route is resolved by marked the late bus as cancelled in the control chart.

3.4.4 Selection of *Manav-Vikas* buses

Manav-vikas bus services are those whose purpose is to aid human development. These buses act as school buses and college buses, act as a village-town, village-city connect to otherwise disconnected villages. The bus-service is selected on the basis of % of SC-ST population in a village based on census data and the school / college plying time.

3.4.5 Creation of new routes

Any new route creation takes many steps. Approval to start a new bus-service / route is given by division office to the depot, upon suggestion of depot manager. They are as follows:

Step. 1 A new bus route is proposed by the depot manager on letter to division office

Step. 2 Divisional traffic officer will allocate a Surveyor along with a trainee bus driver

Step. 3 A team of Surveyor-trainee driver start GPS and stop watch from Shahapur Depot to the destined location and record the total turn around time

Step. 4 If there are any repair work required on the road or the route is deemed unsafe then it is reported to the Divisional Traffic Officer and Depot Manager

Step. 5 If that repair work is related to PWD then a letter is drafted by depot manager the Chief Engineer of PWD and then they take up the task of repairing the said route

Step. 6 For repair works the contractor designated to take care of the road is summoned and is asked to do the repair work and report the fitness of the road after the repair

Step. 7 Once the fitness of road is received, Chief engineer confirms to depot manager on letter

Step. 8 If the road is *kuccha* then it is reported by the team and road construction under MGNREGA, PMGSY takes place by involving relevant departments

Step. 9 Depot manager continues from *Step. 1* to *Step. 6*

3.4.6 Crew Management

Crew Management is mostly done by the Traffic controller and Depot manager. There is a shift allocation roster which is in hard-copy which is followed in allocating shifts to the crew.

3.4.7 Ticket vending in buses

Every conductor for any bus-service needs to get an ETIM issued from cashier along with cash change. In the cashier's cabin there are many charging ports which charge the unused ETIMs. These ETIM, their data management is outsourced to TRIMAX company. As any crew duty begins the crew enters the crew-id and service id in the machine and then starts issuing tickets. For every ticket sold the amount along with the timestamp is stored in the database. Once the duty is over the crew ends the service in the machine and the entire data is flushed, committed to the database server of TRIMAX. In case of unavailability of ETIM or power cut or any unforeseen circumstances,there is a backward compatibility with storing old ticket vending data in register along with the tin tray is used.

3.4.8 Storage of data

Data in depot is stored in both hard-copy and soft-copy. The form 4, ABC data is available as spreadsheets, ETIM data is stored in TRIMAX servers. Whereas the crew allocation, control charts etc. are stored as hard-copy.

3.4.9 GIS Based Systems available with MSRTC

i) **GIS Portal:** The GIS portal is managed by *Riddhi enterprises*. The portal consists of data which can be queried as range queries, displaying of histograms of earning /revenue at real time. This data is coupled with census data as well.

ii) **Availability of GIS data at Taluka level** GIS data is not available at Taluka level. They only have a point geometry and a polygon geometry.

iii) **Portal for ETIM** Each depot is given one technical staff from TRIMAX to assist them with repair of ETIMs and the portal. The ETIM portal displays the data of the tickets vended and revenue earned by issuing tickets. This data is not downloadable it can only be printed. This printed data is then given to the Traffic controller to prepare the ABC table

iv) **Vehicle Tracking System** VTS is currently taken as a pilot project contracted to *Rose-marta* company. They have been given an office space for monitoring the vehicles from Mumbai-central office. The monitoring portal alerts in case of over-speeding, harsh braking, route deviation etc.

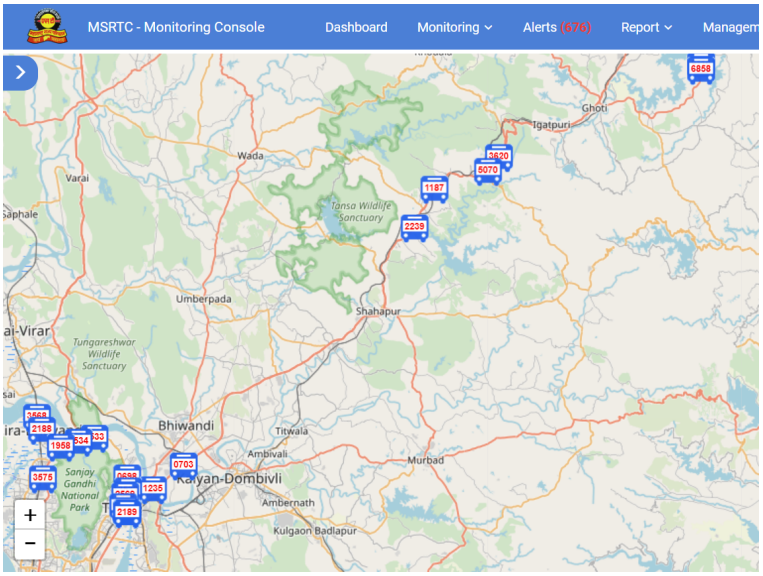


Figure 3.8: Vehicle Tracking System of Nashik District

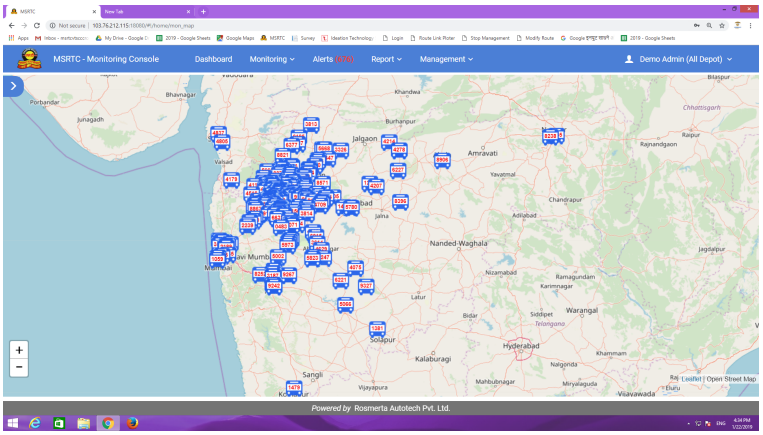


Figure 3.9: Vehicle Tracking System of Nashik District

v) **Availability of latest technology** As it turns out the technological stack in MSRTC is very heterogeneous. At depot level the MS-Excel version used is 2003 and Operating system is also outdated. On the other hand they employ Gmail for communication and Rediffmail for higher officials like GM traffic, Dy. GM IT, VCMD MSRTC etc.

3.4.10 Non-MSRTC service providers

The illustration of various non-MSRTC service providers is as follows:

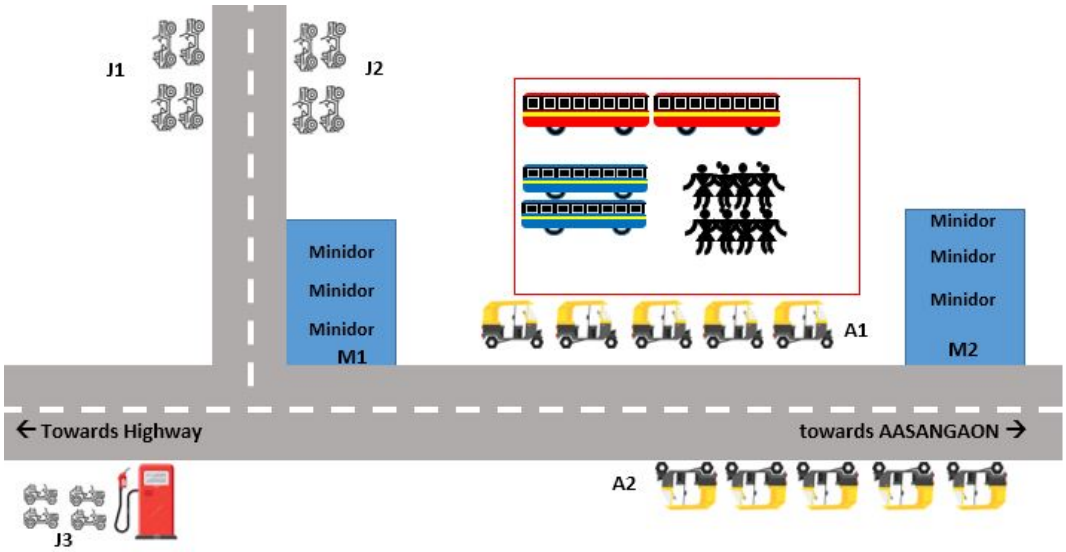


Figure 3.10: Illustration of Non-MSRTC Service providers

Here,**A1, A2** : Auto-rickshaw stands

J1, J2, J3 : Jeep Stands

M1, M2 : Minidor Stands

Jeep stand J3 has a garage also where these drivers do their vehicle's maintenance. Almost all of them were upper-castes. They all practiced rain-fed agriculture. They treated driving as a full-time job. They (except the minidors) had an association that determined the prices. All the minidors were in dilapidated condition. The popular choice of vehicle amongst jeep drivers was "Mahindra Max".All drivers worked on FIFO policy. Very few of them were doing 2-3 trips daily.Most of the roads were under construction hence gave an upper hand to smaller 4 wheelers than MSRTC buses. Autowallahs schedule was in sync with the local train schedule of Asangaon. The jeeps ply to the nearest locations within a distance of 10-15kms to *Aghai, Bhatasa, Khardi, Sarlambe, Hiv, Lenad, Shenave, Kinhavali, Dolkhamb, Sakalbav, Kothera, Gegaon and Murbad via Lenad Route*. Minidors ply to the smaller routes to *Dhasai, Vashind, Nadgaon*. The prices are as follows:

i) Auto-Rickshaw : 15 Rs. per seat

ii) Minidor : 15 Rs. per seat

iii) Jeep : 30 Rs. per seat; 40 Rs. per seat (*Murbad*)

3.4.11 Stakeholder Regulatory Mechanisms

i) **Panchayat samiti meeting** Following is the illustration of a typical Panchayat Samiti Meeting:

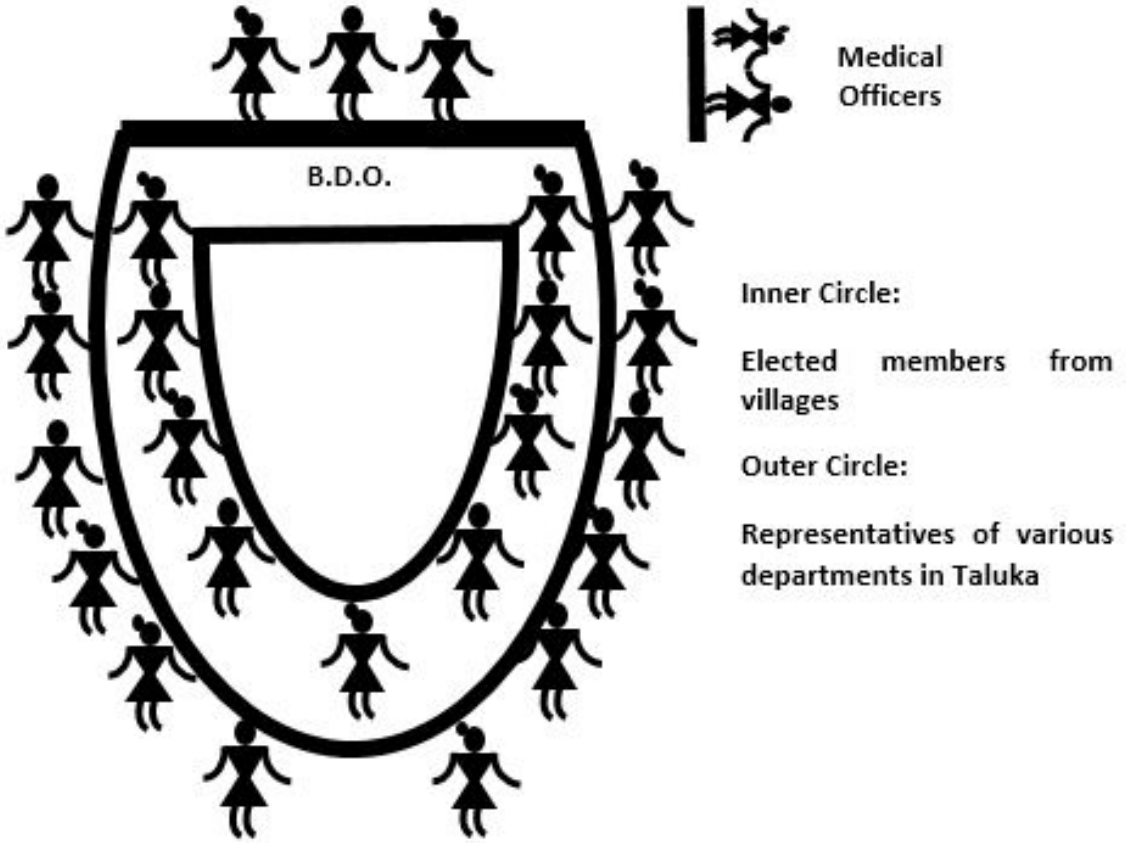


Figure 3.11: Illustration of Panchayat Samiti Meeting arrangement taken place at Panchayat Samiti Office at *Second April 2019*

As evident from the figure the inner circle consists of the elected members and outer circle consists of the various designated personnels like school teacher, veternary doctor, PHC head, Depot manager and so on. They present their monthly work in the meeting to the elected members in the presence of BDO and other elected members of block. The meeting takes in two halves. First half consists of a combined meeting of elected members and representatives. Second half consists of meeting of BDO with the representatives of various departments. Depot manager presents the number of trips operated

and revenue earned in the last month in a summary on a mic. This meeting typically takes place at the first working day of the month.

ii) ***Vahatuk* associations** As understood from the literature review and field work there is a presence of *Vahatuk associations* in Shahapur Taluka. This association is of Autorickshaws and Jeeps. The jeep driver association office is located at *Kinhavali*. The auto-rickshaws' association is located in *Shahapur* itself. These associations regulate the prices of the trips and help government in ensuring proper licensing of drivers and vehicles' papers are in place. They also have political support from *Ma.Na.Se. or Shivsena*.

iii) **Worker Unions within MSRTC** There is a strong presence of MSRTC worker's Union in the corporation. Apart from worker union there are Ambedkarite unions within the MSRTC. These unions strive to serve and protect the interests of the employees of MSRTC.

3.4.12 Infrastructure

i) **Proximity with Asangaon Railway Station** *Asangaon* railway station is hardly 2 kms away from Shahapur depot and acts as a source of passengers to both autorickshaw and Shahapur depot.

ii) **Proximity of National Highway** National Highway towards Nashik is in proximity of 1 kms from depot because of which many jeeps ply for long distances travels and many passing jeeps stop by Shahapur. The highway connects *Shirdi, Nashik, Indore* ably.

iii) **Availability of Infrastructure** The following infrastructure is available in Depot which is internet, LED TV, CCTV cameras, email, computer, printing facility, *pucca* building for housing passengers, employees, a well functioning workshop etc.

iv) **Road Construction work in taluka** Currently a lot of construction work is going on pan taluka. The road construction will reduce the time for commutation to *Murbad* by 20 mins.

Figure 3.12: Road Construction in *Shahapur - Murbad road via Lenad*

3.4.13 Seasonality

Since Shahapur lies in hilly terrain and also in high rainfall zone, seasonality becomes very important factor in deciding bus services during monsoons. Apart from that there is a special load of passengers going for *Dindi Yatra Pandharpur* etc. During the month of August the buses go to Nashik depot to cater the increased demand for religious activities.

3.4.14 Grievance redressing mechanism

There is a complaint book in the traffic controller office on which the passengers can register a complaint. Mostly the passengers complaint orally to the depot manager and no official complaint is lodged in written format.

3.4.15 Role of Announcer

Announcer is responsible to record the arrival and departure timings of the bus service. He/she is also responsible for recording the cancelled or late bus services in the control

chart.

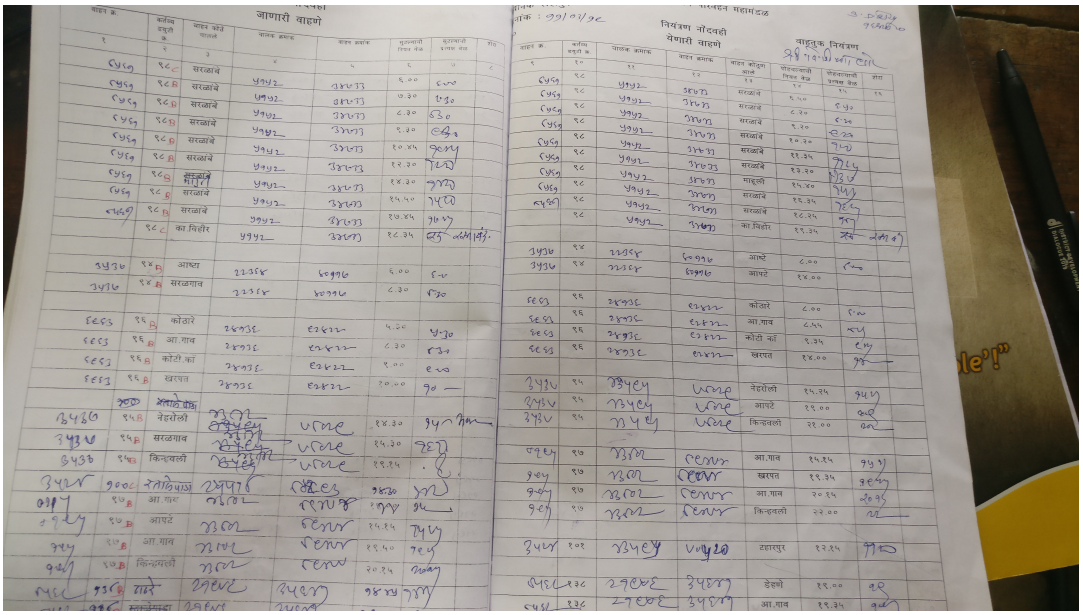


Figure 3.13: Image of Control Chart

3.5 Problems with existing system

Following are the problems identified:

Problem 1) Lack of convergence of Transportation, GIS and Demographics data

Problem 2) Drudgery in preparing ABC operational data

Problem 3) No synchronization between ABC and form 4

Problem 4) Lack of GIS data at taluka level

Problem 5) Absence of a unified database for demand estimation and service provisioning

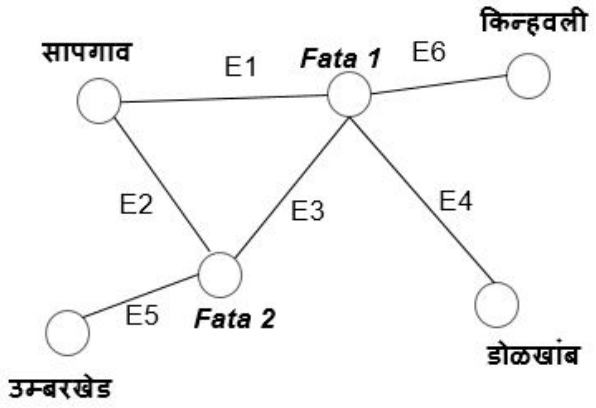
Chapter 4

Digital Geography

4.1 Graph Theory

A graph **G(V,E)** is a data structure consisting two non-empty sets **V** and **E** where:

- **Node** or a vertex represented by **V**.
- **Edge** is a connection between ordered set of nodes *(*u,v). Ordered pair because there is an inherent property of direction in graphs. In case of digraphs(explained in subsequent section) *(u,v)* does not equal to *(v,u)*. Set of edges is represented by **E**.



E = *{E1, E2, E3, E4, E5, E6}*
V = *{* सापगाव, डोळखांब, उम्बरखेड, किन्हवली, *fata1,fata2}*

Figure 4.1: A sample graph

4.1.1 More on Graphs

i) **Adjacent Node:** A node *v* is said to be adjacent to *u* if and only if there exists an edge *e(u,v) and/or e(v,u)* between them.

ii) **Degree of a Node:** A degree of a node or **deg(v)** can be defined as the number of edges incident to that node. For a directed graph there can be both in-degree deg^{+}**(v)** and out-degree deg^{-}**(v)**. In-degree can be defined as the incoming edges to the vertex whereas out-degree can be defined as outgoing edges from the vertex.

iii) **Path:** A path is a trail in which neither vertices nor edges are repeated i.e. if we traverse a graph such that we do not repeat a vertex and nor we repeat an edge. It can be given as an ordered sequence of **n** length between two vertices **v** and **u** consisting of **n+1** nodes, with the exception that the source and destination are the same.

$$\textbf{P(u,v)} = \{ v_1, v_2, v_3..v_{n+1} \}$$

iv) **Planar Graphs** A graph is said to be planar if it can be drawn on a plane without any edges crossing. Such a drawing is called a planar representation of the graph.

4.2 Bus Networks as a Graph (1)

Surface street networks are a great examples of graphs and become a substrate for many graph theory based questions. Network properties that interest in the transportation area are mostly towards connectivity, complexity, coverage and directness. Methodology proposed by Derrible and Kenned (2010) to redraw metro networks into graphs G(V, E) by removing the intermediate vertices and considering the end and transfer edges. A Transfer station can be defined as the stations where it is possible to change routes without leaving the system. Mathematically the number of vertices can be expressed as :

$$V = V^T + V^E \text{ (1) where,}$$

V^T : Transfer station, V^E : End station

4.3 What is digital geography?

A *digital geography* is an undirected, planar graph **G= *(V, E)* where:**

***V* is a set of vertices.**

***E* is a set of edges.**

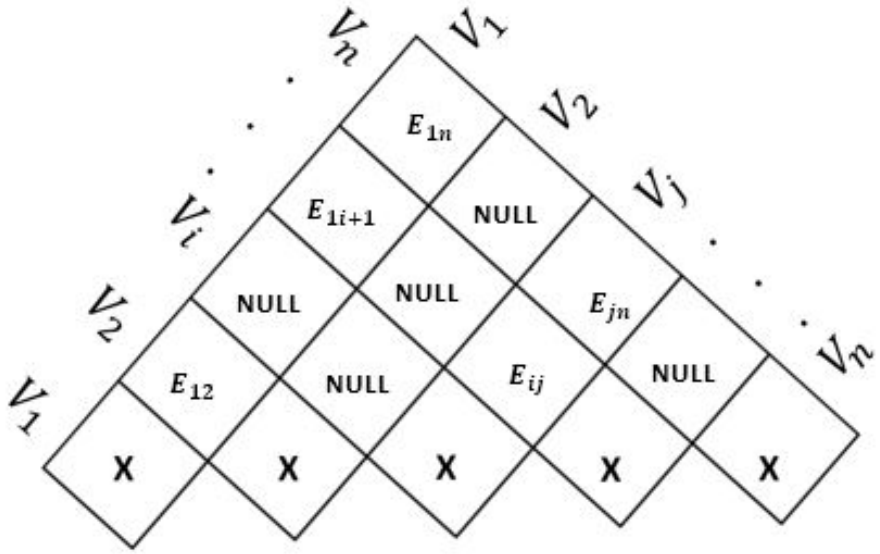


Figure 4.2: Schematic of Digital Geography

4.3.1 Properties of a Vertex

property 1 Each vertex is a *Point* geometry.

property 2 Each vertex has a latitude and longitude.

property 3 A vertex may have an attribute as school, market place, hospital etc.

4.3.2 Properties of an Edge

property 1 Each edge is a *Polyline* geometry.

property 2 Each edge e is an ordered set of vertices (v_i, v_j) such that v_i and v_j ε **V**.

property 3 An edge cannot have intermediate points belonging to V.

property 4 An edge subsequently can have further attributes like type of road, length of the edge, traffic on the edge, profitability of the edge etc.

4.3.3 Route-segment

A route segment RS_i is a path between two termini. It is an ordered set of edges.

i.e. $RS_i = \{ E_{i1}, E_{i2}, E_{i3}..E_{in}\}$ where, ***n= number of edges in*** RS_i

and

$\{E_{i1}, E_{i2}, E_{i3}..E_{in}\} \varepsilon E$

$\boldsymbol{E} = RS_1 \cup RS_2 \cup RS_i.. \cup RS_m$ where,

m= number of Route segments in in RS

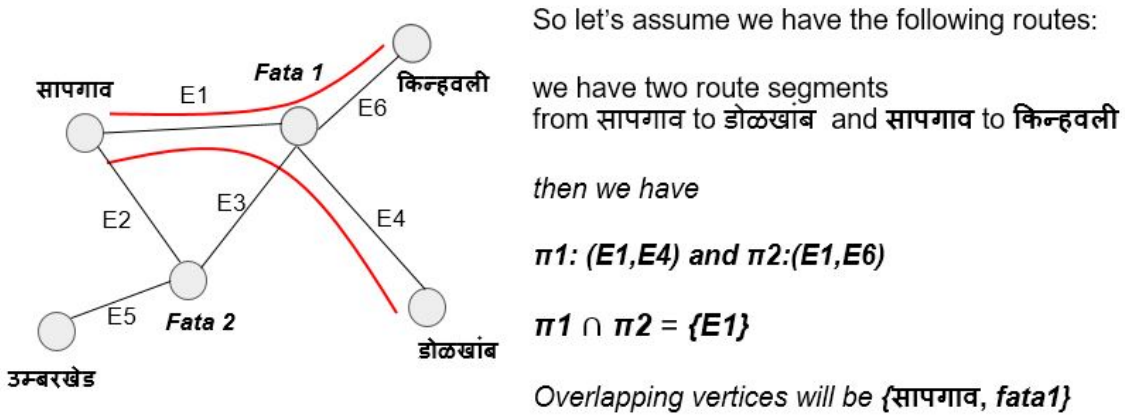


Figure 4.3: Route segment with an example

4.3.4 Graph theory in real life

Consider the following scenario as shows below

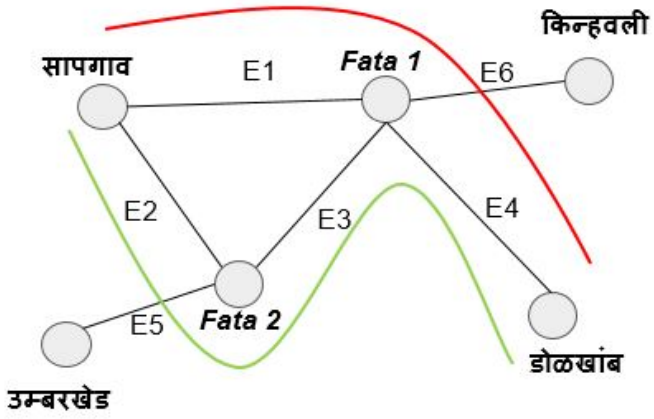


Figure 4.4: Real life example

The question arises here that if a person wants to travel from *Sapgaon* to *Dolkhamb* there can be two pathways to go about it. Now further questions that arise from this problem are:

Q. What is the requirement?

Q. Which stakeholder am I?

A Depot manager would want the route-segment be profitable, maximum coverage, minimum distance and minimum time.
A Tourist would want to explore the scenic beauty of the way to *Dolkhamb* during monsoons. So the paths come out as follows:

$$\pi_1 = \{E_1, E_4\}$$
$$\pi_2 = \{E_2, E_3, E_4\}$$

These π_1 , π_2 are essentially route-segments.

4.4 Application of Digital Geography

Digital geography finds its application in the following areas and beyond:

i) Public Transportation:

Digital geography has geospatial properties which makes it ideal for transportation planning especially in rural areas. In Urban planning it will help the planners in estimating the probable demand and beneficiary analysis of any new infrastructure that's coming up for example like a metro station.

ii) Watershed Management:

Digital geography coupled with DEM file can help in modelling the stream network for a given watershed.

iii) Network modelling:

Network modelling of flow of materials, humans, service etc. from one place to another can be modelled using Digital Geography.

iv) Urban Planning:

Digital geography will prove very useful to the planners because it will reduce the need for surveying and can be easily updated. It will aid better decision making to the planners.

4.5 Problem statements

i) *"Given a finite set of points and a finite set of interconnected lines such that the points ALWAYS lie on the lines. How to develop a digital geography?"*

The challenge here is, since government does not have any GIS data of bus-stops we do not have a finite set of points. So how to arrive at such set of points which is empirical to the bus-stops' data if it was available.

ii) *"Given a digital geography how to add taluka bus transportation operational data along with it."*

The challenge here is, the operational data available is not in proper consistent format. Form 4 and ABC data lack in data consistency amongst themselves. So data cleaning becomes an essential part of database creation and population.

Datasets used are **form 4** and **ABC operational form** details of which are in previous chapter:

(a) **Form 4**

(b) **Operational Form**

4.5.1 Database Design

Scenario: A terminal *is a* vertex. A *fata is a* vertex. Route-segment *has two* terminals. Route-segment *has many* edges. Route-segment *has many* vertices. An edge *has two* vertices. In a form4 many schedules ply. A schedule can have multiple crew duties. A crew duty has many bus services. A bus service is a trip between two termini at any given arrival time t_{arr} and departure time t_{depart}. Each combination of termini has a route-segment. Each route-segment has line geometry. The Entity-relationship diagram is as follows:

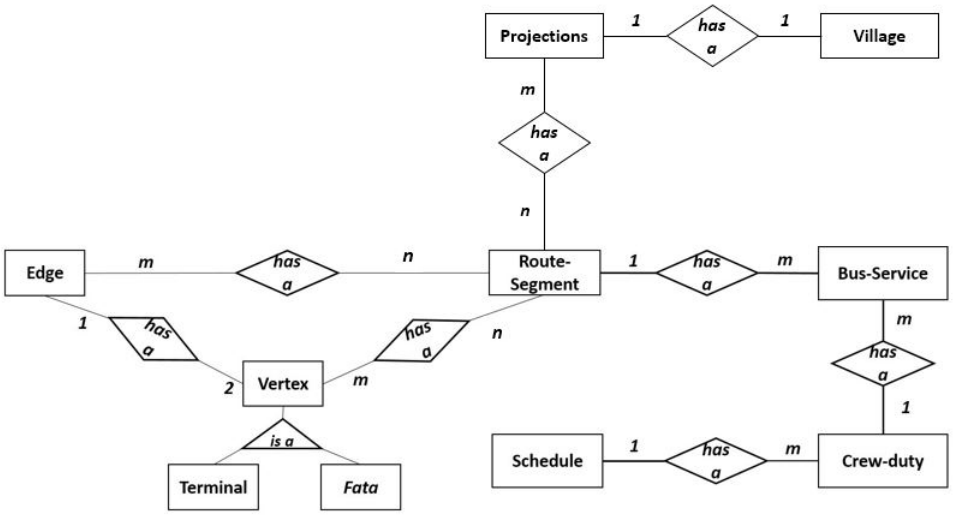


Figure 4.5: Entity-Relationship diagram for Database

Upon inspection we can form the following entity tables:

i) **vertex**: stores the information of vertices.

ii) **edge**: stores the information of edges.

iii) **route-segment**: stores the information of route-segment.

iv) **terminal**: stores the information of termini.

v) ***fata***: stores the information of fatas.

vi) **Schedule:** stores the data of schedules operated

vii) **Crew-duty:** stores the crew-duty ids of the crew

viii) **Bus-service:** stores the data of the bus-services operated.

Upon inspection we can form the following relationship tables:

i) $e\_intersect\_rs$: stores the information of the relationship between edges and route-segments.

ii) $v\_intersect\_rs$: stores the information of the relationship between vertices and route-segments.

iii) $v1\_v2\_e$: stores the information of the relationship between the vertices and edges.

4.5.2 Schema

Field	Type	Description
fid	character varying	Unique identifier
geom	geometry(Point,4326)	Geometry type
name	character varying(30)	Name of the terminal
name_mar	character varying(30)	Name of terminal in Marathi
village	character varying(30)	Name of Village in which terminal lies
taluka	character varying(30)	Name of Taluka
taluka_mar	character varying(30)	Name of Taluka in marathi
div	character varying(30)	Name of division
div_mar	character varying(30)	name of division in marathi

Table 4.1: Schema of Termini

Field Name	Field Type	Description
vert_id	character varying(30)	Unique id of a vertex
geom	geometry(Point,4326)	Point geometry of the vertex

Table 4.2: Schema of Vertex

Field Name	Field Type	Description
edge_id	character varying(30)	Unique id of an Edge
geom	geometry(LineString,4326)	Polyline geometry of that edge

Table 4.3: Schema of Edge

Field Name	Field Type	Description
route_segment_id	character varying(30)	Unique id of Route-segment
geom	geometry(LineString,4326)	Polyline geometry of the route segment

Table 4.4: Schema of Route Segment

Field Name	Field Type	Description
route_segment_id	character varying(30)	Unique id of route-segment
edge_id	character varying(30)	Unique id of Edge
seq	integer	sequence of occurrence of an edge

Table 4.5: Schema of Relationship between Edges and Route Segment

Field Name	Field Type	Description
route_segment_id	character varying(30)	Unique id of a Route segment
vert_id	character varying(30)	Unique id of Vertex
seq	integer	Sequence of occurrence of vertex on route-segment

Table 4.6: Schema of Relationship between Vertices and Route Segment

Field Name	Field Type	Description
route_segment_id	character varying(30)	Unique id of Route-segment
census201	integer	Unique id of census village

Table 4.7: Schema of Relationship between Projections and Route Segment

Field Name	Field Type	Description
termini1	character varying(30)	Unique id of terminal
termini2	character varying(30)	Unique id of terminal
via	character varying(30)	Unique id of Via terminal
route_segment_id	character varying(30)	Unique id of route segment
bus	boolean	Flag to indicate Bus route
jeep	boolean	Flag to indicate Jeep route
minidor	boolean	Flag to indicate Minidor route
rickshaw	boolean	Flag to indicate Bus route

Table 4.8: Schema of Terminal and Route-segment relationship table

Fields	Type	Description
scheduleid	numeric(30, 0)	Unique id of schedule
dutyid	character varying(50)	Unique id of crew duty
serviceid	character varying(50)	Unique id of Bus service
source_eng	character varying	Name of source village
source_mar	character varying	Name of source village in marathi
destination_eng	character varying	Name of Destination village
destination_mar	character varying	Name of Destination village in marathi
arrival	timestamp(6) without time zone	Arrival time
depart	timestamp(6) without time zone	Departure time
distance	numeric(10, 0)	Distance between the two termini
route_segment	character varying(50)	Unique Route segment Id

Table 4.9: Schema of Form 4

Fields	Type	Description
scheduleid	numeric(10,0)	Unique id of Schedule
dutyid	numeric(10, 0)	Unique id of Crew-Duty id
serviceid	character varying(50)	Unique id of Bus service id
source	character varying(50)	Unique id of source terminal
destination	character varying(50)	Unique id of destination
seat_capacity	numeric(10, 0)	Bus seating capacity
arrival	time(6) without time zone	Arrival Time of Bus
depart	time(6) without time zone	Departure Time of Bus
distance	double precision	Distance between the termini
fare	real	Total fare to travel between termini
trips_optd	numeric(10, 0)	Number of trips operated

		in a month
tray_earn_ad_book	numeric(10, 0)	Tray earning by issuing tickets
student_pass	numeric(10, 0)	Earning from Student Pass
senior_citizen	numeric(10, 0)	Earning from Senior citizen pass
ahilya_holkar	numeric(10, 0)	Earning from Ahilya holkar concession pass
other	numeric(10, 0)	Other earnings
luggage_earning	numeric(10, 0)	Earning from luggage
reservation	numeric(10, 0)	Earning from Reservation
passengers	numeric(10, 0)	Number of passengers
remark	character varying(50)	Remark
month	character varying(50)	Month of the year
manav_vikas	character varying(50)	Bus lying in Manav-vikas

Table 4.10: Schema of Operational Data

4.5.3 Data available

The following data is available:

i) MRSAC data of Road network of Undivided Thane.

ii) Set of terminals obtained from form 4, ABC data and field survey of non-MSRTC service providers

iii) Polygon file of villages of Undivided Shahapur taluka along with census data in attribute table

4.5.4 Tools and Technology Stack used

Application: QGIS 2.18 las palmas

Tools:pgadmin4

DBMS: postgreSQL (PostGIS extension for geospatial data)

Scripting: python 2.7

Packages: PyQt4, networkAnalysis

4.5.5 System Configuration

Pre-requisite:

i) QGIS and PostGIS must be connected by a db connection. Steps of which can be found in appendix.

ii) Python 2.7 is already installed in the system.

iii) All the shapefiles are imported in the form of PostGIS tables.

Assumptions:

i) All the roads are assumed to be one-laned and bidirectional.

ii) The data source is MRSAC and all the route-network is based on that data.

iii) Census data is only considered for *Shahapur Taluka* only

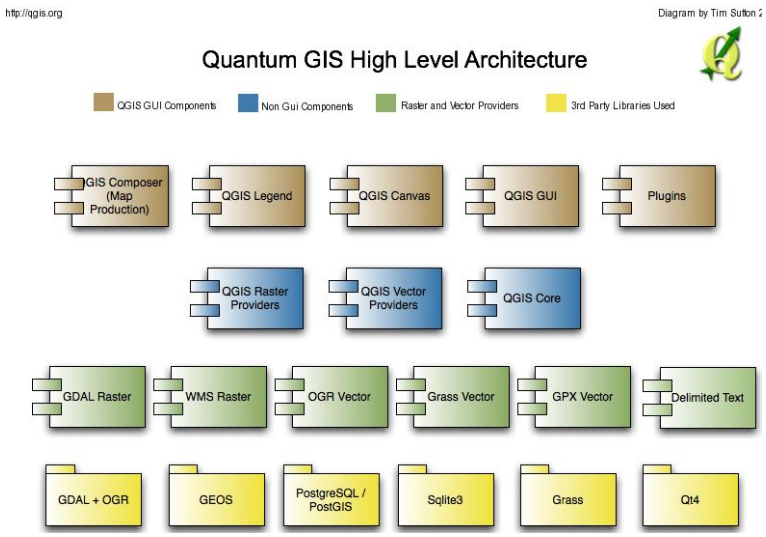


Figure 4.6: Diagram of High-level QGIS architecture

4.5.6 Methodology

The methodology is as follows:

i) Consideration of via routes in the route-segment file i.e. there are two bus-services from *Shahapur* to *Murbad* via *Kinhavali* which is a longer route to *Murbad*, other is from *Shahapur* to *Murbad* via *Lenad* which is a smaller route. Such via routes are now catered by the system.

ii) Earlier $\boldsymbol{V} = T \cup F \cup P$, this was the approach being used to generate the **V** set. Now, with the updated methodology I have found all the *fatas* on the road network that lie on the bus-transport network. These **fatas** along with termini give much better insight to the actual system because a villager will access the *fata* to reach for bus service.

iii) The projections (P) set that was used earlier in Vertex set is now used independently with route-segment.

iv) Integration of Non-MSRTC service provider's route-segments in the system. The updated system tries to create a super-set of route-segments, subset of those relevant to that service provider can be constructed.

v) Distance between vertices is restricted to greater than 300 metres as per the rural planning norm. This is a conscious choice because if a bus stops frequently that causes delay and discomfort to the passengers. Apart from that it also reduces unnecessary computations.

vi) More uniform size of Edges. In earlier system edge length ranged from 20-25kms to 30 metres because earlier assumption was to cater to people in Shahapur Taluka only. The new system considers not only this but also the practical aspect of bus-stops in routes outside the taluka. There is still an exception to this which is the Nashik and Borivali route, which couldn't be decomposed because of the unavailability of data of roads for these places.

vii) Greater tolerance for the imperfect geometries. The system now handles geometries with better tolerance to give better intersection data for analysis.

4.5.7 System Design

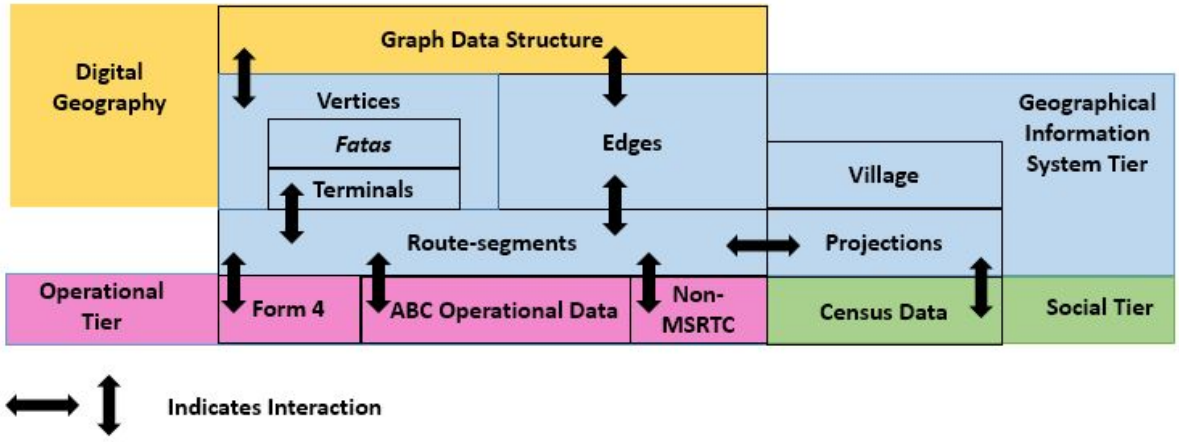


Figure 4.7: Conceptual framework of the system

As evident from the figure there are three tiers to this conceptual framework. The first one is the **Geographical Information System**. This tier encompasses the geographical objects like vertices, edges, route-segments and projections. A vertex object is made up of *fatas* and termini. Together vertices and edges when stored in a mapping help in building a graph data-structure whose node elements are vertices and linkages are edges. Route-segment consists of termini and edges hence there is an interaction. Apart from edges and termini, route-segments interact with vertices. There is also village polygon shapefile. The **Geographical Information System** tier interacts with the other two tiers namely **Operational** tier by route-segment object and **Social** tier by projections object. The **Operational** tier consists of the various operational data frameworks used by *taluka* bus-depot namely form 4 and ABC operational data. Along with this there is non-MSRTC service providers routes data that interacts with route-segments. The projections interact with both route-segments and social tier. In social tier there is census data which interacts with projections data along with the village polygons.

4.5.8 Terminus (Set T)

A ***terminus*** or **Set T** is a set of points which are terminus. A terminus is a point that is either the beginning or the end point of any Bus Route.

4.5.9 Fatas/ Forks/Junctions (Set F)

A ***Fata*** or **Set F** is a set of points / vertices that have degree greater than 2. A fata can be a village fata that is on the ST bus road network which is derived out of the entire road network of Thane. A fata can be a ST bus fata which the point where there is a diversion from the route for an ST bus.

4.5.10 Projections (Set P)

A ***projection*** or **Set P** is a set of points / vertices that are the shortest hub points from the village polygon's *geometric centroid*.

4.5.11 Route Segments

A route segment RS_i is a path between two termini. It is an ordered set of edges.
i.e. $RS_i = \{ E_{i1}, E_{i2}, E_{i3}..E_{in}\}$ where, ***n= number of edges in*** RS_i
and
$\{E_{i1}, E_{i2}, E_{i3}..E_{in}\} \varepsilon E$

A union of all the route segments gives us the set ST which is essentially the subset of all the roads in the taluka and the roads from which the State transport buses pass.

$$\boldsymbol{ST} = RS_1 \cup RS_2 \cup RS_3 .. \cup RS_m$$

where,
m= number of Route segments in in RS

4.6 Data Preparation

In this section I'll try to enlist all the approaches taken in creating Digital geography and how through each iteration I refined the same.

4.6.1 Assumptions

The assumptions are fairly simple:

i) Only villages inside the Shahapur Taluka are taken into account

ii) Certain villages do not have a geometry because village boundaries are very fluid and keep on changing with each census, villages that do not have a geometry are ignored in the subsequent steps

iii) Since the scope of the project is transportation intra-taluka and nearby talukas hence inter-city transportation is not considered in any step

iv) Any road is treated as a line i.e. if there is a four-lane highway it is treated as one polyline only so as to avoid further complications.

v) Fatas are the points from where majority villages access the transportation. Hence it is assumed that fatas will be the bus-stops.

4.7 Steps to get Digital Geography

Pre-requisites:

i) Polygon file of Villages in Shahapur Taluka with the Census data. Which is as follows:

Figure 4.8: Shahapur Taluka Boundary

shahapur_taluka_boundary_validated :: Features total: 223, filtered: 223, selected: 0

	district_c	district_n	taluka_cod	taluka_nam	census_201	ward_no	area_name	area_type	hh_tot_tot	hh_tot_g	hh_tot_l	hh_tot_d
1	517	Thane	4167	Shahapur	552767	0	Patol	Rural	100.00000	30.60000	53.20000	16.20000
2	517	Thane	4167	Shahapur	552791	0	Hedvali	Rural	100.00000	79.30000	13.20000	7.40000
3	517	Thane	4167	Shahapur	552909	0	Dahivali	Rural	100.00000	8.00000	84.20000	7.70000
4	517	Thane	4167	Shahapur	552713	0	Koshimbade	Rural	100.00000	40.50000	59.00000	0.50000
5	517	Thane	4167	Shahapur	552756	0	Vashala Bk	Rural	100.00000	77.60000	17.40000	5.00000
6	517	Thane	4167	Shahapur	552820	0	Shilottar	Rural	100.00000	34.90000	59.70000	5.40000
7	517	Thane	4167	Shahapur	552690	0	Aghai	Rural	100.00000	64.00000	31.30000	4.70000
8	517	Thane	4167	Shahapur	552794	0	Ranvihir	Rural	100.00000	58.50000	28.90000	12.50000
9	517	Thane	4167	Shahapur	552879	0	Khutghar	Rural	100.00000	81.50000	16.10000	2.40000
10	517	Thane	4167	Shahapur	552796	0	Babare	Rural	100.00000	46.00000	49.20000	4.80000
11	517	Thane	4167	Shahapur	552904	0	Vithobachegaon	Rural	100.00000	79.40000	10.50000	10.00000
12	517	Thane	4167	Shahapur	552883	0	Nadgaon (Lonad)	Rural	100.00000	42.20000	55.40000	2.40000
13	517	Thane	4167	Shahapur	552704	0	Sakharoli	Rural	100.00000	59.00000	40.40000	0.60000
14	517	Thane	4167	Shahapur	552711	0	Vehlonde	Rural	100.00000	16.30000	69.20000	14.50000
15	517	Thane	4167	Shahapur	552873	0	Valshet	Rural	100.00000	77.80000	21.00000	1.20000
16	517	Thane	4167	Shahapur	552714	0	Piwali	Rural	100.00000	85.00000	14.40000	0.60000
17	517	Thane	4167	Shahapur	552754	0	Umbravane	Rural	100.00000	15.00000	55.00000	30.00000
18	517	Thane	4167	Shahapur	552889	0	Lenad Bk.	Rural	100.00000	52.70000	45.50000	1.80000
19	517	Thane	4167	Shahapur	552817	0	Kulhe	Rural	100.00000	30.90000	63.90000	5.20000

Figure 4.9: Shahapur Taluka Polygon Attribute Table

ii) Road network of Undivided Thane *source: MRSAC*

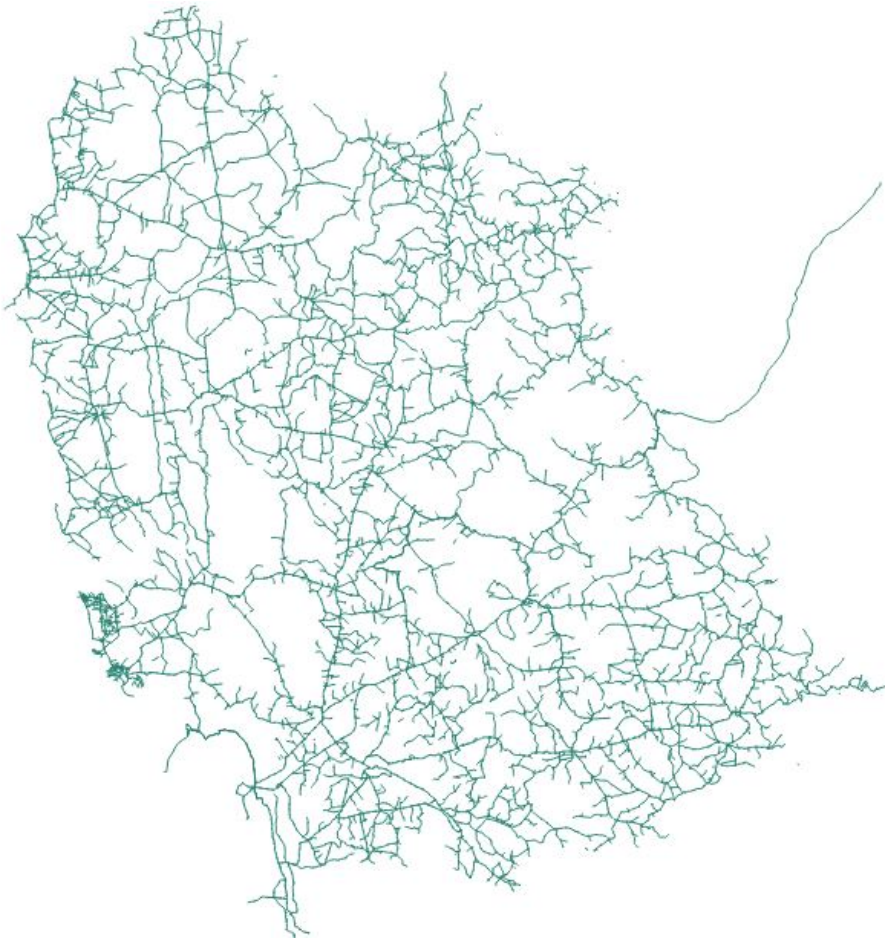


Figure 4.10: Road Network

Its attribute table is as follows. Notice the Road_type, type and sub_type columns, length_m.

	LENGTH	ROAD0_	ROAD0_ID	TALUK_CODE	SRIMS_CODE	PWD_TYPE	PWD_CODE	ROAD_TYPE	TALUK	TYPE	SUB_TYPE	LENGTH_M	ROAD_CODE
1	724.35838	1	205	0032	60	VR-3	003260003	Village Road	Talasari	Metalled - Black T...	Village Road	754.29000	0104
2	18.75583	2	205	0032	60	VR-3	003260003	Village Road	Talasari	Metalled - Black T...	Village Road	18.76000	0104
3	17.78309	3	206	0032	60	VR-3	003260003	Village Road	Talasari	Metalled - Black T...	Village Road	17.78000	0104
4	213.66290	4	23997	0032	10	NH-8	003210008	National Highway	Talasari	Metalled - Black T...	National Highway	225.23000	0101
5	741.78566	5	232	0032	60	VR-49	003260049	Village Road	Talasari	Metalled - Black T...	Village Road	741.79000	0104
6	535.31644	6	199	0032	60	VR-3	003260003	Village Road	Talasari	Metalled - Black T...	Village Road	535.32000	0104
7	1671.28680	7	232	0032	60	VR-49	003260049	Village Road	Talasari	Metalled - Black T...	Village Road	1671.29000	0104

Figure 4.11: Attribute table of Road network

Step . 1 Termini(T)

Termini set consists of unique terminals along with their geometry. These lat-long can be obtained from Google API and required certain manual work with the help of village polygon file. Care should be taken that these termini should lie on the road network.

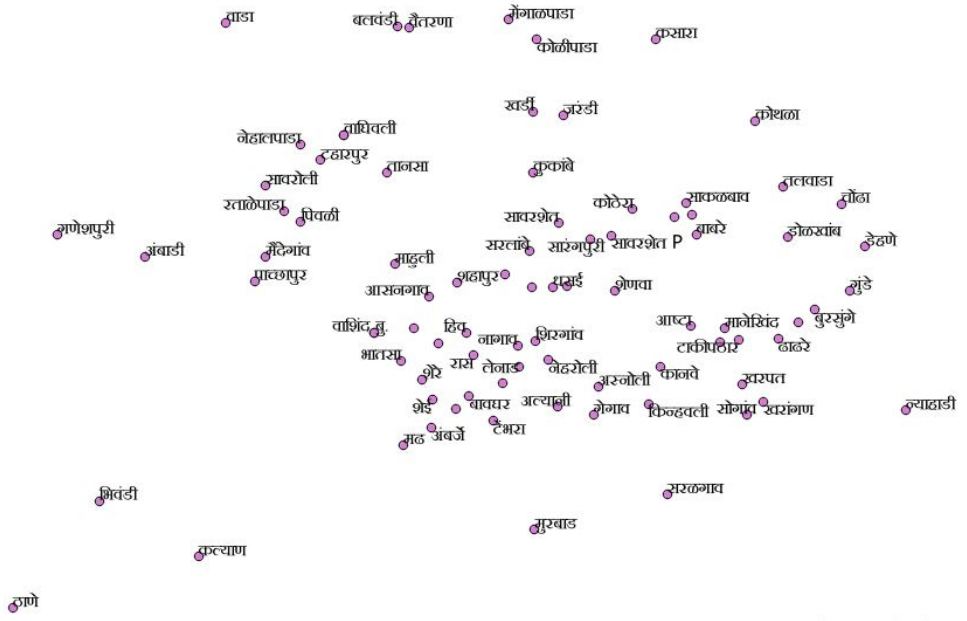


Figure 4.12: Terminals (T)

The attribute table is as follows:

	fid	name	name_mar	village	taluka	taluka_mar	div	div_mar
1	T1	BHIVANDI	भिवंडी	Bhivandi	BHIVANDI	भिवंडी	THANE	ठाणे
2	T2	GANESHPURI	गणेशपुरी	Ganeshpuri	BHIVANDI	भिवंडी	THANE	ठाणे
3	T3	AMBADI	अंबाडी	Ambadi	BHIVANDI	भिवंडी	THANE	ठाणे
4	T4	SAVROLI	सावरोली	Savaroli Kh.	SHAHAPUR	शहापुर	THANE	ठाणे
5	T5	RATALEPADA	रतालेपाडा	Koshimbade	SHAHAPUR	शहापुर	THANE	ठाणे
6	T6	PIWALI	पिवळी	Piwali	SHAHAPUR	शहापुर	THANE	ठाणे
7	T7	VASHIND	वाशिंद	Vashind (CT) - W...	SHAHAPUR	शहापुर	THANE	ठाणे
8	T8	VASHIND_B	वाशिंद बु.	Vashind (CT) - W...	SHAHAPUR	शहापुर	THANE	ठाणे

Figure 4.13: Attribute table of Terminals

Step . 2 Route Segments(RS)

The challenge to begin with is that there are no edges and vertices. The methodology takes advantage of the overlapping in the route-segments as explained in previous sections. Also the path or route was not available to us. To mitigate that problem **Dijkstra's Shortest Path Algorithm** was used. A route segment is created with the help of the combinatorics obtained from various unique routes obtained from form4 and ABC table. Upper-triangular matrix as shown below is used to tackle the duplication as the routes are bidirectional. The figure below can be understood as between any pair of termini T_i indexed at $\boldsymbol{i}$ and T_j indexed at $\boldsymbol{j}$ the route segment thus generated should be named as RS_{ij}. In case of *via* routes T_k from the naming becomes RS_{ijk}

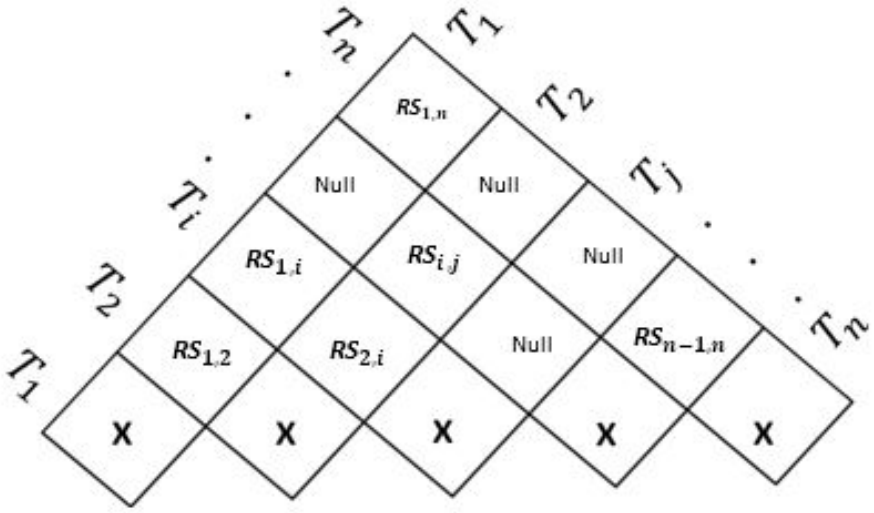


Figure 4.14: Combinatorics of Termini to give Route Segments

A simple schematic in the next page explains the creation process of these route segments.

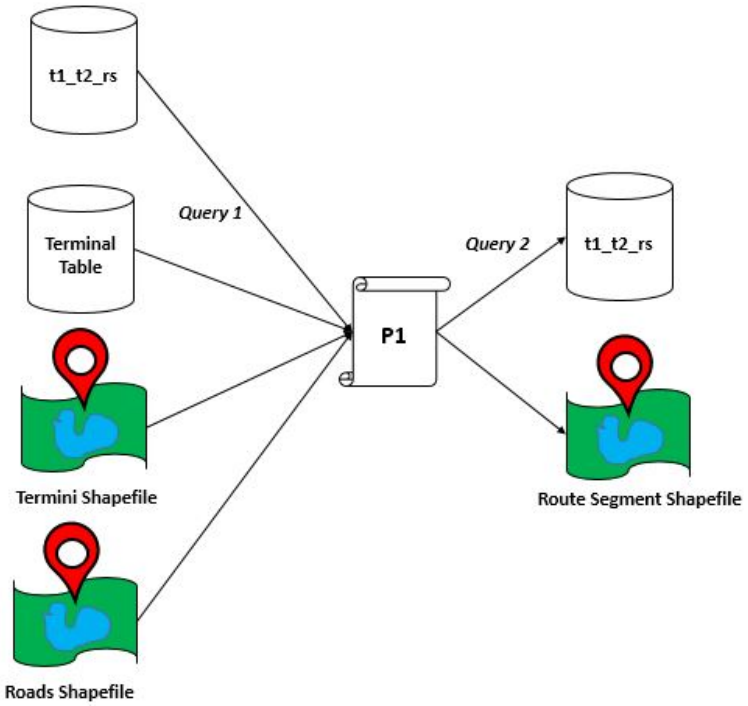


Figure 4.15: Input, Processing and output blocks for route segment creation

Legend

Query 1 : select rs.termini1 as term1, ST_X(t1.geom) as geom1_X, ST_Y(t1.geom) as geom1_Y, rs.termini2 as term2, ST_X(t3.geom) as geom3_X,ST_Y(t3.geom) as geom3_Y, rs.rs_id as rsId from t1_t2_rs as rs inner join t_31052019 AS t1 on t1.name = rs.termini1 inner join t_31052019 AS t3 on t3.name = rs.termini2 where rs.via1 = '' ORDER BY 1, 3;

Query 2 : Update the table *t1_t2_rs* with the route segment id

P2: Python script for connecting the database, firing the **Query 1**, Create path between the termini, generate route segment id, update the **t1_t2_rs** with the route segment id and create a shapefile of route segment and update the shapefile with new route segments.

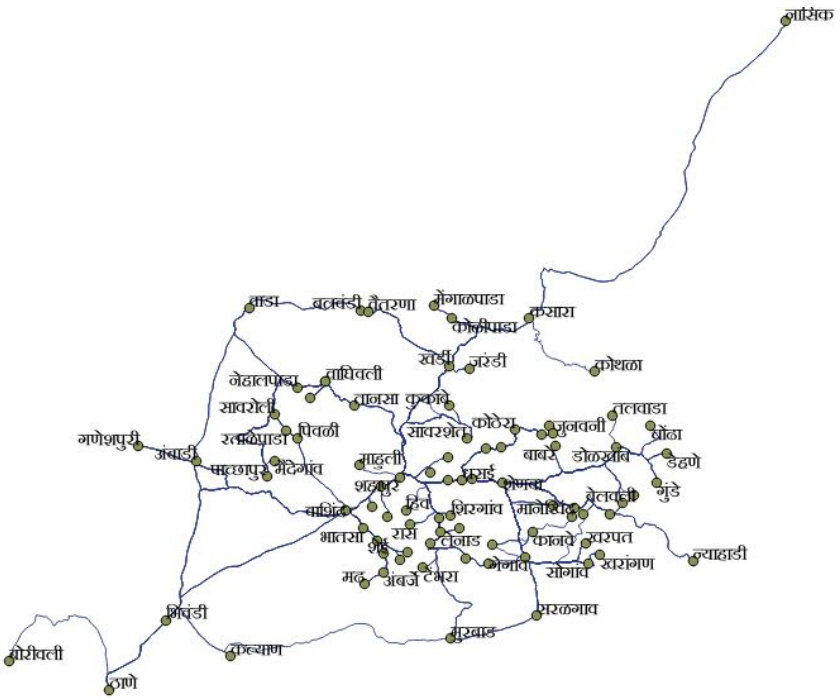


Figure 4.16: Generated Shapefile of the route segments

Step . 3 *Fatas*(F)

A *fata* is a bifurcation / cross-road / junction and is a common point of access to transport to the villagers. A *fata* can be defined mathematically as a node on a planar, undirected graph which has degree of 3. A cross-road will have a degree greater than equal to 4.

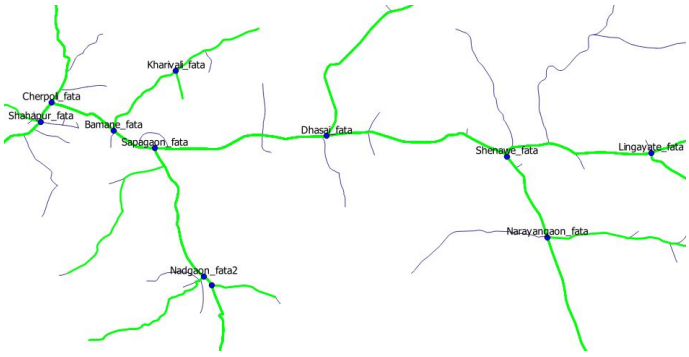


Figure 4.17: Generated shapefile for fatas of ST road network

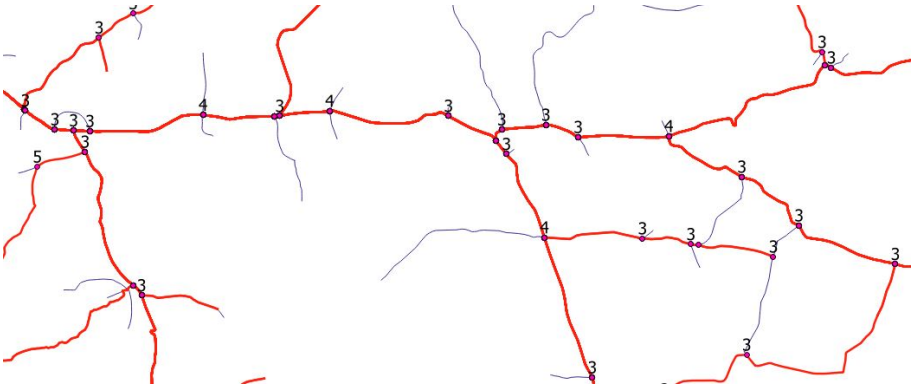


Figure 4.18: Generated shapefile for fatas of Road network along with their degree

Step . 4 Projections(P)

A projection is point of least distance from village centroid to ST road network. These projection points also help us in assessing the number of villages covered and other census parameters with respect to transportation. This analysis is further elaborated in chapter 6.

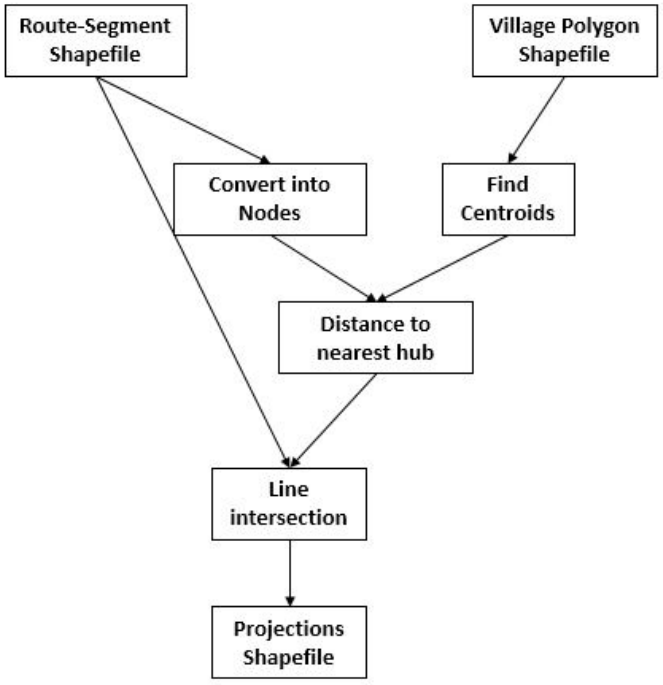


Figure 4.19: Steps to get the projections set

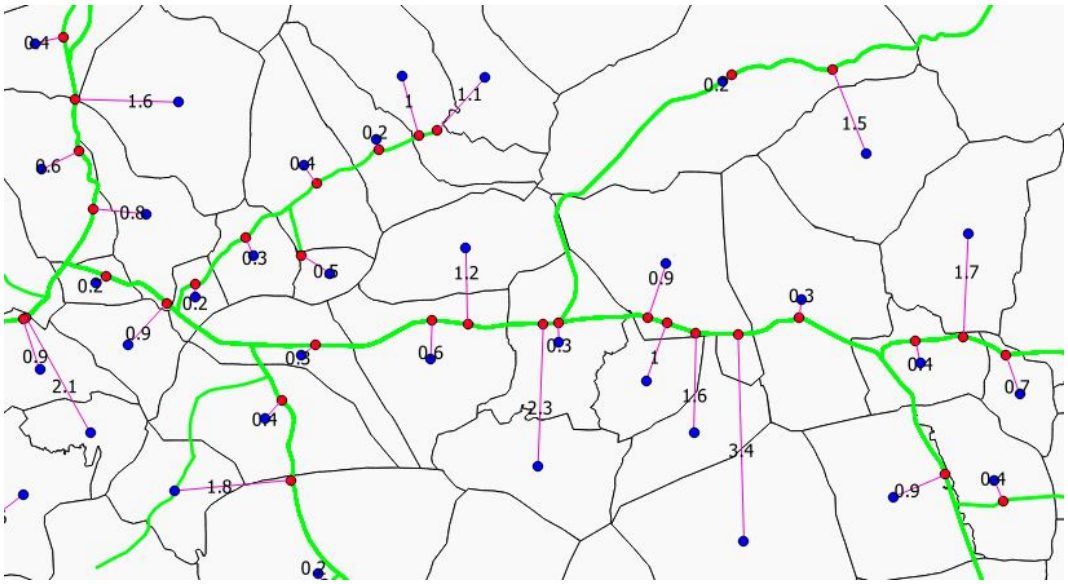


Figure 4.20: Projections on the State transport network, along with their hub-distances

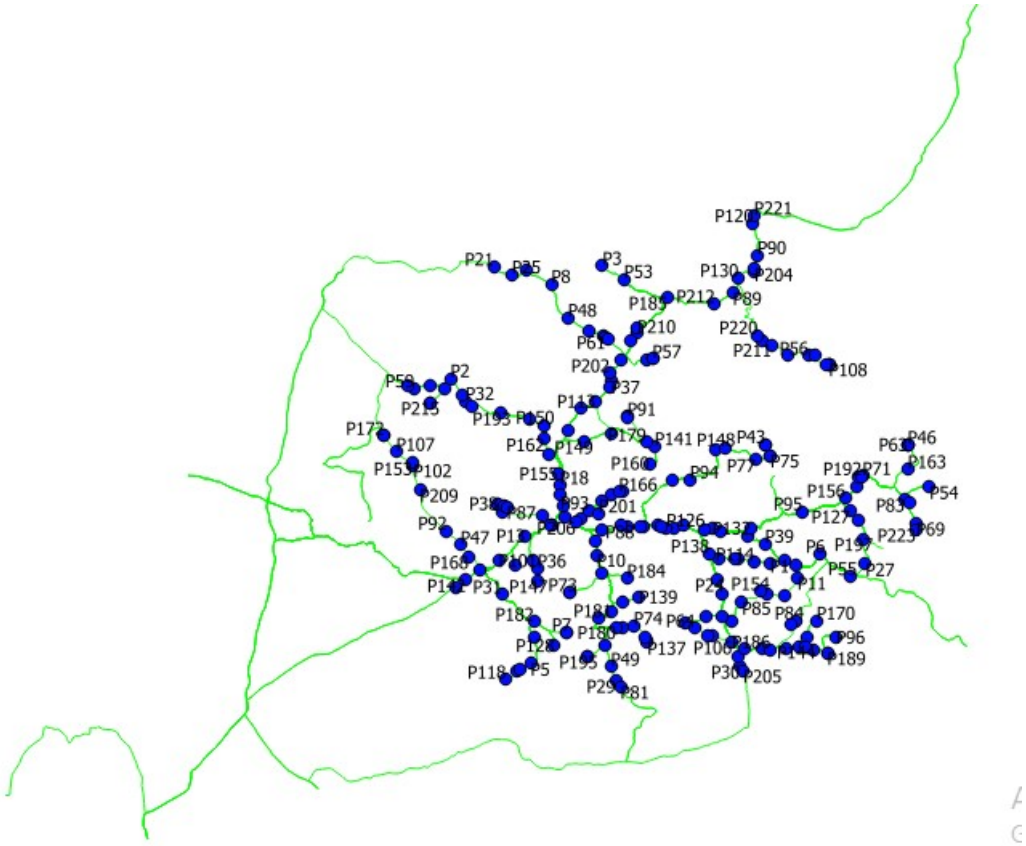


Figure 4.21: Generated shapefile of Projections

Step . 5 Set of Vertices(V) Now that we have three set of points namely ***T, F and P***. A set of vertices **V** can be defined as,

V = $T \cup F$ where,

T, F contain only geometry. We name those vertices with unique ids. Also to reduce spurious vertices which are nearer i.e. less than 300 metres of distance we clean them up. So we get the vertiexset as follows:

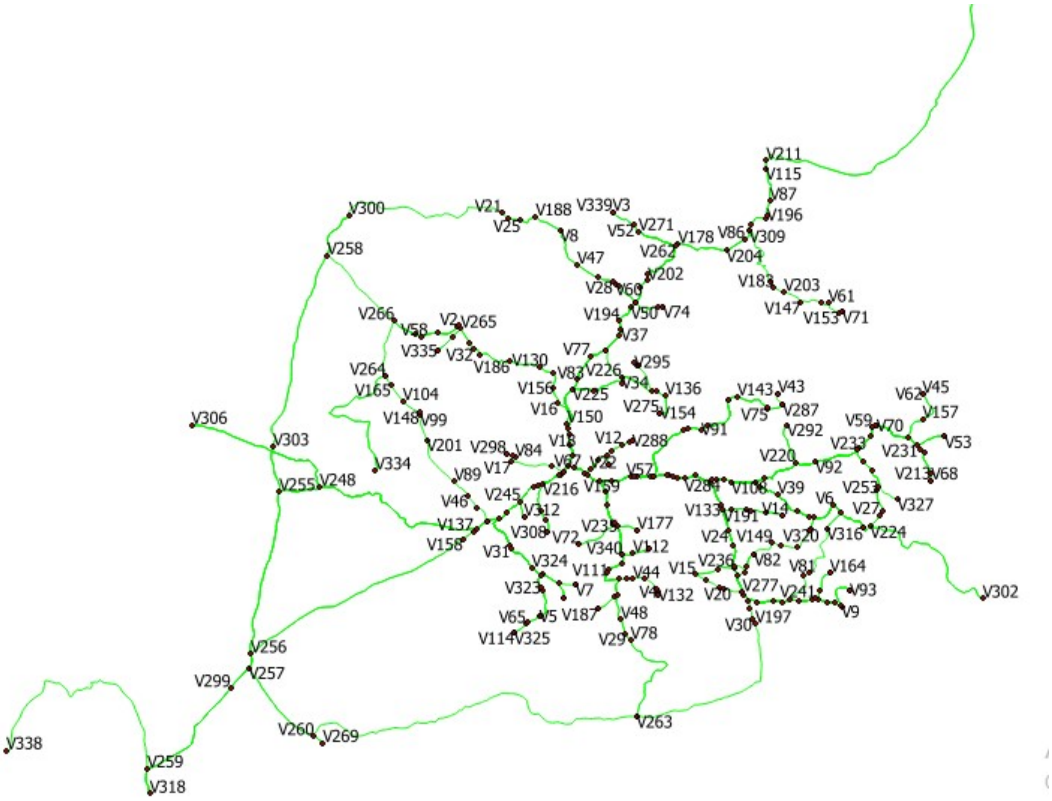


Figure 4.22: Generated shapefile of vertices

Step . 6 $V \cap RS_i$ set generation The following steps were followed to generate the $V \cap RS_i$ set. This shapefile is generated by intersecting the shapefiles of vertices and route-segments. So the output essentially maps route-segments with the vertices that lie on that route-segment. Before we proceed with the intersection operation a buffer of 10m is advisable around route-segment shapefile for better results. The following

schematic explains this:

i) Using Fixed distance buffer option or v.buffer option from processing toolbox generate a buffer of 10 metres around the road network

ii) Using the intersection algorithm, use the buffered route-segment shapefile and vertex shapefile to generate $V \cap RS_i$

iii) Care must be taken for invalid and null geometries, use v.clean algorithm from processing toolbox to accomplish the same

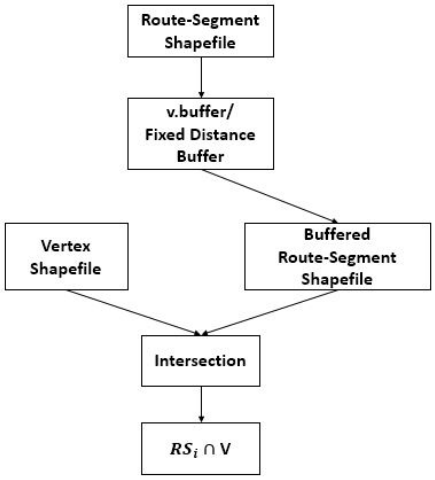


Figure 4.23: Schematic of $V \cap RS_i$ set generation

The outputs look like the following:

	vert_id	rs_id
1	V1	RS_17_60
2	V1	RS_17_42
3	V1	RS_16_56
4	V1	RS_16_46
5	V1	RS_16_57
6	V1	RS_16_75
7	V1	RS_16_48
8	V1	RS_16_57_v_55
9	V1	RS_16_60
10	V1	RS_17_45

(a) Attribute table with Vertex kept constant

	vert_id	rs_id
1	V35	RS_0_13
2	V42	RS_0_13
3	V43	RS_0_13
4	V44	RS_0_13
5	V45	RS_0_13
6	V60	RS_0_13
7	V68	RS_0_13

(b) Attribute table with route-segment kept constant

The above figures ably highlight that one vertex is being shared by many route segments and one route-segment is having many vertices. The advantage of this will become evident in subsequent sections.

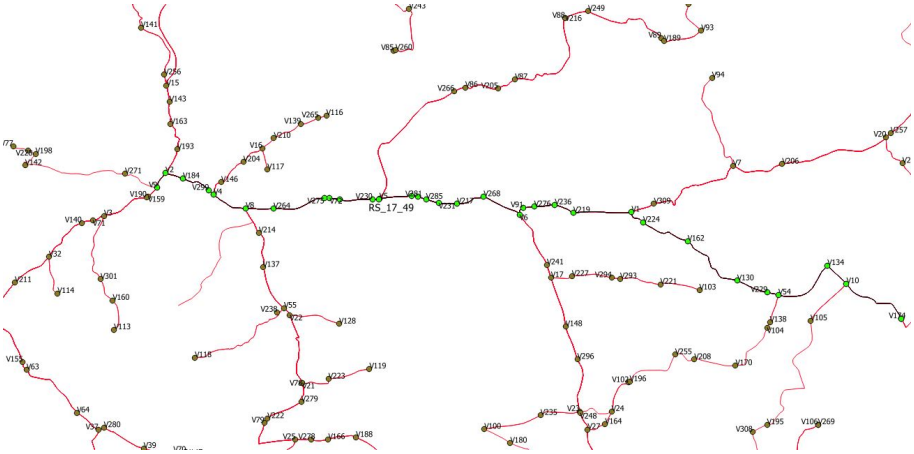


Figure 4.25: Snapshot of the Shapefile

In this figure the green dots represent the vertices lying on the ***RS_17_49*** route-segment. whilst the dirty green ones represent the set of all the vertices. Red lines represent all the routesegments.

Step . 7 $P \cap RS_i$ set generation

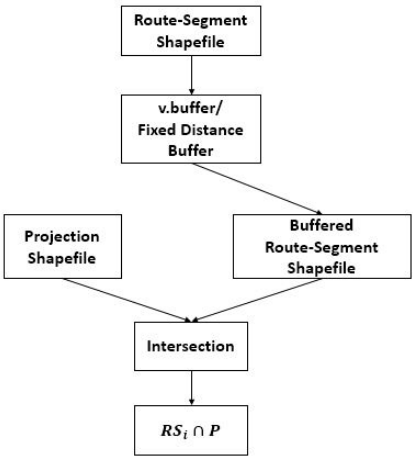


Figure 4.26: Schematic of creation of the $P \cap RS_i$

Step . 8 Set of Edges(E)

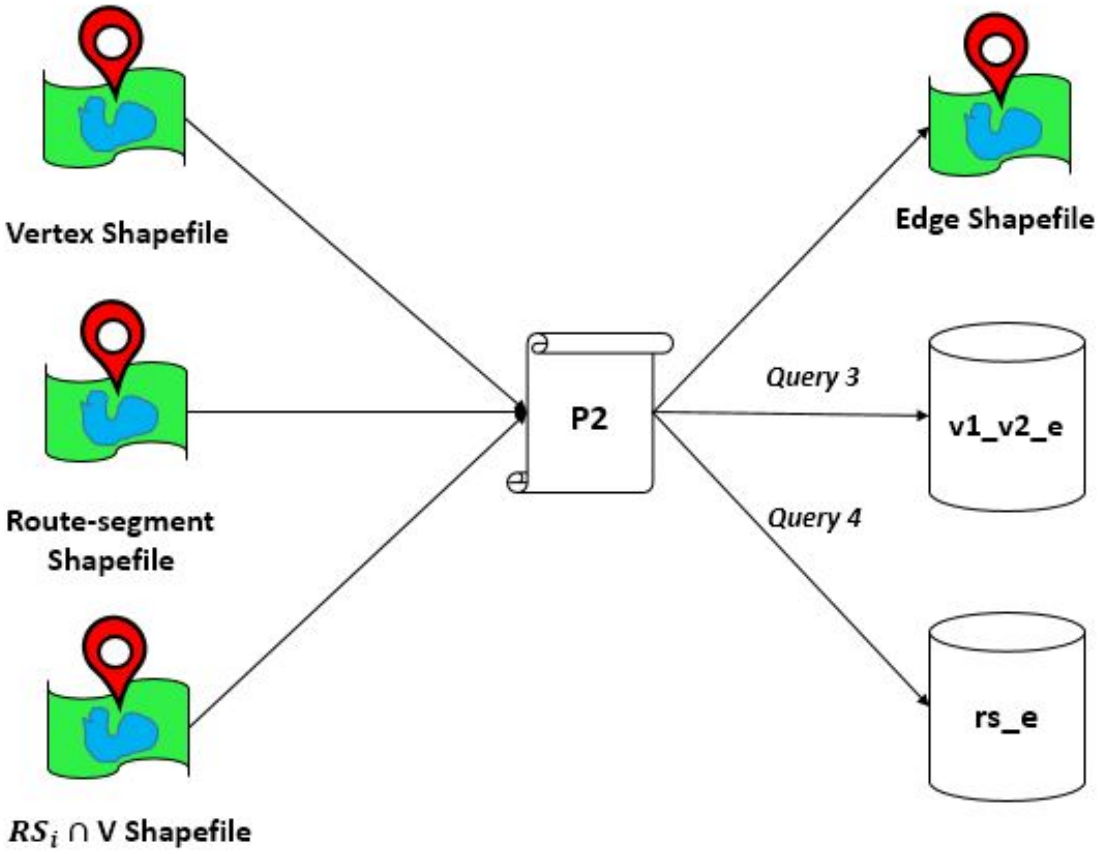


Figure 4.27: Schematic of edge creation

where,

Query 3: Updates the ***v1_v2_e*** table with the mapping of vertex V_i to vertex V_j for edge E_{ij}

Query 4: Updates the ***rs_e*** table with the mapping of RS_{mn} with edge E_{ij} along with the sequence of its occurrence.

P2: The python script uses the vertex shapefile, route-segment shapefile and $V \cap RS_i$ shapefile to reorder the vertices and generate edges between them for each route-segment.

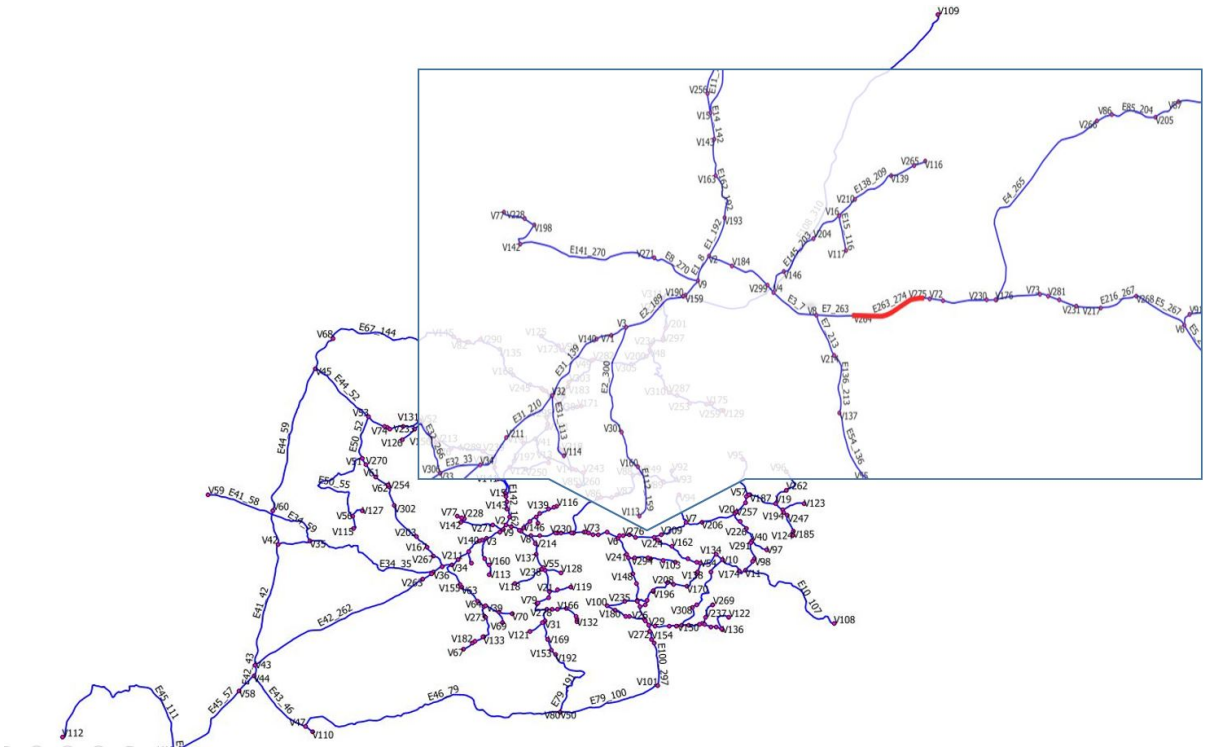


Figure 4.28: Edge Shapefile. (picture-in-picture: close-up)

4.7.1 Shapefiles

Step. 1 **Termini**:

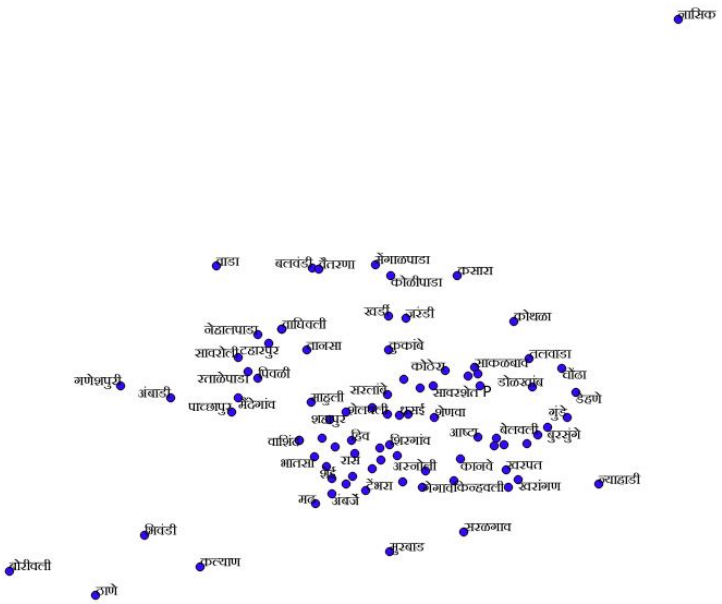


Figure 4.29: Set of Terminals

Step. 2 **Route-Segments**:

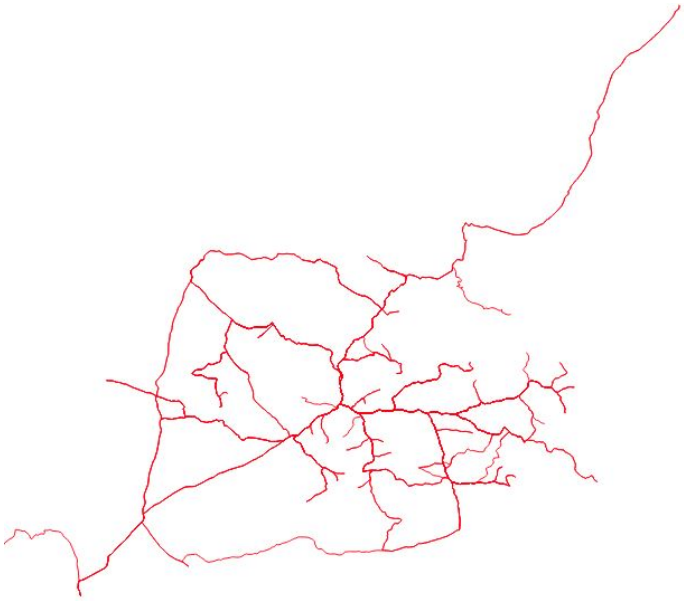
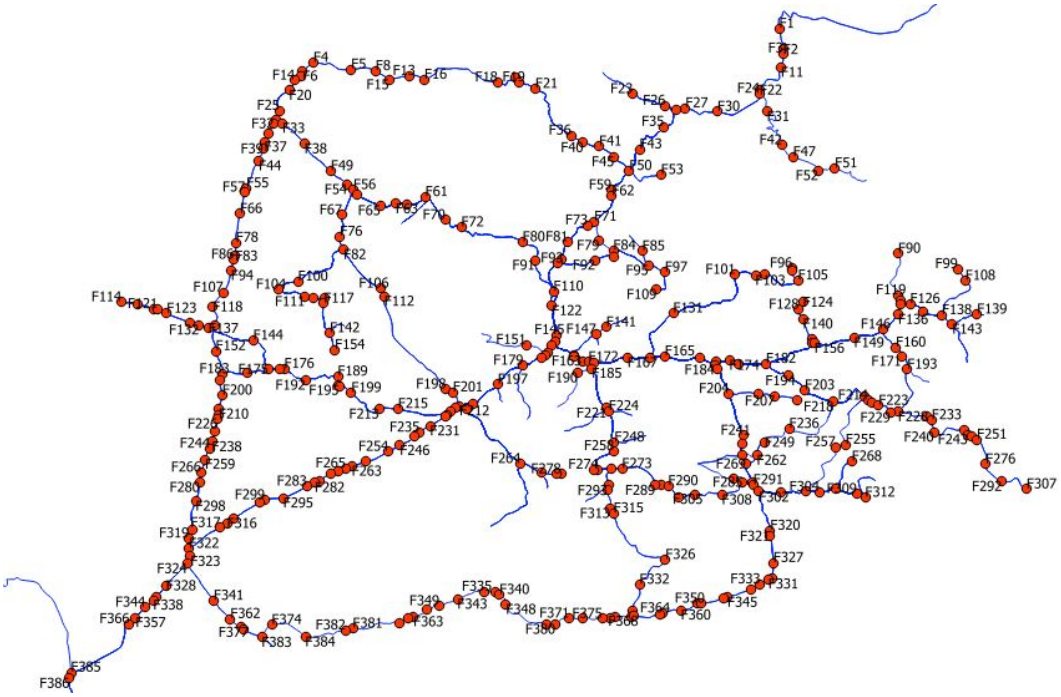
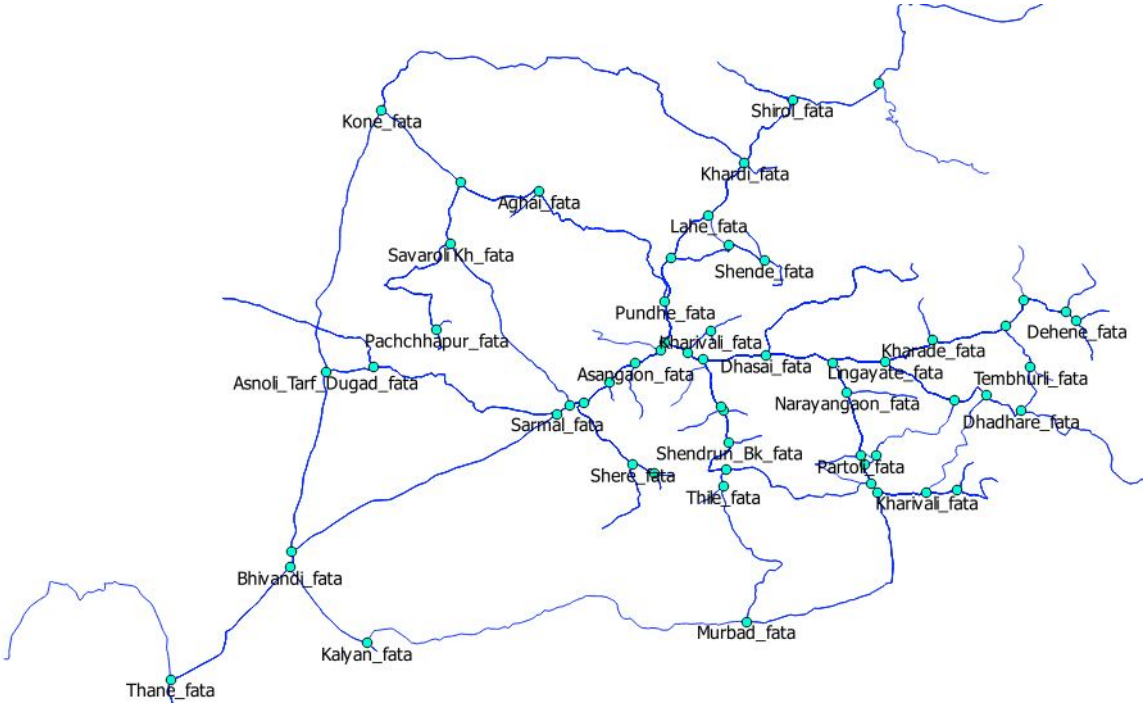


Figure 4.30: Set of all Route-segments(bus, jeep, minidor, auto-rickshaw)

Step. 3 ***Fatas***:



(a) All *Fatas* of road-network lying on the route-segment network



(b) *Fatas* of State Transportation network

Step. 4 **Vertices**:

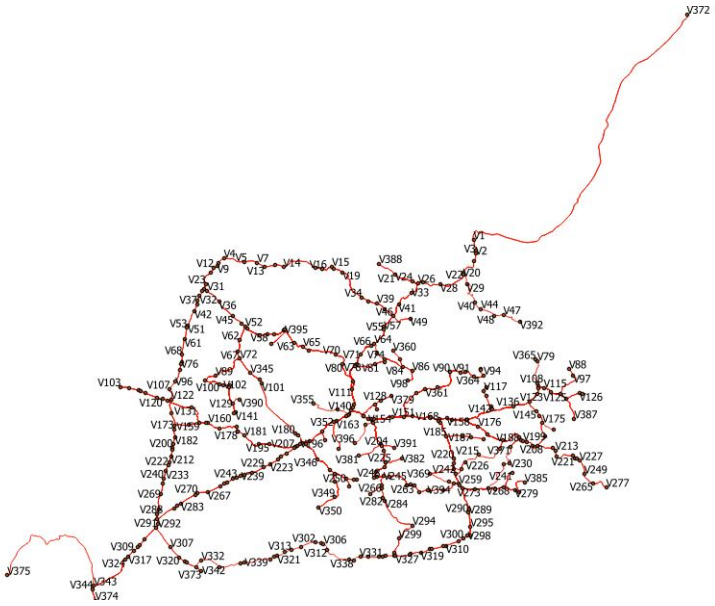


Figure 4.32: Set of Vertices after cleaning the vertices which were less than 250 meters apart

Step. 5 **Projections**:

Figure 4.33: Set of Projections and their hub-distances from village centroid

Step. 6 **Edges**:

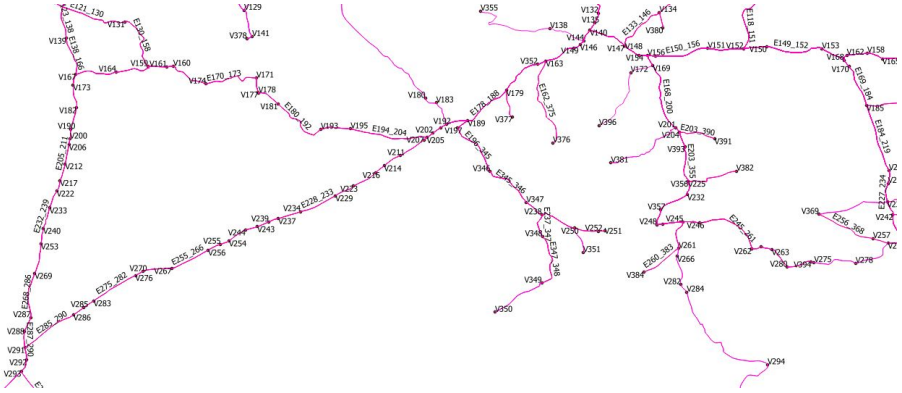


Figure 4.34: Close-up of Set of edges

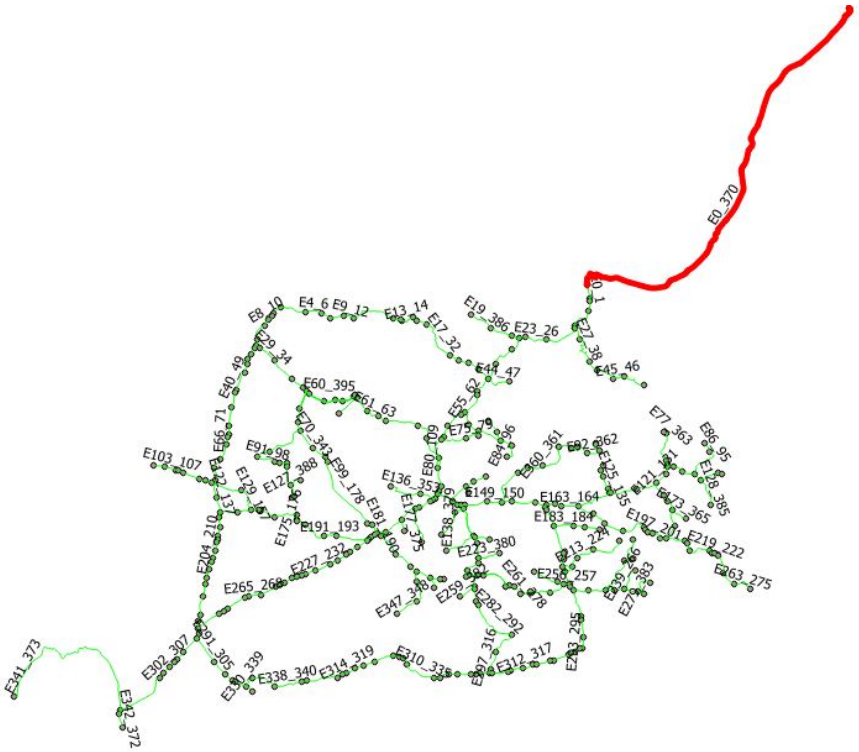


Figure 4.35: Set of edges

One thing as a disclaimer I want to state is that there were certain vertices that didn't get through the V intersect RS set because of an inherent bug in QGIS. However the convergence is good as out of 410 edges 407 were detected (.5% error).

Step. 7 **ABC data**:

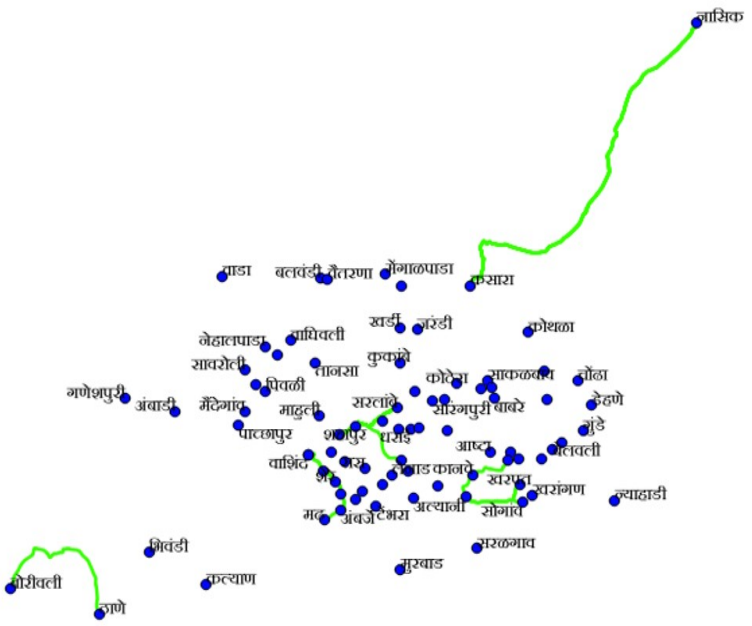


Figure 4.36: A type bus services

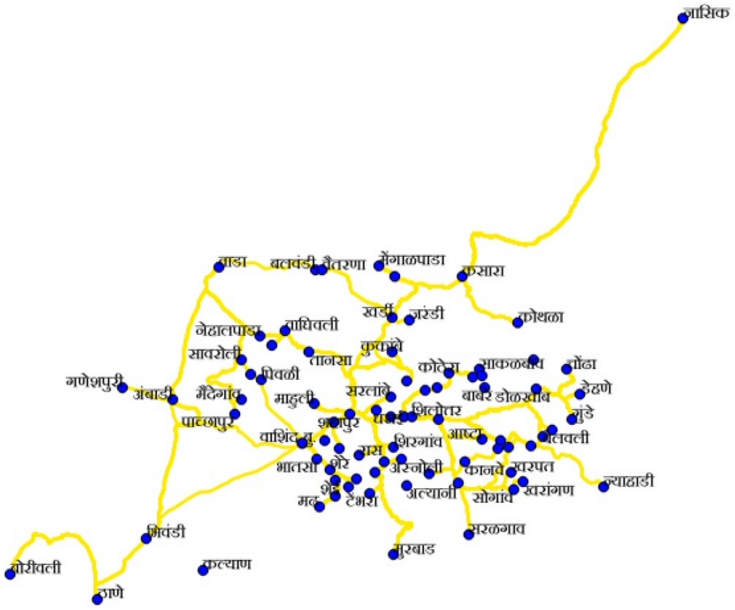


Figure 4.37: B type bus services

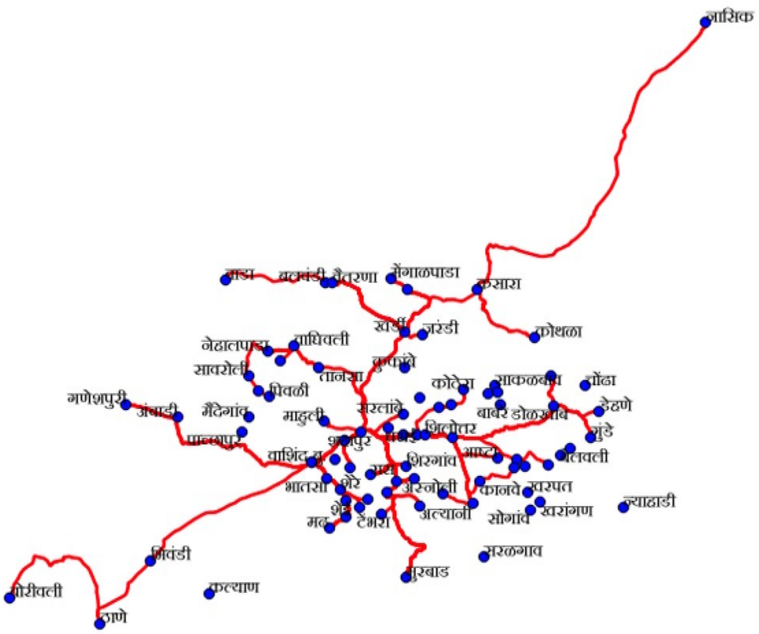


Figure 4.38: C type bus-services

Step. 8 **Count of Services**:

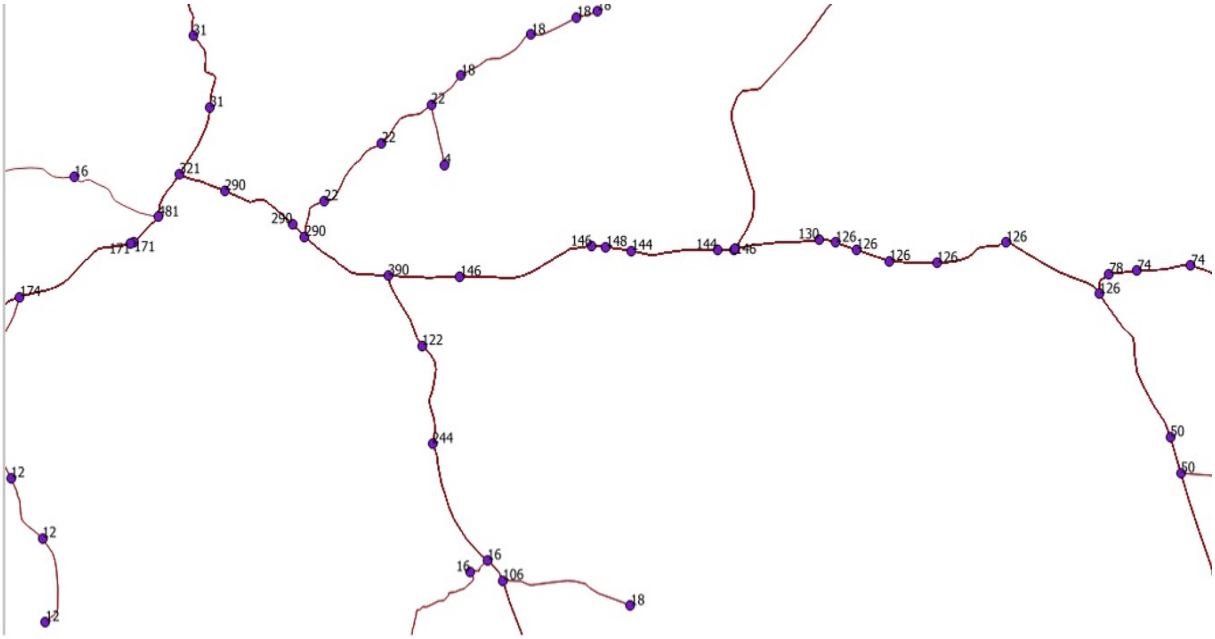


Figure 4.39: Count of bus-services at any point of importance

4.7.2 Limitations

The following are the limitations of Digital geography:

i) This system works well for intra-taluka transportation but a different layer using similar approach is required for inter-taluka, inter-city transportation.

ii) This system does not take into account the inter-city/ long route buses.

iii) The type of bus-services used here are strictly *lalpari* or ordinary buses.

iv) The scripts only work with single part geometries i.e. point or line geometries not multi-line or multi-point geometries, care must be taken in converting the multi-part geometries to single part.

v) QGIS gives limited control to the python layer hence manual work to inspect cannot be completely eradicated. There will be certain missing points and edges which need to be fixed manually. https://gis.stackexchange.com/questions/267645/qgis-coordinate-precision

Chapter 5

Field Work

Field-work forms an essential part of the rural-transportation planning process. The field-work was undertaken in Shahapur taluka bus-depot, MSRTC Thane Division Office, MSRTC Mumbai Central Office, Interviews, surveys and Participation observation at various jeep stands, auto-rickshaw stands, minidor stands, bus-stand, Bus depot traffic controller's office, Depot manager's office, Depot Workshop and travelling to villages in taluka.

5.1 Objectives of field-work

Field-work was needed for the following reasons:

i) To understand the bureaucracy in bus-transportation system.

ii) To understand the working style of various key actors enlisted in Chapter 2.

iii) To understand the daily schedule of a bus-depot.

iv) To know the reality of a non-msrtc driver.

v) To know the economics, feasibility of jeeps, minidors and auto-rickshaws.

vi) To understand the key lacunae which are becoming a bottleneck in delivering quality service.

vii) To ground truth the conjectures made through Digital Geography.

viii) To collect relevant operational data from MSRTC offices.

5.2 Plan of field work

Pre-requisites:

I took the permission to work in Shahapur Taluka Depot from MSRTC Mumbai Central office and Shahapur Depot Manager. Second set of permissions were sought for getting the Operational Data and form 4 of Shahapur Taluka from MSRTC Mumbai Central Office. The third set of permissions was to obtain the ETIM data from Trimax from MSRTC Mumbai Central Office.

If look from a planning perspective there are three aspects to this field-work, namely demand, supply and infrastructure. My field-work was planned accordingly. The supply side included:

i) Presentation of my MTP research question and work done to depot manager

ii) Meeting Shahapur Taluka Depot Manager and other employees and understanding their role

iii) Working from Shahapur depot for 3 days to observe the schedule of the depot

iv) Visiting the jeep-stands, minidor stands and auto stands

v) Travelling to Murbad via Lenad route and observing the construction work being undertaken in the entire road

vi) Interviewing and surveying the Jeep, minidor drivers.

vii) Visiting Thane Division office to talk to Divisional Traffic Officer and understand his world view

viii) Visits during first week of month to Shahapur Taluka depot to attend the Panchayat Samiti meeting

ix) Visits to understand the development of ABC data

x) Visits to MSRTC Mumbai central office. There were 3 meetings; first, in Planning department and with Chief Statistical Officer, second, with General Manager Traffic and Dy. General Manager IT, third with Vice Chairman and Managing Director MSRTC for further research proposal.

5.3 Field Survey

5.3.1 Interview / Questionnaire design

S.No	Question	Type	Purpose
1	Village	**S**	to understand which villages are major source of transportation in taluka
2	Caste	**S**	to understand which community is active in non-MSRTC transportation
3	Education	**S**	to understand the education level of the driver
4	License	**S**	to understand the level of illegal/ non-licensed vehicles in taluka
5	When started	**US**	to understand when the person started transportation
6	Why did you start the service	**US**	to understand respondent's reality in entering transportation business
7	Route	**US**	to understand the service area
8	Operating timings	**US**	to understand the service timings
9	Frequency	**US**	to understand the service frequency
10	Number of Passengers	**US**	to understand overloading

11	Fare	**US**	to understand the controlling authority of fares
12	Daily Income	**US**	to get the daily income of the service
13	Diesel expenditure (Daily)	**US**	to get the daily diesel expenditure
14	Op-Maint expenditure (monthly)	**US**	to get the monthly maintenance expenditure
15	Where is repair shop?	**SS**	to get the locations of prominent repair shops
16	Source of Fuel	**SS**	to get information on type of fuel
17	Vehicle Type	**S**	to get the popular choice of vehicle
18	Vehicle Model and year	**US**	to get the oldness of vehicle
19	Cost of Vehicle	**US**	to get the cost
20	Ownership	**S**	to get the number of ownerships the vehicle has passed before ending up as a shuttle
21	Any recent Accident?	**SS**	to understand safety factor

where,

S: Structured

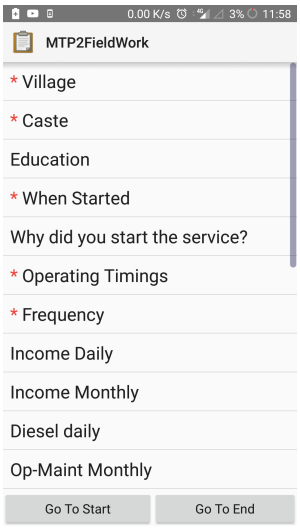
US: Unstructured

SS: Semi-Structured

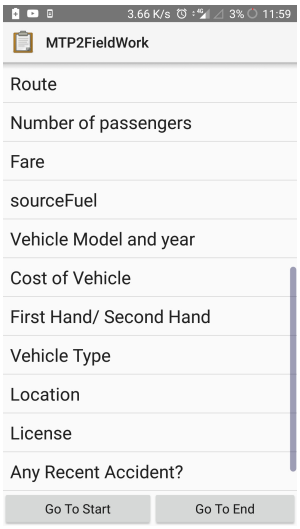
Tools: ODK Build to build the survey,

OSM tracker to geotag and mark track points,

Google Sheets to collect data.



(a) Screen shot of service provider survey form



(b) Screen shot of service provider survey form

Interviews were very informal hence jogging notes were taken. Care was taken during both interview and survey that anonymity is maintained so as to not to intimidate the respondent.

5.3.2 Survey results

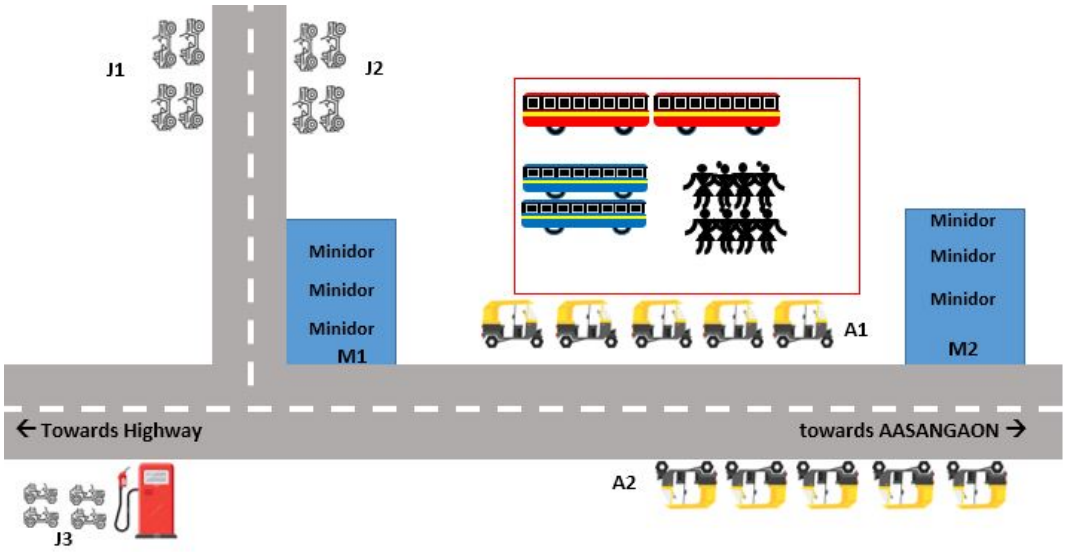


Figure 5.2: Plan of various service providers in Shahapur Taluka

15 non-MSRTC drivers were surveyed, 6 others were interviewed in group, apart from that 1 minidor driver was interviewed one to one to understand the field reality. The following points summarize the survey results:

i) There were around 200 jeeps operating in Shahapur taluka alone because of the proximity of highway and railway station.

ii) Kinhavali formed one of major stands for jeeps, they start forming queue from 4 AM in the morning.

iii) Mostly drivers could operate 1-2 trips maximum on daily basis.

iv) Fuel costed another Rs. 350 daily per to and fro trip.

v) The ownership of all the vehicles was either second or third.

vi) Operation and maintenance costed another Rs. 5000.

vii) In case of Minidors, *Nadgaon* formed a major source of the minidor drivers of stand **M2**

viii) The minidor services were shuttle services only and operated 4-5 trips on daily basis.

ix) The condition of minidor were dilapidated.

x) All the minidors surveyed were first hand but were very old models circa 2000.

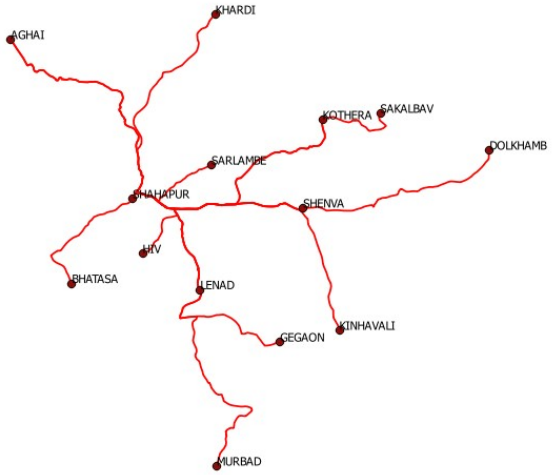
xi) All the drivers surveyed were literate and studied till middle-school except for 1 who was illiterate.

xii) Jeep drivers mostly preferred *Mahindra Max (Model 2003)* over any other model because of less maintenance. Apart from *Mahindra Max* other models were *Tata Sumo, Bolero*.

xiii) Almost all of them were upper-castes.

xiv) Only one driver was a tribal who was hired to do the job.

Following are the shapefiles of the routes operated by various non-MSRTC service providers using the methodology used in Chapter 4.



(a) Routes operated by Jeep

(b) Routes operated by Minidors

(c) Routes operated by Auto-Rickshaws

Overall Scenario of transportation service provisioning in Shahapur Taluka is:

i) The penetration of jeep is very high, hence are one of the toughest competitor in service provisioning in Shahapur Taluka

ii) *Shahapur-Asangaon* route has the most competition followed by *Shahapur-Dhasai and Shahapur-Vashind*. *Asangaon and Vashind* are local train stops as well, hence it is quite obvious.

iii) Jeeps are servicing longer routes like *Murbad, Dolkhamb, Kinhavali* that shows poor gauging of demand and poor service provisioning by Shahapur Taluka depot

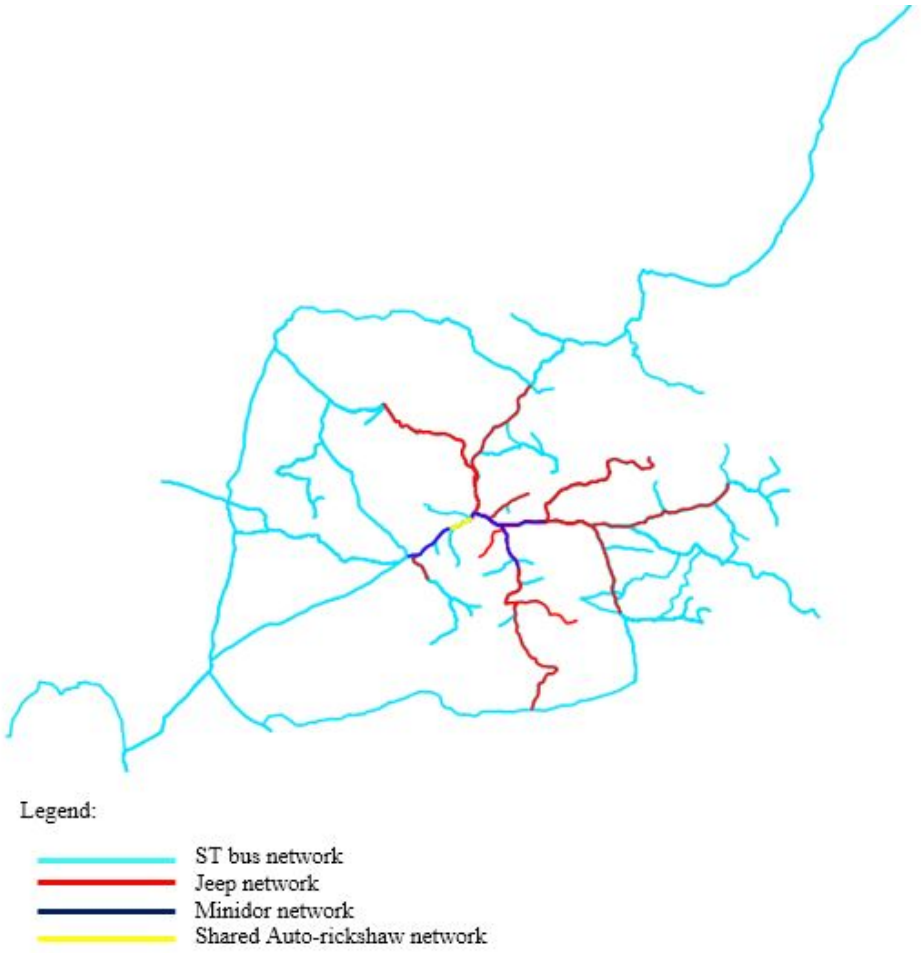


Figure 5.4: Overall Transporation scenario in Shahapur Taluka

5.4 Field Observation

Scene. 1 **Location: Traffic Controller's Office**

"Sir, bagha tumcha ABC cha data kasa aalay"(Eng: Sir, Look how's your ABC data is represented). Response to this sentence was used as an indicator of willingness and enthusiasm amongst the employees (2 in number) in Traffic control office.

Emp1: *(ignored)* despite repeated attempts to bring his attention to the project

Conjecture: If he sees it, this system management doesn't comes under his purview as he's responsible for maintaining the communication; he feared that this work

will also fall as additional work-load. Hence chose to ignore.

No response is neither yes nor no.

Emp2: *(acknowledged) "Me baghto thodya velane.(Eng: I'll see in some time.)"*.

Didn't see the work. "Hyane hi khurchi jail na? (Eng: Will I loose my post?)"

The underlined sentence highlights the fear/ resistance / apprehension towards automation and insecurity for the job.

Conjecture: As he was not able to understand the system and was quite overwhelmed by the maps; this behaviour is very much expected from an otherwise hardworking clerk of depot.

A major request was put forward by Traffic controller for making a software for managing Daily Crew Allocation Schedule to monitor and allocate crew duties to the driver-conductor pair. This is a typical system dynamics problem:

i) An employee chooses to take holiday as EL

ii) Employee who reported was asked to do double duty on his/her behalf

iii) The employee put in double duty is in hurry of finishing the second duty as early as possible

iv) As a result there is always an inherent hurry to finish the duty by reducing the wait time. For instance *Shahapur-Kinhavali (10:45 AM bus)*, this bus is scheduled ot wait till 11:30 AM. The bus arrives at 11:15 AM, picks up the passengers till 11:20 AM and just leaves without waiting (complaint of which was done by a passenger in the office, NO Written complaint was registered)

v) This affects the income

vi) Additionally, this very employee will take EL and the cycle continues

This system when viewed by the new recruits (100 in number) was considered as a **normative workplace behaviour** and they also started taking holidays uninformed.

Reprimand Mechanism

i) Depot Manager sits in traffic controller office in the first half and ordeal is taken for reporting Driver-Conductor pair for their behaviour

ii) No punishment/ penalty is awarded

iii) Conjecture: Casual sexism and since depot manager is new to the system she is taken for granted by the otherwise senior lot, hence they take her for a ride and the mismanagement continues

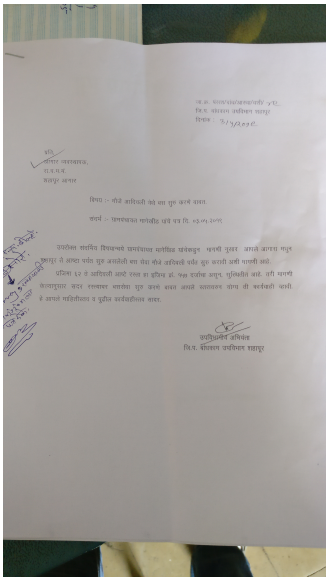
Scene. 2 **Location: Bus-Depot Manager's Chamber**

2 men from *Mauje-Adivali* village visited with a letter of approval from PWD regarding starting bus service till their village. The reason was 10^{th} class students who wanted to take tuitions from a teacher in Shahapur Taluka. They had:

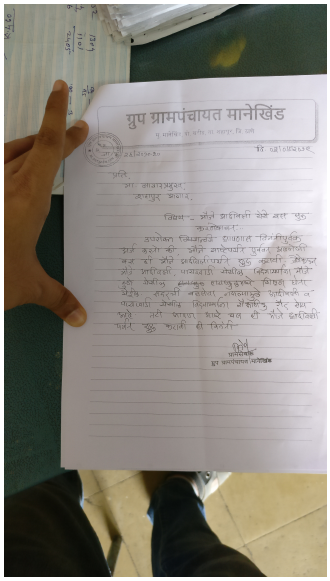
(a) Letter from Gram Sevak (GGP Manekhind)

(b) Letter from PWD regarding repair of *Suraksha Bhint* (Safety wall) on the bridge

(c) Earlier also similar request came, which was forwarded by Depot manager to the Division Manager



(a) Image of letter



(b) Image of letter

Observation:

i) There is lack of proper convergence of information amongst Depot, PWD and Panchayat Samiti Office

ii) The demand estimation and route allocation is done at divisional office

Scene. 3 **Location: Panchayat Samiti Hall**

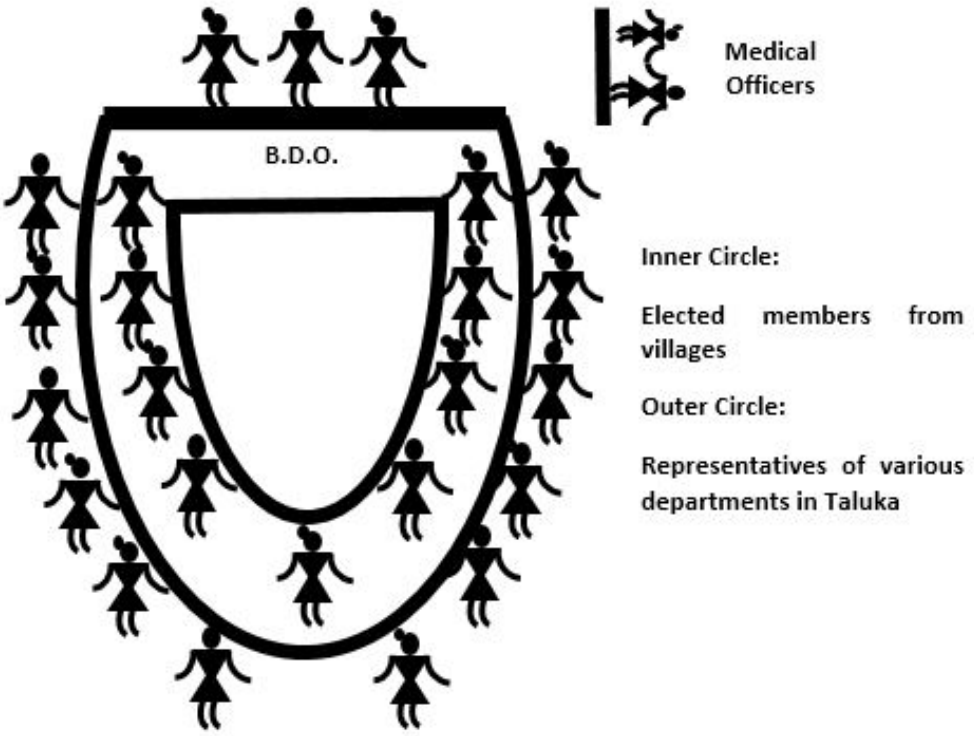


Figure 5.6: Seating arrangement in Panchayat Samiti Meeting held on 2^{nd} of April 2019

Observation:

i) Most of the elected members were women and were busy on their android phones

ii) Representatives from department were coming one by one on mic and speaking of some numbers

iii) In case of Bus Depot, Traffic Controller represented Depot manager

iv) Only details of revenue earned in last month and trips operated was announced

v) None of the members questioned

Comments:

i) The BDO was more concerned in getting over with the meeting and conducting it seamlessly.

ii) In most cases the service provider representatives brought the data written on a piece of paper rather than a complete report.

iii) None was paying attention hence the motive of having such meeting was defeated.

Chapter 6

Operational Analysis of Shahapur Taluka Bus Depot

6.1 Coverage

Total Population of Shahapur Taluka is **309653** with the area of **1696.75**km^2.

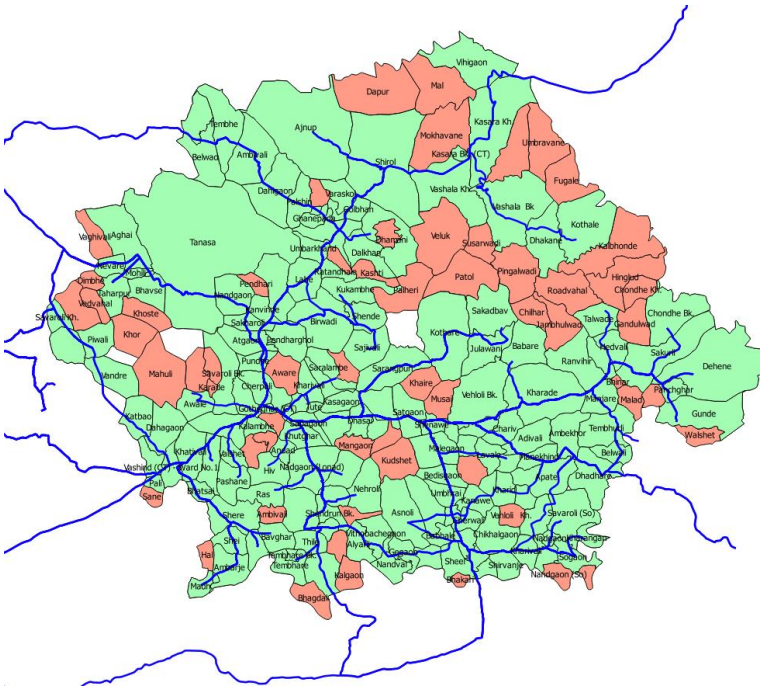


Figure 6.1: Coverage by bus Transportation in Shahapur Taluka

Total population covered by State Transportation bus network is **303739** which makes it **98.1%** of the total population and area covered is **1623.2**km^2 which makes it **95.66%** of the total area of Shahapur Taluka.

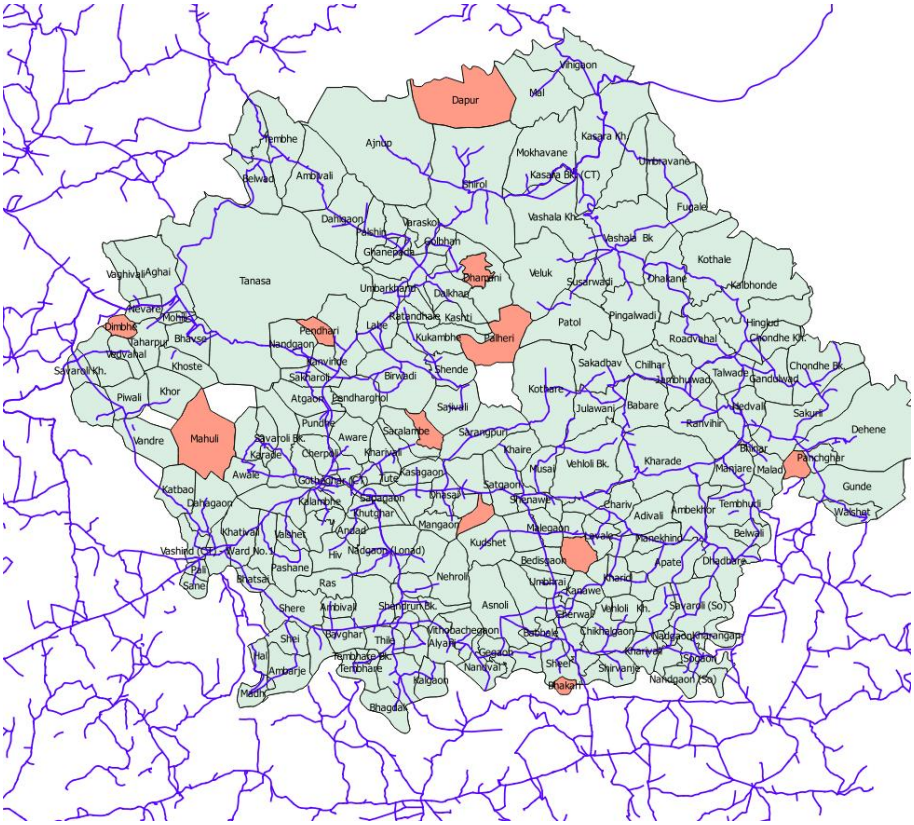


Figure 6.2: Coverage by roads in Shahapur Taluka *source: MRSAC*

Total population covered by State Transportation bus network is **268626** which makes it **86.75%** of the total population and area covered is **1300.71**km^2 which makes it **76.65%** of the total area of Shahapur Taluka

6.2 Demographics and Transportation

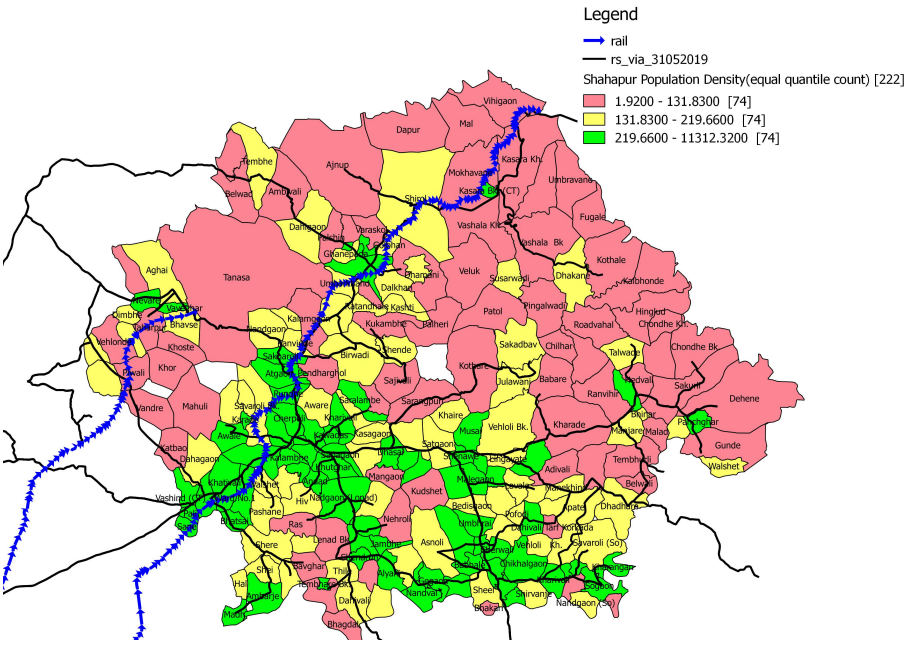


Figure 6.3: Trends of Population Density in Shahapur Taluka (4)

In the above figure equal quantile count method was used in QGIS. Interestingly, the places where there was local station like *Kasara bk., Vashind, Asangaon* the population density was high. Along with that if we see places like *Dolkhamb, Kinhavali, Lenad* forming another set of high population density areas. It is also reported that upper Shahapur taluka is sparsely dense because of hilly terrain compared to the plainer terrain of lower Shahapur.

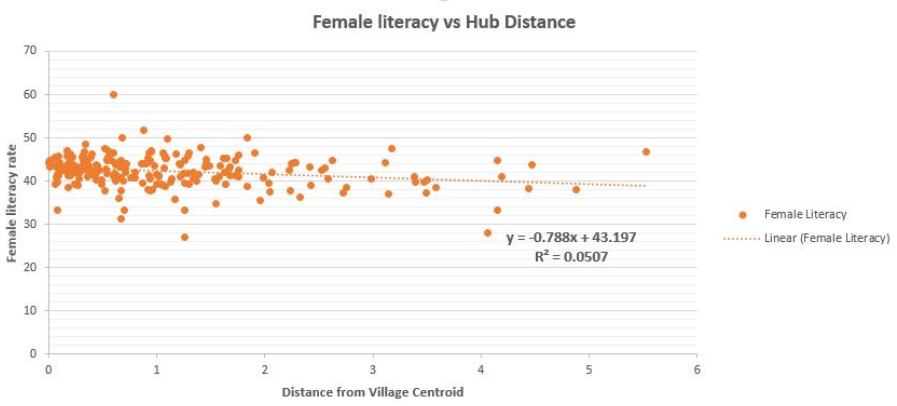


Figure 6.4: Female literacy versus Hub Distance from State Transportation Network

In the figure above we can see that there is no significant linear correlation between distance from hub to female literacy percentage(8). Further investigation needs to be taken in this area for commenting anything concretely.

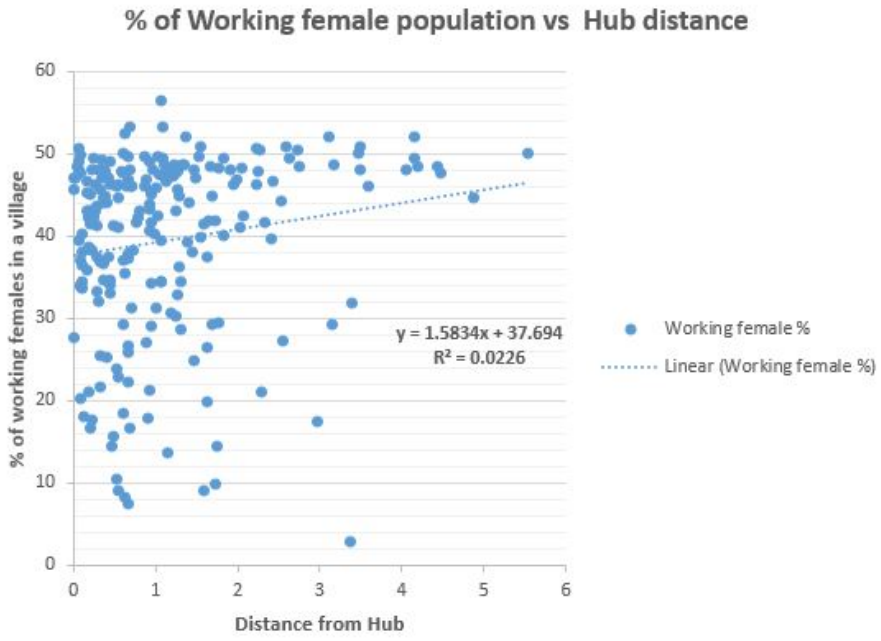


Figure 6.5: Percentage of Working females with Total working population versus Hub Distance from State Transportation Network

Working females form **37.12%** of the total working population which is **136391** compared to **50631**. In the above figure as well there is no significant linear correlation coming out between hub distance to percentage of female working population with the total working population in Shahapur taluka. One might get tempted to see the trends of number of working females with hub distance.

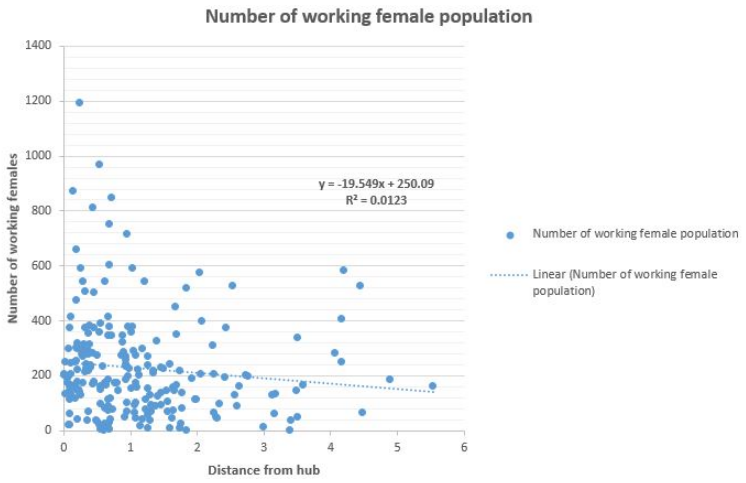


Figure 6.6: Number of Working females versus Hub Distance from State Transportation Network

In this figure we can see by observation that there is no linear correlation however between the number of working females and hub distance but the density of points in distances less than 2 kms is significantly higher than the distances greater than 2 kms. So let's see the % of working female population less than 2 kms versus the total working female population. We see that **43203** females are working in distances less than 2kms compared to total working females that are **50631** which constitute **85.33%** of the total working females in Shahapur Taluka.

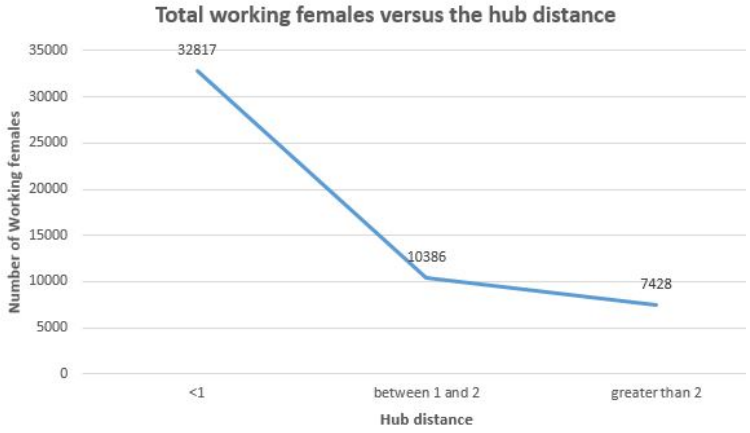


Figure 6.7: Number of Working females versus Hub Distance from State Transportation Network

Figure ably represents a steep drop by a factor of 3 when the distance is increased by 2 kms which supports the literature and observations. Further investigations must be taken by the researchers to explain the causality and more deeper investigation is needed to comment anything over these trends.

Routes with maximum population demand are *Shahapur-Nashik, Shahapur-Kasara, Bhatasa-Khardi* etc. Please note that these are the sum of the population of residents of Shahapur Taluka for one-side of route. Interestingly if we want to see the Population demand per kilometer the routes change

From	To	Total Population demand	Total Female demand	Length	Population demand/km	Female population demand per km
SHAHAPUR	NASHIK	51330	25190	94	543	267
SHAHAPUR	KASARA	42404	20731	33	1284	628
BHATASA	KHARDI	41284	19826	29	1410	677
KHARANGAN	AASANGAON	36706	18101	39	930	459
KHARPAT	AASANGAON	36512	17977	37	990	487
SOGAON	AASANGAON	34363	16910	36	960	473
SHAHAPUR	TALWADA	32844	15998	36	908	442
AASANGAON	CHONDHA	32550	15990	43	760	374
AASANGAON	GUNDE	32358	15941	42	769	379

Table 6.1: Population demand and total female population demand on any route of *Shahapur Taluka*

Now let's see the top 10 population demand per kilometer routes

From	To	Total Population demand	Total Female demand	Length	Population demand per km	Female population demand per km
VASHIND	BHATASA	22267	10600	5	4790	2280
AASANGAON	KRUSHNACHI WADI	14801	6928	4	4029	1886
KRUSHNACHI WADI	AASANGAON	14801	6928	4	4029	1886
SHERE	VASHIND	22267	10600	7	3087	1470
VASHIND	SHERE	22267	10600	7	3087	1470
KRUSHNACHI WADI	SHAHAPUR	19167	9183	6	3007	1441
SHAHAPUR	MAHULI	16830	8286	7	2559	1260
SHEI	VASHIND	22267	10600	9	2352	1120
MASAVANE	VASHIND	24997	11963	11	2183	1045
BAVGHAR	VASHIND	25185	12060	12	2176	1042

Table 6.2: Top 10 Population demand per kilometer and total female population demand per kilometer on any route of *Shahapur Taluka*

Chapter 7

Suggestions for Improvement of Transportation as service in Shahapur Taluka

7.1 Convergence of Bureaucracy

Supply, Demand and Infrastructure form the pillars of the transportation system and its service provisioning. Certain gaps were identified through the field-work.

7.1.1 Bus-Depot

i. **Bus-Depot must be made an independently functioning unit** where majority decision making should be shifted towards the depot. For instance Form 4 is updated and created at division level which must be created and managed at the depot level and must be published for the passengers for visualization.

ii. **Crew Management and Scheduling** should be through software / finger printing and reprimand mechanisms should be tighter so that shift faltering can be controlled and bettered.

iii. **Development of ABC forms** is currently full of drudgery and human errors to the level that the values reported are wrong and hence false 20-point might be generated which

must be monitored and audited for correctness.

iv. **Availability of GIS data at Taluka level** because there is no bus-stop data with depot hence it cannot be represented on maps. Our methodology gives an empirical idea about the transportation situation in taluka but it is not adequate. This gap of lack of data does not allow customers to inquire "where is my bus, if I am standing near *Sapgaon* fata?"

v. **Range of B type routes** is currently between EPKM 22.1 to 43.2 which is a large range and must be divided into three categories which are top 15% B routes, middle 70% and bottom 15% routes. The bottom 15% can be considered as threat and top 15% can be considered as opportunities.

vi. **Auto generation of ABC data** is important because when the reports are generated it is already 11^{th} of the month and any detour can be taken after month ends. But as it turns out for example February report's output can be implemented in the month of April by which the situation of the bus-services will be even poorer. One of the major gaps is forecasting mechanism to MSRTC that forewarns the decision maker about the bad routes.

vii. **Punctuality and Profitability** is not monitored currently for making decisions which is a huge gap when we try to see this a social enterprise which also must be efficient and should be self sufficient without any help from Government.

viii. ***Manav-Vikas*** buses are decided on the basis of census data which is fair in some ways but are those bus helping and by how much ? How much *manav-vikas* is actually *manav-vikas* this quantification has to be done.

ix. **Geotagging and Survey of institutions** like offices, hospitals, schools, colleges etc. will give a clear estimate of demand which will be less fluctuating to MSRTC. Separate shuttle buses for pass-holders, women should be plied which makes sure that no passenger is standing which will attract population to buy pass in exchange of better services. Identification of routes with housing societies will also help MSRTC to ascertain the

pockets where an increase of ticket price can be afforded by the masses in exchange of service.

x. **Approaches to bring the depot in profit** should be made because social-welfare can only be affordable to MSRTC when it is self-sustainable. A loss stricken enterprise can hardly contribute to the social-development. And if it could that will be half-hearted effort which will only increase the troubles of MSRTC.

7.1.2 Public Works Department

Public Works Department is responsible for erecting and maintaining the bus-stops, infrastructure that is roads and its quality, safety wall etc. structures. PWD should in tandem with the depot should work together for service provisioning in Taluka. Right now the only communication that happens between the depot and PWD is only on paper. There is a lack of an integrated system that helps not only in better transportation planning. For example *Shahapur-Murbad via Lenad* route is one of the most profitable routes for MSRTC but it is under-construction. MSRTC was not consulted before the commencement of the construction as a result of which the passengers also suffered with poor serviceability and suffered subsequent losses. These roads can be maneuverd by jeeps and since the roads are all dug up there are steep chances of accidents thereby jeopardizing with the safety of the passengers.

7.1.3 Panchayat Samiti and Villages

As we are talking about convergence of bureaucracy. One thing must be taken into account is the demand side of the transportation. This demand is created by the society, institutions, markets, festivals etc. BDO through *Gram-sevaks* must ask the villagers to put Transportation planning as an agenda of the bi-monthly *Gram-Sabha* regarding what timings the villagers want the service, where they want to go and what are the obstacles. Once these things can be gauged they can be collated together and can be given to PWD and depot for infrastructure building and service provisioning respectively.Panchayat Samiti meetings proceedings must be made public.

7.2 Participatory based Rural Transportation Planning

A large portion of women still resides in villages which does not travel through buses at all. So through Participatory based transportation planning must be initiated as per United Nations protocol and certain agencies must be involved to gauge this demand so that for every village we'll be able to understand what are their demands of transportation?, who is getting benefited?, Who will use the service? questions can be answered. PWD along with *Tehsildar Office* can work together based on GIS data to resolve the legality of the road construction as well.

7.3 TRIMAX portal

The TRIMAX portal doesn't allow depot employees to download the data in excel format for maybe compliance issues but the outcomes of such decision leads to high level of drudgery for Traffic Controller and Announcer etc. In fact TRIMAX should make a unified portal that not only helps depot traffic manager but also auto generates control charts and other data frameworks required for depot management. The current portal does not have facility to insert data / update data etc. it only displays data on the webpage and allows taking print-outs. So, here we see technology not helping in reducing the work load of an employee but increasing it which I think is one of the major gaps in service provisioning by MSRTC.

Recommendation to MSRTC regarding TRIMAX:

i) Trimax must upgrade the portal where at depot level operational data like *manav-vikas*, senior-citizen, *Ahilyabai-Holkar* etc data can be added.

ii) One more recommendation which may be a long term solution is that MSRTC must issue chip cards to all the pass holders which can be loaded with money at depot and can be swiped on the ETIM. This will save huge amounts of time-efforts and the portal will also display better data.

iii) Trimax must also publish the data of punctuality of a bus for example if the session

on ETIM was started by a time range of 15 mins a notification must go to the Depot manager about late coming of bus, also this data must be correlated with the profitability.

7.4 Regulatory Actions and monitoring of Non-licensed vehicles in Taluka

Currently there are about 400 auto-rickshaws, 250 jeeps and 30 minidors operating in the taluka. Following are the actions that will reduce the gaps in service provisioning in taluka:

i) From survey it was found that the jeeps' ownership is third-hand. This poses not only a serious threat on income of the drivers but also on the safety of passengers

ii) Unregistered vehicles and non-licensed drivers are rampant in the taluka because of the corruption amongst traffic police deputed.

iii) All the substitute services overload their vehicles for regulating the costs for customer and poorer masses prefer affordability over serviceability.

iv) Currently there is no official count of non-MSRTC vehicles by RTO in taluka. This rampant service provisioning is harming MSRTC because in official methodology they do not factor the availability of other means of transport while service provisioning. Hence there are pockets of over-service and under-service.

v) Mechanisms to collaborate with the jeep drivers following the Ola, Uber model for service provisioning i.e simply put bring your vehicle, we'll check it for fitness, if condition is good then can be deputed to the routes which are loss-making for MSRTC (bus capacity is 44) but can be a profitable to a jeep driver given he/she doesn't overload and speed limit is not breached.

Chapter 8

Conclusion

The aim of this report was threefold. Firstly we tried to understand the working of Taluka bus-depot and service provisioning in Shahapur Taluka. Secondly we tried to ascertain certain data-structure based model which integrates GIS, Transportation and Demographics data, which can be queried and displayed. Third was to undergo rigourous field-work which involved meeting the stakeholders right from MD MSRTC to a villager/jeep driver etc. Overall we tried to comeup with a methodology / protocol to develop digital geography for a taluka with minimum data availability based on empirical approaches.

There are gaps in service provisioning of transportation in Shahapur Taluka. Mainly because of the proximity of Asangaon/Vashind/Kasara stations the settlement has become very much distributed. Shahapur has pockets of high population density like Kasara lying next to the very less population density, such disparity makes it difficult to rural transportation planners to ascertain a sustainable social transportation policy that not only takes care of the service quality, affordability, profitability but also social responsibility.

Digital geography has a great potential to be scaled up and questions can be worked out for optimization, maximum coverage and all the other graph theory questions which can have a direct impact in the decision making process. The methodology developed in previous chapters needs to be extensively tested in field with different geographies and demographics and the protocol must be tightened. Having said that MSRTC does not have a R&D wing to do these kind of sophisticated researches for them. This is where IITs, IISERs, IIITs, NITs and

regional engineering colleges should take the steering wheel by doing the much necessary regional transportation plan development with IITs as the knowledge centre.

It may be concluded that the intent for social-development is at the right place in not only service-providers, consumers, infrastructures, regulators and knowledge centers but the convergence of all these departments for overall social development of a Taluka is not there. It will take something greater than intent that will bring appropriate application technology for the development of the society. This appropriateness will come when all the stake-holders will sit together and develop a regional transportation development plans that divides the taluka into zones of under-service, over-service, population density, income groups, women and institutions then only the holistic development through Taluka Transportation will take place.

It is necessary and possible to create the metrics for appropriate allocation of resources. This planning can be done at the granularity of talukas as shown in this paper. It is possible to extend the indices like RAI(Rural Access Index) by adding digital geography. By sharing these metrics with public this can even increase community participation and in turn community satisfaction.

Chapter 9

Future Work

The nature of the research was more of an exploratory in nature hence a lot of work went into understanding the bus transportation system and its interdisciplinary nature. The premise that have been set up gives way to the following future works:

Future work: 1 **Development of a web-based application**:

The current understanding of system has highlighted the drudgery undertaken by a depot office staff despite the availability of technology and solutions. If a web-based application is developed for MSRTC that will greatly reduce the work-load of the traffic department.

Future work: 2 **WebGIS open-source portals:**

The shapefiles developed can be made public for researchers using a webGIS portal. This portal will allow user to play around with the data and shapefiles online. Further this gives way to crowd sourcing of data for better service provisioning.

Future work: 3 **Vehicle tracking system:**

MSRTC is undertaking Vehicle Tracking System in Nashik District. It can be studied and expertise can be expanded on the subject matter.

Future work: 4 **Tightening the methodology:**

Implementing the methodology proposed in other talukas like *Sinnar, Mal-*

van, Bhivandi etc. and tightening the methodology with the help of ETIM data and MSRTC.

Future work: 5 **Graph connectivity and discrete computational geometry problems posed:**
Current system opens avenues to critically examine Shahapur Taluka Depot bus-network as a graph and various parameters associated with its connectivity, coverage. Availability of a graph along with geometrical data also open new avenues of Discrete geometry and might attract researchers towards the same.

Future work: 6 **Development of an API and subsequently plugin:**
Currently digital geography as a data structure will need a set of methods to insert, update, delete, seek etc. and detailing of the data structure is needed. Once done, will lead to development of an API and subsequently a protocol to develop digital geography without much hassles hence a plugin.

Future work: 7 **Development aspect:**
My work cajoles with the idea of social development in this project. A deeper dwelling in this is needed. The aspects of woman's requirement and expectation from a bus-transportation system, under-privileged people and bottom 80% is required. The system provides a firm base to develop a hypothesis.

Future work: 8 **Qualitative research:**
Qualitative questions like "What are the factors that lead to poor productivity of an employee of MSRTC?" , "What can be the ways to quicken the participatory rural transportation planning process?", "What are the factors that lead to illegal service provisioning of jeeps in Shahapur Taluka?" and various other system dynamics problems.

Future work: 9 **Analytics:**
One of the outcomes of the project is that now we got hold of the ETIM

data of one year in Shahapur Taluka. This data was obtained very late in the project hence not much could be done with it. We also still don't have the GPS data of bus-stops. However it opens up an opportunity for data analytics and understanding the trends of punctuality and profitability, till what bus stop MSRTC makes profit and way forward. Since there is also census data latched with operational data we can also develop probabilistic models to gauge the demand on various routes in Taluka.

Future work: 10 **Rural Planning reforms:**

Current rural planning still needs better evidence from the field reality and the understanding at the higher level of bureaucracy is still bird-eyed. A research can be undertaken taking evidence of this report to determine the lacunae in the system and systematically develop methodology to tackle the same.

Chapter 10

Annexure

10.1 Annex 1: Setting up the environment

10.1.1 pgAdmin3 Installation

The steps are as follows:

Step 1. Update your system.

#sudo apt update

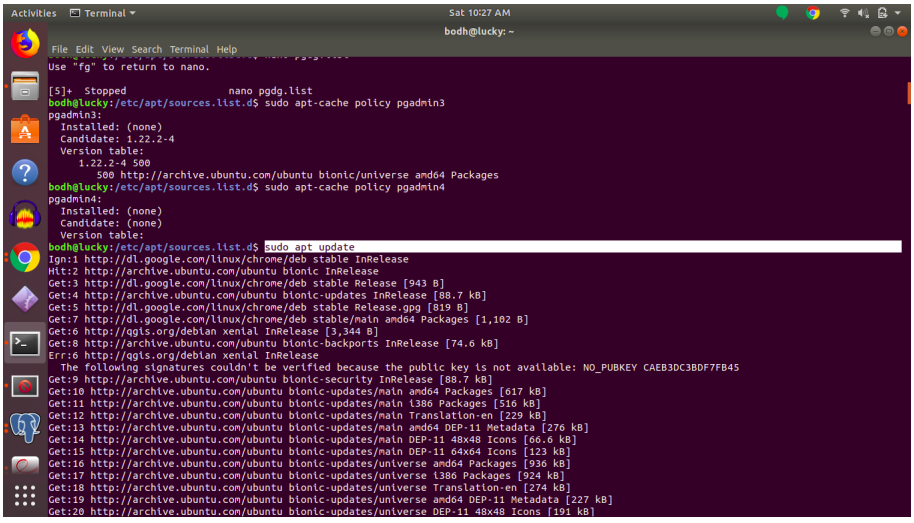


Figure 10.1: Step 1 pgAdmin3 Installation

Step 2. Upgrade your system.

#sudo apt full upgrade

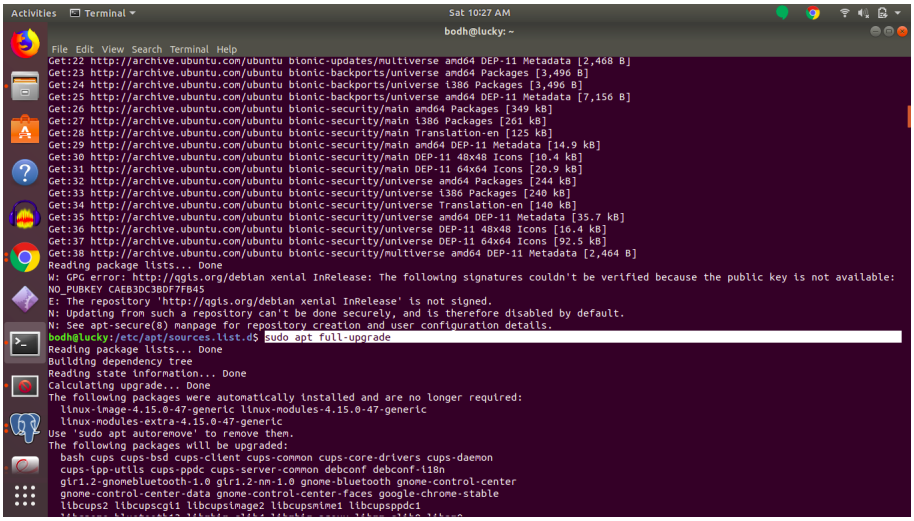


Figure 10.2: Step 2 pgAdmin3 Installation

Step 3. Check if pgadmin3 is present.

#sudo apt-cache policy pgadmin3

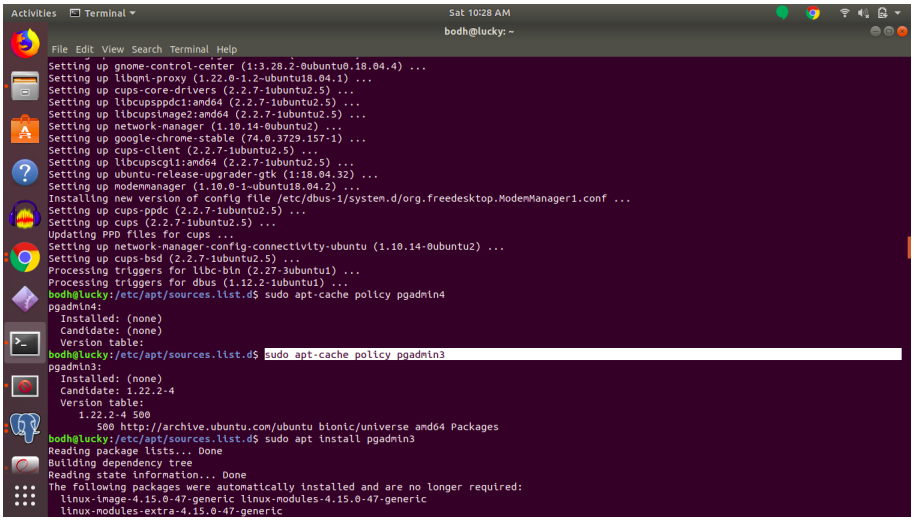


Figure 10.3: Step 3 pgAdmin3 Installation

Step 4. Install pgadmin3.

#sudo apt install pgadmin3

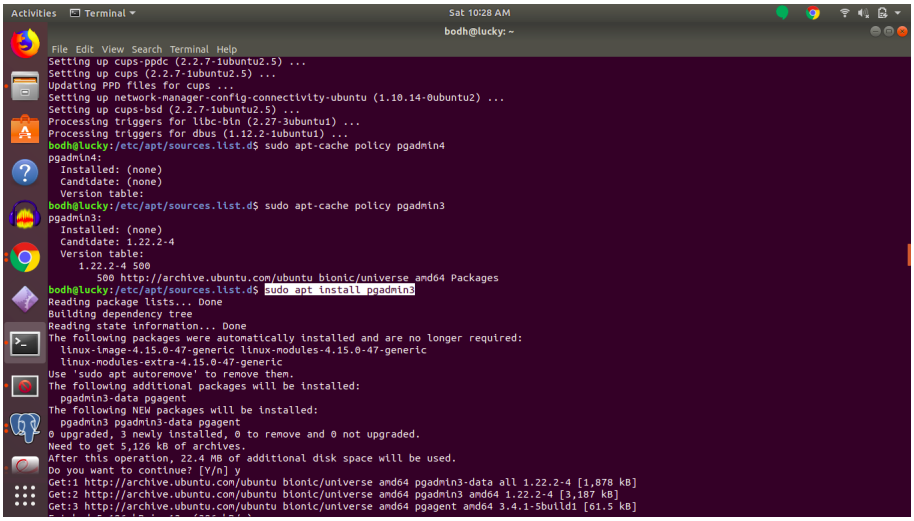


Figure 10.4: Step 4 pgAdmin3 Installation

Step 5. Check if postgresql is installed.

#sudo apt-cache policy postgresql

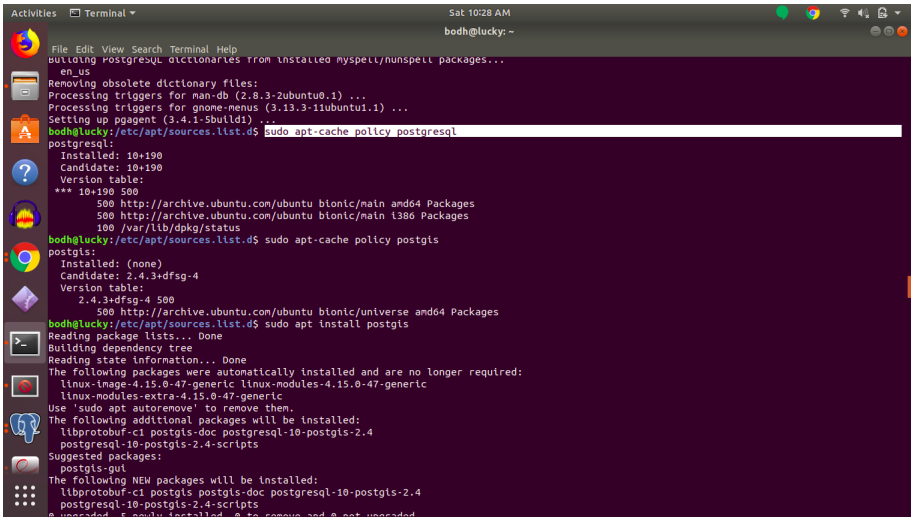


Figure 10.5: Step 5 pgAdmin3 Installation

Step 6. Check if POSTGIS is installed.

#sudo apt-cache policy postgis

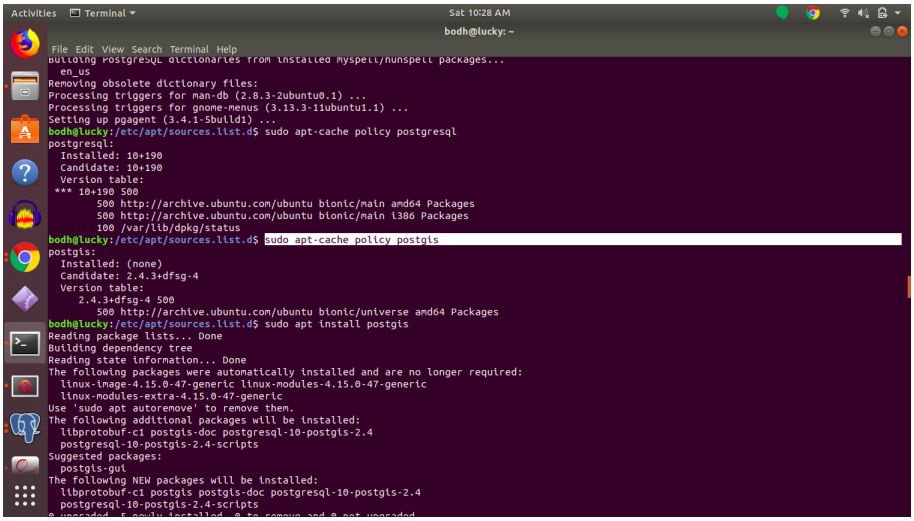


Figure 10.6: Step 6 pgAdmin3 Installation

Step 7. Installing POSTGIS.

#sudo apt install postgis

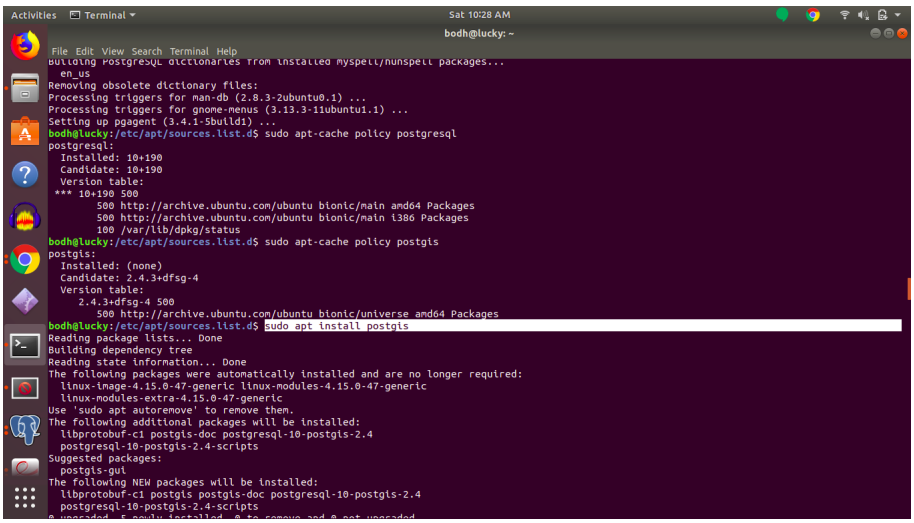


Figure 10.7: Step 7 pgAdmin3 Installation

Step 8. Open pg_hba.conf from/etc/postgresql/10/main/

#sudo cat /etc/postgresql/10/main/pg_hba.conf

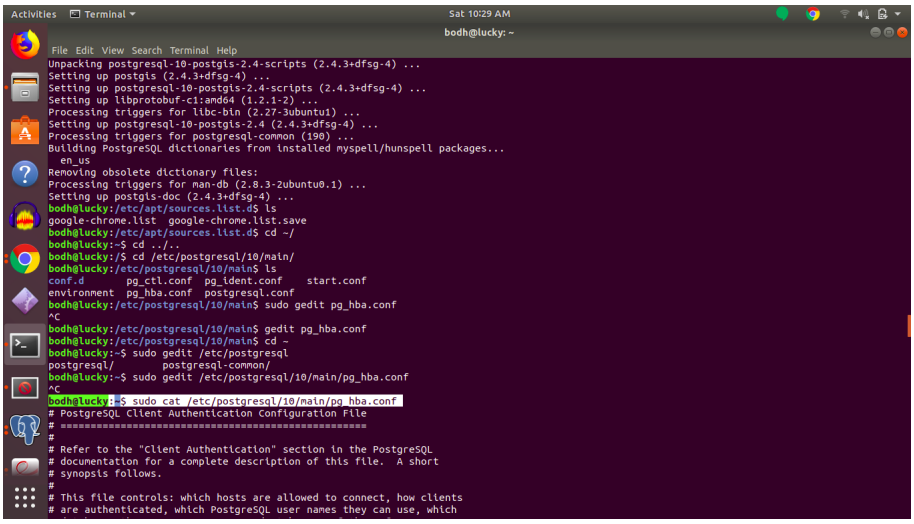


Figure 10.8: Step 8 pgAdmin3 Installation

Step 9. Look at this highlighted section of pg_hba.conf file.

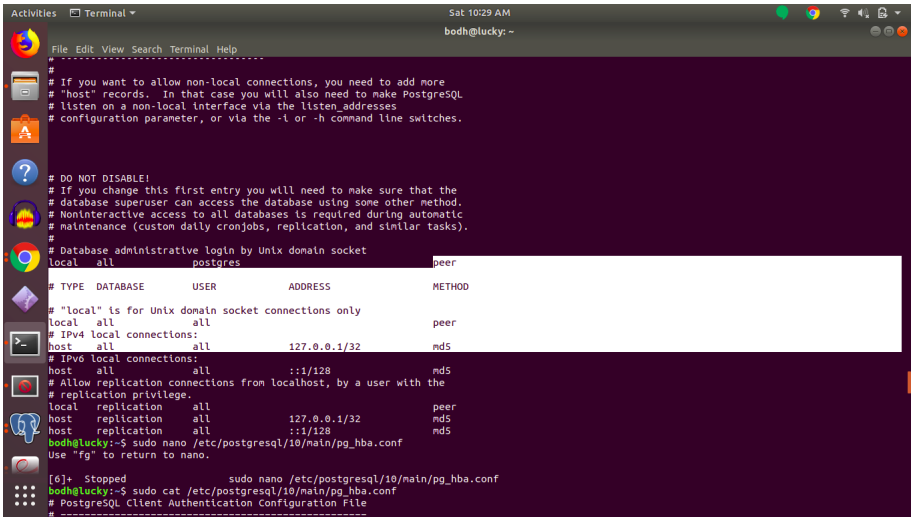


Figure 10.9: Step 9 pgAdmin3 Installation

Step 10. To edit the file use nano command, you have to change ‘peer’ and ‘md5’ to ‘trust’

#sudo nano /etc/postgresql/10/main/pg_hba.conf

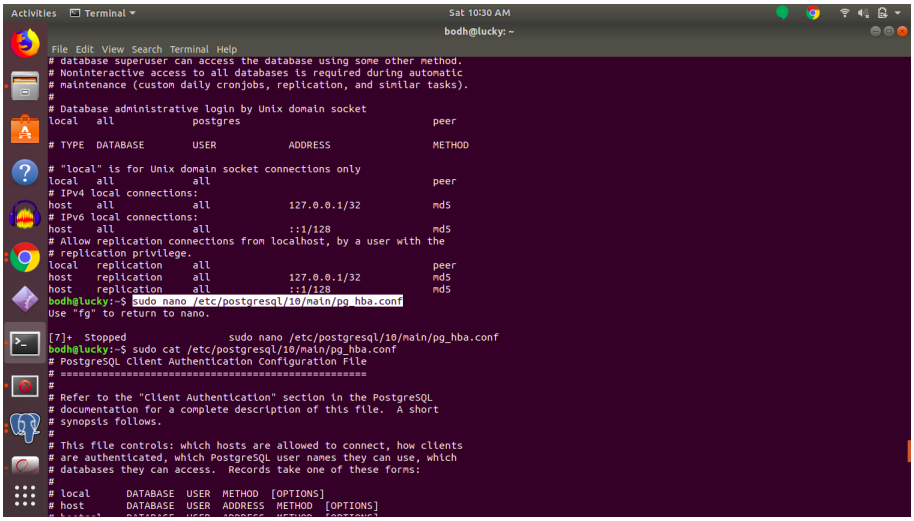


Figure 10.10: Step 10 pgAdmin3 Installation

Step 11. Open the file again to see if changes persist.

#sudo cat /etc/postgresql/10/main/pg_hba.conf

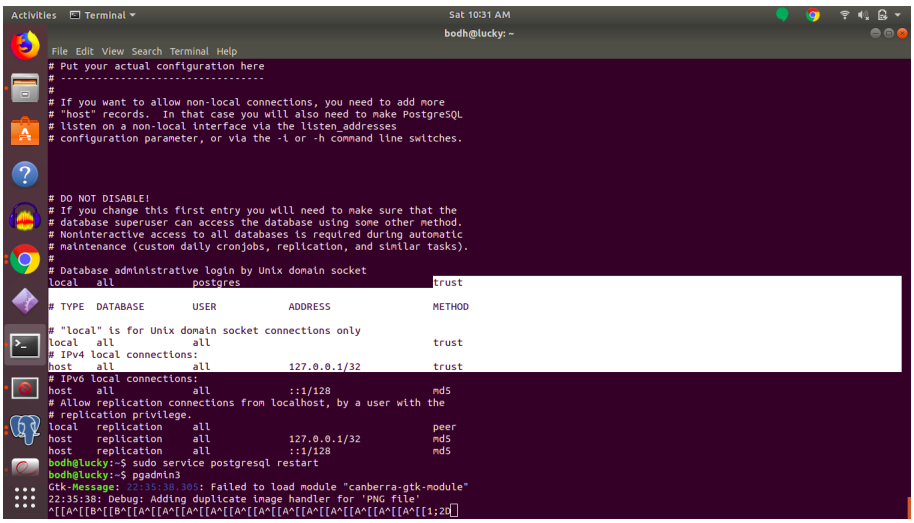


Figure 10.11: Step 11 pgAdmin3 Installation

Step 12. Restart postgresql for it to configure all the changes.

#sudo service postgresql restart

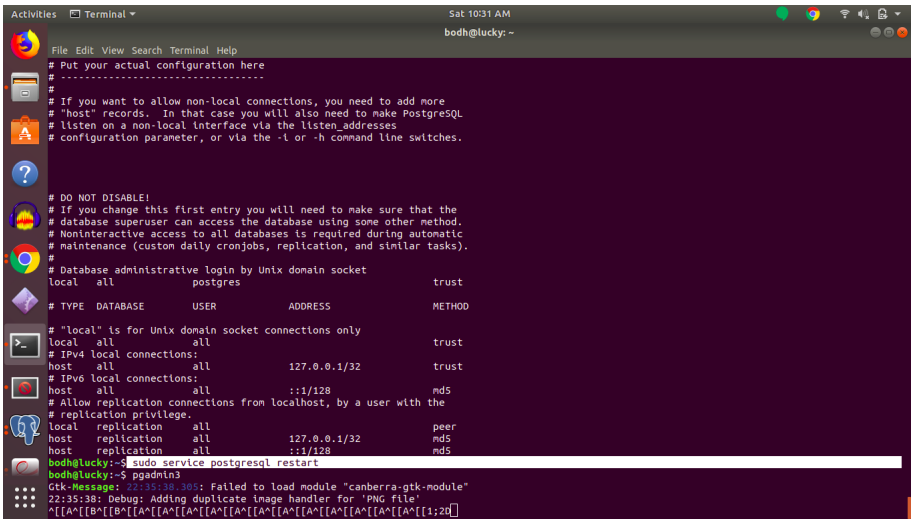


Figure 10.12: Step 12 pgAdmin3 Installation

Step 13. Open pgadmin3.

#pgadmin3

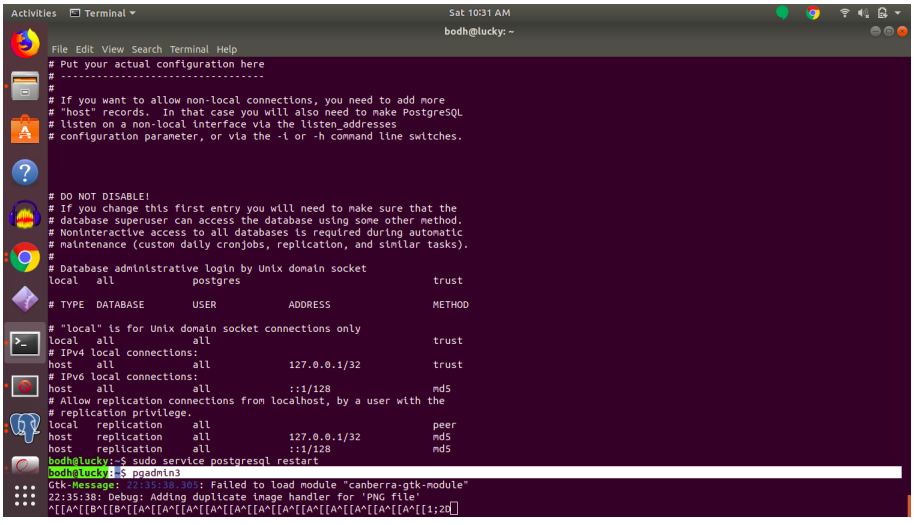


Figure 10.13: Step 13 pgAdmin3 Installation

Step 14. Goto File - Add Server

Enter a name for your server.

In Host field enter “localhost” or 127.0.0.1 to create a local database server.

Keep the port as it is, 5432 is default port used by postgres.

Enter a password of your choice.

Check or uncheck the store password checkbox based on your need.

Press OK.

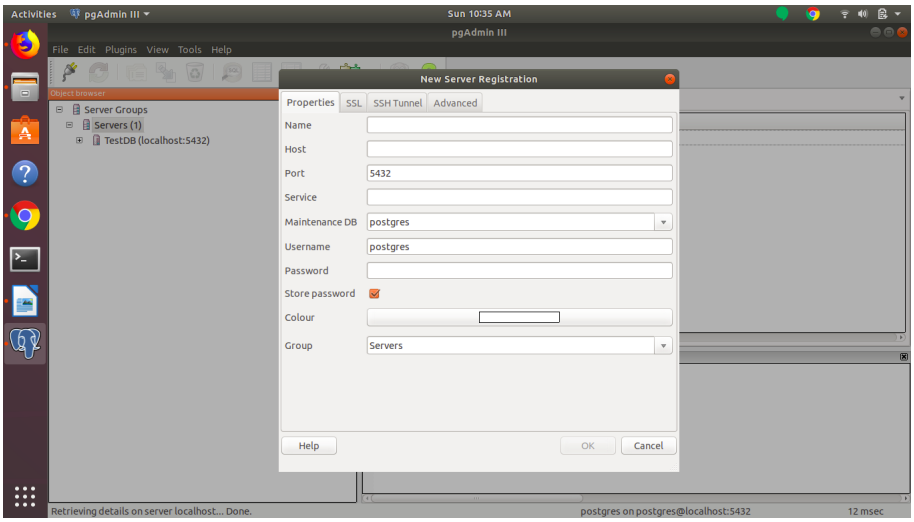


Figure 10.14: Step 14 pgAdmin3 Installation

Step 15. A server created by you will appear on browser panel on left.

Click on the + sign you will see the option of

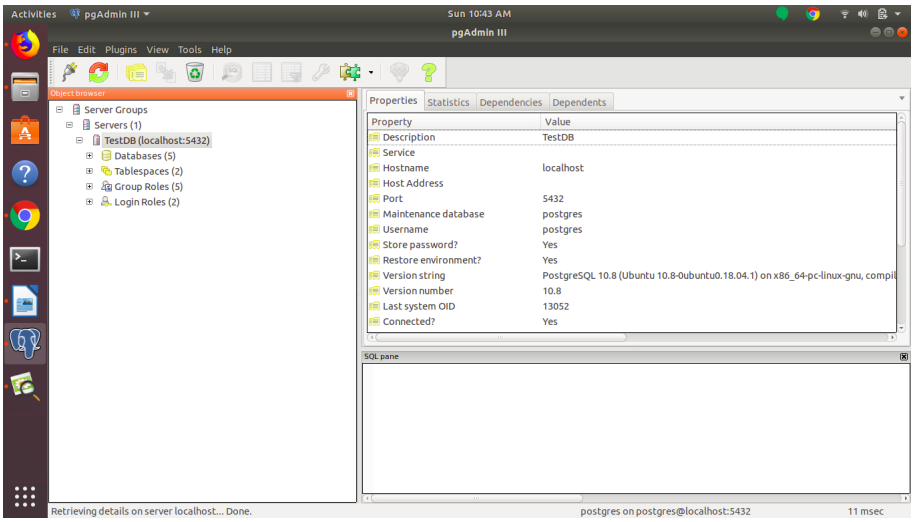


Figure 10.15: Step 15 pgAdmin3 Installation

Step 16. Right click on databases ¿ New Database

Enter a suitable name.

Put owner as postgres.

Click OK.

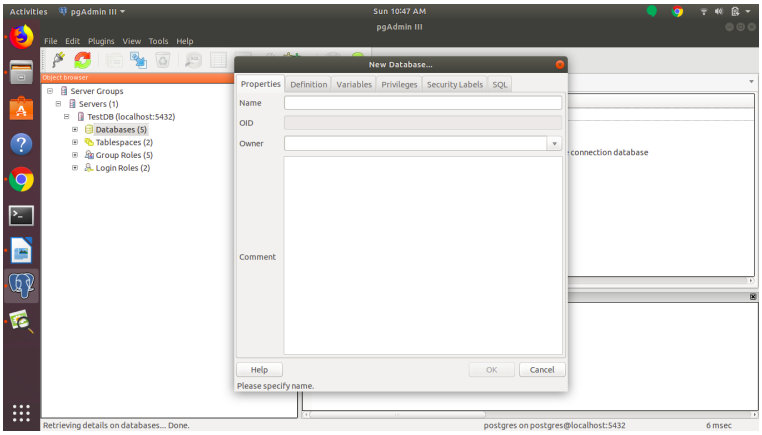


Figure 10.16: Step 16 pgAdmin3 Installation

Step 17. Expand the Database you created.

Goto Extensions ¿ New Extension

Select postgis from the dropdown list for names and in Definition choose version 2.4.3.

Click OK.

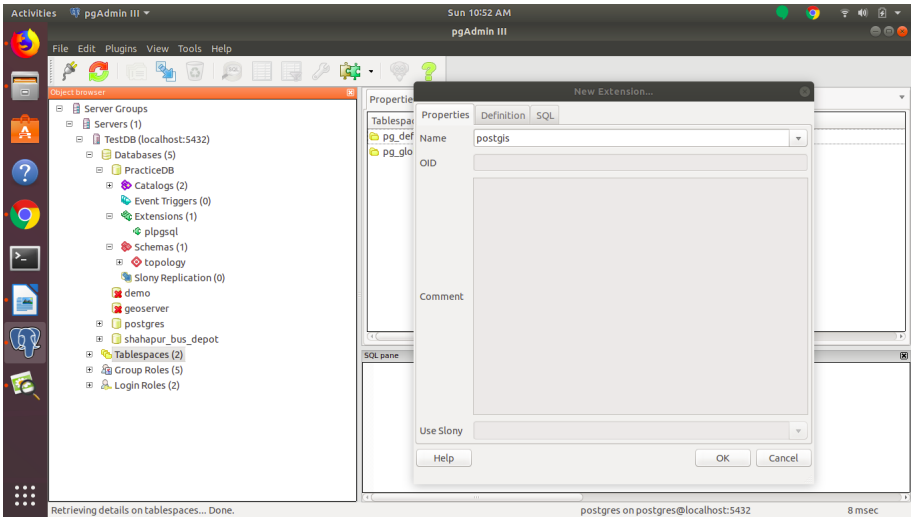


Figure 10.17: Step 17 pgAdmin3 Installation

10.1.2 QGIS 2.18 Las palmas Installation

Step 1. Download Binary Package- Qgis_2.18.17+dfsg-1_amd64.deb

From the site in the reference OR from above link and save it in your home folder.

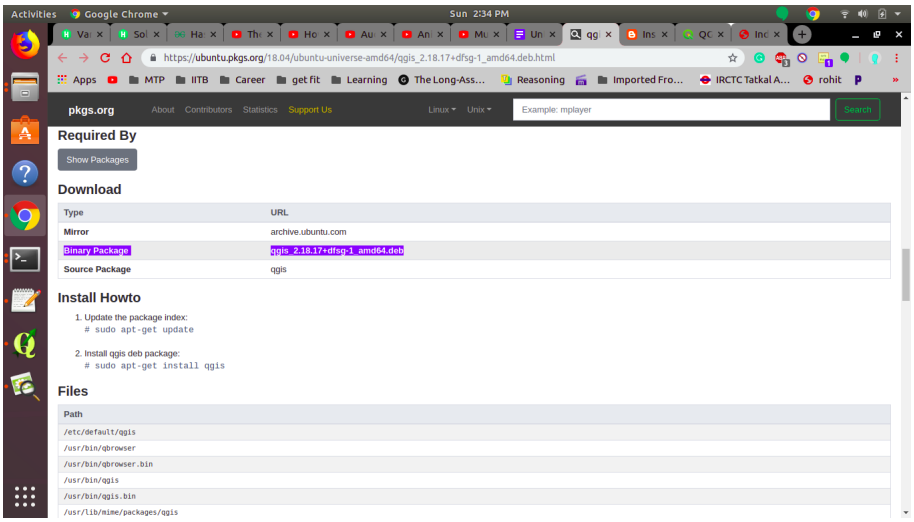


Figure 10.18: Step 1 QGIS2.18 Installation

Step 2. Open terminal from your home directory.

Update your system using: #sudo apt-get update

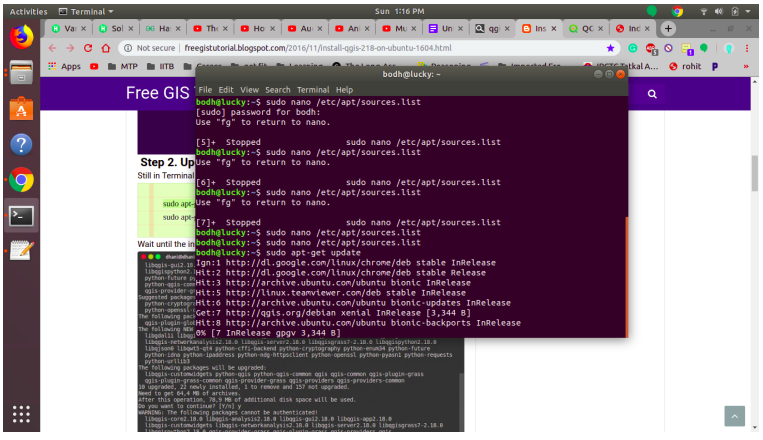


Figure 10.19: Step 2 QGIS2.18 Installation

Step 3. Install QGIS using command:

#sudo apt-get install qgis

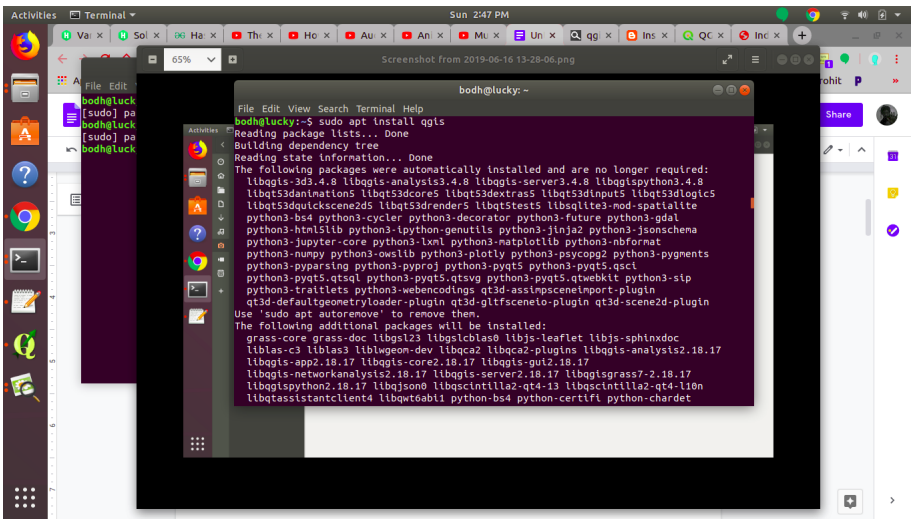


Figure 10.20: Step 3 QGIS2.18 Installation

Step 4. Enter: qgis

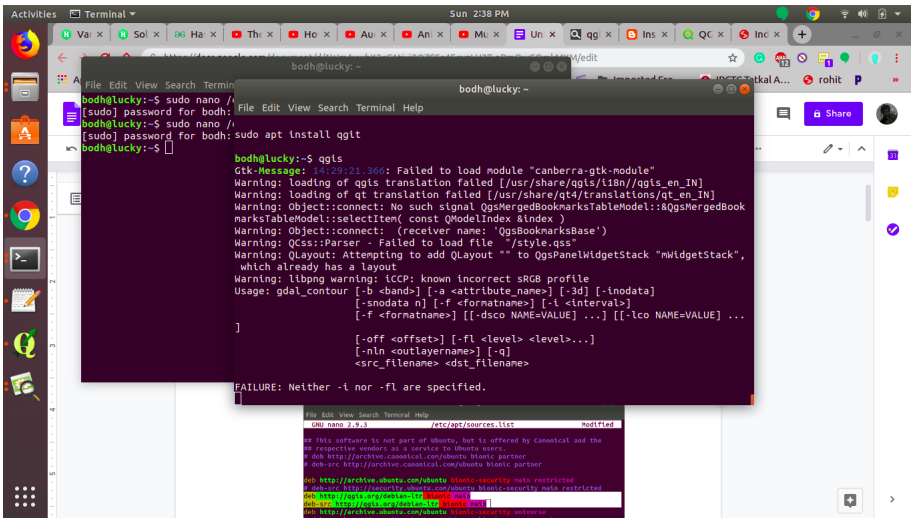


Figure 10.21: Step 4 QGIS2.18 Installation

Step 5. You have successfully installed QGIS 2.18.17 las palmas on Ubuntu 18.04.

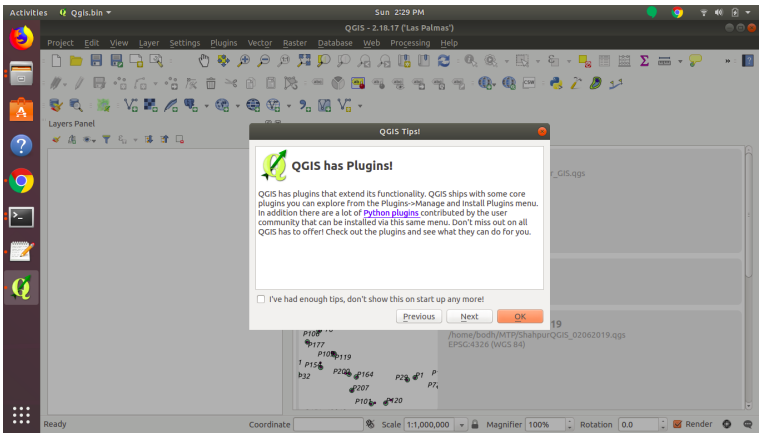


Figure 10.22: Step 5 QGIS2.18 Installation

Step 6. In case such an error occurs where a dependency is not installed.

For example highlighted line shows 'python-qgis' dependency is not installed. Now install all dependencies that are shown in such situation using:

#sudo apt install python-qgis

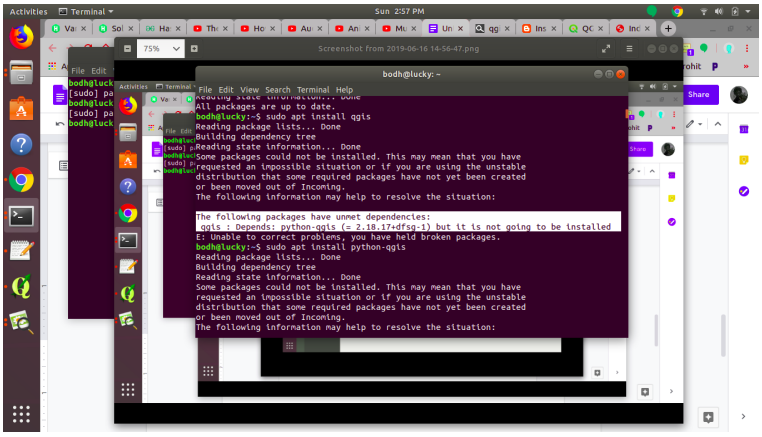


Figure 10.23: Step 6 QGIS2.18 Installation

In general: #sudo apt install dependency-name

Once all dependencies are installed do the step 3.

10.2 Annex 2: Questions to ask and people to meet on a 2-day visit to any taluka bus-depot

People	Document	Sample Questions
Bus Depot Manager	Form-4, Inward-Outward letter, 20-Point report, User interface of portal	Seasonality/festivals where buses are redirected,what is his/her daily routine in depot, How any village can ask for bus-stop? How is a terminal/route decided/updated/ scrapped, number of buses/routes, manav-vikas routes? What is manav-vikas? Panchayat-Samiti monthly meeting proceedings? Who goes in Panchayat Samiti meetings? How manav-vikas feris calculation is done? Who decides the manav-vikas feris? How are they decided? How many categories in which MSRTC offers rebate?
Traffic Controller	ABC-Operational Data, Shift schedule	What is ABC data? What steps he/she follows to get that? Where does this document go? From where the information is collected? What is done of type C routes? How a route is decided? What are the major issues with crew? Are they punctual? Has any of them got suspended?Why? If automation in crew management is to be done, what features are expected? On what issues passengers fight with the Traffic controller? What is the complaint redressal mechanism? a) Internal b)External
Announcer	Control Chart	What is a control chart? How it is prepared/updated/stored? Who supervises/audits the control chart? What is his proficiency with Computer/Android phone? How does late-coming of buses recorded? Which buses are late frequently? Which Bus-service is the most frequent? What automation in Control chart needs to be done, so that it eases his work?
Driver-Conductor	Ticket/ETIM/Tray	What is a tray? How earlier ticket was prepared using punch holes and stapler? Which is the company that provides those machines? How has ETIM eased/increased work? Has there ever been a loot of the money-pouch? Do you do double duty? How are rest-houses for crew? What facilities do they offer? What are the charges of one day utilisation of resthouse?

People	Document	Sample Questions
Block Development Officer	Any communication related to new bus-stop creation / Gram-sabha proceedings for creating a new bus-stop	How does BDO and Depot manager communicate officially? What are the cases that fall into BDOs purview in terms of transportation? Any idea about the illegal transportation within taluka? How traffic police reports the violaters? Any new PMGSY roads coming up? Any NREGA works for road construction going in Taluka?
PWD,Deputy Engineer	Communication regarding fitness of roads	How PWD office and Depot manager communicate officially? What are the cases that fall into Deputy engineer's purview? Is fixing pot-holes and road construction Geo-Tagged? If yes How? Any road construction works going under PWD of the taluka?
Jeep Stand/ Auto Stand/ Minidor Stand	Survey Document	Survey Questions
Sarpanch	Gram Sabha proceedings on ST bus	Was there any agenda on bus stand? How people commute to work here? How commutation happens during Perni/ Lavni/ Harvest seasons? How children commute to Higher secondary school?
Local MLA		What are the issues faced by the people in taluka regarding Transportation? How are they addressed?

Table 10.1: Important questions to be asked in a 2 Day taluka Depot visit

Bibliography

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