GIS-based Enterprise-level Decision Support framework for State Public Bus Transportation, Maharashtra, India (MSRTC)

A Master's Thesis Report
Submitted in partial fulfillment of
the requirements for the degree of
Master of Technology
by

Anshul Kumar
(Roll No. 183350002)

Supervisor:
Prof. Milind Sohoni

Centre for Technology Alternatives for Rural Areas
Indian Institute of Technology Bombay
Mumbai 400076 (India)

21 June 2020

Acknowledgements

I would like to thank Prof. Milind A. Sohoni for his keen guidance and constant support. All the meetings and discussions were highly helpful in gaining the required insights into the work. A very special thanks to Prof.Jitendra Shah for his valuable suggestions and helpful discussions throughout the MTP work. Also a very special thanks to Mr. Sudanshu kulkarni.

I also would like to thank Sinnar Taluka Depot Manager Mr. Bhushan Suryavanshi of Division office for their assistance and improving my understanding of the system.

I also would like to thank Ms. Anshu Kant (M.Tech Intern GISE lab), Ms. Ramya Sharma (Phd. IIT Bombay), Animeesh Natiyal (T.D.S.C. IITB) and Sunny Johari (M.Tech, CTARA), for their valuable input

I would also like to thank Prof. Ujwala Bhangale (KJ Somaiya College Of Engineering, KJSCE) and Prof. Jyothi Rao (KJ Somaiya College Of Engineering, KJSCE) and four students from KJ Somaiya College Of Engineering (KJSCE), Mr. Aaditya Mahadevan, Ms. Anina Pillai, Ms. Jigyassa Lamba, Mr. Tarush Rajput for load sharing.

Anshul Kumar
IIT Bombay
21 June 2020

Acceptance Certificate

Centre for Technology Alternatives for Rural Areas

Indian Institute of Technology, Bombay

The Master thesis report entitled "GIS-based Enterprise-level Decision Support framework for State Public Bus Transportation, Maharashtra, India (MSRTC)" submitted by Anshul Kumar (Roll No. 183350002) may be accepted for being evaluated.

Date: 21 June 2020

Prof. Milind Sohoni

Declaration

I declare that this written submission represents my ideas in my own words and where others' ideas or words have been included, I have adequately cited and referenced the original sources. I declare that I have properly and accurately acknowledged all sources used in the production of this report. I also declare that I have adhered to all principles of academic honesty and integrity and have not misrepresented or fabricated or falsified any idea/data/fact/source in my submission. I understand that any violation of the above will be a cause for disciplinary action by the Institute and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been taken when needed.

Anshul Kumar

Date: 21 June 2020 (Roll No. 183350002)

Abstract

In this study, an attempt has been made to improve the technical processes within a State bus transport organization of Maharashtra, India, i.e., MSRTC by proposing a GIS-based Enterprise-level decision-making framework. Further, some of the applications of the proposed GIS-based framework have also been illustrated. For the development of a graphical interface, a case study of Sinnar Taluka, Nashik district, Maharashtra has been considered. Field visits have been done to understand how a GIS-based interface can be developed for better visualization of MSRTC internal bus traffic-related operations. Further, a QGIS plugin is also made based on a GIS-based framework to demonstrate how the GIS-based framework can be useful in real-time by validating in 'MSRTC'. Also what other technology can be used to improve efficiency and productivity. In this report, some suggestions for the additional problems related to the MSRTC employees that were encountered in the field have been given. Finally, we finish with recommendations and scope for future improvements.

Keyword: MSRTC, Enterprise decision making, GIS

Background

Transportation is considered very important for development. Transportation provides access to markets, livelihood, medical facilities, education facilities, etc., 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 Golegaon Palam in Purna Taluka of Parbhani District, a hamlet of the size of 163 households. In our village, there was a pucca road about 3 Km far from our village and hence no bus transportation service was there. As a result, there is poor connectivity from the city and people without vehicles have to struggle a lot to reach the city. Also because of the poor road connectivity and public health, market accessibility becomes a problem especially in the rainy season which completely disconnects the village for about 4 months. Hence, I wanted to learn more about transportation in rural India and how technology can be used for the enhancement of rural transportation in India.

Table of Content

List of Images

List of Tables

List of Abbreviations

QGIS	Quantum Geographic Information System
MRSAC	Maharashtra Remote Sensing Application Centre
MSRTC	Maharashtra State Road Transport Corporation
GIS	Geographical Information System
ICT	Information and Communication Technology
EPKM	Earning Per Kilometre
ETIM	Electronic Ticket Issuing Machine
VTS	Vehicle Tracking System
GM	General Manager
IT	Information Technology
OSM	Open Street Maps
PWD	Public Work Department
ST	State Transport
FY	Financial Year
DTO	Divisional Traffic Officer
YOY	Year-on-Year

Table 1. List of Abbreviations

1. Chapter: Introduction

Technological competence is considered very much important for any organization. It helps an organization to provide better services to its customers, make an organization cost-effective i.e. reduce cost, reduce dependency on conventional methods, reduce possibilities of error, add new functionalities, and many others. The aim of this study is to improve the technical processes of a state-run government organization (MSRTC) that provides bus transportation services in Maharashtra. Transportation plays a very important role in the social as well as economic development of an area or region. It provides better access to places like markets, temples, schools, tourist spots, medical centers, etc which provides livelihood opportunities, better medical facilities, education facilities, etc. Any improvement in the transportation of a region whether technical or non-technical directly or indirectly helps in the development of that region.

A GIS-based Framework for Bus Transportation known as 'Digital Geography' (explained in later chapters) has been proposed earlier by (Mr. Sudhanshu Kulkarni, 2019), [1]. In this report we build on this framework. In simple words, Digital geography is a mapping of the demography of an area with MSRTC operational data on a GIS-based interface. In current digital geography MSRTC operational data, profitability analysis of bus trips (In MSRTC terminology known as ABC analysis) has been mapped because ABC analysis plays a very important role in various MSRTC traffic-related operations. ABC Analysis currently on MSRTC is stored in the form of long MS-Excel which lacks GIS data. Conventionally MSRTC uses these long Excel sheets for making various decisions based on ABC analysis. Analyzing any data or exploring for any data in these long Excel sheets is done manually which takes a significant amount of time and chances of manual errors are also high in this case. The proposed GIS-based framework provides new functionality i.e. add GIS or geospatial properties to the ABC analysis through which more effective decision making can be done. Not only ABC analysis, but the proposed GIS framework has many other applications also which have been described in a later chapter named "Applications of Digital geography". Finally, some QGIS plugin has been made to demonstrate how a deployable dashboard can be made to use the proposed GIS-based framework in the working of MSRTC.

For the purpose of this study, Sinnar Taluka in Nashik District, Maharashtra State, India has been considered.

1.1. MSRTC-

1.1.1. Introduction to MSRTC-

The Maharashtra State Road Transport Corporation, shortened as (MSRTC, or basically ST), is the state-run transport administration of Maharashtra, India which serves courses to villages, towns, and urban communities inside Maharashtra just as to its neighboring states.

During the FY 2016-17, MSRTC operated an average 15585 schedules on 18765 routes & carried out 206.61 crores effective Km. operation. Further. The percentage Load Factor including the value of concession in the FY 2016-17 was 68.75. During the same year, MSRTC was serving 91.64% of villages and was able to serve 96.99% population within a range of 3 Km. During the same FY 2016-17, MSRTC was at Rs. 422 Crore Loss which accounts for about 5.64% of total revenue of Rs 7056 Crore. MSRTC had 91.98% operations through Ordinary Services. MSRTC had 7.02% operation through Semi Luxury service and 0.99% through Air Conditioned services in the same financial year. In the same FY 2016-17, MSRTC has operated 1.93 crores Kms. on account of fairs and festivals and earned revenue of Rs 66.46 crore which accounts for about 0.94% of total revenue. MSRTC had received revenue of Rs 58.60 crore by operating Casual Contracts in FY 2016-17 which accounts for about 0.83% of total revenue. (Data Source- MSRTC Annual Report 2016-17).

1.1.2. Financial Losses of MSRTC-

Financial losses of MSRTC YOY (Year-on-Year) from a period of 2007-17 has been shown in *Figure 1.*

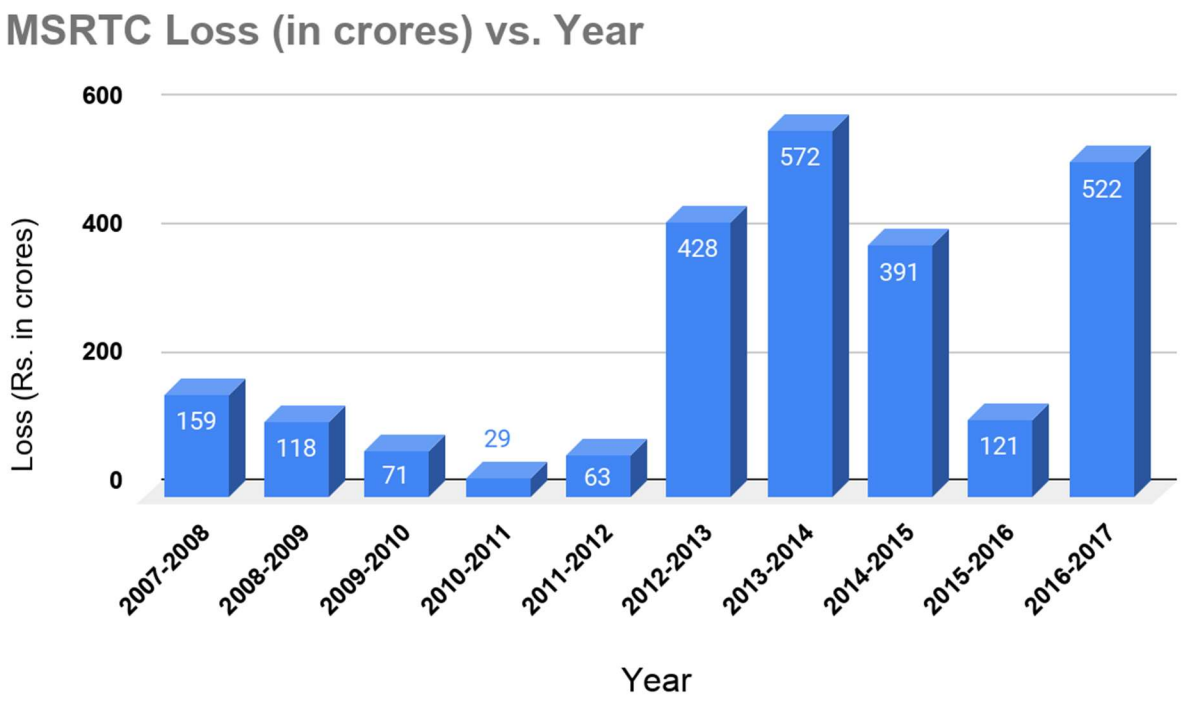


Figure 1. MSRTC losses over the years 2007-17. (Data Source: MSRTC Annual Report 2016-17)

1.2. Technological competence for MSRTC:

MSRTC is currently running into financial losses. Technological improvement can help MSRTC to reduce losses by reducing human resources required or reducing the time required for any operations. For example in the creation of a new bus route, after the path of the new bus route is proposed. MSRTC runs a few trial buses to estimate time prediction at various Bus Stops involved in the path. These can be done using a GIS-based interface by estimating bus travel speed at 30 km/hr to predict bus arrival time or departure time which has been explained later. After the proposal of routes, MSRTC runs trial buses for checking the conditions of roads also. Through GIS interface condition of roads can also be checked in the preliminary stages of new routes creation and a lot of time can be saved. GIS besides having these applications has many more applications. Currently, much of MSRTC's current work is done manually and MSRTC is trying to reduce manual work. Technological improvement also helps in reducing the chances of human errors by providing technological advancement.

National Transport Development Policy Report, 2014 (NTDPC, 2014) also highlights the need of Technology specifically Information and Communication Technology (ICT) in the road transportation sector to mitigate with the following challenges: (Source: NTDPC vol 2 Report, 2014)

A. Good quality to support evidence-based policy making.
B. Increase in efficiency of the road transport system and satisfaction of its users.
C. Management of safety and care of the injured.

1.3. Chapter Orientation:

The entire report is divided into 11 chapters. Chapter 1 sets the premise of the report, posing the research question and broad societal concern. Chapter 2 gives the information of Sinnar Taluka on which the study has been done. Chapter 3 tells all the data which have been collected and used in this study. Chapter 4 puts forward the mathematical definition of Data structure Digital Geography. Chapter 5 illustrates some of the applications of digital geography. Chapter 6 illustrates the benefits of GIS interface based on digital geography for MSRTC. Chapter 7 tells the observations in field visits. Chapter 8 explains the plugins made for the MSRTC to demonstrate how GIS interfaces can be beneficial for MSRTC according to the requirements proposed by MSRTC employees. Chapter 9 additional works done. Chapter 10 tells the future scope of the project. In Chapter 11, we finally conclude the project.

1.4. Broad Societal Concern:

The following is the Broad Societal Concern (BSC):
"Poor Technological competence of State Public Bus Transportation Maharashtra, India”

1.5. Research Question(s):

The research questions are as follows:

1. What are the applications of the proposed GIS-based framework (Digital geography)? How is it beneficial in transportation?.
2. What are the MSRTC stakeholders (like DTO and Bus Depot Manager) requirements from the proposed GIS framework?

1.6. Objective:

The objectives of the project are as follows:

1. To create Digital geography i.e., proposed GIS-based framework for Sinnar Taluka, Nashik, Maharashtra, India
2. To map MSRTC operational data on the proposed GIS-based interface.
3. To understand the requirements of various stakeholders involved in MSRTC Enterprise level decisions which can be fulfilled by the proposed GIS-based framework.
4. Based on the requirements of stakeholders, develop a QGIS plugin to demonstrate how the proposed GIS-based framework can adapt to the requirements of MSRTC stakeholders.

1.7. Methodology-

The following methodology was undertaken:

1. Visits to Sinnar Taluka depot, Nashik Divisional Office, and MSRTC head office.
2. Meeting and interviewing various stakeholders i.e. Bus Depot Manager, Depot Staff, Divisional Traffic Officer, Dy General Manager IT.
3. Analysis of MSRTC operational data i.e. ETIM data.
4. Collection of required data from MSRTC, MRSAC.
5. Development of proposed GIS-based framework i.e., Digital Geography.
6. Development of some QGIS plugins.

1.8. Proposed Outputs-

The following are the proposed outputs:

1. An integrated system of GIS data, Operational data on QGIS based framework i.e, Digital Geography.

2. Illustrations of Applications of Digital geography.
3. QGIS plugin demonstrating the real-time application of digital geography for MSRTC.

2. Chapter: Sinnar Taluka Bus Depot

2.1. About

Figure 2. Google Street Maps image of Sinnar Depot

Sinnar is one of the 15 talukas of Nashik district (census 2011). It operates around 80 buses as of February 19, 2020, on 228 routes in July 2019 on 685 trips in January 2020. The details of the buses are given in *Figure 3*. Sinnar does not have its own Railway station. The railway station is Deolali which is about 25 Km and it often acts as a source of passengers to the depot.

महाराष्ट्र राज्य मार्ग परिवहन महामंडळ

सिन्नर आगार, नाशिक विभाग

आगारातील वाहनांची आसन क्षमता

अ.क्र.	बस क्रमांक	आसन संख्या	अ.क्र.	बस क्रमांक	आसन संख्या	अ.क्र.	बस क्रमांक	आसन संख्या
१	३८३	४४	२८	४४१८	४४	५५	८२७२	४८
२	३८६	४४	२९	४५१२ सिटी	४४	५६	८३६९	४८
३	४८३	४४	३०	४५१३ सिटी	४४	५७	८३९४	३९
४	४८४	४४	३१	५०५६	४४	५८	८५५९	४८
५	५६०	४४	३२	५०५७	४४	५९	८५७५	४८
६	७५०	४४	३३	५६६३	४४	६०	८६६३	३९
७	७७१	४४	३४	६००९	४८	६१	८८३५	४४
८	७७२	४४	३५	६२२१	४४	६२	८८७९	४४
९	९२९	४४	३६	६२३६	४८	६३	८८९३ निमआराम	३९
१०	१३३२	४४	३७	६८०४	४४	६४	८८९७ निमआराम	३९
११	१३३३	४४	३८	६८१९	४४	६५	८९७६	४४
१२	१३३१ सिटी	४७	३९	६८३३	४४	६६	८९९३	४४
१३	३५४७	४४	४०	६८३४	४४	६७	९०४६	४४
१४	३५०६	४४	४१	६८५८	४४	६८	९०५१	४४
१५	३६२१	४४	४२	६८६५	४४	६९	९०५३	४४
१६	३६२३	४४	४३	७१०४	३९	७०	९०८१	४४
१७	३६३४	४४	४४	७१७५ सिटी	३९	७१	९०९३	३९
१८	३६३५	४४	४५	७३०३	३९	७२	९१०४	३९
१९	३६३८	४४	४६	७३२१ सिटी	३९	७३	९१०५	३९
२०	४०७५	४४	४७	७३२९	४४	७४	९११८	३९
२१	४०७६	४४	४८	७३४९ सिटी	३९	७५	९१६०	३९
२२	४०७९	४४	४९	७८७४ सिटी	३९	७६	९१६४	३९
२३	४०८२	४४	५०	७८९८	४८	७७	९२०५	४४
२४	४११७	४४	५१	७८९९ मिनीबस	३१	७८	९४२१ सिटी	४३
२५	४१३२	४४	५२	७९३१	४८	७९	९४२२ सिटी	४३
२६	४४१६	४४	५३	७९८३	४८	८०	९४२४ सिटी	४३
२७	४४१७	४४	५४	८१०८	४८	आगार व्यवस्थापक (क) रा.प.सिन्नर आगार		

Figure 3. Details of Buses under Sinnar Bus depot as of 19th February 2020

Type of Bus	Number of buses
Ordinary Bus	67
Minibus	1
City Bus	10
Nim Aaram bus	2
Total Buses	80

Table 2. Buses under Sinnar Depot as of Feb 19, 2020

Figure 4. A typical scenario at Sinnar bus depot as of 28th September 2019

2.2. Load Factor of Sinnar Depot:

Load factor of Sinnar bus depot as told by Sinnar Bus Depot Manager (this data hasn't been verified by any document).

- 54-58% (without concession), which increases to 70% during the wedding season.
- 65% (with concession)

2.2.1. Load Factor calculation method used at MSRTC:

The method used by MSRTC for calculation of Load factor of Bus trips is shown below.

2.2.1.1. EPKM :

EPKM stands for Earning per kilometer. This is a parameter used by MSRTC for analyzing whether a Bus trip is profitable or not. This is calculated by-

$$\square\square\square\square = \square\square\square\square\square\square\square\square\square\square \square\square\square\square\square\square\square\square \div \square\square\square$$

where,

Passengers earning is the money collected by the tickets on that particular bus trip

kms is the kilometers for which the bus trip ran.

2.2.1.2. Load Factor:

The expected rate for a bus trip used by the Sinnar Bus Depot is provided by Nashik Divisional office and Sinnar Bus depot uses the same Expected rate for every bus trip irrespective of the type of bus whether minibus or normal bus.

$$\square\square\square\square \square\square\square\square\square\square \% = \square\square\square\square \div \square\square\square\square\square\square\square\square \square\square\square\square$$

However, Expected rate of bus trip can be calculated by

$$Expected\ Rate = Fare\ of\ complete\ trip * Bus\ Capacity \div kms$$

where,

Fare of the complete trip is the amount of fare for an adult from Starting bus stop of the bus trip to ending bus stop of the bus trip

Bus Capacity is the seating capacity of a bus

2.3. ABC Analysis:

ABC analysis is a parameter used by MSRTC to classify a bus trip into profitable or loss-making. As of now if the EPKM of a bus trip is greater than 43.2 then the bus trip is considered a profitable bus trip and marked as ‘A’. If a bus trip is having EPKM between 22.1 to 43.2 then the bus trip is marked as ‘B’ and if a bus trip is having an EPKM less than 22.1, then the bus trip is considered as loss-making and marked as ‘C’. ‘B’ category buses are considered not profitable and also not loss-making.

2.4. Infrastructure

1. Proximity with Nearest Railway Station. Devlali railway station is about 25 km away from Sinnar depot.
2. Availability of Infrastructure The following infrastructure is available in Depot which is the internet, LED TV, CCTV cameras, email, computer, printing facility, pucca building for housing passengers, employees, a well functioning workshop, etc.
3. Proximity to National Highway- Two highways pass through the Sinnar Taluka.

2.5. Sinnar Bus Depot Manpower:

The Sinnar Bus Depot Manpower as of February 19, 2020, is shown in *Table 3*

Drivers	184
Conductors	150
Workshop Staff	50
Total (including rest of the staff)	410

Table 3. Sinnar bus depot Manpower as on Feb 19, 2020

2.6. Hierarchy at MSRTC Bus Depots

Hierarchy at Sinnar Bus Depots have been shown in *Figure 5.*

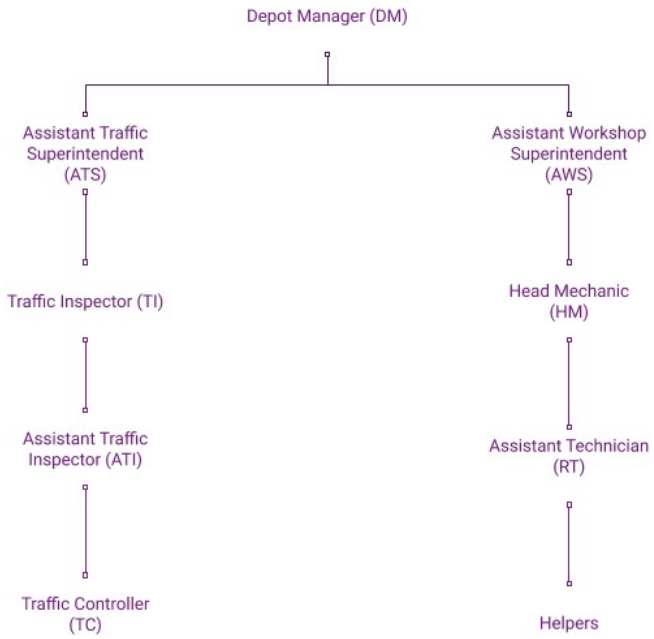


Figure 5. Hierarchy of Sinnar Bus Depot

2.7. GIS-based System Available with MSRTC

- VTS System (Vehicle Tracking System): This system provides real-time monitoring of vehicles.

2.8. Problems with the existing system

- Lack of convergence of Transportation, GIS at Taluka level-

  For the past two years, a GIS-based system (VTS) is running in MSRTC, In 1st year this system was running in trials in Nashik district. Now, this system is being replicated to further Maharashtra but hasn't been implemented completely as of Feb 19, 2020.

- Drudgery in preparing ABC operational data.-

  From January 2020, manual work of preparing complete ABC operational data on MS-Excel by Depots has been replaced by automatic ABC analysis generation using a portal by the company named Trimax. However, that still has some bugs because that automatic ABC analysis generation lacks a few columns like "Value of concession", etc, and columns

based on column ‘Value of concession’ like ‘EPKM after Value of concession’ which are then manually added by bus Depots.

- Lack of Integration of data between various 3rd party like Trimax, Rosmarta, etc

  As of now, MSRTC has outsourced a few projects to other companies like Trimax, Rosemarta, Comvision, etc. who then work on the projects and store the data on their own internal database, MSRTC doesn't store this data on their database. If any other party wants to access this data and provide a new output which is possible as a collective output after integration of their 3rd party’s data is not happening.

  For example Trimax stores the data for all the tickets issued which is used to do ABC analysis, Rosmarta stores the GIS data of Nashik as it provides the VTS system. So after the integration of these two data ABC analysis can be visualized on the GIS interface but this is not happening.

  MSRTC has started one ERP project for integration of data but put it on hold due to some reason as of Feb 19, 2020.

3. Chapter: Data Available:

3.1. Data received:

1. Nashik Bus Stops: This data contains the Latitude and Longitude of Nashik MSRTC bus stop codes and their names. This Lat-Long data has been received by Trimax IT Infrastructure & Services Ltd on September 7, 2019, and Bus stop code with Bus stop name has been received by MSRTC and is available in table "Nashik All Stop Master file" described later. Sample Dataset of this file can be seen in *Table 4.*

Bus Stop Code	**Bus Stop Name**	**Latitude**	**Longitude**
AAKSN	AGASKHIND	19.80965	73.81743
ADASNK	AADWADI (LAST)	19.73819	73.92372
AKLE	AKOLE	19.54036	74.0077
ALPT	ALEPHATA	19.1828	74.0958
ANGRMWD	AHMEDNAGAR MALIWADA	19.08584	74.73573

Table 4. Sample dataset of Nashik Bus Stops

2. Nashik Road Network: This data contains GIS data of the Nashik road network in the shapefile(.shp) format. (Data Source: MRSAC). Sample dataset of the file is shown in *Table 5*

ROAD_TYPE	**TYPE**	**SUB_TYPE**	**Shape_Leng**
Other District Road	Metalled - Black Topped (BT) or Bitumen Roads	District Road	396.1384914
Other District Road	Metalled - Black Topped (BT) or Bitumen Roads	District Road	531.537973887
State Highway	Metalled - Black Topped (BT) or Bitumen Roads	State Highway	175.485720357

State Highway	Metalled - Black Topped (BT) or Bitumen Roads	State Highway	1537.24407092
Village Road	Metalled - Black Topped (BT) or Bitumen Roads	Village Road	1799.94448638

Table 5. Sample Dataset of Nashik Road Network

3. Nashik Route segment: This data has been created by using the shortest path algorithm via the road network. This data contains GIS data of the route segment of all the Nashik routes in shapefile format.

Route_no	**Source**	**START_KM**	**Destination**	**END_KM**
1142	KSM	6	THNCBS	36
1142	THNCBS	36	BVD	53
1142	BVD	53	PDGHA	67
1142	SHPR	86	KHARID	103
1142	KSRA	117	GHT	143

Table 6. Sample Dataset of Nashik route Segment

4. ABC Analysis- We have ABC analysis data of Sinnar of October 2019, and July 2019.

	DUTYNO	Sr.No	TRIPCODE	Route_no	Projected_x	Projected_y	Route From	To	Time	TypeOf Trips(I/s,LD,MLD,Night,Short Dist(SD)	RouteKms	Fare	SC
2	19/20	1	m10252	1470	73.44777	19.76816	NASIK	PUNE	10.15	SL	212.8	365	39
3	19/20	6	m10214	1143	73.44777	19.76816	PUNE	NASIK	19	SL	212.8	365	39
4	70/71	7	m10257	1470	73.44777	19.76816	NASIK	PUNE	14.45	MLD	212.8	270	44
5	70/71	8	m10258	1143	73.44777	19.76816	PUNE	NASIK	6.15	MLD	212.8	270	44
6	14/15	2	m10079	18701	73.44777	19.76816	BHAGUR	PUNE	8.45	MLD	213.8	365	44
7	14/15	10	m10080	1143	73.44777	19.76816	PUNE	NASIK	5.45	MLD	212.8	365	44
8	77/78	11	m10087	1470	73.44777	19.76816	NASIK	PUNE	23	MLD	212.8	365	44
9	77/78	3	m10088	1143	73.44777	19.76816	PUNE	NASIK	14.45	MLD	212.8	365	44
10	48/49	4	m10085	1514	73.44777	19.76816	NASIK	NAGAR	14.15	MLD	171.7	215	44
11	48/49	14	m10086	1511	73.44777	19.76816	NAGAR	NASIK	5.3	MLD	171.7	215	44
12	61/62	15	m10241	1514	73.44777	19.76816	NASIK	NAGAR	17.3	MLD	171.7	215	44
13	61/62	16	m10242	1511	73.44777	19.76816	NAGAR	NASIK	6.3	MLD	171.7	215	44
14	93/94	17	m10075	1514	73.44777	19.76816	NASIK	NAGAR	17.45	SL	171.7	215	39
15	93/94	18	m10076	1511	73.44777	19.76816	NAGAR	NASIK	8.3	SL	171.7	215	39
16	60/60A	19	m10187	1514	73.44777	19.76816	NASIK	NAGAR	8.3	MLD	171.7	295	44
17	60/60A	5	m10188	1511	73.44777	19.76816	NAGAR	NASIK	13	MLD	171.7	295	44
18	82/83	21	s228439	7112	73.44777	19.76816	SINNAR	NASHIK	8.45	ORD	31.3	40	44
19	82/83	22	s228758	9678	73.44777	19.76816	NASHIK	SINNAR	15.5	ORD	31.3	40	44
20	5/6.	23	s228662	7112	73.44777	19.76816	SINNAR	NASHIK	8	ORD	31.3	40	44
21	5/6.	24	s228304	9678	73.44777	19.76816	NASHIK	SINNAR	17	ORD	31.3	40	44
22	19/20	25	s228665	7112	73.44777	19.76816	SINNAR	NASHIK	9	SL	31.3	50	39
23	19/20	26	s228667	9678	73.44777	19.76816	NASHIK	SINNAR	1	SL	31.3	50	39
24	70/71	27	s228633	7112	73.44777	19.76816	SINNAR	NASHIK	13.3	ORD	31.3	40	44
25	70/71	28	s228733	9678	73.44777	19.76816	NASHIK	SINNAR	11.3	ORD	31.3	40	44
26	14/15	29	s228009	7108	73.44777	19.76816	SINNAR	BHAGUR	7.3	ORD	26.4	45	44
27	14/15	30	s228010	9678	73.44777	19.76816	NASHIK	SINNAR	11	ORD	31.3	50	44

Figure 6. Sample Dataset of Sinnar October 19 ABC Analysis data

5. Nashik All Stop Master file: This contains the route sequences of all routes of Nashik.

	A	B	C	D	E	F	G	H	I	J
1	Route_auto	ROUTE_NO	BUS_STOP_CD	BUS_STOP_NM	STOP_SEQ	SUB_STAGE	KM	INTRA_STATE_DISTANCE	INTER_STATE_DISTANCE	STAGE_N
2	83547	1142	BVINC	BORIVALI NANCY COLONY	1	OO	0	0	0	
3	83548	1142	BVISWD	BORIVALI SUKURWADI	2	SO	3.9	3.9000000954	0	
4	83562	1142	KSM	KASHIMIRA	3	S-	6.1	6.0999999046	0	
5	83555	1142	GHOHE	GHODUNDHE	4	SO	9.3	9.3000001907	0	
6	83549	1142	BYARPD	BHAYANDAR PADA	5	OO	18.5	18.5	0	
7	83543	1142	ADF	ANELINE DY STUF	6	SO	20.6	20.6000003815	0	
8	83552	1142	KRDAKAR	KHRIDI GANESH FATA	7	OO	24.7	24.7000007629	0	
9	83577	1142	THNCBS	THANE CBS	8	OO	35.7	35.7000007629	0	
10	2653944	1142	KLNFTK	KALYAN FATA	9	OO	48.5	48.5	0	
11	83546	1142	BVD	BHIVANDI	10	SO	52.9	52.9000015259	0	
12	83568	1142	PDGHA	PADGHA	11	OO	66.6	66.5999984741	0	
13	83573	1142	SHPR	SHAHAPUR	12	OO	85.6	85.5999984741	0	
14	83561	1142	KHARID	KHARID	13	O-	103.3	103.3000030518	0	
15	83563	1142	KSRA	KASARA	14	SO	117.4	117.4000015259	0	
16	4431861	1142	IAPRIN	IGATPURI FATA	15	OO	128.5	128.5	0	
17	83544	1142	BHRTE	BHORATE	16	O-	138.7	138.6999969482	0	
18	83557	1142	GHT	GHOTI	17	OO	143.1	143.1000061035	0	
19	83556	1142	GNDE	GONDE	18	SO	159.5	159.5	0	
20	83580	1142	WIHEFT	WADIVARHE FATA	19	OO	161.8	161.8000030518	0	
21	83579	1142	VINLI	VILHOLI	20	SO	169.2	169.1999969482	0	
22	83572	1142	PVLN	PANDAV LENE	21	OO	172.1	172.1000061035	0	
23	83570	1142	RAEAR	RANENAGAR	22	SO	175	175	0	
24	166641	1142	NSKMRG	NASIK MAHAMARG	23	SO	178.8	178.8000030518	0	
25	2807384	1142	NWCBS	NEW CBS	24	SO	179	179	0	
26	83566	1142	NSKCBS	NASIK CBS	25	SO	179.8	179.8000030518	0	
27	83668	1143	SNGR	SHIVAJI NAGAR PUNE	1	OO	0	0	0	
28	83608	1143	DWA	DAPODI WORKSHOP FATA	2	O-	6.9	6.9000000954	0	

Figure 7. Sample dataset for Nashik All Stop Master file

6. Nashik form 4 (2019-20): This data contains Schedules of Nashik bus trip taluka wise.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
13						21) वडगावपिंपळा 22) सिन्नर 23) कांजी 24) खितांगळी 25) दहकारी 26) पंढरपुर						चालक वाहक परतीचे जयापरी वेसांक 39 + टिआगप 2 = 41						
14						27)लासलगाव						चालक / वाहक मुक्कम वेसांक 17 + टिआगप 2 = 19						
15		शटल सेवा																
16		कामगिरी क्र	कोड नंबर		फेरी क्र.	मार्ग		कि.मी	वेळ		शेरा जुचेज, थांबा, स्कुल फेरी, ट्रेन कनेक्शन टपाल इ.	दु	कामगीरीचे तास		चा/शा कि.मी	वाहन कि.मी	वाहन वाथर	अतिका भत
17						पासुन	पर्यंत		पासुन	पर्यंत			विस्तारीत तास	चक्र तास				
18		सिन्नर -1	S228617	शटल	1	सिन्नर	नाशिक	31.3	6.00	7.00	साधी सर्व थांबे	1	08:15:00	07:25:00	187.8	375.6	12:00:00	
19		सिन्नर -1	S228618	शटल	2	नाशिक	सिन्नर	31.3	7.16	8.16	साधी सर्व थांबे							
20		सिन्नर -1	S228619	शटल	3	सिन्नर	नाशिक	31.3	8.20	9.20	साधी सर्व थांबे							
21	131	सिन्नर -1	S228621	शटल	4	नाशिक	सिन्नर	31.3	9.46	10.46	साधी सर्व थांबे							
22		सिन्नर -1	S228409	शटल	5	सिन्नर	नाशिक	31.3	11.00	12.00	साधी सर्व थांबे							
23		सिन्नर -1	S228638	शटल	6	नाशिक	सिन्नर	31.3	12.15	13.15	साधी सर्व थांबे							
24									कामगार भोजन									
25		सिन्नर -1	S228878	शटल	7	सिन्नर	नाशिक	31.3	13.31	14.31	साधी सर्व थांबे	1	08:15:00	07:25:00	187.8			
26		सिन्नर -1	S228879	शटल	8	नाशिक	सिन्नर	31.3	14.45	15.45	साधी सर्व थांबे							
27	131A	सिन्नर -1	S228668	शटल	9	सिन्नर	नाशिक	31.3	16.01	17.01	साधी सर्व थांबे							
28		सिन्नर -1	S228868	शटल	10	नाशिक	सिन्नर	31.3	17.16	18.16	साधी सर्व थांबे							
29		सिन्नर -1	S228867	शटल	11	सिन्नर	नाशिक	31.3	18.30	19.30	साधी सर्व थांबे							
30		सिन्नर -1	S228666	शटल	12	नाशिक	सिन्नर	31.3	19.46	20.46	साधी सर्व थांबे							
31											इंधन व देखभाल							
32		सिन्नर -2	S228944	शटल	1	सिन्नर	नाशिक	31.3	6.15	7.15	साधी सर्व थांबे	1	08:15:00	07:25:00	187.8	375.6	12:00:00	
33		सिन्नर -2	S228945	शटल	2	नाशिक	सिन्नर	31.3	7.30	8.30	साधी सर्व थांबे							
34	132	सिन्नर -2	S228946	शटल	3	सिन्नर	नाशिक	31.3	8.40	9.40	साधी सर्व थांबे							
35		सिन्नर -2	S228180	शटल	4	नाशिक	सिन्नर	31.3	9.50	10.50	साधी सर्व थांबे							
36		सिन्नर -2	S228181	शटल	5	सिन्नर	नाशिक	31.3	11.15	12.15	साधी सर्व थांबे							
37		सिन्नर -2	S228949	शटल	6	नाशिक	सिन्नर	31.3	12.30	13.30	साधी सर्व थांबे							
38									कामगार भोजन									
39																		

Figure 8. Sample Dataset for Nashik Form 4

7. Nashik form 1 (2019-20): This data contains the Nashik all bus trips load factor across the year 2019 taluka wise.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1														
2		तक्ता क्र.०१ सन २०१८-२०१९ खालील प्रमाणे									रा.प.सिन्नर आगार			
4		अ.क्र.	मार्ग		अंतर	धाववेळ	एकूण मंजूर फेऱ्या		एकूण मंजूर कि.मी.		सरासरी भारमान		शेरा	
5			पासुन	पर्यंत			बारमाही (BASIC)	पुनरारंभी (TRS)	बारमाही (BASIC)	पुनरारंभी (TRS)	विनासवलत	सवलतीसह		
6														
7		१	२	३	४	५	६	७	८	९	१०	११	१२	
8		१	नाशिक	पंढरपुर	359	8.45	1		359.0		65	80		
9		२	पंढरपुर	नाशिक	359	8.45	1		359.0		65	80		
10		३	नाशिक	पाटोदा	278.3	7.10	1		278.3		61	72		
11		४	पाटोदा	नाशिक	278.3	7.10	1		278.3		64	76		
12		५	नाशिक	पुणे	212.8	5.00	4		851.2		68	82		
13		६	पुणे	नाशिक	212.8	5.00	4		851.2		65	68		
14		७	नाशिक	अ.नगर	171.7	4.15	4		686.8		70	87		
15		८	अ.नगर	नाशिक	171.7	4.15	4		686.8		57	68		
16		९	सिन्नर	नाशिक	31.3	1.00	76		2378.8		47	76		
17		१०	नाशिक	सिन्नर	31.3	1.00	76		2378.8		47	92		
18		११	नाशिक	शिर्डी	90.2	2.30	12		1082.4		79	90		
19		१२	शिर्डी	नाशिक	90.2	2.30	12		1082.4		68	85		
20		१३	सिन्नर	माळेगांव	8.9	0.15	12		106.8		39	100		
21		१४	माळेगांव	सिन्नर	8.9	0.15	12		106.8		22	74		
22		१५	सिन्नर	मुसळगांव	9	0.15	12		108.0		16	76		

Figure 9. Sample Dataset for Nashik form 1

8. Nashik Reverse Route Pairs. This file has been created by using the Master file of all Nashik routes received by MSRTC. This file contains the reverse route number of a route.

Route Seq 1	**Route Seq 2**
1514	1511
2198	2132
2201	2135
2203	2137
2213	2148

Table 7. Sample dataset of Nashik Reverse Route Pairs

9. Sinnar PHC- This data contains the Latitude and Longitude of Sinnar PHC (Data Source: https://arogya.maharashtra.gov.in/Site/GIS/phdgis.aspx) Accessed on 1 April 2020.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
1	gid	census_201	village_co	village_na	phc_num	phcs_num	lati	longi	trtmnt_min	maternal_S	delivery_s	resuscitat	NHP_servic	VCDC	Reg_arogya	Dr_visit_p	outpatient	indoorpati
2	24209	551230	551230	Dapur	1	1	19.73	74.03	1	1	1	0	1	1	1	1	1	1
3	25563	551204	551204	Pandhurli	1	1	19.82	74.05	1	1	1	0	1	1	1	1	1	1
4	25325	551141	551141	Naigaon	1	1	19.94	73.97	1	1	1	0	1	1	1	1	1	1
5	25327	551187	551187	Deopur	1	1	19.86	74.15	1	1	1	0	1	1	1	1	1	1
6	25594	551235	551235	Thangaon	1	1	19.7	73.92	1	1	1	0	1	1	1	1	1	1
7	25750	551252	551252	Wavi	1	2	19.81	74.23	1	1	1	0	1	1	1	1	1	1

Figure 10. Sample Dataset for Sinnar PHC

10. Sinnar Sub-PHC- This data contains the Latitude and Longitude of Sinnar PHC (Data Source: https://arogya.maharashtra.gov.in/Site/GIS/phdgis.aspx) Accessed on 1 April 2020.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
1	gid	census_201	village_co	village_na	phc_num	phcs_num	lati	longi	trtmnt_min	maternal_S	delivery_s	resuscitat	NHP_servic	VCDC	Reg_arogya	Dr_visit_p	outpatient	indoorpat
2	24672	551177	551177	Nimgaon Sinner	0	1	19.89	74.17	1	1	1	0	1	1	1	1		
3	24113	551166	551166	Somthane	0	1	19.93	74.21	1	1	1	0	1	1	1	1		
4	24114	551200	551200	Paste	0	1	19.84	73.94	1	1	1	0	1	1	1	1		
5	24115	551209	551209	Sonambe	0	1	19.76	73.92	1	1	1	0	1	1	1	1		
6	24209	551230	551230	Dapur	1	1	19.73	74.03	1	1	1	0	1	1	1	1	1	
7	24145	551172	551172	Vadangali	0	1	19.92	74.14	1	1	1	0	1	1	1	1		
8	24178	551218	551218	Manegaon	0	1	19.8	74	1	1	1	0	1	1	1	1		
9	25562	551197	551197	Vadgaon Pingala	0	1	19.86	73.88	1	1	1	0	1	1	1	1		
10	24241	551239	551239	Chas	0	1	19.69	74.07	1	1	1	0	1	1	1	1		
11	25563	551204	551204	Pandhurli	1	1	19.82	74.05	1	1	1	0	1	1	1	1	1	
12	24269	551253	551253	Pangari Bk	0	1	19.8	74.19	1	1	1	0	1	1	1	1		
13	24296	551246	551246	Pathare Bk.	0	1	19.83	74.31	1	1	1	0	1	1	1	1		
14	24424	551210	551210	Shivade	0	1	19.78	73.88	1	1	1	0	1	1	1	1		
15	24757	551244	551244	Mirgaon	0	1	19.83	74.28	1	1	1	0	1	1	1	1		
16	24758	551255	551255	Marhal Bk.	0	1	19.78	74.15	1	1	1	0	1	1	1	1		
17	24811	551247	551247	Pathare Kh.	0	1	19.98	74.11	1	1	1	0	1	1	1	1		
18	25137	551158	551158	Datli	0	1	19.81	74.08	1	1	1	0	1	1	1	1		
19	25245	551262	551262	Dodi Bk.	0	1	19.74	74.1	1	1	1	0	1	1	1	1		
20	25325	551141	551141	Naigaon	1	1	19.94	73.97	1	1	1	0	1	1	1	1	1	
21	25327	551187	551187	Deopur	1	1	19.86	74.15	1	1	1	0	1	1	1	1	1	
22	25391	551222	551222	Patole	0	1	19.77	73.99	1	1	1	0	1	1	1	1		
23	25445	551186	551186	Panchale	0	1	19.86	74.2	1	1	1	0	1	1	1	1		
24	25593	551194	551194	Chincholi	0	1	19.88	73.91	1	1	1	0	1	1	1	1		
25	25594	551235	551235	Thangaon	1	1	19.7	73.92	1	1	1	0	1	1	1	1	1	
26	25663	551216	551216	Konambe	0	1	19.77	73.9	1	1	1	0	1	1	1	1		
27	25691	551155	551155	Kundewadi	0	1	19.76	74.24	1	1	1	0	1	1	1	1		
28	25750	551252	551252	Wavi	1	2	19.81	74.23	1	1	1	0	1	1	1	1	1	

Figure 11. Sample Dataset of Sinnar Sub-PHC's

11. Nashik Rail Network: This data contains the GIS data of the Nashik rail network in the shapefile(.shp) format. (Data Source: MRSAC).

	RAIL_TYPE	RAIL_DET	DETAIL	Shape_Leng
1	Broadgauge	Single Track	Railway line to Deolali at Nashik	756.955623...
2	Broadgauge	Single Track	Railway Line to Eklahara Power(Nashik)	6771.42106...
3	Broadgauge	Double Track	Central Railway Main Line	47.0787478...
4	Broadgauge	Double Track	Central Railway Main Line	724.862544...
5	Broadgauge	Double Track	Central Railway Main Line	5005.88073...
6	Broadgauge	Double Track	Central Railway Main Line	2107.68909...
7	Broadgauge	Double Track	Central Railway Main Line	7057.57113...
8	Broadgauge	Double Track	Central Railway Main Line	46545.9694...
9	Broadgauge	Single Track	Railway line to Deolali at Nashik	778.497856...
10	Broadgauge	Single Track	Railway line to Deolali at Nashik	646.748447...
11	Broadgauge	Single Track	Railway line to Deolali at Nashik	857.160996...
12	Broadgauge	Double Track	Central Railway Main Line	77529.8771...
13	Broadgauge	Double Track	Central Railway Main Line	436.404559...
14	Broadgauge	Double Track	Central Railway Main Line	511.984418...
15	Broadgauge	Single Track	Central Railway Daund Manmad Branch	6964.18932...
16	Broadgauge	Single Track	Central Railway Daund Manmad Branch	49855.5023...
17	Broadgauge	Double Track	Central Railway Main Line	23282.0068...
18	Broadgauge	Double Track	Central Railway Main Line	67740.0643...
19	Broadgauge	Single Track	Central Railway Daund Manmad Branch	7202.06395...
20	Broadgauge	Double Track	To Ojhar from Central Railwy Main Line in Niphad Taluka, Nashik	12397.8039...
21	Broadgauge	Single Track	Railway line to Deolali at Nashik	595.612946...

Figure 12. Sample Dataset of Nashik Rail Network

3.2. Important terminologies-

3.2.1. Bus Stop:

A bus stop is a place where the bus halts for picking up or dropping up bus passengers. In *Figure 13,* The yellow points shown denotes Bus stops. The bus stops code of bus stops present in *Figure 13* are SNNR, GURE, GNDEFT, MTEDIS, DDIM, DBD, NAEE, etc.

3.2.2. Bus Route:

A bus route is a path covered by a bus from one place to another where a bus travels regularly. In *Figure 13.* The path shown in blue color denotes the Bus route.

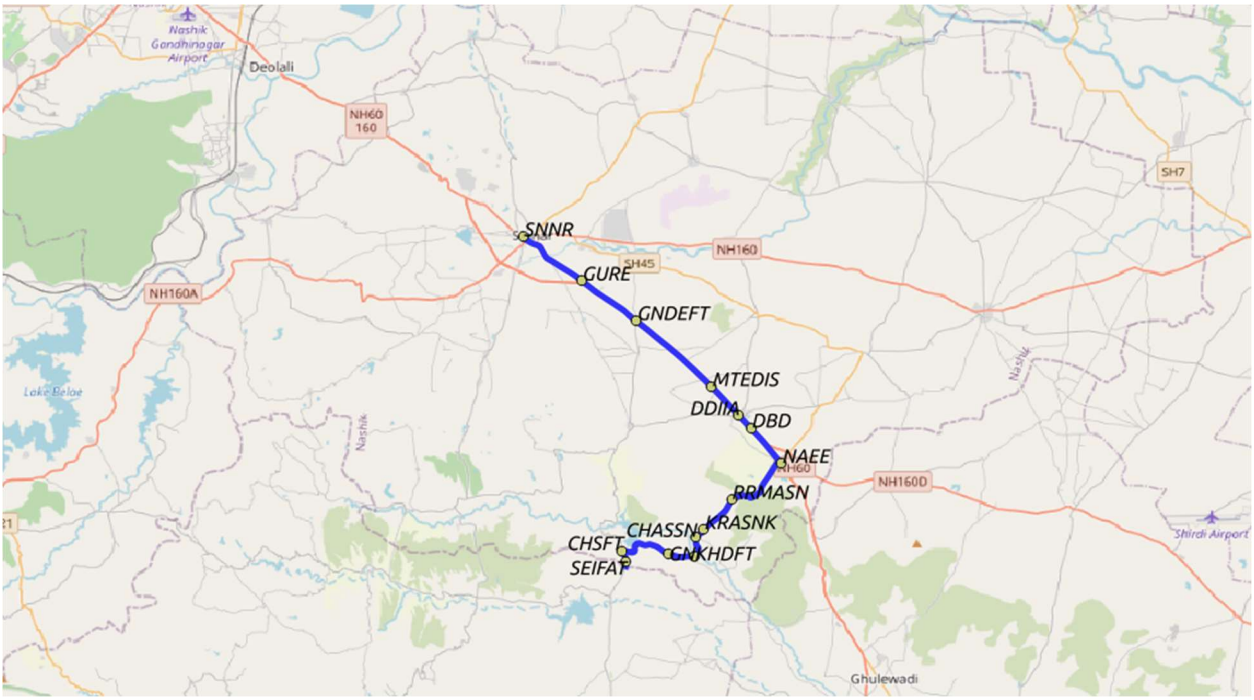


Figure 13. A typical bus route with bus stops

3.2.3. Bus Trip:

A Bus trip is a scheduled bus journey from one place to another place. In *Figure 13* if a bus service or bus journey is scheduled on a particular day at 6:00 AM from SNNR to CHSFT bus Stop on the displayed route, then this bus service will be called a bus trip.

3.2.4. ETIM data:

Here, ETIM data means the tickets data issued by bus conductors using Trimax ETIM (Electronic Tickets Issuing Machine) for the bus service provided by MSRTC. This data is stored by a company named Trimax IT Infrastructure & Services Limited. Apart from Trimax ETIM, bus conductors also use a tray method for issuing tickets.

3.2.5. Route segment:

A route segment is a path or part of the bus route between consecutive bus stops of a Bus Route.

4. Chapter: Digital Geography

Digital Geography *in simple words and in our case* is a representation of MSRTC Bus Network with its operational data on a GIS-based graphical interface along with the demography of the region.

Digital Geography has been built on the concept of Graph theory.

4.1. Graph Theory:

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

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

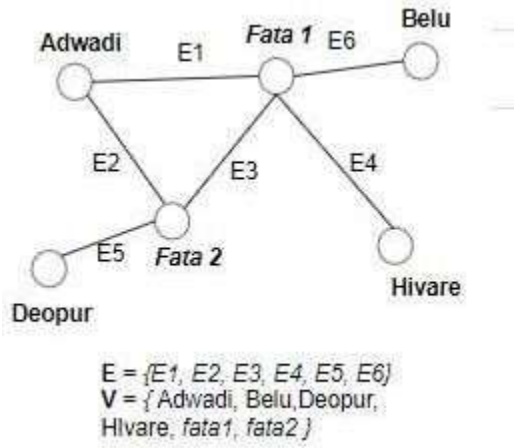


Figure 14. A sample graph[1]

4.1.1. Planar Graph:

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.

4.1.2. Undirected Graph:

An undirected graph is a graph, i.e., a set of objects (called vertices or nodes) that are connected together, where all the edges are bidirectional.

4.2. Digital geography:

Technically, A digital geography is an undirected, planar graph G= (V, E) where:
V is a set of vertices.
E is a set of edges.[1]

4.2.1. Properties of a Vertex

1. Each vertex is a Point geometry.
2. Each vertex has a latitude and longitude.
3. A vertex may be an important location like Bus Stop, schools, PHC, Sub-PHC, tourist locations, Market place, etc,.

4.2.2. Properties of an Edge

1. Each edge is a Polyline geometry.
2. Each edge e is an ordered set of vertices (v_i ,v_j) such that v_i and v_j ε Vertices.
3. An edge subsequently can have further additional properties (attributes) like type of road, length of the edge, traffic on the route segment, the profitability of the route segment, etc.

4.2.3. Bus Network as Digital Geography:

Bus Network has been represented in digital geography. In this Digital Geography, Bus stops have been represented as vertices, and road networks have been represented as edges. After processing this data (bus stop and road network), further data has been created like, Fatas, ST route segment, Projection lines, Etc. which further helps us to analyze the bus route network.

4.2.4. Route Segment:

A route segment is the path between two consecutive bus stops of a bus route. Route segments have been created based on the Form 4 and their route sequences

4.2.5. Village Projection:

A village projection is a point on the ST route that is the nearest point from village centroid to the ST route. It is assumed that the nearest pick-up point or drop point for the bus passengers for a particular village would be this point for ST buses.

4.2.6. ST Fata:

An ST bus Fata is the point where two bus routes intersect. Or in simple words the point where a passenger can switch buses to change the bus route for going from one place to another.

4.3. Application of Digital Geography:

Applications have been illustrated in the later chapter named ‘Applications of Digital Geography’

4.4. Limitations of Digital Geography:

A. Scripts change with the QGIS version. Some python scripts work in the QGIS 2.x version and some in QGIS 3.x.

B. Some village roads may be missing.

C. Current digital geography doesn’t consider the seasonality of roads.

D. Current digital geography also lacks elevation data.

E. It is assumed that a bus travels the shortest path between two consecutive bus stops of a bus route i.e., the route segment is generated based on the shortest distance. However current digital geography doesn't consider any alterations made by MSRTC to cover nearest important locations like schools, tourist spots, PHC, Market places, etc to maximize social or economic profits or to meet demand.

F. Current digital geography doesn't consider feeder bus services provided by MSRTC, It only considers ordinary bus.

4.5. Schema:

Here, Schema refers to additional information (known as attributes) of the elements used in digital geography.

For example,

- a road is represented by an edge, then additional information about the road can be the type of road (village road, highway, city road), length of the road, construction material used in the road, etc.
- a village is represented by a polygon, then additional properties about the village can be its population, gender ratio, area of the village, etc.

These additional properties (attributes) provide more information about the element. Additional properties of various elements currently used in digital geography are as follows.

4.5.1. Route Segment:

Field Name	**Field Type**	**Description**
gid	Integer NOT NULL	Primary key
route_no	bigint	Route number of which route segment is a part of
source	character varying(30)	Starting Source of Route segment
start_km	numeric	Distance of source from the complete bus route starting point
destinatio	character varying(30)	Ending Destination of Source of Route segment
end_km	numeric	Distance of destination from the complete bus route starting point
geom	geometry(MultiLineString)	Line geometry of the route segment

Table 8. Schema of Route Segment

4.5.2. Route_to_trip:

This file does the mapping of Trip number to respective route numbers based on Sinnar ETIM August 2019 data. *Table 9.* shows the attributes of the 'Route_to_trip' table.

Field Name	Field Type	Description
trip_no	character varying(254)	Trip number of a bus
route_no	bigint	Respective Route number of the trip

Table 9. Schema of Route_to_trip

4.5.3. Sinnar_village_cleaned

This table contains 238 attributes, most of the attributes contain census 2001 data for every village, Rest attributes of this table are shown in *Table 10*.

Field Name	Field Type	Description
area_name	character varying(254)	Sinnar village name
geom	geometry(MultiPolygon)	Polygon geometry of Sinnar village

Table 10. Schema of Sinnar_village_centroid

4.5.4. Route_seq:

The table 'Route_seq' contains the route sequence of Nashik routes. Attributes of this table are shown in *Table 11.*

Field Name	Field Type	Description
Route_no	integer	Route Number of Nashik route
Route_seq	character varying	Route Sequence of the respective route number
No_Bus_Stops	integer	Number of Bus stops as per route sequence
Original_no	integer	Number of Bus stops there should be as per the Nashik Master file.

Table 11. Schema of Route_seq

4.5.5. All_routes_stops_master_file_of_nashik_division

This table contains the Nashik Routes sequences file as received by MSRTC. Attributes of this table are shown in *Table 12.*

Field Name	**Field Type**	**Description**
Route_auto	integer	
Route_no	integer	Route number of the route
BUS_STOP_CD	character varying(254)	Bus stop code of the bus stop
BUS_STOP_NM	character varying(254)	Bus stop name of the bus stop
STOP_SEQ	integer	Bus stop sequence number of respective route number
SUB_STAGE	character varying(254)	
KM	numeric	Distance of bus stop from the route starting point in kilometer
INTRA_STATE_DISTANCE	numeric	
INTER_STATE_DISTANCE	numeric	
STAGE_NO	integer	
FARE_CHANGE_POINT	character(1)	
STATE_CD	character varying(254)	State in which the bus stop exists
IS_INTER_STATE	character(1)	
IS_RESERVATION	character(1)	

Table 12. Schema of All_routes_stops_master_file_of_nashik_division

4.5.6. ABC_july19_filtered

This table contains the ABC analysis of the month of July 19. This analysis has been done by us on the basis of ETIM data. However, the ABC analysis done by MSRTC contains some more attribute ‘Value of concession’ which they add manually on the basis of Bus passes issued in the

month whose data is not present in our ETIM data. The Attributes of this table are shown in *Table 13.*

Field Name	**Field Type**	**Description**
gid	Integer NOT NULL	Primary key
Route_no	integer	Route number
origin	character varying(254)	Source bus stop code of route segment involved in between of trip
destinatio	character varying(254)	destination bus stop code of route segment involved in between of trip
Sr no	bigint	Serial number
trip_numbe	character varying(254)	Trip Number
route_name	character varying(254)	Route name
from	character varying(254)	Initial Source Bus Stop Name of trip
from_code	character varying(254)	Initial Source Bus Stop Code of trip
to	character varying(254)	Final Destination Bus Stop Name of trip
to_code	character varying(254)	Final Destination Bus Stop Code of route segment between the trip
bus servic	character varying(254)	Bus service type
Dept time	numeric	Departure time
kilomete	numeric	length of trip
fare	bigint	fare
Oper trip	bigint	
Operated k	numeric	Operating Km
Psgrs earn	bigint	Passengers earning

Other earn	bigint	Other earning
Total earn	bigint	Total earning of trip
Net earnin	bigint	Net earning of trip
Expt earni	bigint	Expected earning of trip
% load fa	numeric	Load factor of bus trip in percentage
Net epkm	numeric	Net earning per kilometer
abc_status	character varying(254)	ABC status of the bus trip
no of psgr	bigint	Number of passengers traveled in trip

Table 13. Schema of ABC_july19filtered

4.5.7. Reverse_route_pairs

This table contains the Nashik Reverse route number pairs. Suppose MSRTC is providing a bus trip on a route having route number 'R1', then returning bus trip will have a route having route number 'R2'. Here R2 is called the reverse route number of R1 and R1 is called reverse route number of 'R1'. Attributes of this table have been shown in *Table 14.*

Field Name	**Field Type**	**Description**
Seq1	bigint	Route number of a route
Seq2	bigint	Reverse route number of the route

Table 14. Schema of Reverse_route_pairs

4.5.8. Nashik Road Network:

This file contains the Nashik road network geometry. This data has been received from MRSAC as on October 28, 2019. The attributes of this table are shown in *Table 15.*

Field Name	**Field Type**	**Description**

gid	integer NOT NULL	Unique id
road_type	character varying(20)	Road type (state highway, village road, etc,.)
type	character varying(20)	Construction type of road
sub_type	character varying(20)	Road sub-type
shape_leng	numeric	Length of road
geom	geometry(MultiLineString)	Road geometry

Table 15. Schema of Nashik road segment

4.5.9. Sinnar Fatas-

Sinnar Fatas are MSRTC ST fatas lying inside in Sinnar Taluka. The attributes of this table have been described in *Table 16.*

Field Name	**Field Type**	**Description**
gid	integer NOT NULL	Unique id
route1	bigint	Route number 1 of intersected route
route2	bigint	Route number 2 of intersected route
nearest_bu	character varying(254)	Nearest Bus stop from Fata
distance_f	numeric	Distance of nearest bus stop
geom	geometry(Point)	Point geometry of the Fata

Table 16. Schema of Fatas

4.6. Shapefiles

4.6.1. Sinnar Villages:

The GIS image of the Sinnar village shapefile is shown in *Figure 15.*

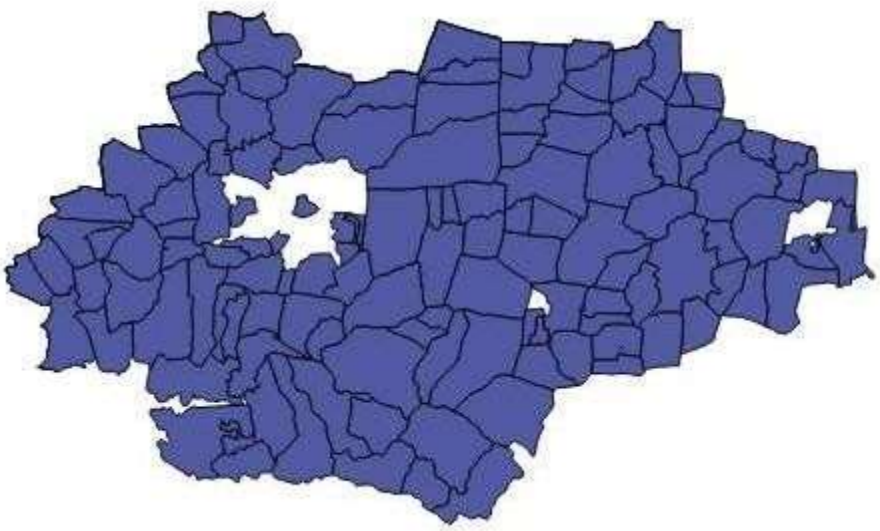


Figure 15. Sinnar Villages

4.6.2. Nashik Road Network:

The GIS image of the Nashik Road Network shapefile has been shown in *Figure 16.* Black lines in the figure represents Nashik roads

Figure 16. Nashik road network (Data source: MRSAC)

4.6.3. Nashik ST Route Network:

The GIS image of Nashik ST Route network has been represented in *Figure 17.* Green lines represent Nashik ST route Network over Black lines representing Nashik roads.

Figure 17. Nashik ST route network in green color over Blackline Nashik road network

4.6.3.1. Methodology used for Nashik ST Route Creation -

- Obtain all routes and route sequences from 'All_routes_stops_master_file_of_nashik_division' table.
- Create consecutive bus stop pairs of all routes.
- Find the shortest path via road using Dijkstra algorithm for all consecutive bus stop pairs. (In this case Dijkstra algorithm is an algorithm which finds the shortest path between two bus stops via road).

4.6.3.2. Another method possible for Nashik route Network creation-

The current method generates the Nashik ST route network based on the shortest distance via the road network. Nashik ST route network can also be prepared considering the minimum time required to travel from one pair of consecutive bus pair to another of a route

For example- Consider classifying Nashik roads as highway, city road, village road, etc. and assume bus speed at highway, city road, village road at 45km/hr, 30km/hr, 20km/hr respectively. So the generation of Nashik ST route Network based on the shortest time needed for commute between consecutive bus stops of the route.

4.6.4. Sinnar Village Projections:

The GIS image of the Sinnar village projections to Sinnar ST roads has been shown in *Figure 18.* Yellow point denotes Sinnar village centroid, red points denote their projections on ST road. Green lines representing ST road.

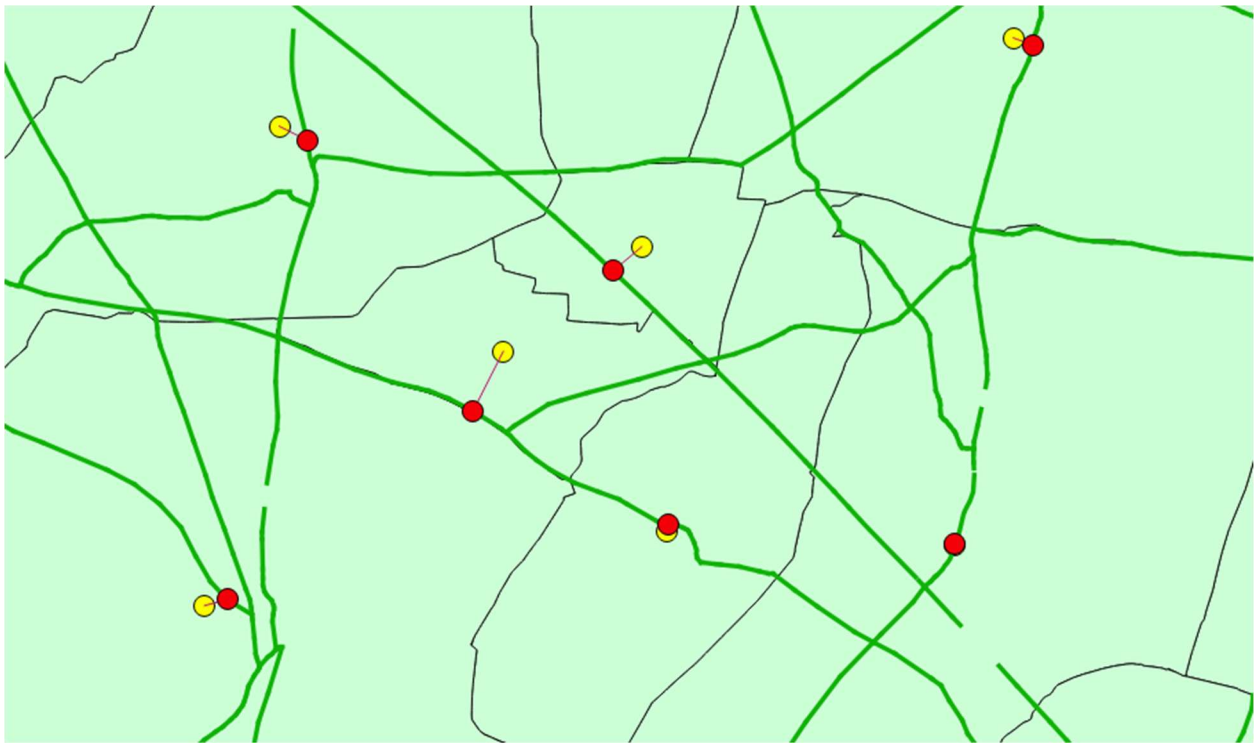


Figure 18. Sinnar Village Projections

4.6.4.1. Methodology for developing Sinnar Village Projections:

- Create Sinnar village centroid from village polygons. (QGIS Plugin Required: RealCentroid).
- Create line Projections from Sinnar villages to ST road. (QGIS tool Required: Hub Distance, Extract nodes).
- Intersect Sinnar ST roads with line projections to get point projection. (QGIS tool Required: Line Intersections).

4.6.5. Sinnar Fatas:

The GIS image of Sinnar Fatas has been shown in *Figure 19.* Purple dots in the figure represent Sinnar ST Fatas over green lines representing Sinnar ST routes.

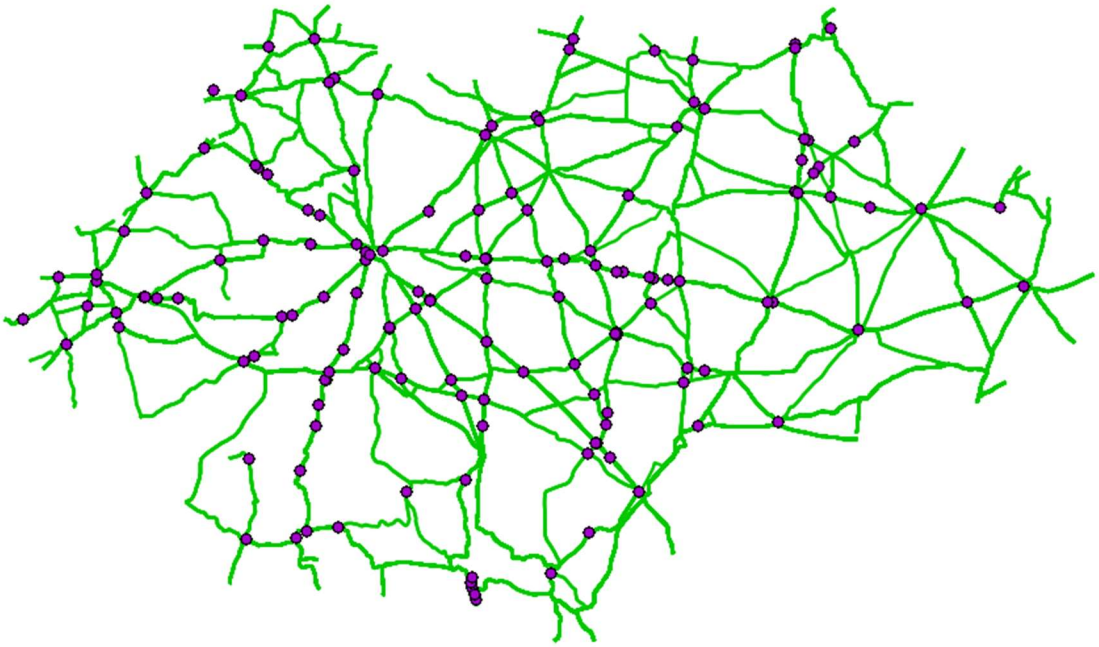


Figure 19. Sinnar ST Fatas in purple dots

4.6.5.1. Methodology for Sinnar Fatas creation:

- Clip Sinnar ST routes from Nashik ST routes.
- Use QGIS plugin 'line Intersection' and the resulting layer will give Sinnar ST Fatas.

4.6.5.2. Note:

- In current Digital Geography, Sinnar Fatas have been created on the Sinnar Routes segment. As route segments have been created based on the shortest path algorithm. In future if route segments are created based on different algorithms or in other words if path of route segments are changed, Sinnar Fatas may also change.

4.6.6. Sinnar road Network:

GIS image of Sinnar Road network has been shown in *Figure 20*

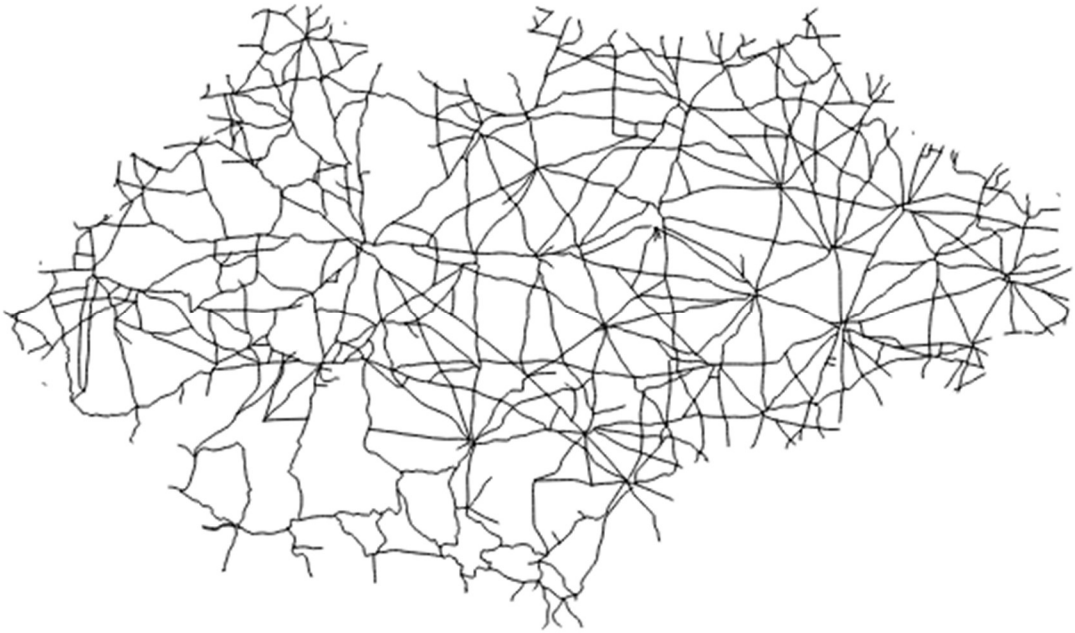


Figure 20. Sinnar road Network

4.6.6.1. Methodology for Sinnar road Network generation:

- Clip Sinnar road from Nashik roads using QGIS ‘Clip’ tool.

4.6.7. Sinnar ST route Network

The Sinnar ST route network has been represented in blue color over Sinnar roads represented by black lines.

Figure 14. Sinnar ST routes in blue lines over Sinnar road network in black lines

4.6.7.1. Methodology for Sinnar ST route Network:

- Clip Nashik ST route Network by Sinnar village boundary using QGIS ‘Clip’ tool.

4.7. Tools and Technology Stack used:

Application: QGIS 2.18 las palmas

Tools: Pgadmin3

DBMS: PostgreSQL (PostGIS extension for geospatial data)

Scripting: Python 2.7

Packages: PyQt4, networkAnalysis

QGIS Important plugins: NNJoin, Networks

QGIS Tools: Line Intersections, Extract Nodes, Clip, Hub Distance.

4.8. Database Design:

The Entity Relationship Diagram of the database has been shown in *Figure 21.*

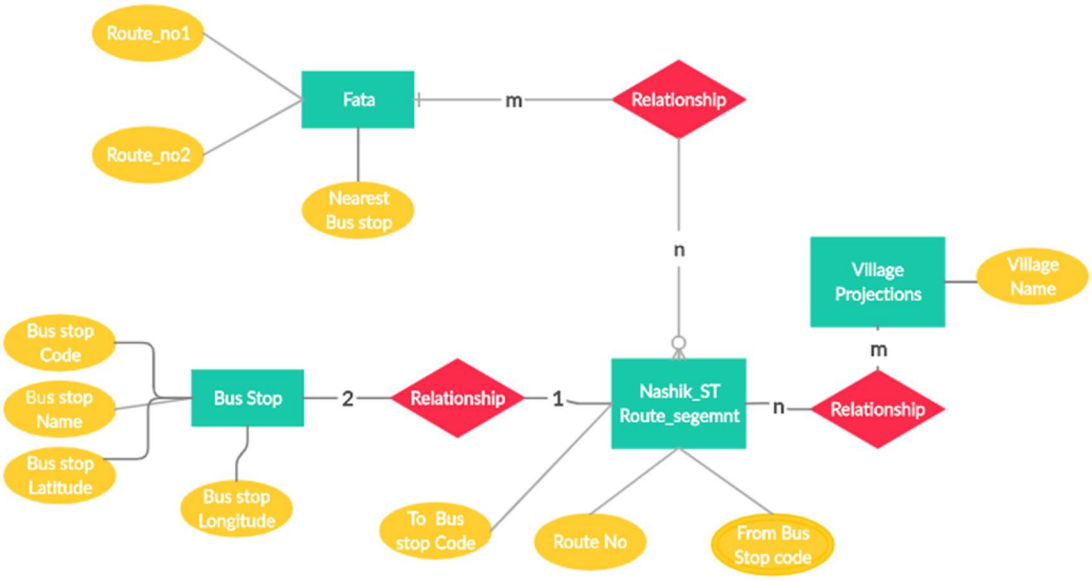


Figure 21. Entity Relationship diagram of Schema

Various entities of Entity-relationship diagram are:

- **Nashik ST Route Segment:** stores the information of all Nashik route segments.
- **Bus Stop:** Stores the information of all Bus Stops
- **Fata:** Stores the information of all Nashik Fatas
- **Village Projections:** stores the information of all Sinnar Projections on Route segment

4.9. Assumptions

A. Only villages inside the Sinnar Taluka are taken into account

B. Certain villages do not have a geometry, villages that do not have a geometry are ignored in the subsequent steps.

C. Roads are simply assumed bidirectional.

D. Some village roads may not be in our data. They have been ignored.

4.10. Representation of ABC Analysis on digital geography

ABC analysis July 2019 has been represented in the form of a route segment as shown in *Figure 22.* Pink lines in *Figure 22.* represent Sinnar ST routes. Redline is the selected route segment by clicking on it. ABC Details of any route can be obtained just by clicking on the respective route segment as shown in *Figure 23. Figure 23.* shows all the trips that pass through the bus trip. Generally, a Bus depot manager or DTO has the requirement to know all the trips from one bus stop to another bus stop, this said feature of just clicking on the route segment can meet their requirement. Further details of any particular bus trip can be obtained by just expanding the required bus trip number as shown in *Figure 24.* The *Figure 24.* shows details of the bus trip 'S228039'

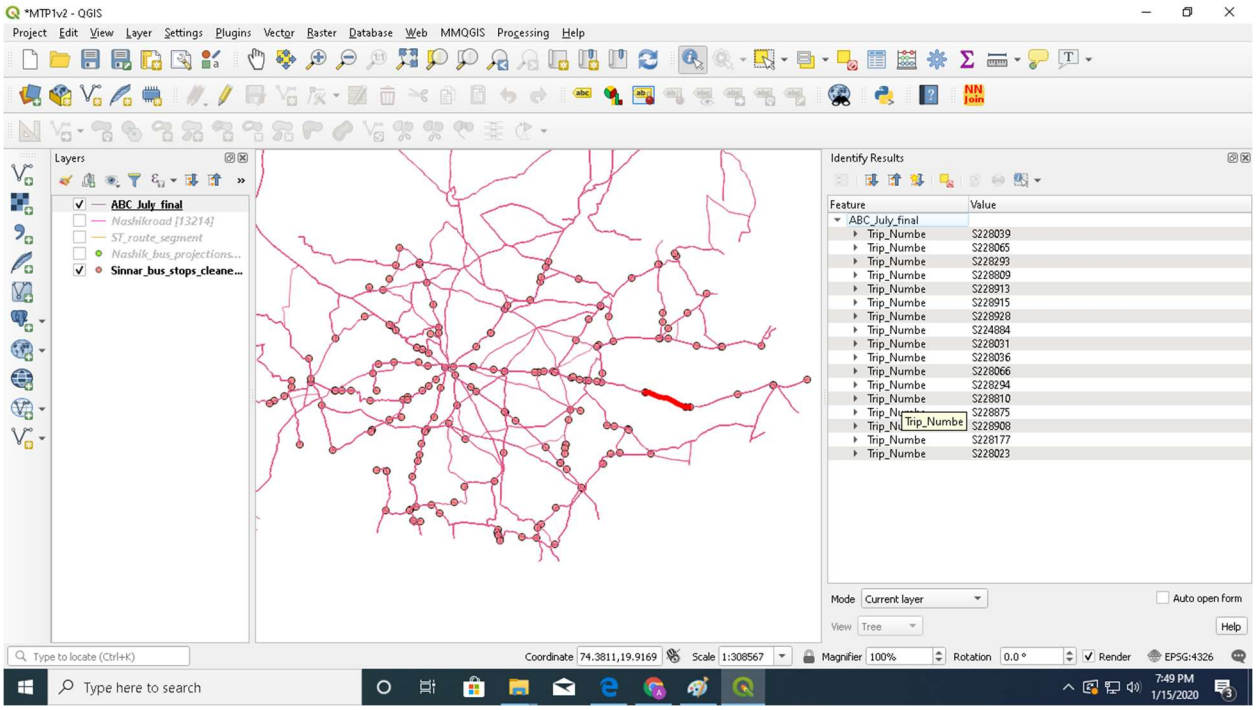


Figure 22. ABC Analysis Representation on Digital Geography

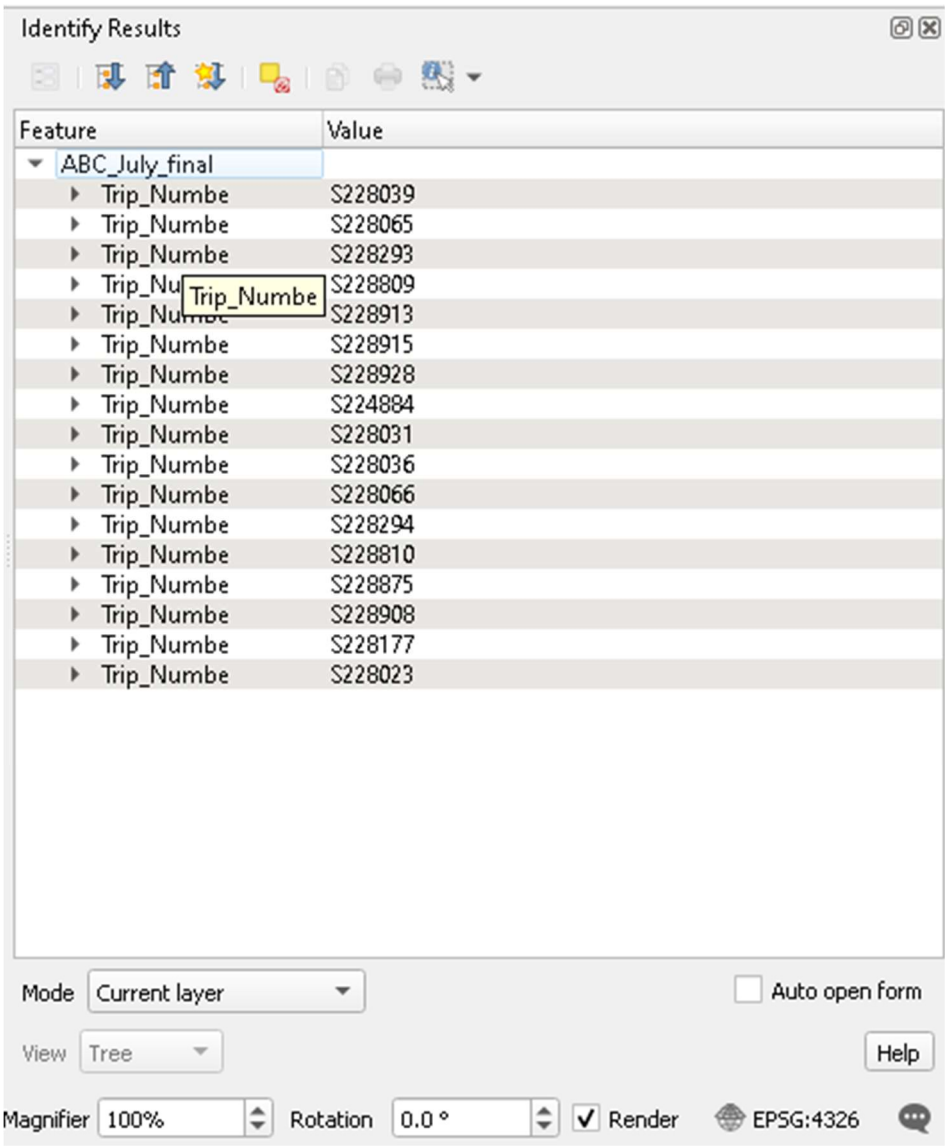


Figure 23. Trips passing through the selected route segment

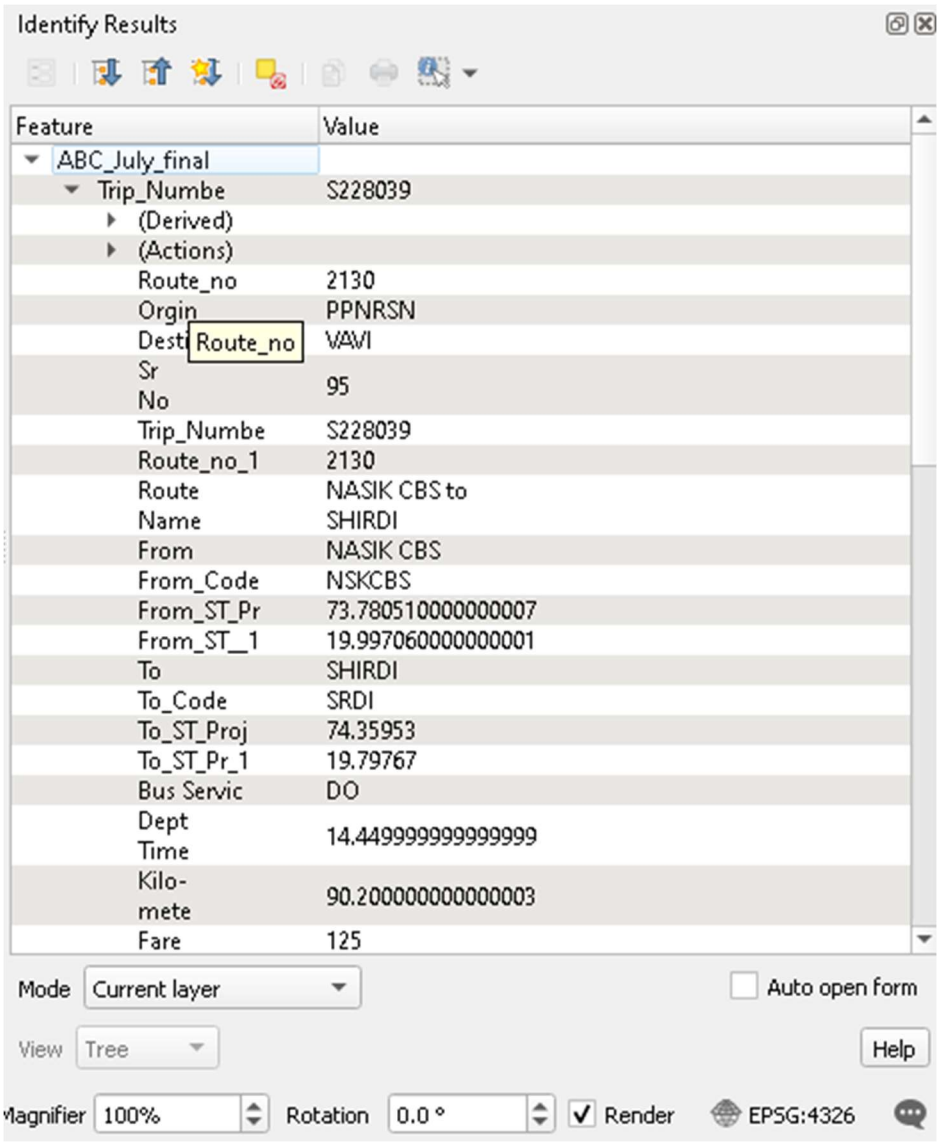


Figure 24. Details of Trip Number- S228039

5. Chapter: Applications of Digital geography:

5.1. Coverage:

Coverage is an important aspect when it comes to accessibility to transportation services or reaches of transportation services. Digital geography can help to calculate areas coverage by ST roads.

5.1.1. Sinnar ST Coverage

In *Figure 25* red regions are those which are beyond the 1 Km distance from ST route network and green regions show ST coverage within range of 1 km from ST route. *Table 17* shows the Sinnar ST route coverage area data generated through digital geography.

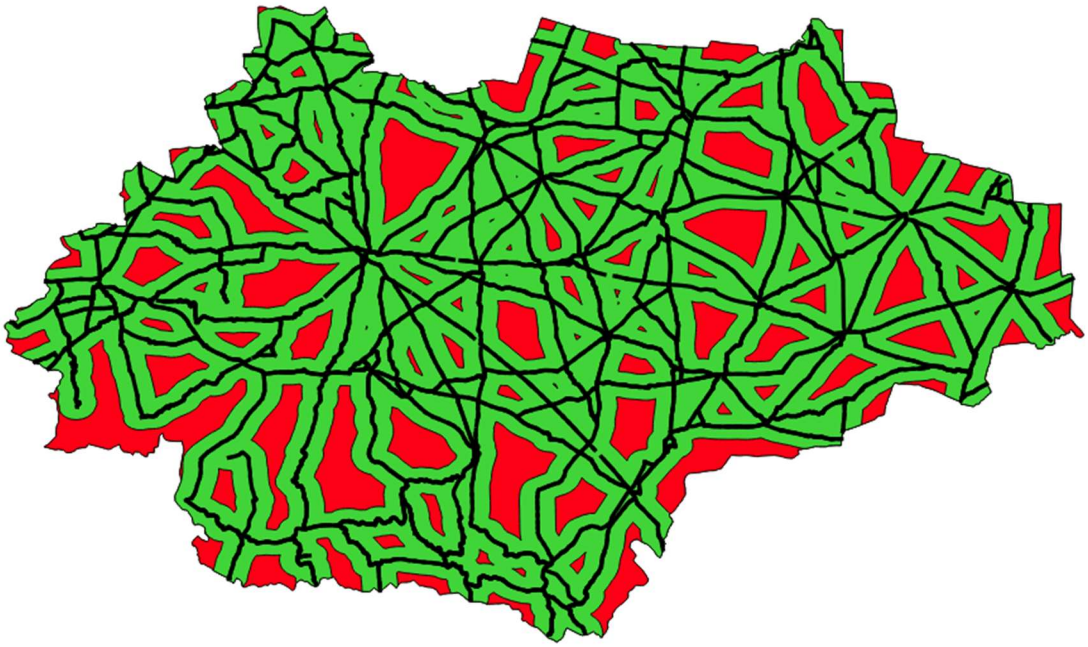


Figure 25. Sinnar ST route coverage 80.07% in green region assuming ST route buffer 1 km

Sinnar ST coverage assuming the 1 Km buffer	1,151 sq. Km
Sinnar village area	1,438 sq. Km

Sinnar Coverage	80.07%

Table 17. Sinnar ST area coverage (80.07%) (Data generated through Digital Geography)

5.1.1.1. GIS Multi-range ST coverage representation-

In *Figure 26* green color represents the area covered ST bus under 500 meter in Sinnar Taluka, yellow color represents the area covered under 500 meter to 1 Km and red area represents area beyond 1Km of ST coverage. This type of GIS representation gives more information about ST area coverage. *Table 18* and *Figure 27* show the amount of area covered under different ranges.

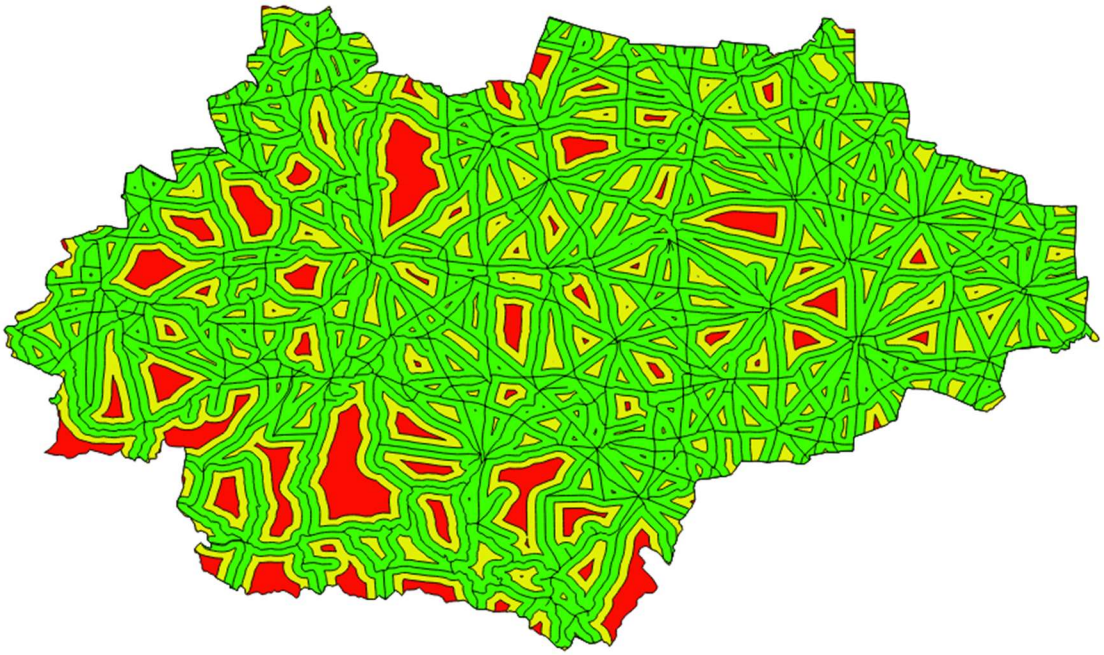


Figure 26. Sinnar ST coverage GIS multi-range representation

Particulars	**Area (in square Km)**	**Cumulative Area (in square Km)**
Coverage Area under 500 m	1016	1016
Coverage Area between 500 m & 1 Km	136	1152

Coverage Area beyond 1 Km	287	1438

Table 18. Sinnar ST area coverage (Data generated through Digital Geography)

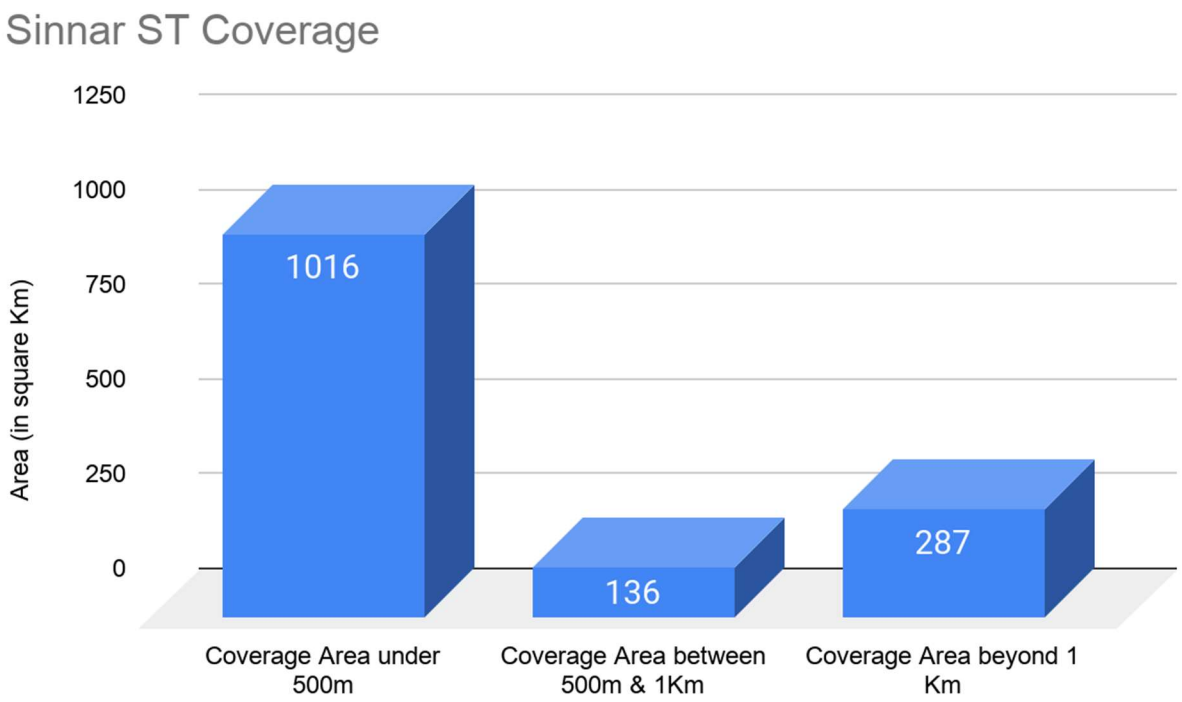


Figure 27. Sinnar ST coverage (i)

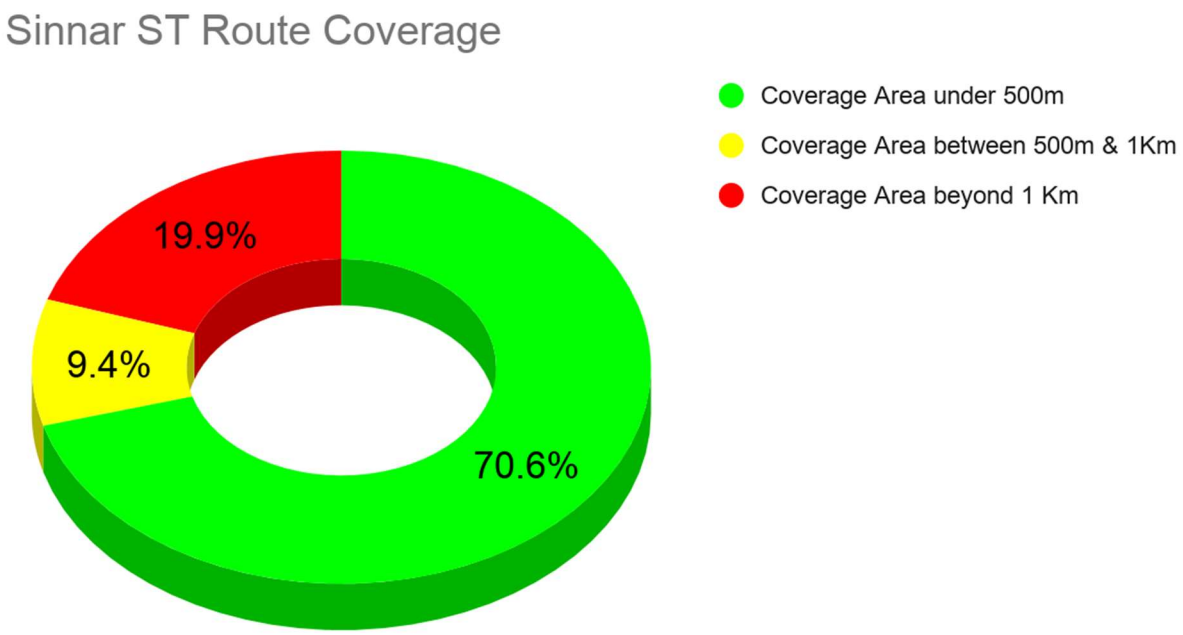


Figure 28. Sinnar ST coverage (ii)

5.1.1.2. Physical Significance-

Digital geography can be used to know the coverage of ST-Road Network in a village. Also, it can be used to know which are the areas that need attention where the ST route network is beyond a range of certain distance. MSRTC can work on those areas to improve coverage. The larger the red region requires more attention it requires as more remote the place is.

5.1.2. Sinnar Road Coverage:

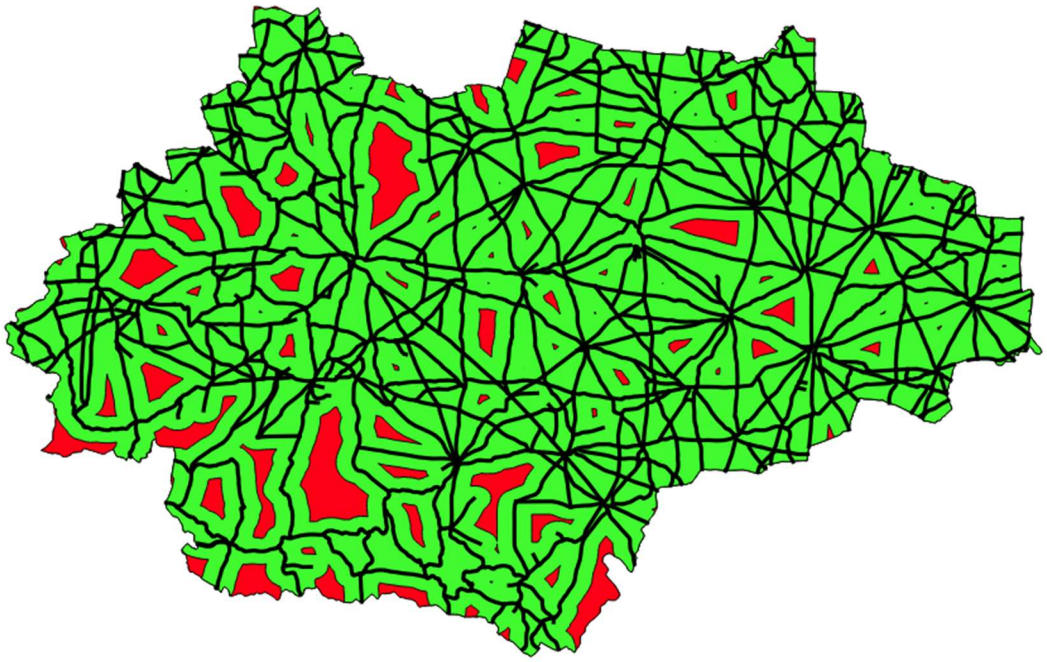


Figure 29. Sinnar road coverage 92.55% in green color

In the *Figure 29* red regions are those which are beyond the 1 Km distance from the Sinnar road network. *Table 19* shows Sinnar ST area coverage (92.55%) (Data generated through Digital Geography)

Sinnar road coverage assuming the 1 Km buffer	1,331. sq. Km
Sinnar village area	1,438 sq. Km
Sinnar Coverage	92.55%

Table 19. Sinnar ST area coverage (92.55%) (Data generated through Digital Geography)

5.1.2.1. Physical Significance-

Digital geography can be used to know the coverage of Road Network in a village. Also, it can be used to know which are the areas that need attention where the road network is beyond a range of certain distance. PWD can work on those areas to improve coverage.

5.2. Sinnar Road Coverage Analysis:

In the *Figure 23* shows the Sinnar roads where ST runs bus services in green color and Sinnar roads where ST doesn't run bus services in the red line.

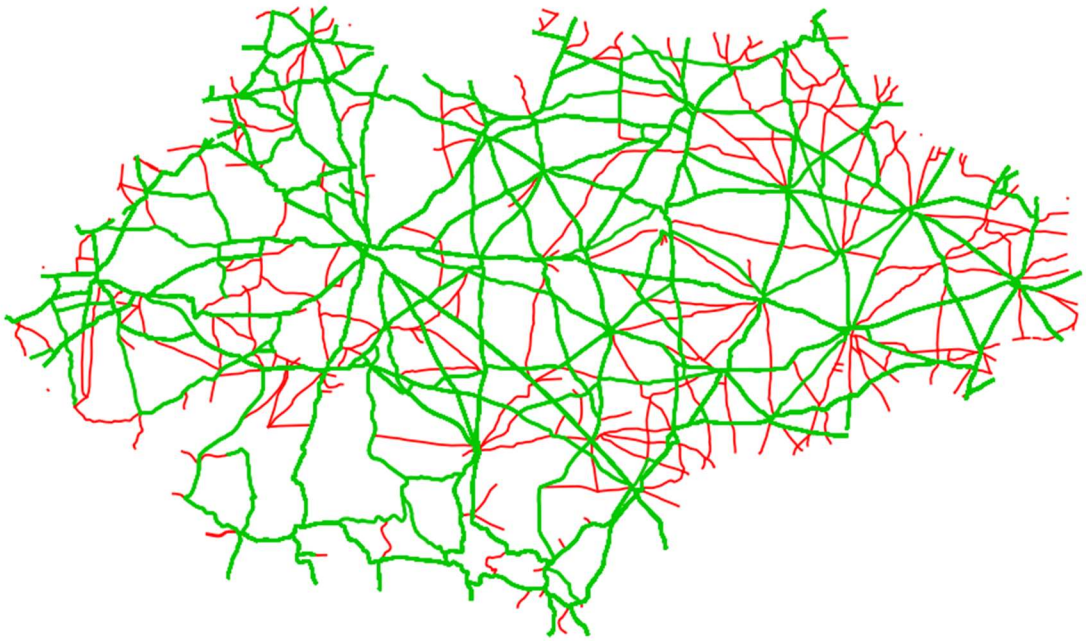


Figure 30. Sinnar roads coverage (66.91%) by ST represented in Green lines

Sinnar Road Length:	1,545 Kilometer
Sinnar ST route Length:	1,033 Kilometer
Sinnar Road coverage by ST:	66.91%

Table 20. Sinnar road coverage (Data generated through Digital Geography)

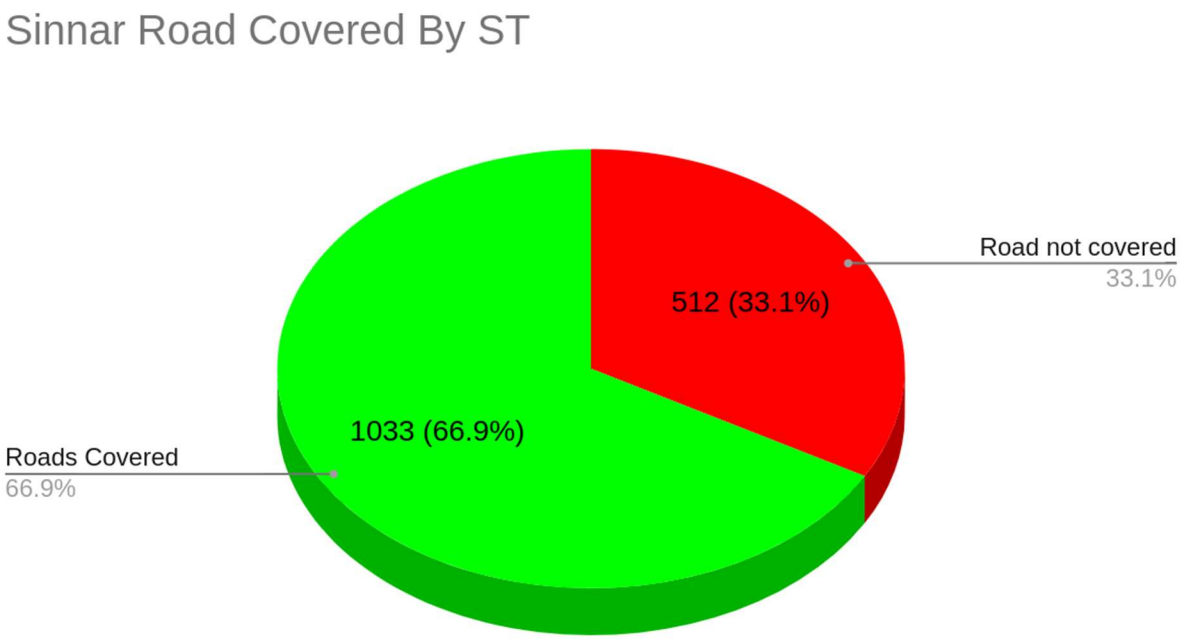


Figure 31. Sinnar ST road coverage

5.2.0.1. Methodology:

- Use the QGIS tool 'Dissolve' for both Sinnar ST road and Sinnar Roads and calculate the length of Sinnar ST roads and Sinnar roads.

5.2.0.2. Physical Significance:

Digital Geography can show which roads are not being covered by ST routes and which roads are not being covered by ST routes. If MSRTC wants to improve its road coverage they can easily know through digital geography which roads can be covered.

5.3. Bus Stop Dependency Analysis:

This data analyses the imbalance number of passengers coming and going from a bus stop. This analysis has been done on Sinnar ETIM August 2019 data. In this analysis, we analyzed how many passengers are coming to a bus stop via other bus stops i.e. incoming passengers and how many passengers are taking to go to other bus stops from the same bus stop i.e. outgoing passengers.

The incoming passengers have been calculated as number of tickets issued for a bus top (i.e. tickets for a particular destination bus stop) and Outgoing passengers have been calculated as the number of tickets issued from a bus stop i.e. (tickets issued from a particular source bus stop)

GIS Representation of Sinnar Bus Traffic Analysis on QGIS depending upon Incoming tickets issued (Incoming passenger) and outgoing tickets issued i.e. (outgoing passengers) has been shown in *Figure 32*. In *Figure 32*, the green color circle represents more incoming passengers compared to outgoing passengers on that bus stop location and red circles vice versa. Bigger is the circle, more imbalance is the outgoing tickets issued and incoming tickets issued on that bus stop. Size of circle is calculated by-

Size of circle for green circle = 3* (Incoming passengers+ 100)/(Outgoing passengers+100) in millimeters.

Size of circle for red circle = 3* (Outgoing passengers+ 100)/(Incoming passengers+100) in millimeters.

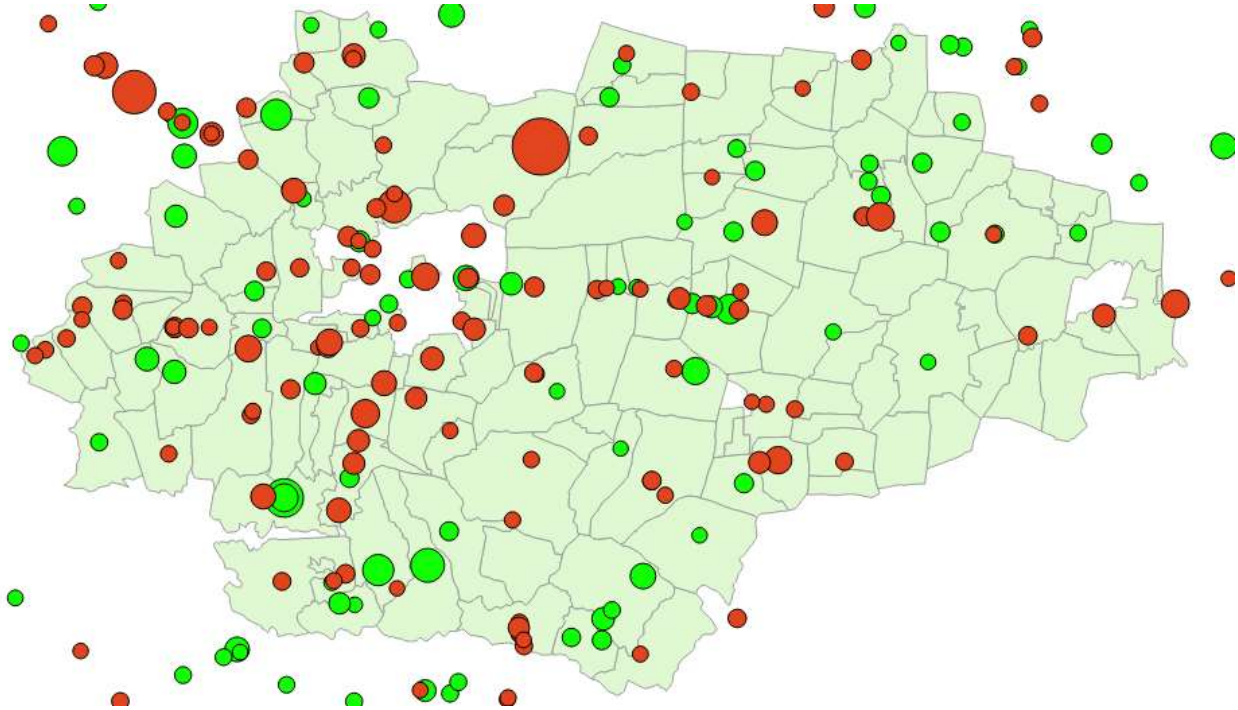


Figure 32. Sinnar Bus stop dependency Analysis (August 2019)

5.3.1. SQL Query

The SQL query used for Sinnar KCL analysis on ETIM data is as follows-

"Select t1.bus_stop, t1.incoming_pass, t2.outgoing pass
from
(Select count(no_of_tickets) as incoming_pass, distinct(source_bus_stop) as bus_stop from ETIMSinnarJuly19 group by source_bus_stop) as t1,
(Select count(no_of_tickets) as outgoing_pass, distinct(destination_bus_stop) as bus_stop from ETIMSinnarJuly19 group by destination_bus_stop) as t2
where
t1.bus_stop=t2.bus_stop"

5.3.2. Limitations:

1. This data only considered the tickets issued under Sinnar bus depot jurisdiction i.e. originated from Sinnar Taluka in the month of August 2019. For tickets issued by the other Talukas are not considered.
2. Currently, only 1-month data has been considered, better results can be obtained if year-long data is considered.
3. This data can give approximate good results for the bus stops lying inside the Sinnar Taluka but not for the bus stops lying outside the Sinnar Taluka.

5.3.3. Physical Significance:

The bigger the circle, the more the imbalance between incoming passengers or outgoing passengers at a bus stop. This shows passengers are using the bus mode of transport for coming to a bus stop and another mode of transport like private transportation like jeep, auto, etc for going outside of a place or vice versa. In other words availability of other means of transport. However, this reason has not been validated through any field survey.

5.4. Selection of Routes considering providing access to PHC-

During the COVID-19 epidemic, bus capacities have been reduced so in this section we tried to optimize the number of bus services to meet the requirements of MSRTC. i.e, by selecting a set of routes having a minimum number of routes required to provide maximum coverage to Sinnar village in minimum possible routes providing access to PHC and proposing a time table based on it.

5.4.1. Selection of bus routes logic used

1. As we increase the number of routes, the coverage of the village increases so to limit or having a minimum number of routes to cover most Sinnar Taluka, *I have restricted 1 route/PHC*. For Every PHC, the nearest pick-up or drop point considered is the nearest Bus stop.
2. Routes are selected having such that it passes through the nearest Bus stop of respective PHC.
3. Routes are selected on the basis which can cover a maximum number of distinct bus stops lying inside Sinnar village. Bus stops lying outside Sinnar Taluka are not considered. (It is assumed that the more distinct bus stops are covered, more is the coverage.) (Total number of Sinnar bus stops covered considering 1 route/PHC are 66 out 189 shown in image).
4. Every PHC has been tried for assigning a distinct route for load distribution.
5. Using the Greedy approach, adding routes that cover a maximum number of distinct bus stops is not covered yet till 75% of the total bus stops are covered.

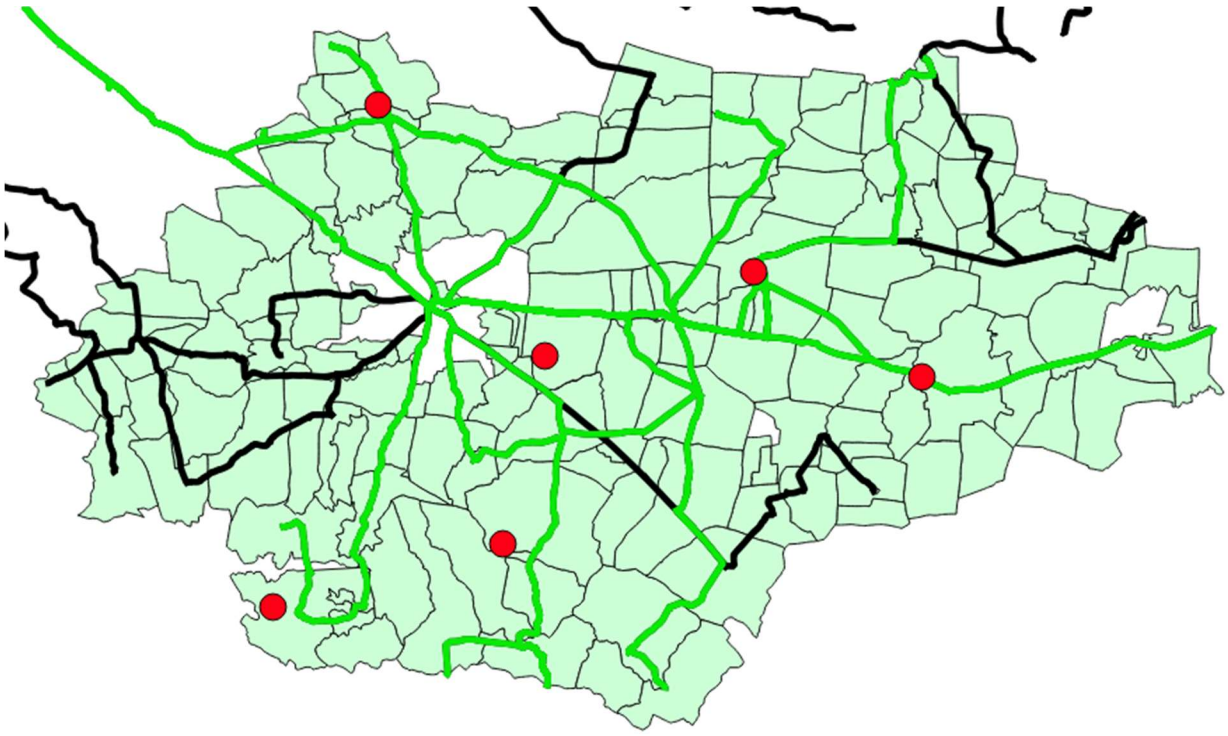


Figure 33. Selected routes in green lines providing access to PHC's

Figure 33 shows the GIS image of selected routes providing Bus stop coverage max. 75% in the least number of routes possible. Green lines show PHC routes, black routes show non-PHC routes.

5.5. Nearest BusStops for PHC's -

Nearest BusStop selection from PHC has been done based on the shortest spatial distance.

PHC Village	Nearest Bus Stop Code
Wavi	VAVIK
Dapur	DULWIA
Thangaon	TTAGSN
Pandhurli	MUSON
Naigaon	JGN

Deopur	DOPUIA

Table 21. Nearest Bus stop for Sinnar PHC's

5.5.1. GIS image:

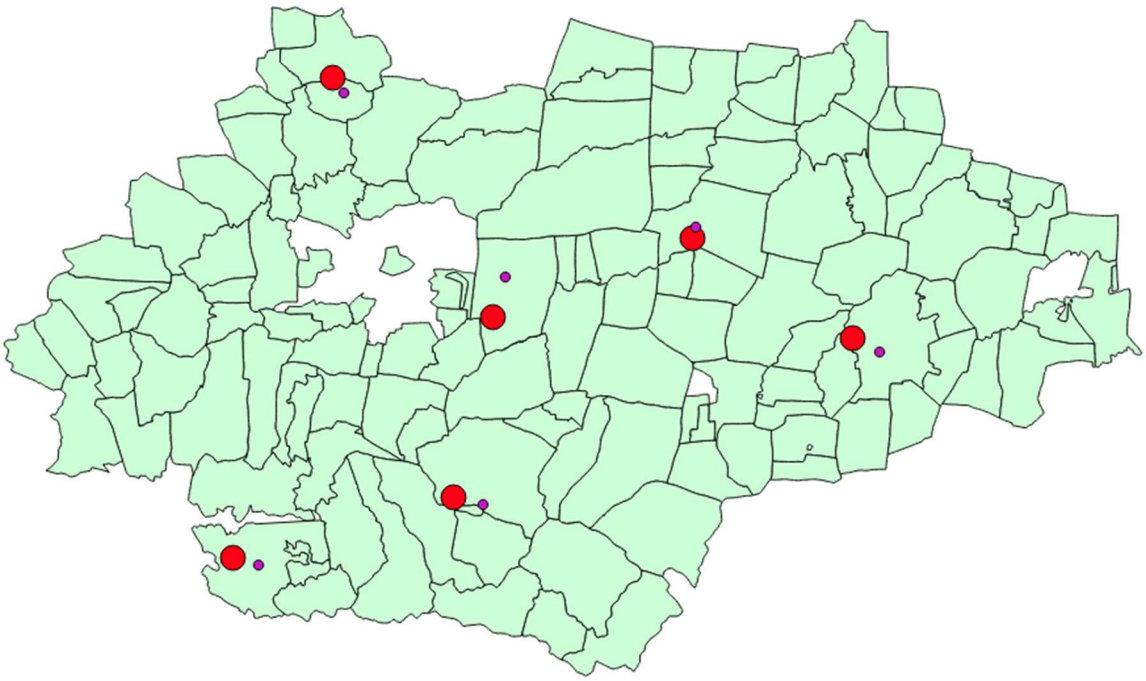


Figure 34. QGIS image showing nearest bus stop location in purple color

5.5.2. Physical Significance-

This nearest bus stop to PHC analysis can help to know the nearest bus for a PHC which then further can help in the selection of routes or creation of routes better-providing access to PHC. The same methodology can be extended to schools, tourist spots, etc.

5.6. Sinnar PHC Time table creation and GIS representation-

As the COVID-19 epidemic has started spreading in India from January 2019, Government needs proper planning PHC and Sub-PHC's needs. People will need transport to access these, and if patients are admitted, to give care.

In this section, an attempt has been made to create an ideal Sinnar time table for PHC and represent it on GIS.

5.6.1. Assumptions while creating timetable-

- Only Sinnar Taluka villages have been considered.
- Bus Travel Speed = 30 km/hr (average speed of the bus)
- Bus Stop Halt Time = 2 min (the time for which the bus stops at bus stop)
- PHC Halt Time = 10 min (the time for which the bus stops at a PHC's nearest bus stop)
- Intersection Bus Stop Halt time or time to switch buses = 30 min (There are some routes where PHC doesn't lie directly on the route i.e. a person may have to switch route between the Non-PHC route to PHC route or vice versa at some common intersection bus Stop to reach PHC or come from PHC.) (Intersection Bus Stop Halt time is the time buffer so that passenger can get bus considering the bus delays)
- Bus Stop Coverage = 75 (min % cover of the bus stops required for the entire taluka). Computing via area coverage is too high computing and takes a lot of time so calculating via covering taluka bus stops. In actual practical use, this can simply be replaced by area coverage. Currently, for research purposes, this method is also giving good area coverage.
- Bus Arrival time at PHC- [09:00 AM and 05:00 PM], Assuming all bus passengers from respective villages will leave for PHC to reach PHC at 9 AM. and all bus passengers will depart from PHC at 5 PM to reach back home.
- All passengers will travel from their home village to PHC and vice versa only.
- Nearest Pick up point or Drop point for a village is considered as the nearest bus Stop from the village.
- Bus Traffic Load Assumptions have been made as 0.1% of total village populations i.e From every village daily 0.1% people of their population would pick a bus from the nearest bus stop and will travel till PHC and the same percentage of people will return.

5.6.2. Data Required:

Data Required for this methodology to work are as follows:

- Digital Geography of Taluka.

- Latitude and Longitude of Bus Stops
- Latitude and Longitude of PHC's.
- Census Population data village wise.
- Taluka Bus Routes.
- Taluka Bus Route Sequence.

5.6.3. Bus Traffic Load Estimation Methodology:

- Selection of routes
- Get Nearest bus stop lying on the selected routes for every village. (Assuming every villager would use this bus stop as pick up point or drop point for MSRTC bus transportation) (QGIS Plugin required- NNJoin)
- Get Nearest bus stop lying on the selected routes for every PHC. (Assuming every villager would use this bus stop as pick up point or drop point for MSRTC bus transportation) (QGIS Plugin required- NNJoin)
- Assume Traffic from every village to be 0.1% of the village population daily. Estimate Traffic on each route segment of route assuming a village would use nearest bus stop as pick up point and nearest PHC bus stop as final drop point. Similarly while returning time a passenger would use pick up point as the nearest bus stop from PHC and drop point as the nearest bus stop from his village.
- Estimate number of bus trips/services required based on the bus traffic load on each route segment assuming maximum bus capacity to be 25.

5.6.3.1. Bus Load Traffic Assumption Example:

Consider an example in *Table 22* for calculating the bus traffic at each bus stop where "Dhulwad Fata" is the nearest bus stop for a PHC. Now when PHC is yet to arrive in a bus trip, assuming all villagers will leave for PHC from respective villages so expected population being served at each bus stop will be previous bus stop expected population being served + Expected population being served due to its own bus stop. At PHC, all already sitting villagers will step out of the bus and the traffic at the PHC bus stop will be due to the population of upcoming villages, so the expected population being served at each bus stop after each bus stop will be previous bus stop traffic minus

traffic due to its own population. So the formula for calculating expected population being served at each bus stop are given by-

Situation 1: When PHC bus Stop not arrived yet

$$P_i=P_{i-1}+P_{BS}$$

$$P_0=P_{BS}$$

Where P_i is Population being served when PHC bus stop not arrived at bus stop,

P_{i-1} is Population being served at previous stop,

P_{BS} population at its own bus stop,

P_0 is the Population being served at first Bus Stop

Where i is greater or equal to 1

And,

Situation 2: When Population PHC bus stop has arrived

$$P_i=P_{i+1}+P_{BS}$$

$$P_k=0$$

Where P_i is Population being served when PHC bus stop not arrived at bus stop,

P_{i+1} is Population being served at next stop,

P_{BS} is Population at its own bus stop,

P_k is the population being served at the last bus stop, As no passenger will issue tickets from this bus stop as the bus trip ends hence population being served at this bus stop is zero.

Where i is always smaller than last bus stop number (k)

Assuming Expected Traffic at each bus stop considering 0.1% population will travel daily.

Table 22. shows a detailed calculation of expected traffic at each bus stop and number of buses required to provide this service for route number 7100 assuming strict social distancing has to be followed. The expected load factor can be predicted by using the formula for calculation of load factor explained in later.

BUS STOP NAME	KM	ROUTE NO	STOP SEQ	Population being served	Expected population being served	Expected Traffic at each bus stop considering traffic =0.1%	No. of Bus Services required considering bus Capacity max=25
GUREWADI	5.1	7100	1	5615	5615	6	1
GONDE FATA	8.4	7100	2	3324	8939	9	1
DAPUR	14.8	7100	3	5902	14841	15	1
DHULWAD FATA	16.8	7100	4	3791	2306	2	1
CHAPADGAON	19.7	7100	5	2306	0	0	1

Table 22. Calculations for Expected Traffic load at each bus stop calculation

5.6.4. Methodology for Sinnar PHC Time Table Data Creation-

- Selection of routes providing a minimum of 75% of bus stops coverage in the minimum number of routes.
- Finding the routes having the nearest PHC bus stop as a halt in their routes or in other words PHC routes. Assign times to these routes.
- For returning time table, returning trip starting time will be adding 10 minutes to it forward trip final destination reaching time.
- Define the intersection points for the remaining routes. On these intersection points schedule the buses as such that they reach 30 minutes before the PHC going bus reaches that stop.
- Round off the times for all the routes.

5.6.5. Some Important point:

- Current method required a total number of 52 Bus Trips to be scheduled for Sinnar.

	A	B	C	D	E	F
1	ROUTE_NO	Trip Type	Departure Time	from	till	Expected Arrival Time
2	2130	Forward	8:15	CHINCHOLI FATA	DARDE FATA	10:35
3	2130	Return	7:30	DARDE FATA	CHINCHOLI FATA	9:50
4	6891	Forward	7:43	SINNAR	DARDE FATA	9:39
5	6891	Return	8:26	DARDE FATA	SINNAR	10:22
6	7100	Forward	8:16	SINNAR	CHAS/NANDUR SHINGOTE FATA	9:31
7	7100	Return	8:34	CHAS/NANDUR SHINGOTE FATA	SINNAR	9:49
8	7103	Forward	7:54	SINNAR	AADWADI (LAST)	9:27
9	7103	Return	8:38	AADWADI (LAST)	SINNAR	10:11
10	7118	Forward	7:47	SINNAR	DEOPUR VILLEGE	8:58
11	7118	Return	9:07	DEOPUR VILLEGE	SINNAR	10:18
12	7161	Forward	8:01	SINNAR	JAKHORI FATA	9:31
13	7161	Return	8:34	JAKHORI FATA	SINNAR	10:05
14	7165	Forward	8:41	SINNAR	DATTA NAGAR	10:46
15	7165	Return	7:19	DATTA NAGAR	SINNAR	9:24
16	85886	Forward	8:40	SINNAR	NALWADI	10:31
17	85886	Return	7:34	NALWADI	SINNAR	9:25
18	7102	Forward	7:41	SINNAR	AUNDHEWADI	8:42
19	7102	Return	6:09	AUNDHEWADI	SINNAR	7:11
20	7107	Forward	7:41	SINNAR	BELU VILLEGE	8:54
21	7107	Return	5:58	BELU VILLEGE	SINNAR	7:11
22	7130	Forward	7:41	SINNAR	KHAPRALE	8:15
23	7130	Return	6:36	KHAPRALE	SINNAR	7:11
24	7131	Forward	7:41	SINNAR	SAYKHEDA FATA	8:35
25	7131	Return	6:16	SAYKHEDA FATA	SINNAR	7:11
26	7139	Forward	7:41	SINNAR	VHIGANWADI	9:33
27	7139	Return	5:18	VHIGANWADI	SINNAR	7:11
28	7147	Forward	7:41	SINNAR	NIRHALE	9:02

Figure 35. Sample Form 4 generated

	A	B	C	D	E	F	G	H	I	J
1	ROUTE_NO	BUS_STOP_CD	BUS_STOP_NM	STOP_SEQ	KM	Departure Time	Arrival Time	Halt Time	Trip Type	Route Type
2	2130	CHOFS	CHINCHOLI FATA	1	0	8:15	8:13	2	Forward	PHC
3	2130	MEARI	MEHADARI	2	3.2	8:23	8:21	2	Forward	PHC
4	2130	MLANF	MALGAON FATA	3	5.9	8:31	8:29	2	Forward	PHC
5	2130	SNNR	SINNAR	4	11.3	8:44	8:42	2	Forward	PHC
6	2130	MUSON	MUSALGAON	5	18.3	9:07	8:58	10	Forward	PHC
7	2130	MSLSNK	MUSALGAON (MIDC)	6	17.1	9:07	9:05	2	Forward	PHC
8	2130	MSLSN	MUSALGAON FATA	7	18.7	9:12	9:10	2	Forward	PHC
9	2130	DTL	DATELI	8	21.9	9:21	9:19	2	Forward	PHC
10	2130	KPDH	KOPADI KHURD	9	23.7	9:26	9:24	2	Forward	PHC
11	2130	KADIBD	KHOPADI BUDRUK	10	24.3	9:30	9:28	2	Forward	PHC
12	2130	SISN	DATTA MANDIR	11	25.6	9:34	9:32	2	Forward	PHC
13	2130	BOASNK	BHOKANI FATA	12	26.2	9:37	9:35	2	Forward	PHC
14	2130	DVURFT	DEVPUR FATA	13	29	9:45	9:43	2	Forward	PHC
15	2130	PPNRSN	PANGRI	14	33.9	9:57	9:55	2	Forward	PHC
16	2130	VAVI	VAVI	15	39.3	10:10	10:08	2	Forward	PHC
17	2130	SYFT	SAYALE FATA	16	40.2	10:13	10:11	2	Forward	PHC
18	2130	PATRE	PATHARE	17	48.5	10:32	10:30	2	Forward	PHC
19	2130	DREKA	DARDE FATA	18	49.8	10:37	10:35	2	Forward	PHC
20	2130	DREKA	DARDE FATA	1	0	7:30	7:29	2	Return	PHC
21	2130	PATRE	PATHARE	2	1.3	7:35	7:33	2	Return	PHC
22	2130	SYFT	SAYALE FATA	3	9.6	7:54	7:52	2	Return	PHC
23	2130	VAVI	VAVI	4	10.5	7:57	7:55	2	Return	PHC
24	2130	PPNRSN	PANGRI	5	15.9	8:10	8:08	2	Return	PHC
25	2130	DVURFT	DEVPUR FATA	6	20.8	8:22	8:20	2	Return	PHC
26	2130	BOASNK	BHOKANI FATA	7	23.6	8:30	8:28	2	Return	PHC
27	2130	SISN	DATTA MANDIR	8	24.2	8:33	8:31	2	Return	PHC
28	2130	KADIBD	KHOPADI BUDRUK	9	25.5	8:37	8:35	2	Return	PHC

Figure 36. Sample PHC Time Table generated

5.6.6. Load Factor of schedules:

The load factor for the methodology has been calculated as-

$$\textit{Load Factor of the route} = (\Sigma((\text{Traffic Load } RS_i) * KM_i))/((\text{Bus Capacity}) * KM)$$

Where,

'Traffic Load RS_i' is the traffic load at each Route segment

'KM_i' is the Length of route Segment

'Bus Capacity' is the capacity of bus and is assumed to be 25

'KM' is the length of complete Bus Trip

$$\textit{Load Factor of a bus trip} = (\textit{Load Factor of the route})/(\textit{Number of trips in Respective Route})$$

Where,

Load Factor of a bus trip is the load factor of a bus trip of a respective route assuming equal traffic load division

BUS STOP NAME	KM	ROUTE NO	STOP SEQ	Population being served	Expected population being served	Expected Traffic at each bus stop considering traffic =0.1%	No. of Bus Services required considering bus Capacity max=25
GUREWADI	5.1	7100	1	5615	5615	6	1
GONDE FATA	8.4	7100	2	3324	8939	9	1
DAPUR	14.8	7100	3	5902	14841	15	1
DHULWAD FATA (PHC)	16.8	7100	4	3791	2306	2	1
CHAPADGAON	19.7	7100	5	2306	0	0	1

Table 23. Traffic at each bus stop for route no. 7100 froward trip

For example- *Table 23.* shows Traffic at each bus stop with the length of each bus stop. Using the above method, Load Factor for Route number '7100' forward trip found is found to be 19.16%. Here Traffic at a route segment will be "**Expected Traffic at each bus stop considering traffic =0.1%**" and respective Length of route segment will be "$\mathbf{KM_{i+1}-KM_i}$"

The load factor calculated per bus trip for every route number forward and reverse route has been shown in *Table 24.*

Route Number	Forward Trip	Reverse Trip
2130	27.02%	23.67%
6891	25.81%	27.60%
7100	19.16%	27.33%

7102	20.48%	28.68%
7103	15.91%	17.00%
7107	43.31%	32.20%
7118	24.23%	16.97%
7130	13.38%	15.17%
7131	25.59%	31.67%
7139	40.94%	19.62%
7147	42.73%	37.49%
7161	14.39%	21.53%
7165	37.16%	37.00%
85886	30.47%	25.99%

Table 24. Load Factor of bus trips in proposed ideal PHC time table

5.6.7. Load Factor of PHC:

5.6.7.1. Assumptions:

- All passengers travelling in PHC routes will prefer PHC lying on the respective to avoid 30 min. delay to switch buses.
- All passengers travelling in Non-PHC routes can go to any PHC because at the common bus stop while changing from Non-PHC route to PHC bus stop, they can prefer any PHC route depending upon their choice like based on availability of beds or where their relative is already admitted etc. For example, as all selected routes pass through Sinnar city, a passenger can pick a bus based on availability of buses.

5.6.7.2. Methodology:

Methodology for calculation of Load Factor at PHC are as follows:

Situation 1: Load Factor due to PHC route:

Load Factor at PHC lying on PHC Route= Population being served by that PHC route

Situation 2: Load Factor due to Non-PHC route:

Load Factor at all PHC due to Non-PHC Route= (Population being served by that PHC route)/(Number of PHC's)

Load factors obtained are as follows for all PHC's:

PHC	**Load as a %age to Population**
DOPUIA	11.2%
DULWIA	17.0%
JGN	13.6%
MUSON	28.3%
TTAGSN	15.8%
VAVIK	14.1%

Table 25.

Load Factor is high at 'MUSON' PHC due to its location, it lies almost in the centre of taluka, further it is the most closest PHC to Sinnar city from where all routes pass through.

5.6.8. Village Covered:

Considering the villages as under 3 Km spatial distance from Nearest ST road point as covered villages. Generally 3 Km is used by MSRTC for village coverage. Through this methodology village coverage is 93.75% i.e. 120 villages got covered out of Sinnar total 128 villages. Coverage can be improved as the number of selected routes is increased. Currently we have used a limited number of routes i.e. 14 routes.

5.6.8.1. Finding Village Coverage methodology used:

- Convert Selected Route into Point form (QGIS plugin- 'Extract Nodes')
- Calculate line distance from village centroid to Selected route in point form. (QGIS plugin- 'Hub Distance')
- Get the village coverage as (number of village under 3 Km distance/total number of villages)

5.6.9. Limitations-

- Traffic is assumed to be uniform. In epidemics like COVID-19, the proposed time table may not be valid as COVID-19 victim people are generally clustered.
- Real-time integration of Dedicated COVID-19 facilities is needed for actual timetable creation. Dedicated COVID-19 facility keeps on updating every 5-10 days.
- Doesn't consider important location's like markets, schools, industry locations, tourist spots.
- Doesn't consider the number of bus resources available at Bus Depots.

5.6.10. Future Improvement Possible:

- Analysis on year long ETIM data to estimate bus traffic on weekdays, weekends, festivals months, at different times of day, school months etc. Currently Sinnar August 2019 data is available, based on the ridership analysis or traffic load on every route on one month data i.e number of trips can be designed on every route and a general time table can be designed. The methodology developed for 1 month can be replicated to complete Full year Time Table. If 10 years of data is available, machine learning algorithms can be used to predict traffic load (ridership) in next year and Time Table making can be completely automated.
- Integration of PHC time table considering other activities like going to schools, going to workplaces to improve load factor of bus trips.

5.6.11. QGIS representation-

QGIS representation of time tables can be done in two ways: Point Layer or Line layer. Further QGIS plugins can be made to customize according to need and make user friendly. A QGIS plugin has been made in 'Chapter- Plugin Development' named 'Plugin 1' which work similarly but for different purpose i.e. Providing ABC analysis of bus trips in a line layer based on some filter (or inputs). Similarly, a QGIS plugin can provide a time table of a bus trip in a Line layer based on some filter (or inputs). Line Layer representation can be done in a similar way as ABC analysis as shown in the Chapter named 'Digital Geography'. The time table point form QGIS representation is shown in *Figure 37.* In *Figure 37.* yellow dots represent bus stops where timetable in point form has been encoded and respective timetables on any bus stop can be fetched by clicking on it.

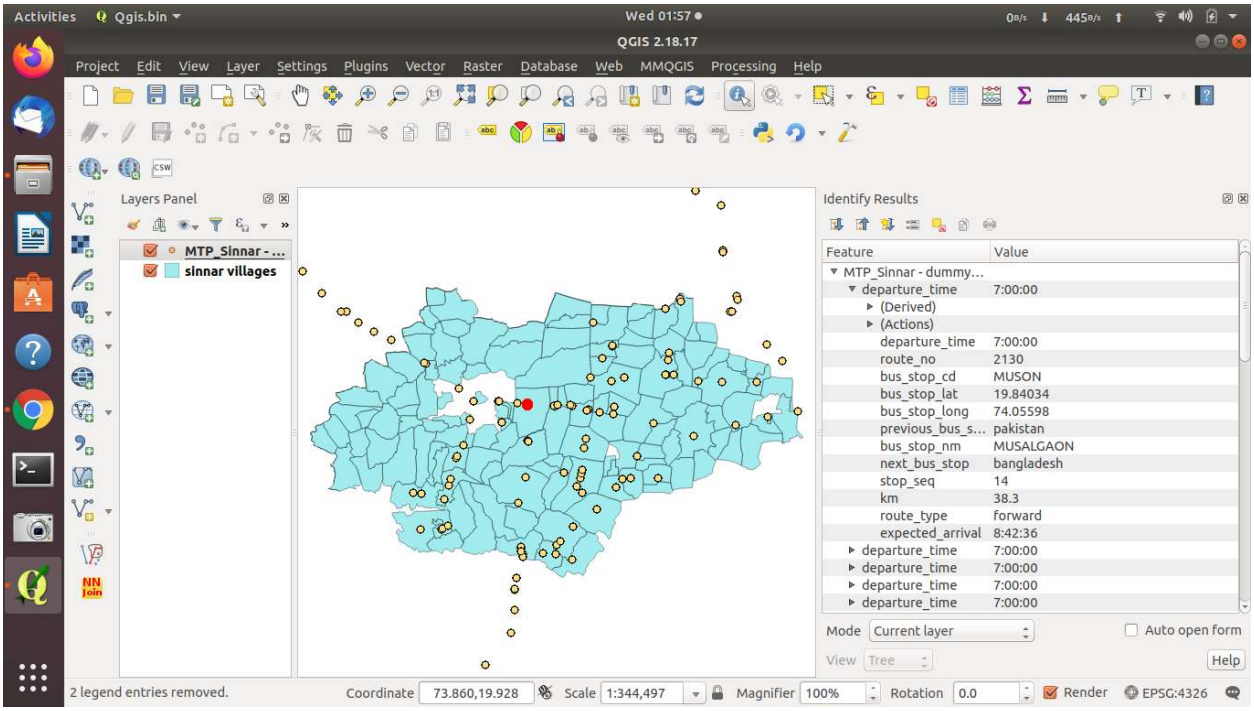


Figure 37. Time Table QGIS representation

5.6.11.1. Logic behind point representation-

Suppose a person wants to pick a bus from Sinnar town to Belu village. That person would be interested in knowing all the buses from the Sinnar bus stop as it is closest to him. He would be a little bit less interested in the path however will be interested in the time taken. So every bus trip has been represented in the form of a bus stop. He can choose then which bus trip to choose based on details right side like time to travel, previous stop representing from where it is coming, next to the bus stop where it is going.

Filter parts can be added later in a plugin to make the user experience better.

5.7. Mapping Sinnar villages to all Sinnar PHC via road :

5.7.1. Physical Significance:

Sometimes a village may have seasonal connectivity via road with a PHC due to monsoon or any other reason, In that case with the help of digital geography, one can know the best possible alternatives based on the shortest distance via road from a village to other PHC's. *Figure 38.* shows

the distance of all Sinnar PHC via road from Sinnar Village ‘Gonde’. This analysis can also help to find us alternative PHC in case the nearest PHC is not functional.

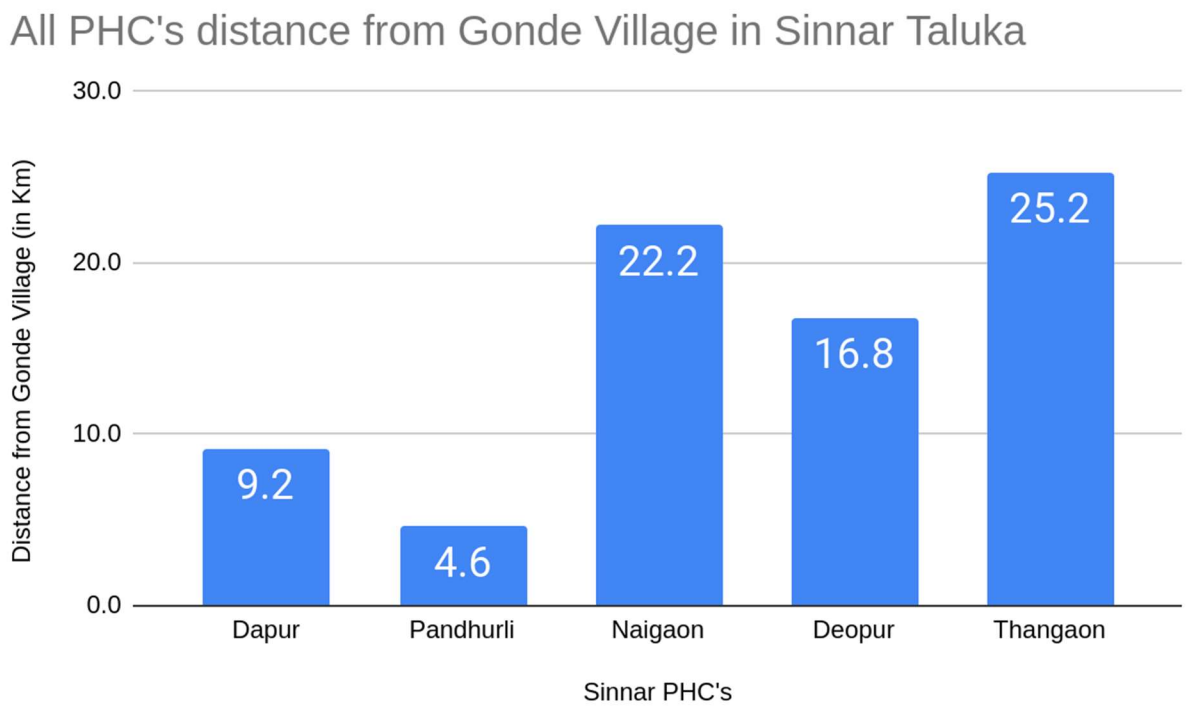


Figure 38. Distance of all PHC’s from Gonde Village of Sinnar Taluka

Village Name	**PHC**	**Distance (in km)**
Gonde	Dapur	9.2
Gonde	Pandhurli	4.6
Gonde	Naigaon	22.2
Gonde	Deopur	16.8
Gonde	Thangaon	25.2

Table 26. Distance of all PHC’s from Gonde Village of Sinnar Taluka

5.8. Mapping villages to nearest Sub-PHC via road:

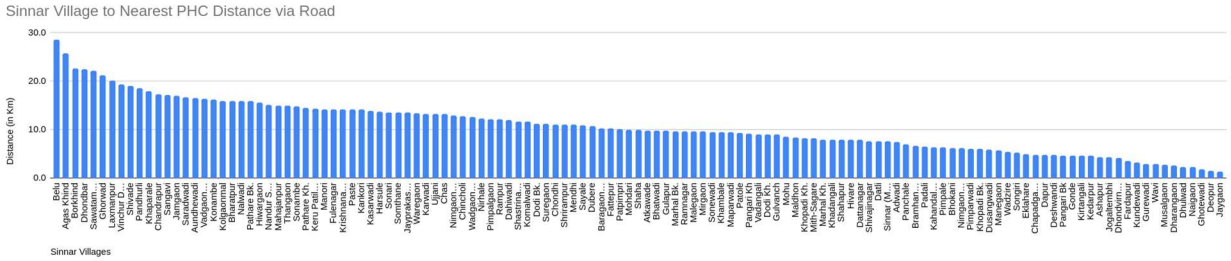


Figure 39. showing Sinnar Village to Nearest Sub-PHC distance

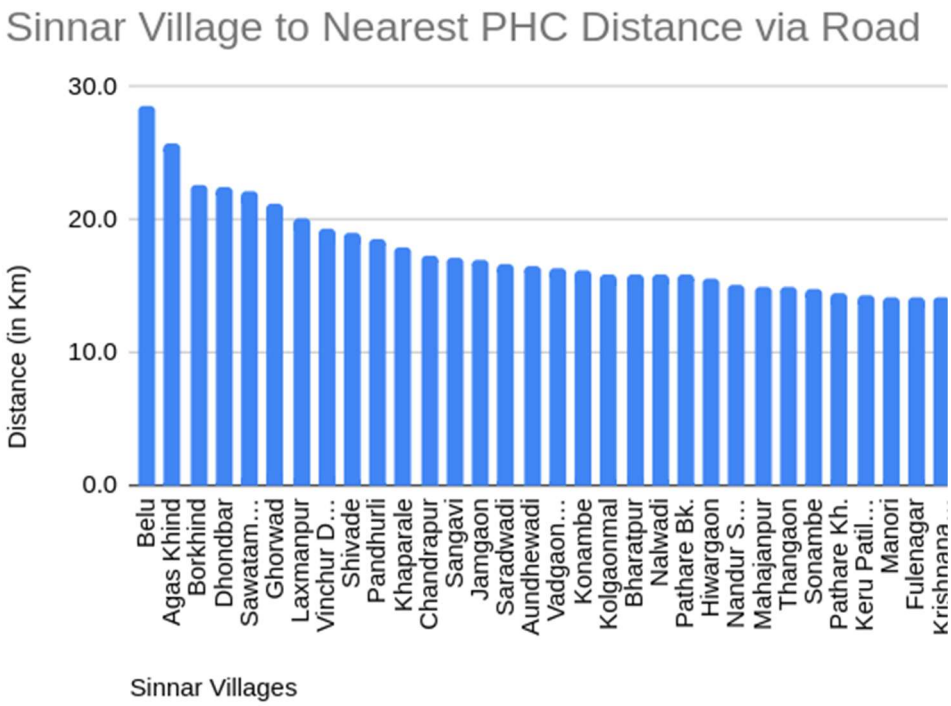


Figure 40. Zoom out of previous Figure 39

5.8.1. Physical Significance-

The *Figure 30* shows the distance between Sinnar villages with respect to nearest PHC which tells the Sinnar villages which need more attention as they are most distant one with their respective PHC

5.9. Mapping Sinnar sub-PHC to all Sinnar PHC via road:

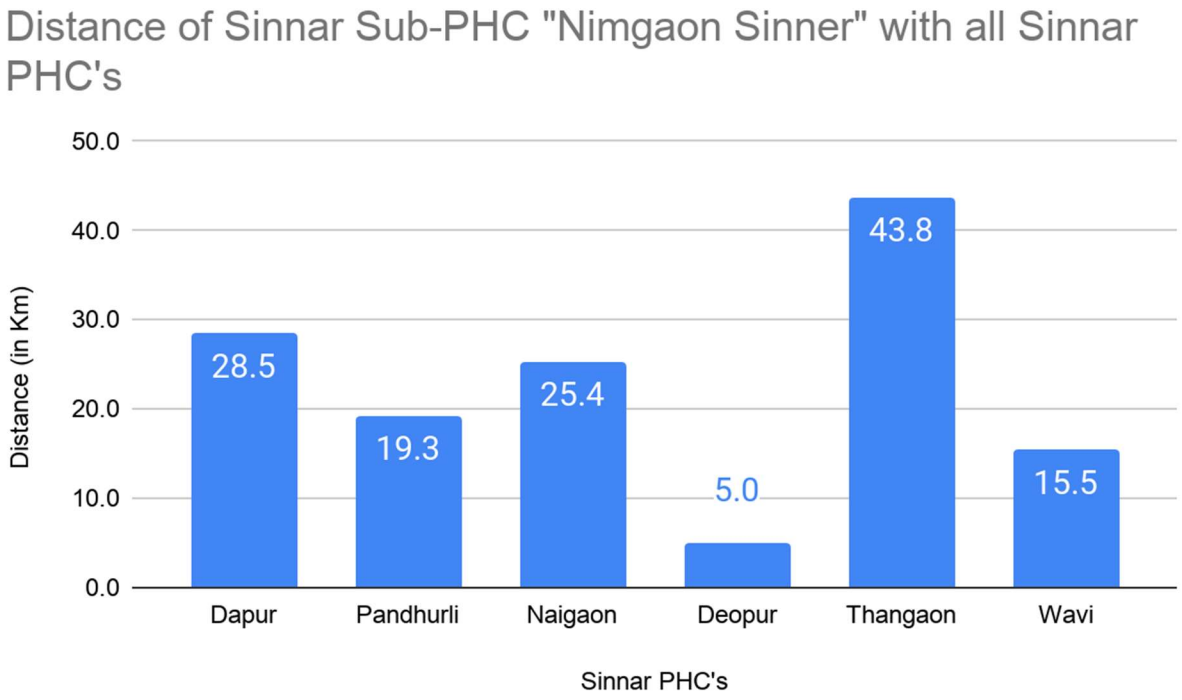


Figure 41. Sinnar Sub-PHC "Nimgaon Sinner" distance to all Sinnar PHC Distance

Sub-PHC	PHC	Distance (in Km)
Nimgaon Sinner	Dapur	28.5
Nimgaon Sinner	Pandhurli	19.3
Nimgaon Sinner	Naigaon	25.4
Nimgaon Sinner	Deopur	5.0
Nimgaon Sinner	Thangaon	43.8
Nimgaon Sinner	Wavi	15.5

Table 27. Sinnar Sub-PHC "Nimgaon Sinner" distance to all Sinnar PHC Distance

5.9.1. Physical Significance-

Figure 41 shows the distance between Sinnar Sub-PHC "Nimgaon Sinner" with respect to the nearest PHC which tells if road connectivity disrupts in any case what are the best possible alternatives based on road distance.

5.10. Sinnar Villages to all Sub-PHC's distance via road:

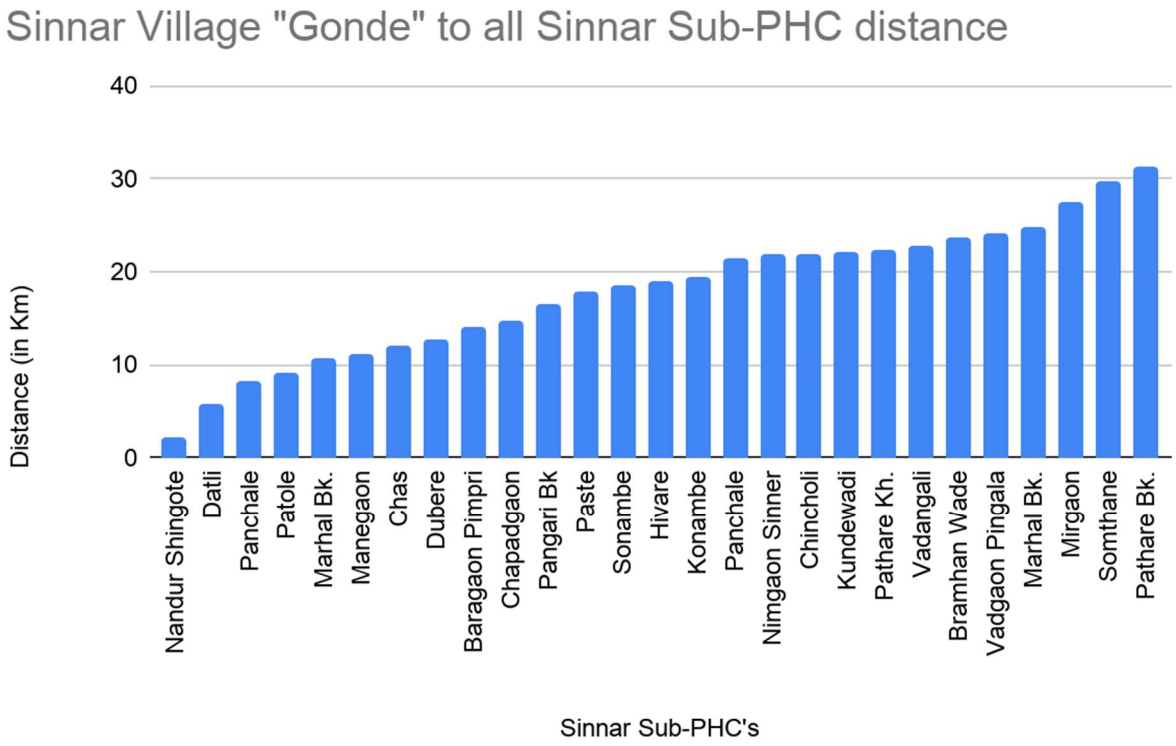


Figure 42. Distance of Sinnar Village Gonde with all Sinnar Sub-PHC's

VillageName	**SPHC**	**Distance (in Km)**
Gonde	Nandur Shingote	2.2
Gonde	Datli	5.9
Gonde	Panchale	8.3
Gonde	Patole	9.2
Gonde	Marhal Bk.	10.8
Gonde	Manegaon	11.2
Gonde	Chas	12.1
Gonde	Dubere	12.8
Gonde	Baragaon Pimpri	14.2
Gonde	Chapadgaon	14.7

Table 28. Top 10 nearest sub-PHC from Sinnar Village "Gonde"

5.10.1. Physical Significance-

Figure 42 shows the distance between Sinnar village "Gonde" with respect to all Sub-PHC which tells if road connectivity disrupts in any case what are the best possible alternatives based on road distance.

5.11. Mapping Sub-PHC's to NearestPHC's via road-

In *Figure 43*, Sinnar Sub-PHC have been mapped to nearest PHC via road distance

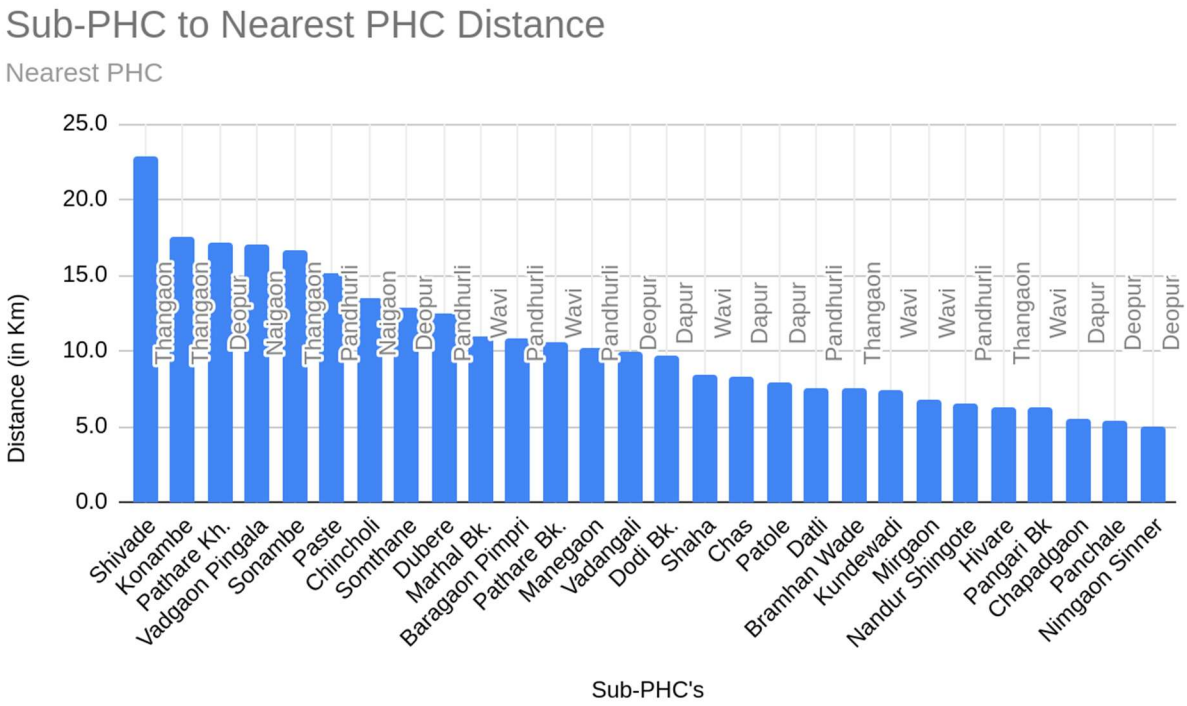


Figure 43. Sinnar sub-PHC's distance to Nearest PHC's distance

Sub-PHC	Nearest PHC	Distance (in Km)
Shivade	Thangaon	22.9
Konambe	Thangaon	17.5
Pathare Kh.	Deopur	17.1
Vadgaon Pingala	Naigaon	17.1
Sonambe	Thangaon	16.6
Paste	Pandhurli	15.2

Chincholi	Naigaon	13.5
Somthane	Deopur	12.9
Dubere	Pandhurli	12.5
Marhal Bk.	Wavi	11.0

Table 29. Top 10 farthest Sub-PHC's to nearest PHC distance

5.11.1. Physical Significance-

The *Figure 43* shows the distance of Sub-PHC village with respect to the nearest PHC which tells the Sub-PHC's which need more attention as they are the most distant one with their respective PHC.

5.12. Villages to nearest PHC's via spatial Distance :

5.12.1. Spatial Distance:

Here, Spatial distance means the length of a straight line directly between two points is spatial distance.

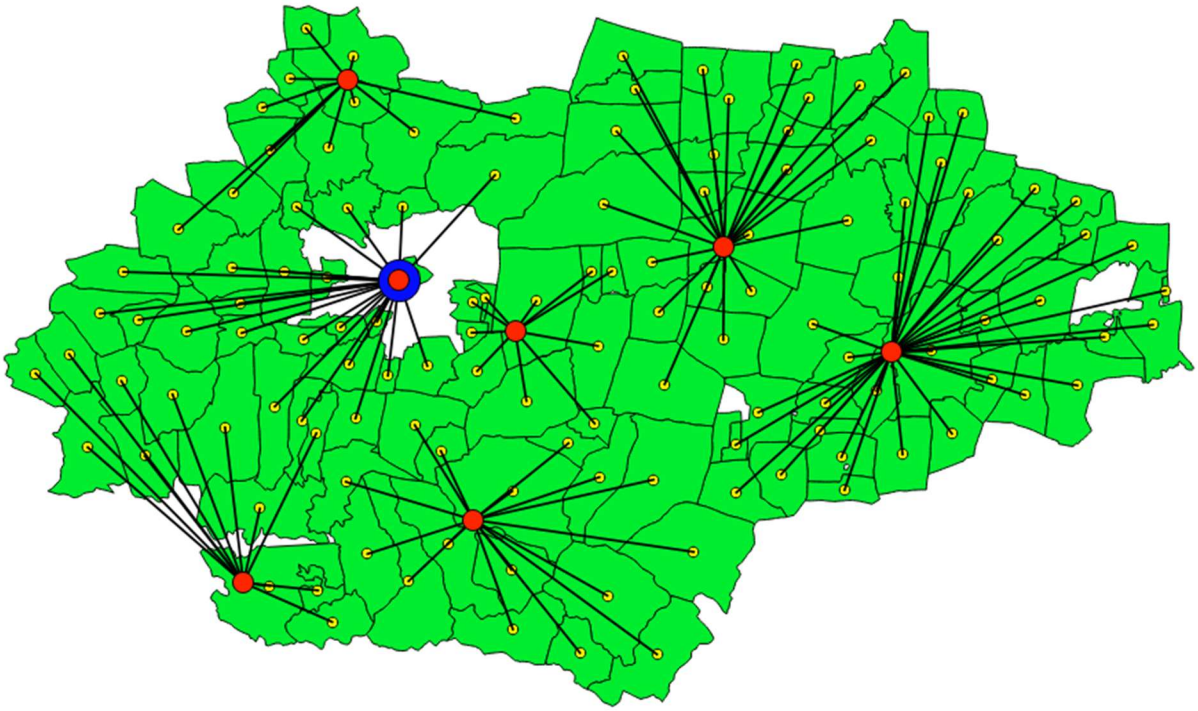


Figure 44. Mapping of Village done based on shortest spatial distance from the centroid to the Nearest PHC

In *Figure 44.* Red points represent PHC, yellow points show village centroid and black lines showing the mapping of villages to nearest PHC based on shortest spatial distance. In this mapping Sinnar bus Depot is also considered as a PHC, because a dedicated COVID facility is present here and represented by a red circle embedded in a blue circle. Generally dedicated COVID facilities are clustered and are located in cities. This may be due to the fact that dedicated COVID facilities are generally schools or colleges etc.

5.12.2. Future Improvement Possible:

- Integration with private health facilities like private hospitals

5.13. ST Road Type Analysis:

Sinnar ST Road Type analysis analyses the type of road being used by MSRTC for providing bus services. In this analysis, roads have been classified into 3 categories as shown in *Table 29.*

Roads	Classification Type	Representation in *Figure 38*
State & National Highways roads	Highway Roads	Green color
District roads	District Roads	Yellow Color
Village and unclassified roads	Village Roads	Red Color

Table 30. Classification of roads

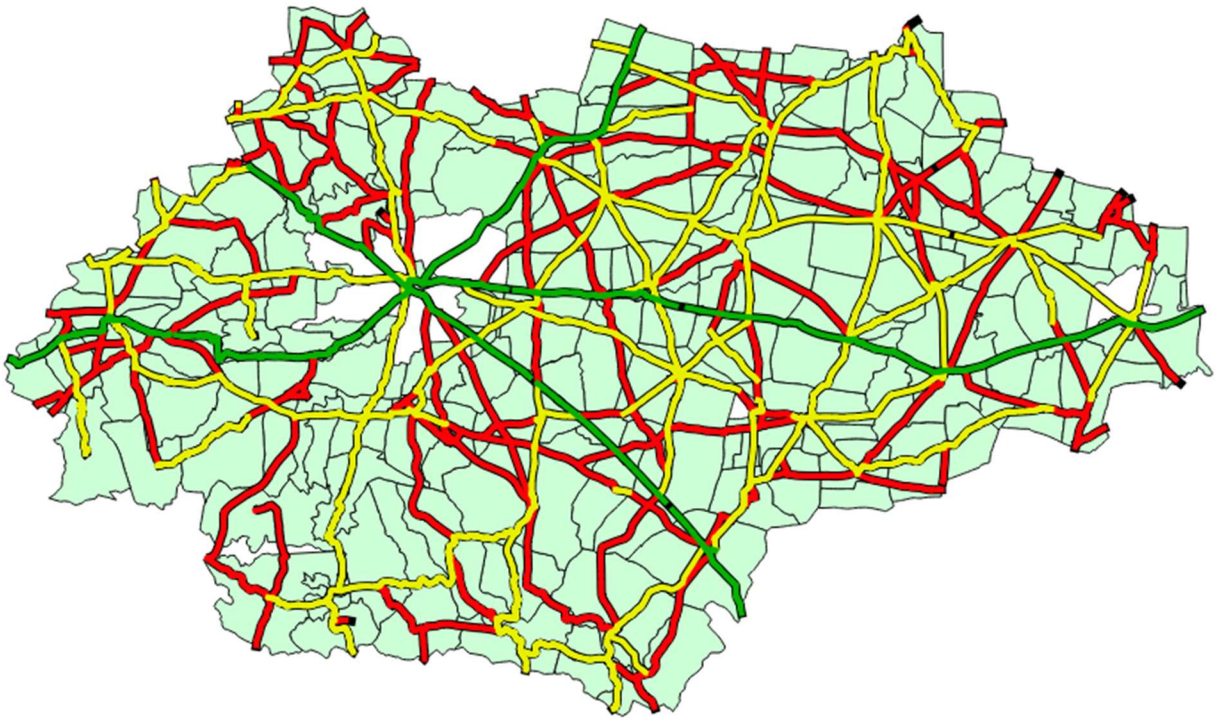


Figure 45. Sinnar Roads based on classification

5.13.1. Physical Significance-

For the creation of new routes, local MSRTC authorities like bus depot managers are generally aware of their local region routes, but at the enterprise level, Divisional Traffic office staff or Head office may not be aware much of a local region. In this case, QGIS visual representation of Type of road analysis can help in providing one more alternative for the "creation of new routes."

Example-

Suppose MSRTC has to design a new route from the easternmost corner of Sinnar to the westernmost corner of Sinnar. MSRTC can, through this type of representation, know from where they can route the new route, they need to maximize the green path. Or give preference as green path > yellow path> red path and verify by their usual process.

Type of Road	Length (in km)
Highway	118

District Road	432
Village Road	466

Table 31. Sinnar road lengths based on classification

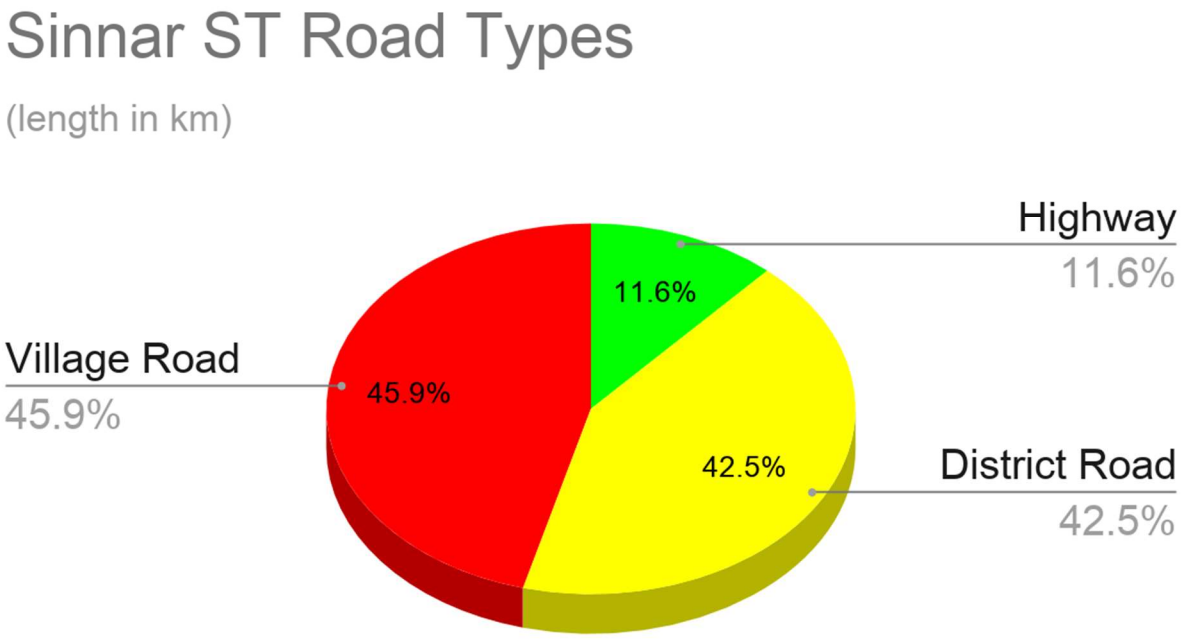


Figure 46. Sinnar Road Classification

6. Chapter: Benefits of proposed GIS interface for MSRTC

In this chapter we tried to look at the importance of the proposed GIS system for MSRTC i.e., how the proposed GIS interface may be beneficial for MSRTC. There are many advantages to the GIS interface for MSRTC. Many applications could be known when the proposed GIS interface would be finally implemented. However, some of the importance of GIS interface is shown as:

6.1. New Routes Creation:

A new route is proposed by a Bus Depot Manager (Taluka) to the Divisional Traffic office based on his knowledge of the region. Divisional Traffic Officer on receiving the request runs a trial bus on the proposed route at least 3-4 times or even more to check the quality/suitability of roads for MSRTC bus transportation and expected arrival and departure time on every bus stop. After knowing the bad quality roads on the proposed route either try to route the proposed route or propose construction/repair of road to the concerned authority (PWD department). With the GIS interface having a type of roads as shown in *Figure 47*, bus depot can check bad quality roads or expected arrival time in the beginning before running a bus trial which can save a lot of costs of fuel on running bus trials instead can use this bus trials to increase the number of bus services in currently high demand routes. Apart from fuel cost it also saves Human resources involved in the process i.e Bus Driver and bus conductor which in this case records bus arrival time and bus departure time instead of issuing bus. Of course, this method doesn't eliminate the current process of running trials for new routes creation but prior estimation can help a lot.

Sinnar Road type has been shown *Figure 47*, red lines represent village roads, yellow lines represent District roads and green roads represent Highway roads. Green and Yellow roads can be considered best for MSRTC bus transportation.

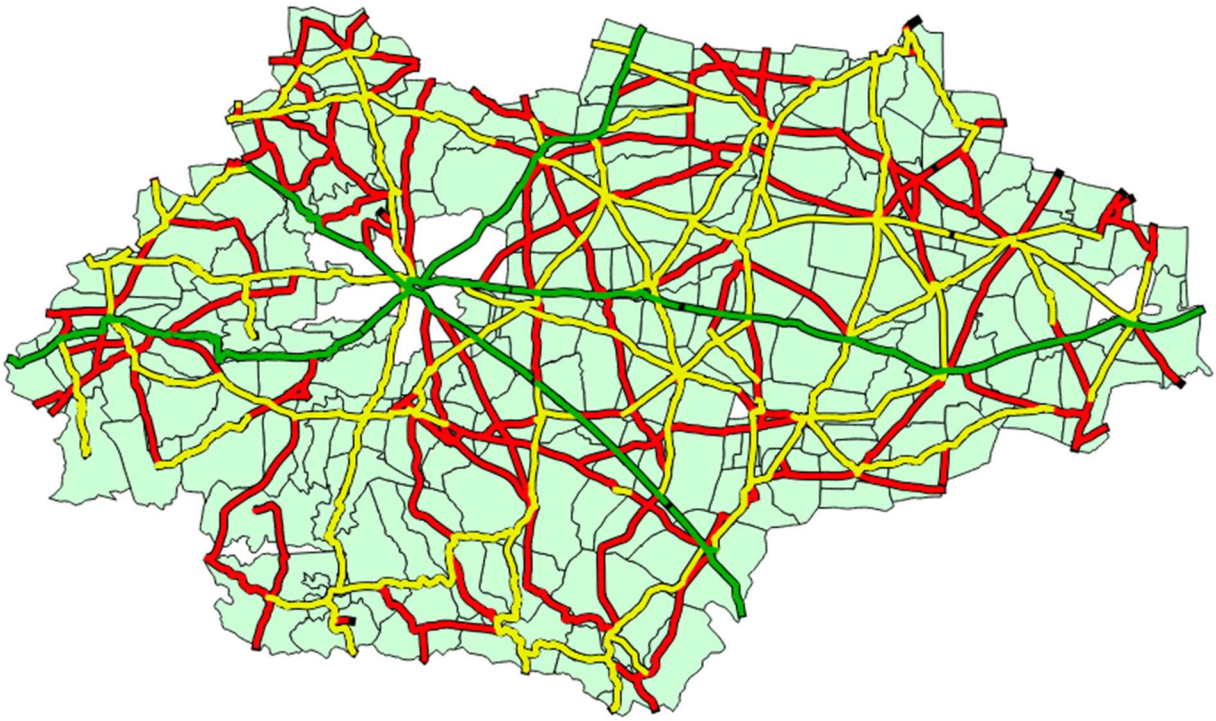


Figure 47. GIS image of Sinnar Road types

6.1.1. Pros:

6.1.1.1. Time-Saving-

6.1.1.1.1. Quality/Suitability of Road

Let us try to understand by an example. Consider a hypothetical situation where time taken for the activities involved in the routes creation in quality/suitability of roads is shown in *Table 31.*

Activity	**Time Required**
Proposal of New Route by Bus Depot Manager and report to DTO	1 Day
Approval of DTO for running the bus trial on the proposed route	1 Day
3 Bus Trials on Proposed new route	3 days
Report to DTO and Bus Depot Manager for	1 day

Quality or suitability of road	
Total Time Required	**6 Days**

Table 32. Time Required in Road quality/suitability check (hypothetical)

The expected time in the current traditional process is 6 Day (Actual time may vary) for quality/suitability of road checking. This time can be reduced to a few minutes using the GIS interface. *Hence, improving the speed for faster decision making.*

6.1.1.1.2. Estimate Arrival and Departure time of Bus Stop:

The GIS interface can also help in estimating expected arrival time and departure prior to running bus trials for estimating arrival time and departure time.

Consider a hypothetical situation where time taken for the activities involved in a new route creation in estimating arrival time and departure time is shown in *Table 32.*

Activity	**Time Required**
Proposal of New Route by Bus Depot Manager and report to DTO	1 Day
Approval of DTO for running bus trial on proposed route	1 Day
10 Bus Trials on Proposed new route	10 days
Report to DTO and Bus Depot Manager for expected arrival time and departure time	1 day
Total Time Required	**13 Days**

Table 33. Time Required in bus arrival time estimation (hypothetical)

The expected time in the current conventional process is 13 Day (Actual time may vary) for estimating expected arrival and departure time. This time required can be reduced to a few minutes using the GIS interface. *Hence, improving the speed for faster decision making.* This method doesn't eliminate the current conventional process of running bus trials for estimation of time but provides an early estimation of arrival time and departure time for further planning like Start time of trip and ending time of bus trip. The exact time can be validated through bus trials.

6.1.1.2. Fuel cost Saving-

6.1.1.2.1. Quality/Suitability of Road Check-

In the road quality/ suitability check, the proposed hypothetical situation 3 bus trials conducted were needed for road quality/suitability check. 3 Bus trials will comprise 3 forward trips and 3 return trips (Road can be one way so both forward trip and return trip need to be checked). *Hence fuel cost of 6 Bus trips can be saved if the prior prediction of quality/suitability GIS interface.* And these benefits can be passed on to increase the number of trips in a taluka.

6.1.1.3. Human Resource Saving

6.1.1.3.1. Quality/Suitability of Road Check-

In the road quality/ suitability check, the proposed hypothetical situation 3 bus trials conducted were needed for road quality/suitability check. 3 Bus trials will comprise one driver and one conductor who will keep recording bus stop arrival time and departure time. *Hence human resource capital cost of 6 Bus trips can be saved if prior prediction of quality/suitability GIS interface.* And these benefits can be passed on to increase the number of trips in a taluka.

6.2. Routing:

Bus services/bus trips are classified into 3 categories (A, B, and C) based on profitability. For B and C category routes as they are not profitable routes, routing can be done to make them profitable based on important locations like tourist places, economic places if available nearby. The GIS interface can help them to view bus route paths, along with all important locations if any like schools, PHC, tourist spots, industry, market, etc nearby. This method has its own limitations and is not a challenging traditional method but having a GIS interface would give an additional method of how GIS can be used in routing a bus trip.

In Figure *48*, the Green line represents a route assuming it is of ‘B’ or ‘C’ category and blue dots and a blue dot encircled between a red circle represent important locations may be school, market, industry or PHC etc. Profitability of this route can be increased if this route can be routed through this blue dot encircled by a red circle which can increase traffic and improve profitability and in case this point is a school or PHC routing can increase social benefits.

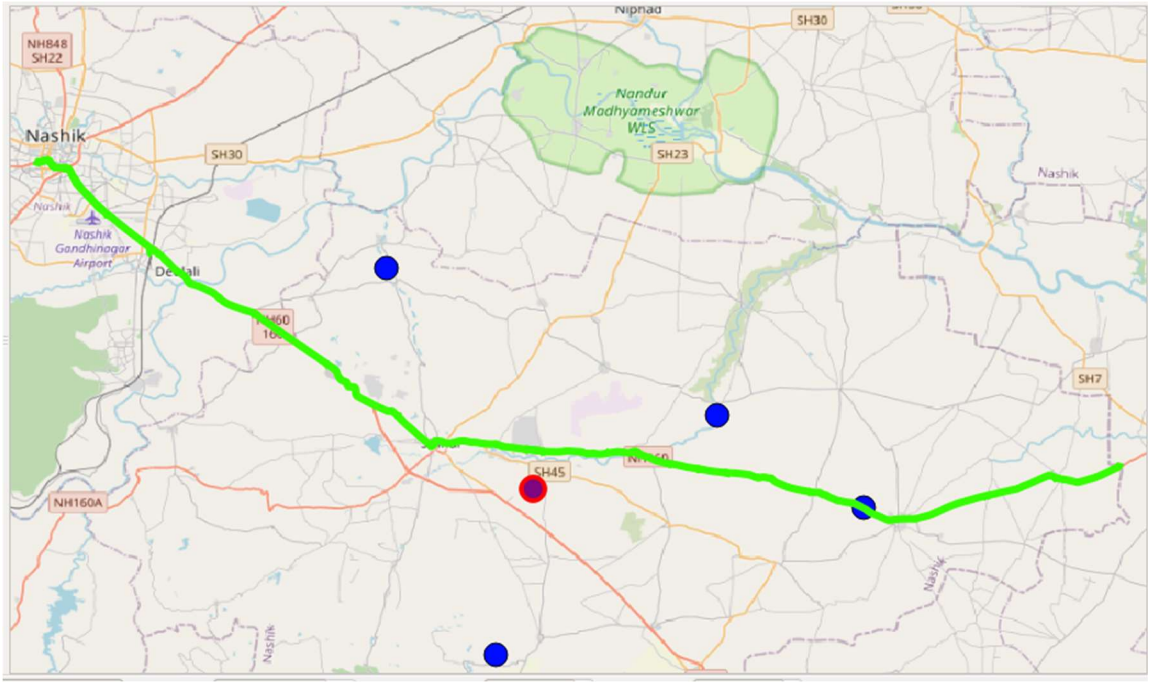


Figure 48. Important locations around a green bus route

6.3. Need for Feeder Buses:

Here, we tried to demonstrate how a GIS interface can be helpful in knowing the places which need a feeder bus for PHC/sub-PHC. A similar approach can be used for schools, tourist places, markets, industries, etc.

Consider an example where the need for a feeder bus can be known through the proposed GIS interface.

During the COVID-19 lockdown period, private transport was restricted and were unable to provide local transportation to carry Corona Victims to PHC or Sub-PHC from the nearest ST route bus drop point, so local people will find it difficult to commute further. So if the feeder bus service can be provided it can boost commute. So based on our QGIS digital geography model, we have found out which PHC or Sub-PHC needs the feeder buses most based on spatial distance. The larger the distance, the farther will be the PHC or Sub-PHC, more problems will be faced to transport corona victims to PHC or sub-PHC, so these places will need the feeder bus most. The distance to the nearest ST route point has been shown in *Figure 49.*

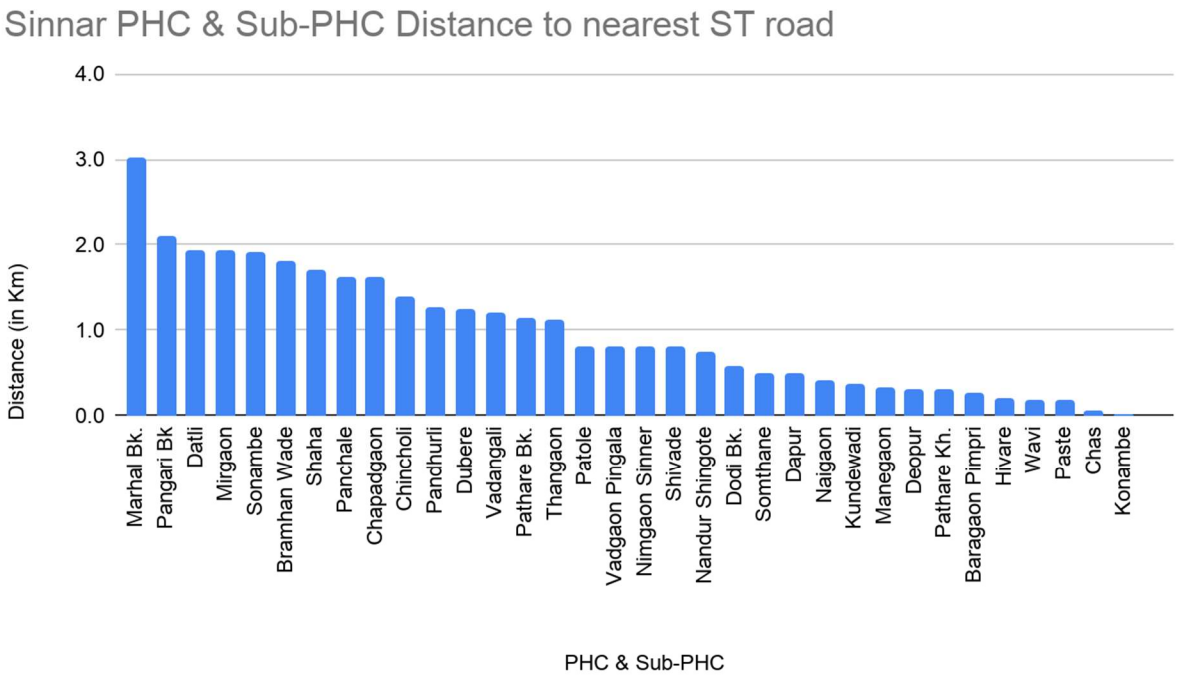


Figure 49. showing PHC & Sub-PHC distance to the nearest ST route point.

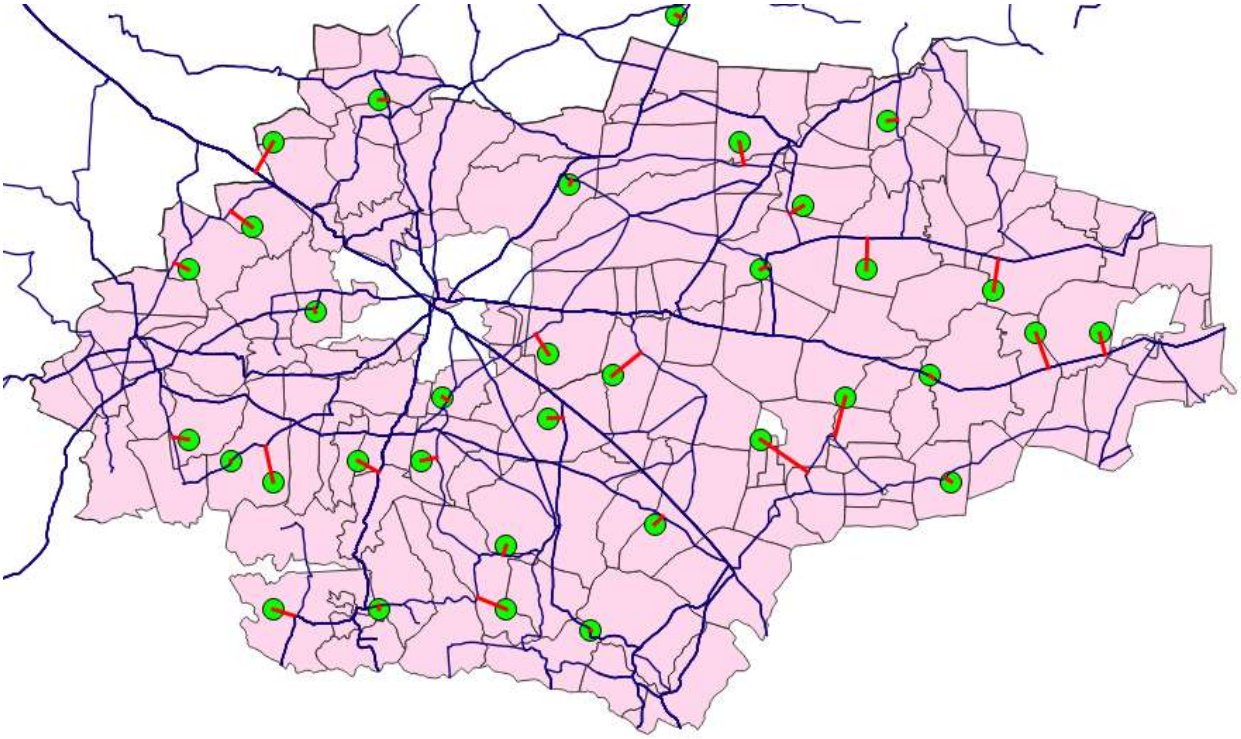


Figure 50. Distance of nearest ST route point from Sub-PHC (red lines)

The longer the red line, the longer the distance and the more significant the need for the feeder bus. Below is the screenshot of PHC's, which needs the most feeder bus based on distance and should be prioritized depending upon the no. of buses Sinnar Taluka has.

PHC or Sub-PHC village	**Distance(in Km)**
Marhal Bk.	3.0
Pangari Bk	2.1
Datli	1.9
Mirgaon	1.9
Sonambe	1.9
Bramhan Wade	1.8
Shaha	1.7
Panchale	1.6
Chapadgaon	1.6
Chincholi	1.4

Table 34. Top 10 farthest PHC or Sub-PHC from ST routes as per digital geography

6.4. Overall Inference of this Chapter:

In this chapter some of the applications where the GIS interface can be beneficial for MSRTC have been demonstrated and with time there will be many more applications seen which cannot be predicted as of now. However, in any of the said methods, we are not challenging the traditional way of working. We are just proposing one more technical alternative for the working of MSRTC operations. Better User acceptability or MSRTC acceptability can be known only after reviews of concerned stakeholders. In the fieldwork- Deputy GM IT, Nashik DTO, and Sinnar Bus depot Manager were found much interested in this type of proposed GIS interface.

7. Chapter: Field Observation

7.1. (18-21 Feb 2020) Field Visit Nashik & Sinnar Summary

7.1.1. Objective-

The objective of the 4 days Nashik, Sinnar field visit was to understand how our digital geography can prove beneficial for various stakeholders (mainly Sinnar Bus Depot Manager and Nashik Traffic divisional office) involved in MSRTC internal operations. This field visit has been conducted by two IIT Bombay students one Mtech Student (Mr. Anshul Kumar) and one Ph.D. research scholar (Ms. Ramya Sharma).

The requirements of said stakeholders from digital geography for the Sinnar Bus depot Manager and DTO (Divisional Traffic Officer) are slightly different.

7.1.2. Requirements of Sinnar Bus depot Manager-

The Sinnar Bus depot Manager hasn't given us much time, he was busy in preparing the Sinnar Budget for the month. Every month between 18th to 22nd day of the month generally a meeting used to be held at Nashik divisional office where all Nashik Taluka Bus depot managers and Divisional officers used to discuss Budgets. If someone is planning a field visit, one should plan the field visit based on these meeting dates to get more information about budgets. From whatever little time we spent with the Bus depot Manager. These were the requirements we understood.

7.1.2.1. Requirements proposed by Sinnar Bus depot-

- He wants a dashboard where he can clearly see the details of probable trips which he can cancel or increase trips based on the following conditions. The conditions may change from Taluka to Taluka-
    - Cancel Trips conditions for Sinnar Taluka-

i. If a route has 3 or less than 3 trips on that route then he doesn't cancels the trips.If the load factor is less than 30-40%
ii. If the trip is not obligatory.
iii. If schools are on holiday.

- Increase Trip Conditions for Sinnar Taluka-
  iv. If the load factor is high >80% i.e. profitable route.

7.1.3. Requirements proposed by Nashik DTO-

- Taluka Bus depot Manager has the sole right to cancel and increase any bus trips (In our case Sinnar). He just needs to give prior notification to the divisional office. So, sometimes local people call the DTO and ask why a particular bus trip scheduled at 'X' time at 'Y' bus stop got canceled. So Nashik DTO wants our digital geography to get the trip details when X and Y input are given.
- No. of trips in a month on a particular route.
- A, B, C trips display on digital geography.
- Display Incoming trip load factor and other details along with an Outgoing trip.
- Separate A, B, C analysis for LD (Long distance routes, route length>250 km) and MLD (Medium long-distance routes, route length<250 km and route length>150Km).

7.1.4. Other Observations-

- MSRTC doesn't do Bus stop dependency analysis.

7.1.5. Observations (Out of scope of our work)-

1. A project (ERP) is currently under process for integrating all data like Trimax, ComVision (Working on Crew Management, trial going on in Kolhapur), or any other 3rd party wherever data is.
2. Many people in the bus depot/divisional office are interested in technical intervention for the workshop (maintenance) cost reduction.

3. A 3rd party name ComVision is working on Crew Management where data entries are currently being done manually and which can be done automatically. Currently, trials are being done for it in Kolhapur district.

7.1.6. Data Collected-

1. Nashik Form 1 (It contains Load factor Route-wise and month-wise).
2. Nashik Form 4 (This data contains the Nashik bus schedules for 2020 taluka wise).
3. Sinnar ABC data Sept 2019 (This contains the "value of concession(VOC)" column which was earlier not in Sinnar ABC data generated by us).

7.2. Field visit to Bombay Exhibition center on 26th Feb 2020

A visit was conducted on 26th February 2020 in the Bombay Exhibition Center, Mumbai. There many RFID based card reading companies had their stalls to display their technology.

7.2.1. Objective:

Many of the bus conductors have complained about the problem of RFID card reading in ETIM machines. To understand a probable solution to this problem, a visit has been done to Bombay exhibition center, Mumbai.

7.2.2. Visit Result:

Around 4-5 company's stalls were interviewed. The results are:

- A most probable reason for this problem is when an RFID card came in contact with ETIM machine, it verifies the card data with the online database while traveling in a bus in villages, Machines may get internet connectivity issues and machines generally shows error in this condition and that may be a probable reason for this problem.

7.3. Interview with Mumbai Bus service “BEST” Conductor on 23rd January 2020

A small interview has been conducted with a Bus conductor of the "BEST" bus service provider in Mumbai. They are using the "Balaji" Brand ticket issuing machine. During my interview, he said that a bus conductor doesn't encounter any problem in the ticket machine if a bus conductor uses it correctly. Their machine is also having a power backup of 8 hours the same as Trimax but he was unaware of charging time. Every time a bus conductor shuts down the machine after issuing tickets so that it can last long.

7.3.1. Result:

A probable temporary solution for the ETIM charging problem is every time a bus conductor shuts down the machine after issuing tickets so that it can last long.

8. Chapter: Plugin Development

As per field observations and to meet the requirements of MSRTC stakeholder (Divisional Traffic Officer and Sinnar Bus Depot Manager) from digital geography, a QGIS plugin has been decided to be made to demonstrate how digital geography can meet the requirements of above said stakeholders. These plugins have to be tested by the concerned stakeholders and reviews have to be taken. Due to external circumstances (COVID-19), testing and taking reviews of the plugins couldn't have been possible. After proper testing and their reviews, a web-interface can be made for final deployment.

8.1. Plugin 1- MSRTC Trip Finder

This plugin has been made for the MSRTC Divisional Traffic Officer (Head of Traffic Department District).

8.1.1. Requirement proposed by Nashik DTO-

Taluka Bus depot Manager has the sole right to cancel and increase any bus trips (In this case Sinnar). Bus Depot manager just needs to give prior notification to the divisional office. So, sometimes local people call the DTO and ask why a particular bus trip scheduled at 'X' time at 'Y' bus stop going towards the 'Z' bus stop got canceled. So Nashik DTO wants our digital geography to get the trip details when X, Y, and Z input are given. Also, its path on GIS so that DTO can know the affected nearby villages.

Important Note: Local peoples will only approach the DTO if there are few bus trips let say (3-4 bus trips) in that region providing that bus service. For example, Suppose for Sinnar to Sangamner there are 3 bus trips (let say) and Sinnar to Nashik are 92 bus trips. As there are very limited bus trips between Sinnar to Sangamner, so cancellation of any bus trip would be a concern for local people and local people would approach DTO. However, if any trip from Sinnar to Nashik is canceled, it would be less concerning for local people as there are many other bus trip alternatives for this route available. So this plugin would be used only on those routes where there are very few bus trips.

The purpose of this plugin is to demonstrate that digital geography can meet the above-said requirements of DTO.

QGIS Plugin video link- https://youtu.be/kC1kAjksABE
Plugin code link- https://github.com/anshul-031/MSRTC_Trip_finder/tree/master/No_Of_Trips

8.1.2. Working of Plugin-

This plugin works similar to the IRCTC railway website where a customer can give input like Source and Destinations to get details of trains available for certain routes.
Our plugin provides a QGIS interface where the stakeholders like Bus Depot Managers and Divisional traffic Officer can get details of past Bus trips ran from certain bus Stop (Source) to another bus stop (Destination) in a certain time interval based on Sinnar July 19 month ABC data. Through our plugin, Divisional Traffic officer can simply enter the Source, destination and the respective time of trip which is canceled and can get entire details (like ABC analysis, no. of trips between source and destination, etc.) of the canceled bus trips instead of going through conventional method searching for the respective file in the computer and searching for respective data in excel sheet or contacting the depot manager and asking for details which can be time-consuming and more productive.

8.1.3. Inputs-

This plugin takes 7 inputs as shown in *Figure 51.*

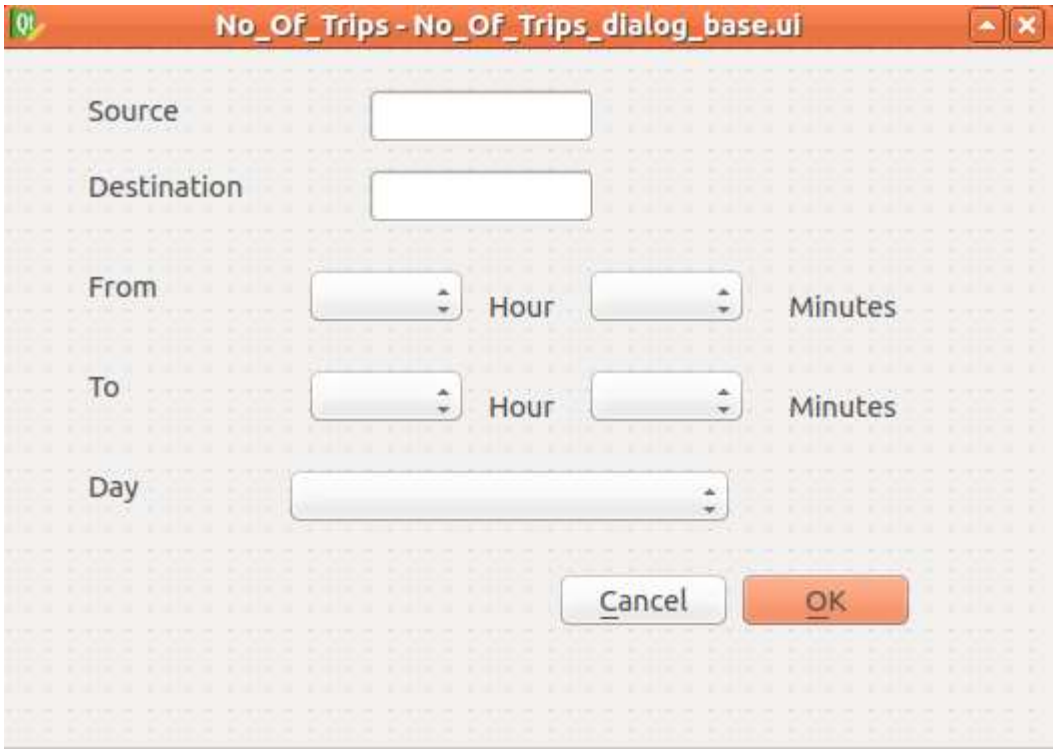


Figure 51. User interface of Plugin

Details of input can be found in *Table 34.*

Field name	***Data Type***	***Description***
Source Bus Stop Code	String	Source Bus stop code of canceled trip
Destination Bus Stop Code	String	Destination Bus stop code of canceled trip
Time From (Hours)	Integer (Range 0-23)	For getting details of canceled a range of time T1 to T2 has been asked because people generally remember a rough figure of time in their mind. So this field will ask for time T1. Time has been considered in HH:MM format. This data takes HH part input. For better visual output provide a time range as small as possible.
Time From (Minutes)	Integer (Range 0-59)	For getting details of canceled a range of time T1 to T2 has been asked because people generally remember a rough figure of time in their mind. So this field will ask for time T1. Time has been considered in HH:MM format. This data takes MM part input. For better visual output provide a time range as small

		as possible.
Time To (Hours)	Integer (Range 0-23)	For getting details of canceled a range of time T1 to T2 has been asked because people generally remember a rough figure of time in their mind. So this field will ask for time T2. Time has been considered in HH:MM format. This data takes HH part input. For better visual output provide a time range as small as possible.
Time To (Minutes)	Integer (Range 0-59)	For getting details of canceled a range of time T1 to T2 has been asked, because people generally remember a rough figure of time in their mind. So this field will ask for time T2. Time has been considered in HH:MM format. This data takes MM part input. For better visual output provide a time range as small as possible.
Day	String (Range-Monday to Sunday)	This field hasn't been used as of now because the ABC data used by Sinnar depots doesn't have days mentioned in which days the trip runs. So this Plugin interface currently will take inputs that are currently being used by DTO. No alternation has been made as of now. This field may come to use in the future.

Table 35. Schema of User Inputs

"Time From" and "Time To" denotes the time interval between which we want to get all the trips for example. We want all the bus trips between 9:15 AM to 10:15 AM. Later the inputs in this variable have been combined in (HH:MM) format and used in the code. Future web-interface should take the same inputs.

For better results, provide a time range as small as possible. Too much large range would mean too many bus trips in that range and hence difficult to segregation of each trip from each other. For example if in a time range of 9 AM to 10 AM, there are 3 bus trips for a certain route and in a time range of 5 AM to 5 PM, there are 25 bus trips, it would be easy to recognize the desired bus trip from the output trips in small time range as output trip range is small.

8.1.4. Methodology-

- Obtain all routes from source to the destination from 'All routes Nashik Master' file. The route numbers obtained can also be used in creating a new bus trip by bus depot Managers

when in case bus depot Managers needs to know all possible routes he can route to. Also, obtain 'KM' attributes data for both source and destination which denotes the distance of source and destination from the route starting point. This will be used in calculating expected departure time from source and expected arrival time to destination till the time one doesn't have arrival time for each bus stop of a bus trip. Once arrival time and departure time data of bus stops are obtained, one no longer needs to obtain 'KM' attributes from here.

- Get all the trip numbers for all obtained route numbers from ‘route_to_trip’ file. This file contains the mapping of all trip numbers to route numbers based on Sinnar August 2019 ETIM data. This data only contains all Sinnar bus trip numbers to route number pairs. This data may not contain some of the bus trip number and route numbers pairs for other months' bus trips because some new bus trips may be introduced by a depot Manager in the upcoming months or some bus trips may have been canceled by bus depot Managers in earlier months.
- Estimate expected departure time for the source bus stop and select all the trips which have source bus time in the time range provided by the user generally DTO.
- Display all the selected bus trip ABC analysis on the QGIS interface.
- Finished.

8.1.5. Output-

The plugin outputs have been shown in *Figure 53-56,* for user input shown in *Figure 52. Figure 53* shows all possible routes from the provided source and Destination as per Nashik routes file. It can also be used by the DTO or Depot Manager to know the possible routes if he wants to create a new bus trip on existing routes. *Figure 54* provides all available bus trips between the provided source and destination to give an answer on how many trips are currently there in the provided source and destination. *Figure 55* provides all the bus trips in the provided time range to tell what other possible alternative could be apart from the canceled trip having the same source and destination at the provided time with their ABC categorization. The ABC categorization can also help in recognizing canceled bus trips, generally, it is ‘C’ category bus trip. Finally plotting all the possible bus trips on the GIS interface where routes of the possible bus trips can be seen as shown in *Figure 56. Figure 56.* also helps in visualizing the affected regions or villages near the bus trip

path. Plotting of each bus trip can also be done separately using Plugin 2 explained after this section. The Plugin 2 acts as a filter to separate desired bus trips from the set of bus trips generated as output as shown in *Figure 55*.

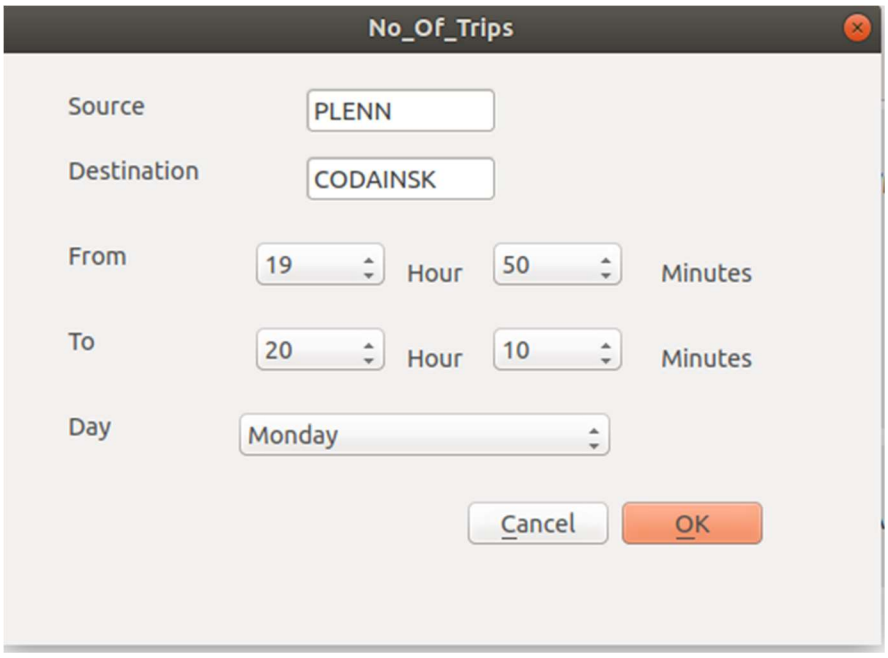


Figure 52. User Inputs

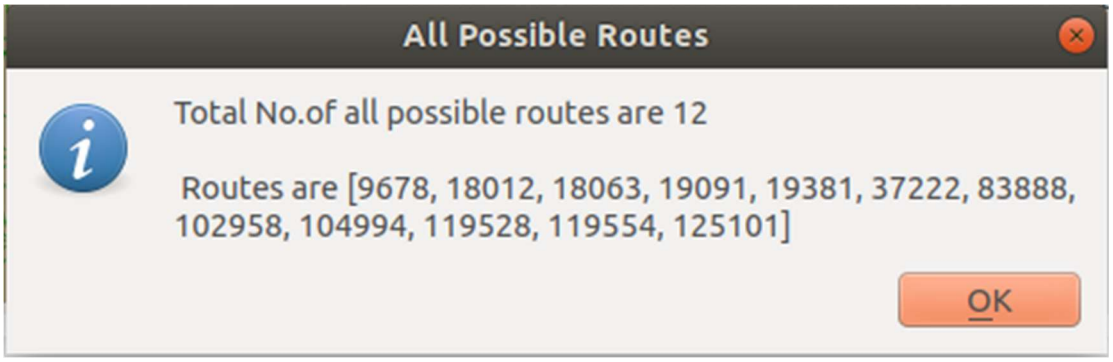


Figure 53. Plugin Output (i)

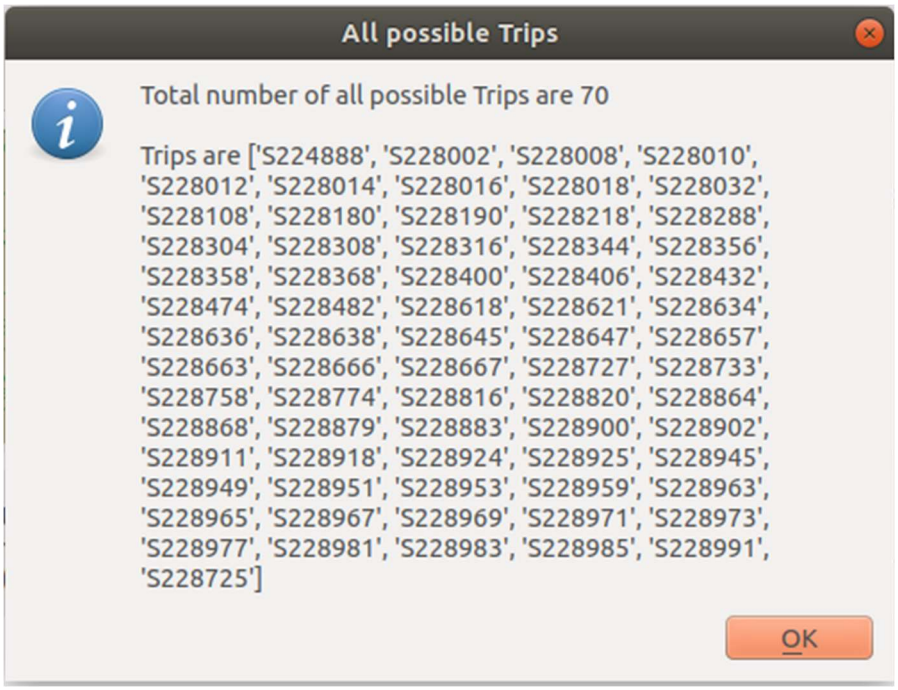


Figure 54. Plugin Output (ii)

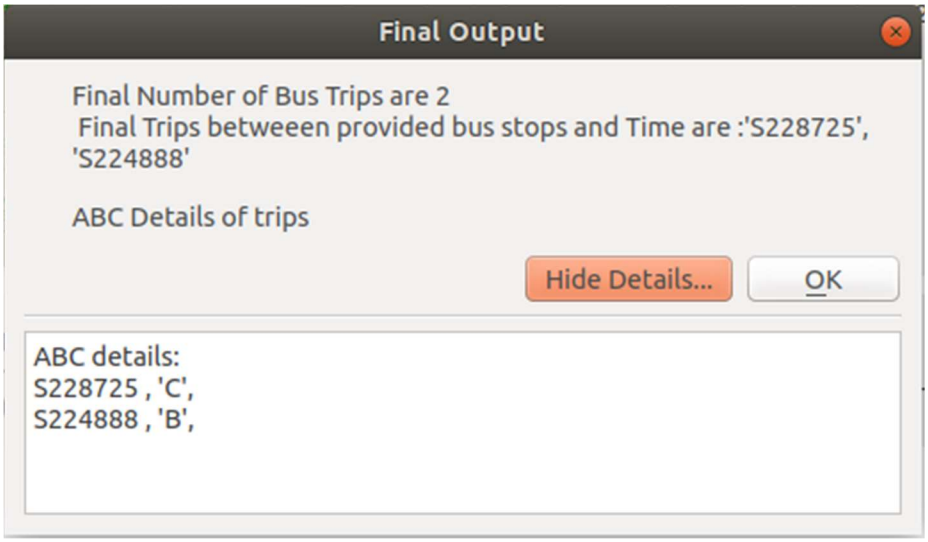


Figure 55. Plugin Output (iii)

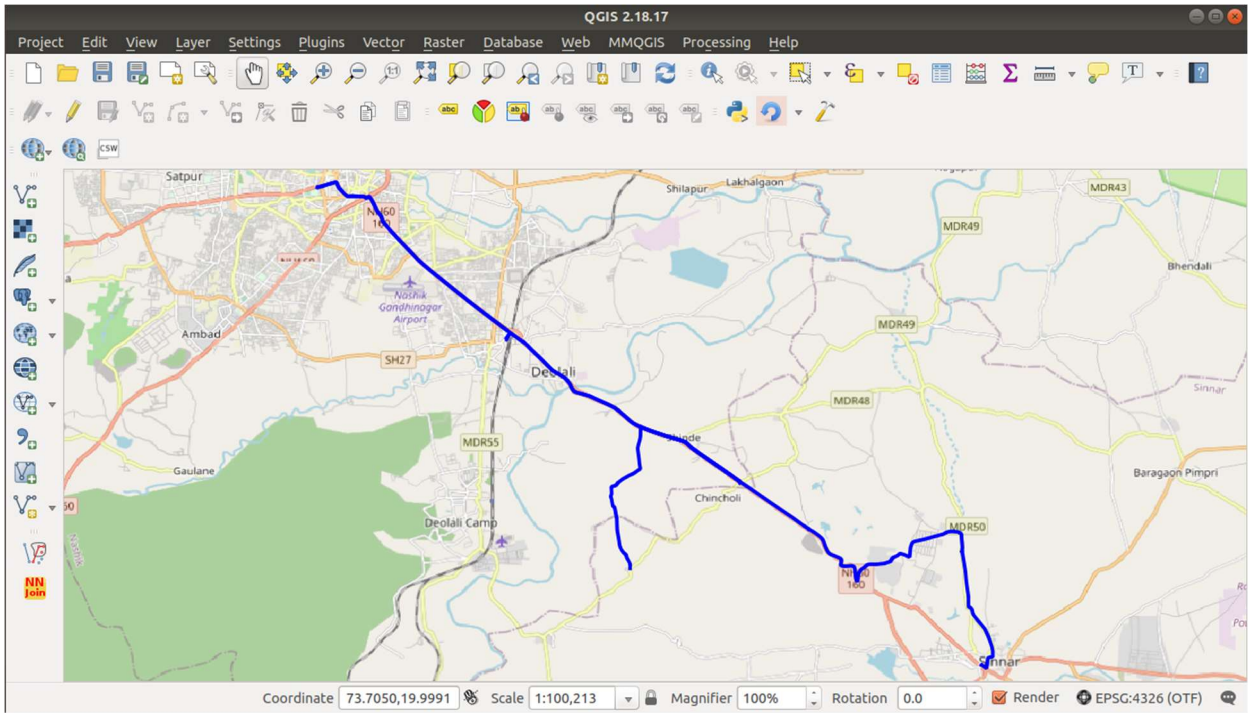


Figure 56. Plugin Output (iv)

8.1.6. Limitations of the plugin-

- This plugin provides better visual output if the time range provided in input is small. For a large time range, there would be more numbers of bus trips lying in that time range. Hence more number of bus trips in output, therefore it becomes difficult to separate all bus trips from each other in visual QGIS representation.
- This plugin requires internet connectivity for proper functioning.
- This plugin built on ETIM Sinnar August 2019 data, ABC July 2019. This plugin will become less useful with time. Imagine DTO is using this plugin in 2025 and making decisions on the basis on 2019 data.
- This plugin works only in QGIS 2.x versions.
- The plugin works better if the time difference between bus trips is large.
- The plugin works better if there are fewer trips between the source and destinations provided in inputs (which is assumed where the DTO can use the plugin).

8.2. Plugin 2- MSRTC Trip Detail

This QGIS plugin shows the path on the GIS interface of any bus service based on the bus trip number.

8.2.1. Physical Significance

This plugin can be used to see nearby regions or areas along the bus route path where the bus service corresponding to the bus Trip number is providing service. In other words, the nearby region or area or villages whose bus service is providing service and the affected region if the said bus service is canceled.

8.2.2. Stakeholders-

- Divisional Traffic Officer (DTO)
- Bus Depot Manager

QGIS PLUGIN VIDEO- https://youtu.be/87j_Mp0Yaj8
QGIS PLUGIN CODE- https://github.com/anshul-031/MSRTC_Trip_finder/tree/master/trip_details

8.2.3. Inputs-

Details of the Input required for this plugin have been shown in *Table 35. '*

Field name	***Data Type***	***Description***
Bus Trip Number	String	Bus trip Number of the MSRTC bus service for which path has to be shown

Table 36. Details of Input for Plugin 2

8.2.4. Working of Plugin-

The user interface of the plugin has been shown in *Figure 57.* The user needs to provide the Bus trip number.

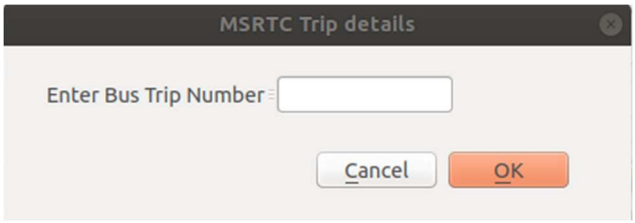


Figure 57. User Interface for Input of Plugin 2

8.2.5. Plugin Output-

Based on the inputs received i.e., Bus trip number as shown in *Figure 58.* , the bus trip path is displayed on the GIS interface as shown in *Figure 59.* In the figure the path shown in blue line represents the path of bus trip number "S228935"

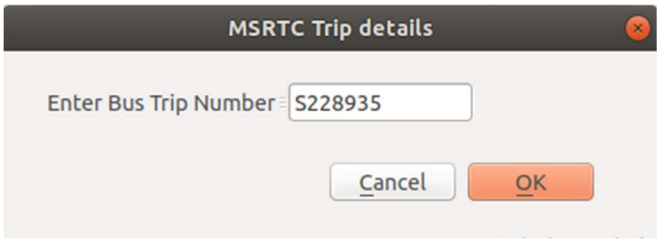


Figure 58. Input for Plugin 2 (Trip number- S228935)

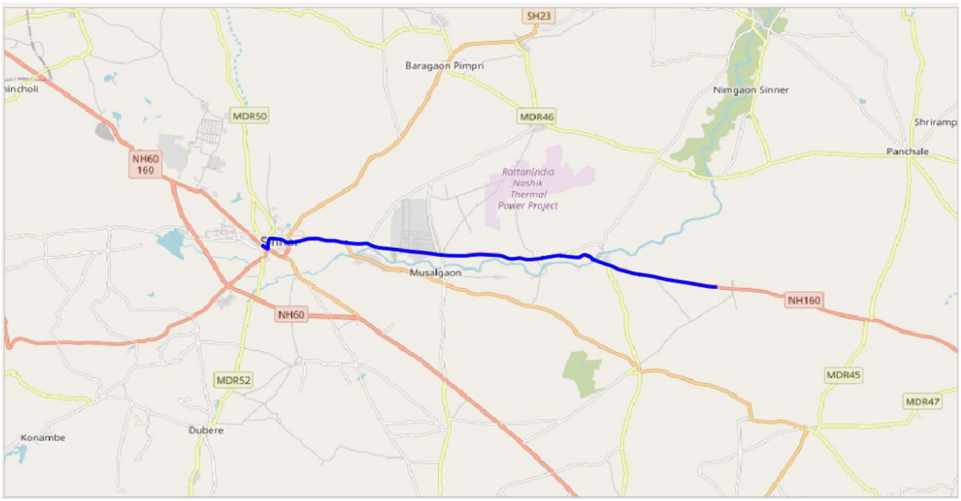


Figure 59. Output of Plugin 2 (Path of Bus Trip Number 'S228935')

8.2.6. Methodology of Plugin working-

- Input bus trip number in the user interface as shown in *Figure 49*.
- Mapping of route number and bus trip number based on Sinnar ETIM August 2019 data.

- Displaying bus trip path along with Sinnar ABC July 2019 data based on route path obtained by route number calculated via shortest road distance via road network based on route sequence.

8.2.7. Limitations

- This plugin doesn't work on real-time data. This data works on Sinnar ETIM August 2019 data and Sinnar ABC July 2019. So this plugin would work only for Bus trips which are common in Sinnar July 2019 and Sinnar August 2019 data.
- Need an internet connection for proper working.
- This plugin works only in QGIS 2.x versions.

8.3. Plugin 3: MSRTC PHC Time Table Creator

This Plugin creates a PHC Time Table for a Taluka.

8.3.1. Stakeholders-

- Divisional Traffic Officer (DTO).
- Bus Depot Manager.

8.3.2. Inputs-

Details of the Input required for this plugin have been shown in *Table 36.* User interface of plugin 3 can be seen in *Figure 60.*

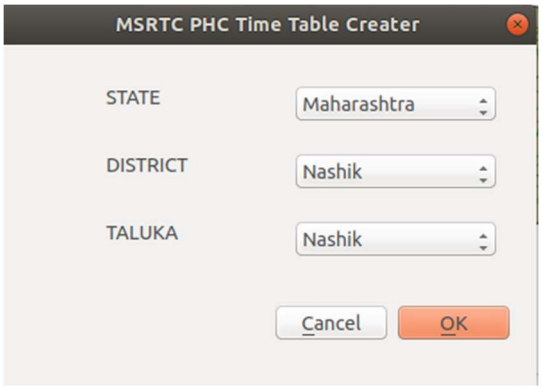


Figure 60. User Interface for Plugin-"MSRTC PHC Time Table Creator"

Field name	*Data Type*	*Description*
State	String	State of Taluka for which Time Table to be created
District	String	District of Taluka for which Time Table to be created
Taluka	String	Taluka for which Time Table to be created

Table 37. Details of Input for Plugin 2

8.3.3. Working of Plugin-

The Plugin works on the methodology of Sinnar PHC TimeTable as already described in the Chapter "Applications of Digital Geography", Section- "Sinnar PHC TimeTable Creation". So limitations are also the same.

8.3.4. Plugin Output-

Plugin outputs two file named "Form4.csv" and "PHCTimeTable.csv" on the Desktop as shown in *Figure 61.*

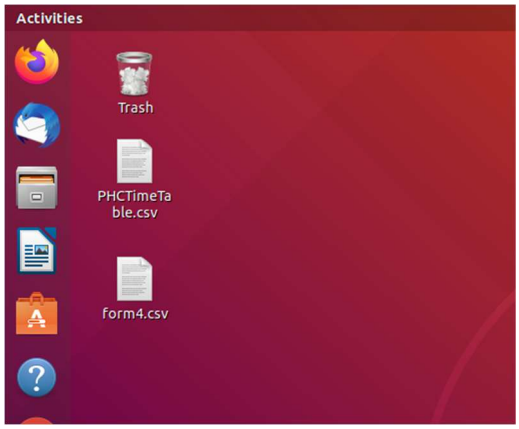


Figure 61. Created Form4.csv and PHCTimeTable.csv at Desktop

9. Chapter: Additional Task Done

Some problems have been observed in the field. Solutions have been proposed in this chapter

9.1. Problem1: Trimax Ticket Issuing Machine Charging problem-

The machine which is used by Bus conductors for issuing tickets provided by Trimax has a major charging problem. The machine has a power backup of 8 hours and it takes 12 hours for charging. The machine mostly remains uncharged. Further due to these problems in spite of having only 72 buses as of August 2019, they have purchased 198 Ticket issuing machines.

A small experiment has been done to understand how we can increase the charging speed of the Machine.

The specifications of the charging machine are shown in *Table 37.*

Charger Brand	OTPL
Input	100-300V AC 47- 63 Hz
Output	10.2 V DC @ 1 Amp

Table 38. ETIM machine charger specifications as of 28th September 2019

Figure 62. Trimax ETIM Charger

9.1.1. Point to note-

1. The experiment has been conducted on a mobile phone named ‘Redmi Note 5’.
2. Reading has been recorded when charging levels are between 10% to 90%.
3. All apps, mobile data, Wifi connection were closed while reading.
4. Chargers have been used, having specifications defined.
   a. Samsung charger having Output 0.5 Amp, 5Volt.
   b. Motorola charger having Output 3 Amp, 5Volt.
   c. OnePlus charger having Output 4 Amp, 5Volt.

9.1.2. Observations-

1. When charging speed is tested with Samsung 0.5 Amp, 5 Volt charger, the charging pattern is shown in *Figure 63.*

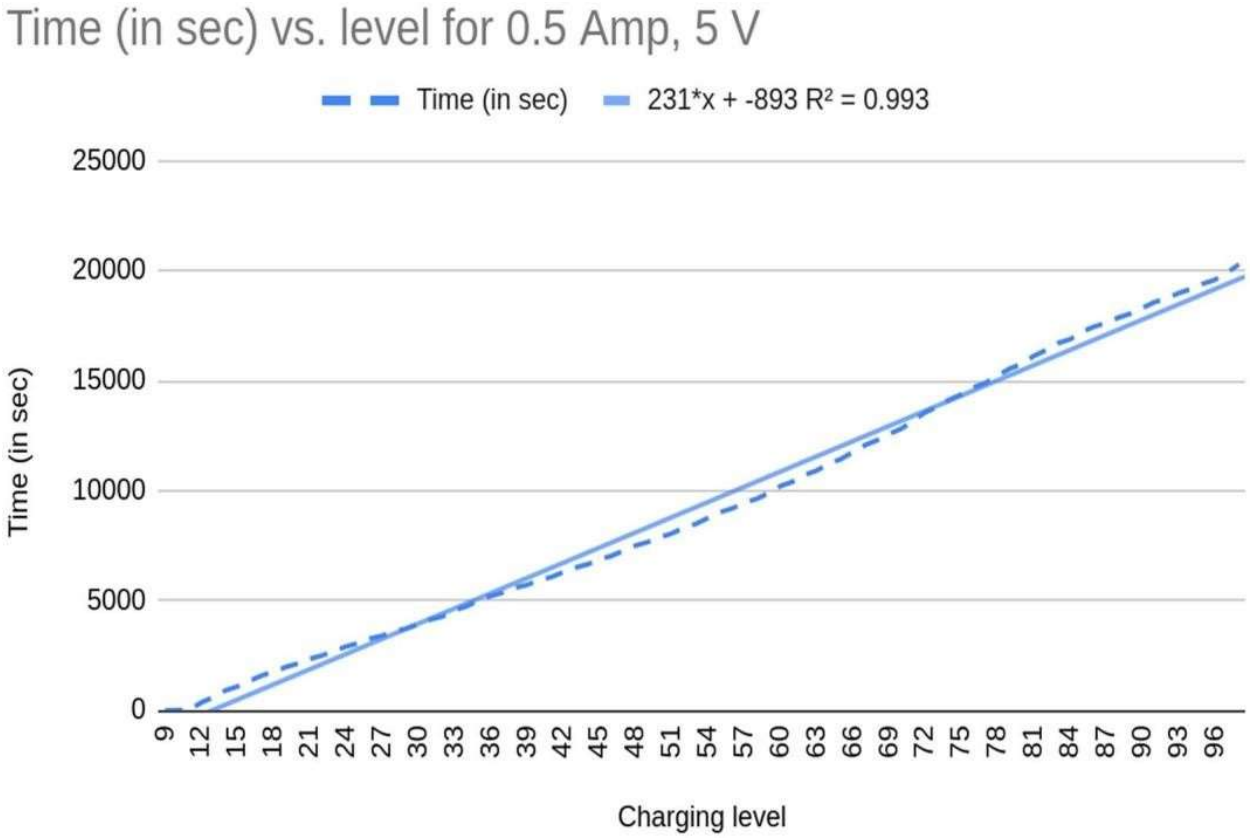


Figure 63. Time taken by mobile w.r.t %age battery level (0.5Amp, 5V).

2. When a Motorola 3 Amp, 5 Volt Charger is used, the graph obtained is shown in *Figure 64.*

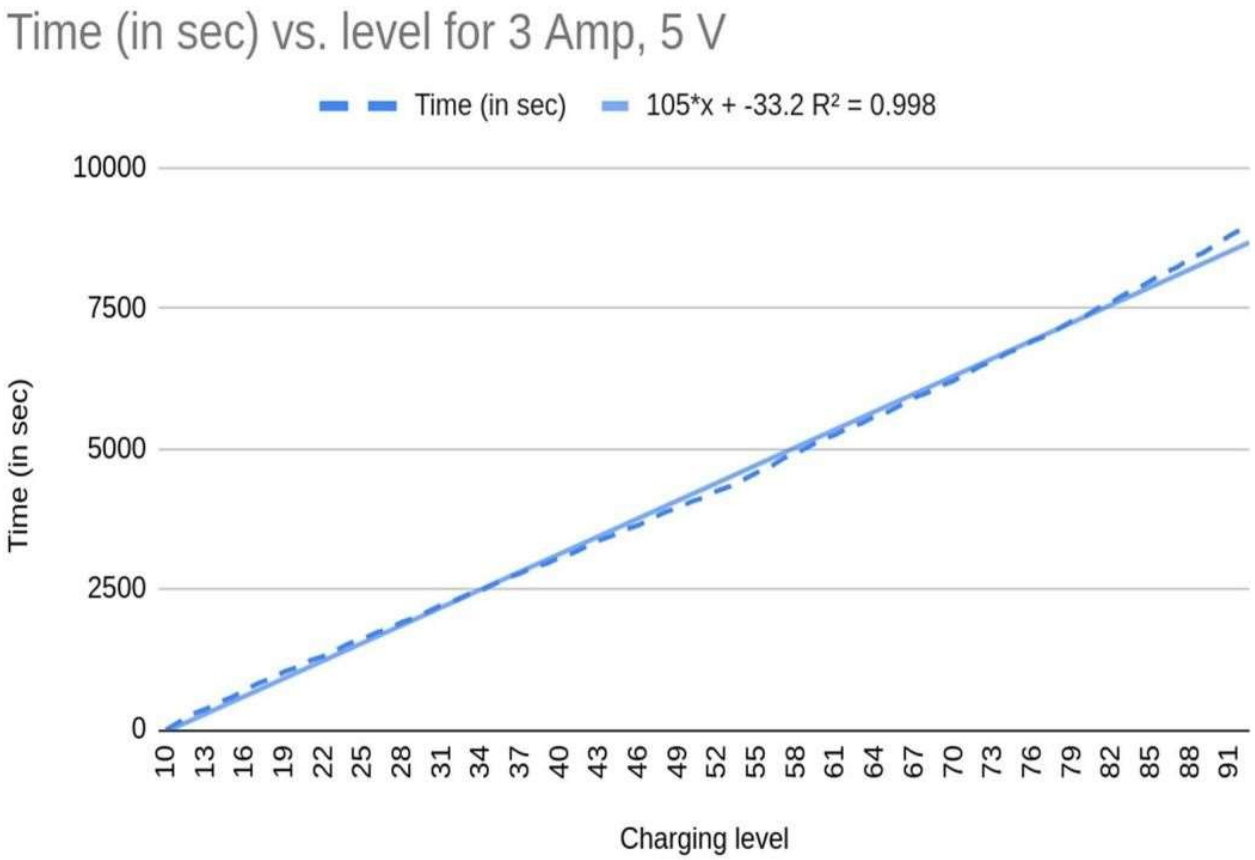


Figure 64. Time taken by mobile w.r.t %age battery level (3 Amp, 5V).

3. When OnePlus 4 Amp. a 5 Volt charger is used, the Graph obtained is shown in *Figure 65.*

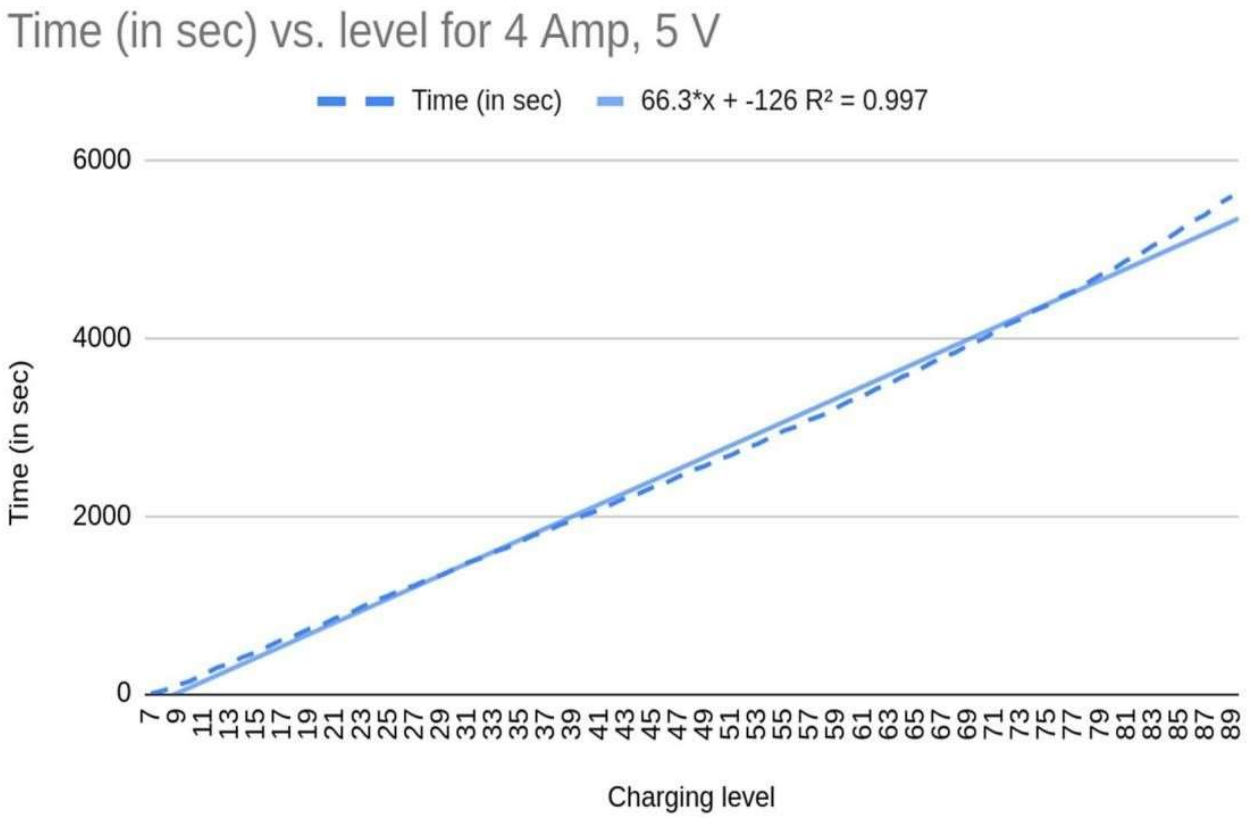


Figure 65. Time taken by mobile w.r.t %age battery level (4 Amp, 5V).

9.1.3. Summary-

Table 38. showing the charging speed using different chargers

Charging Power	**Charging speed**
0.5 Amp, 5 Volt	231 seconds /charging 1%
3 Amp, 5 Volt	105 seconds /charging 1%
5 Amp, 5 Volt	66.3 seconds/charging 1 %

Table 39. Charging speed w.r.t charging power

9.1.4. Result-

As we increase the current, the charging speed of mobile phones is increasing, similar experiments may be performed with the Trimax Ticket Issuing Machine. The charging speed of the machine may increase.

10. Chapter: Future Scope

1. Development of a web-based application:

   A web-based platform which can be accessed from anywhere and any computer system.
2. Development of an API:

   API development can be done because some operations like ETIM data analysis, ABC analysis have to be done every month.
3. Testing of the plugin developed.
4. Optimization of scripts used for the plugins developed.
5. Development of scripts for developing Digital Geography. Currently, much manual work is involved.
6. Study of Interaction with other modes of transport like railway station, nearby airport or water transport (if any). The Nashik railway network has been shown in *Figure 66.*

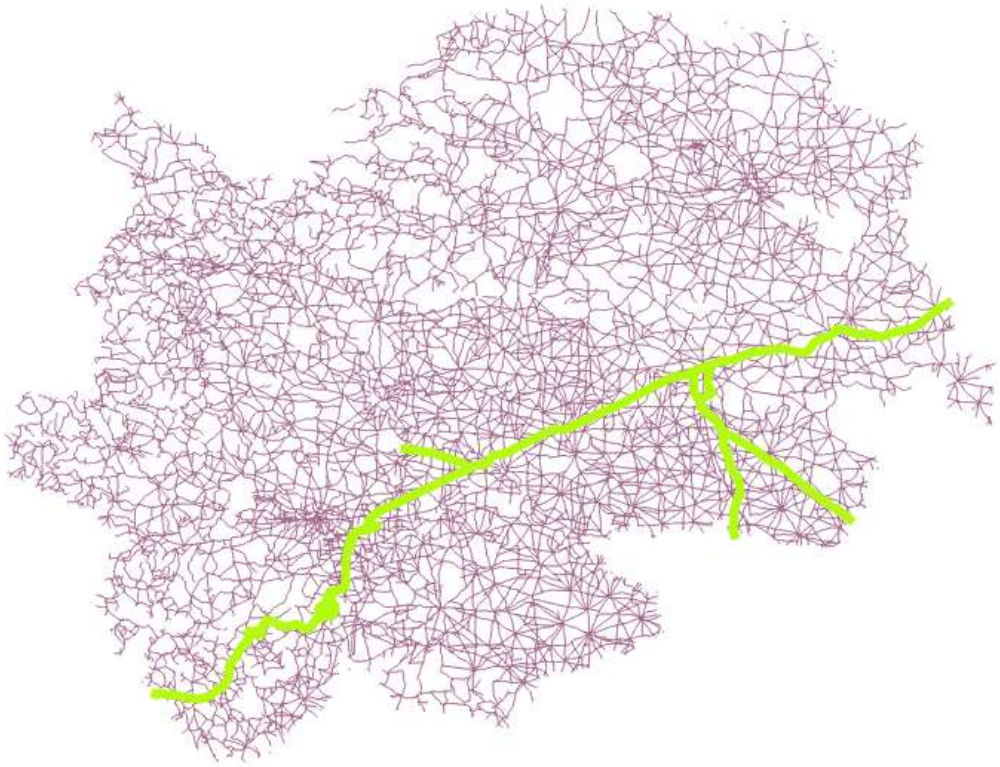


Figure 66. Nashik Railway Network in green color

7. Study of interaction of private mode of transport like rickshaws, jeep, etc with the public mode of transport and integration with digital geography.

8. Field visits and interviews with MSRTC people to validate the work done.

11. Chapter: Conclusion

In today's world, technological competence is very important. Technical importance helps an organization to new functions, new features, reduced cost, etc. An organization like MSRTC or any other organization should spend a significant amount on their R & D expenditure for new technological up-gradation because it can help them in reducing their cost, reducing manual work, and providing a better experience for the end-user (In our case the end-user is Rural population).

12. Appendix:

12.1. How to create Digital Geography:

12.1.1. Adding a New Project-

STEP 1. Press Ctrl+N for a new project.

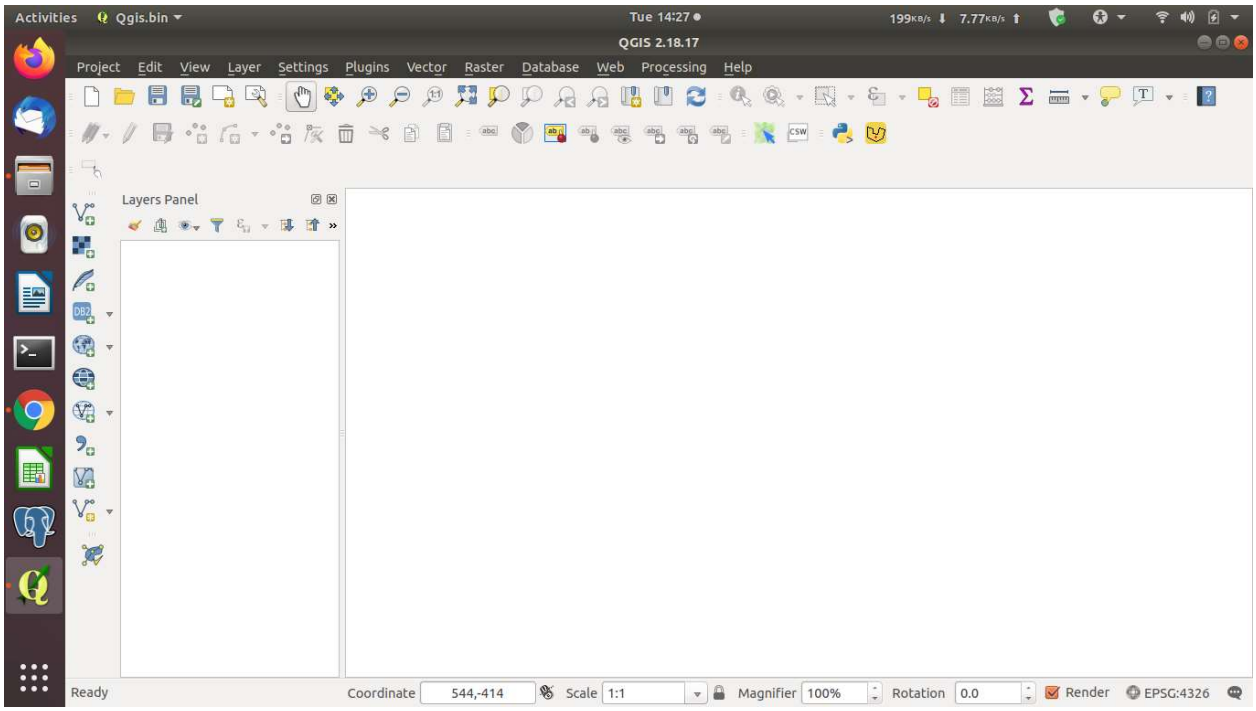


Figure 67. Digital Geography making Process (1)

12.1.2. Adding a New Shapefile-

STEP 2. Go to Layers->Add Layers->Add Vector Layer.

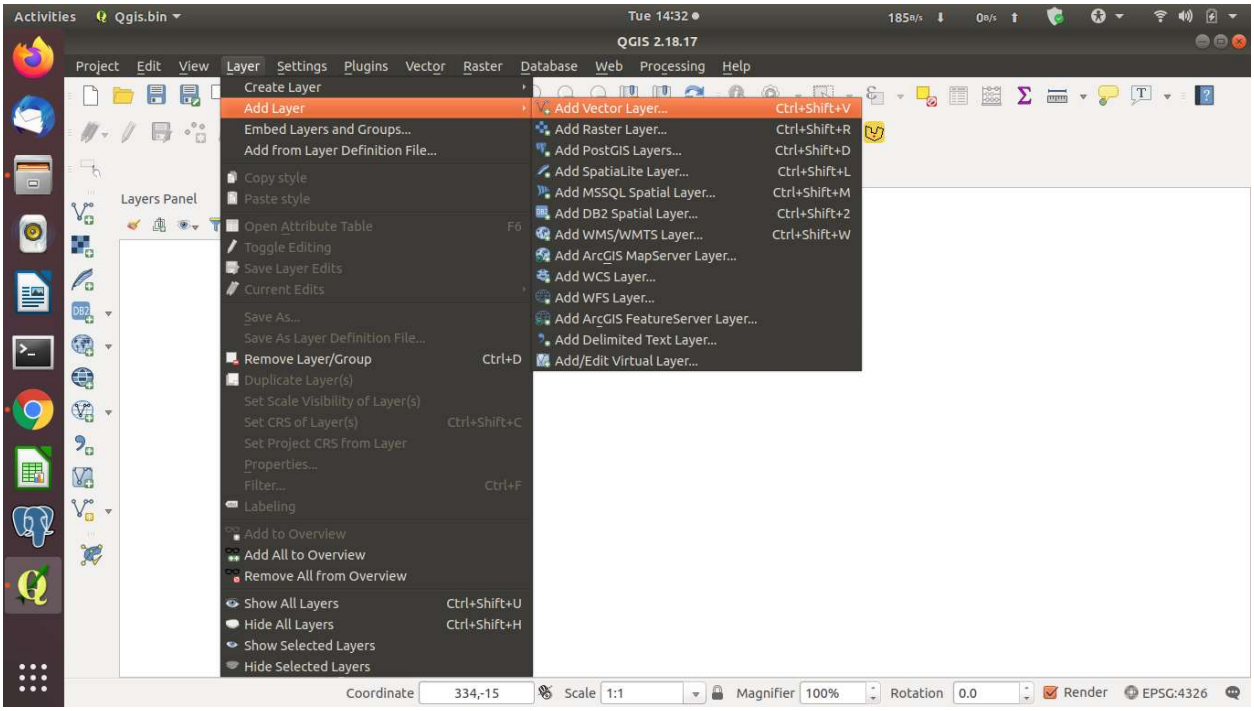


Figure 68. Digital Geography making Process (2)

STEP 3. A dialogue box will appear like this.

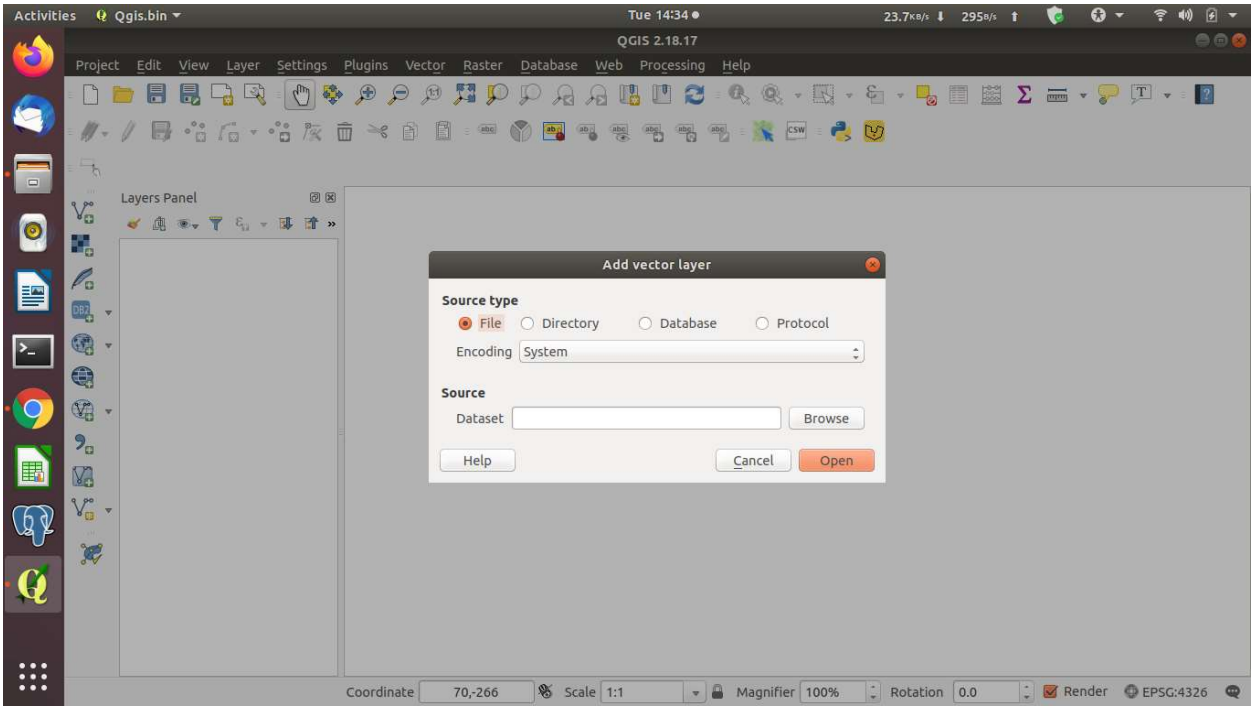


Figure 69. Digital Geography making Process (3)

STEP 4. Click on Browse and Select the Village or region shape file and click Open.

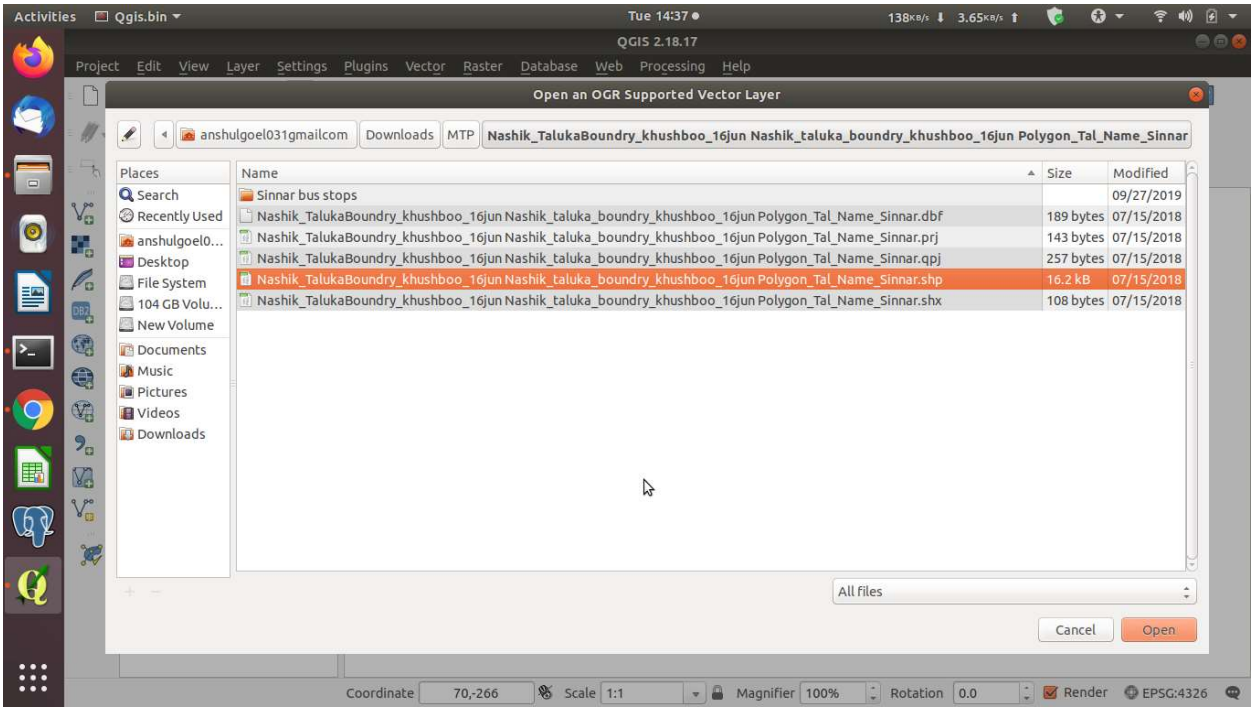


Figure 70. Digital Geography making Process (4)

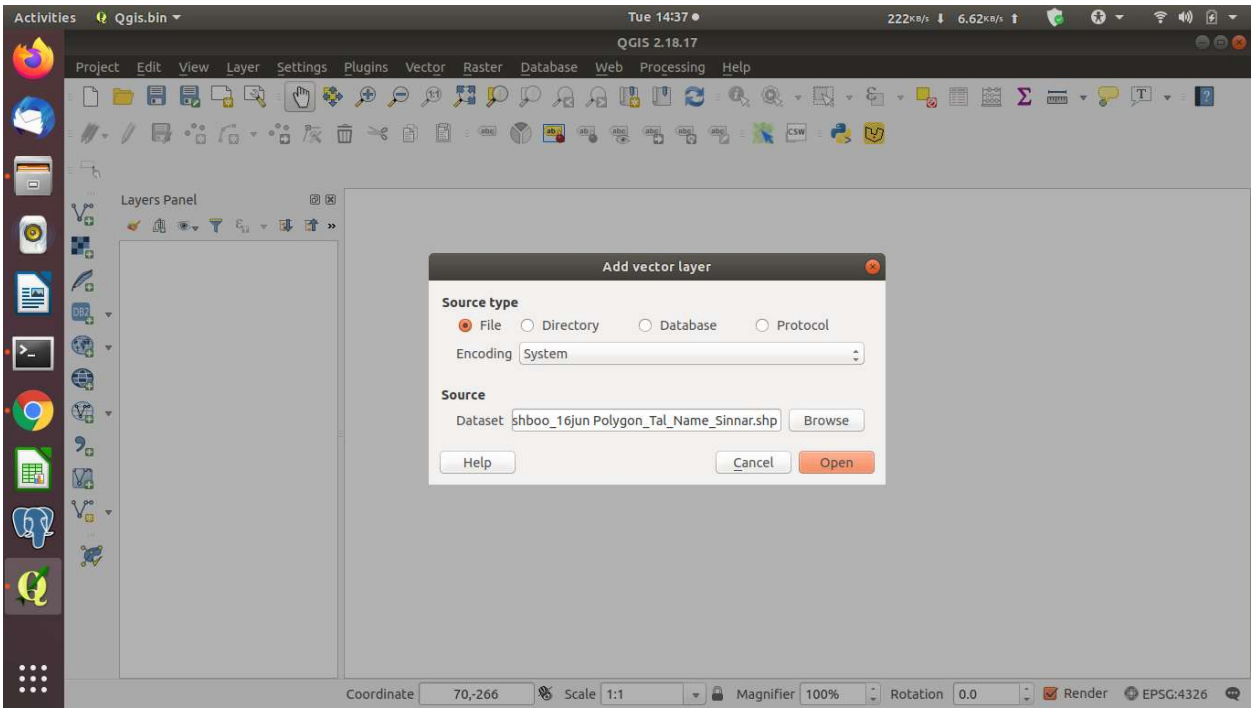


Figure 71. Digital Geography making Process (5)

STEP 5. Click open. Your Shapefile would be loaded.

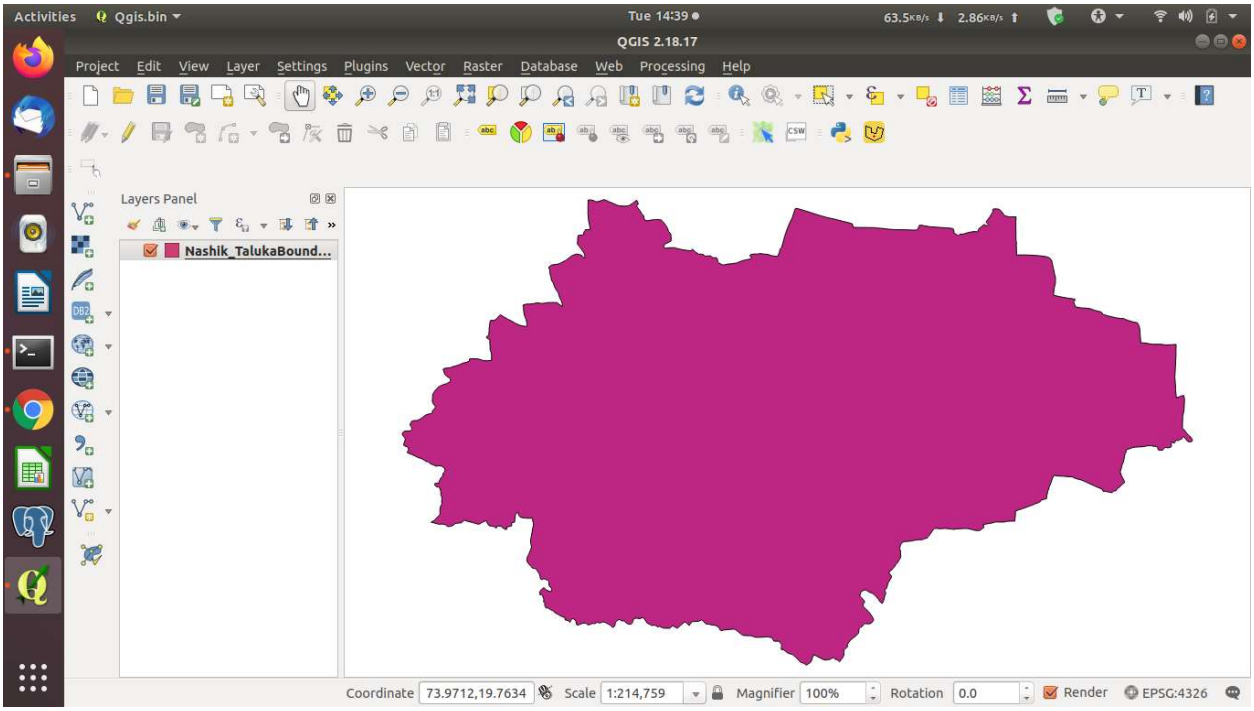


Figure 72. Digital Geography making Process (6)

STEP 6. Add Shapefile for Road Network following the same process.

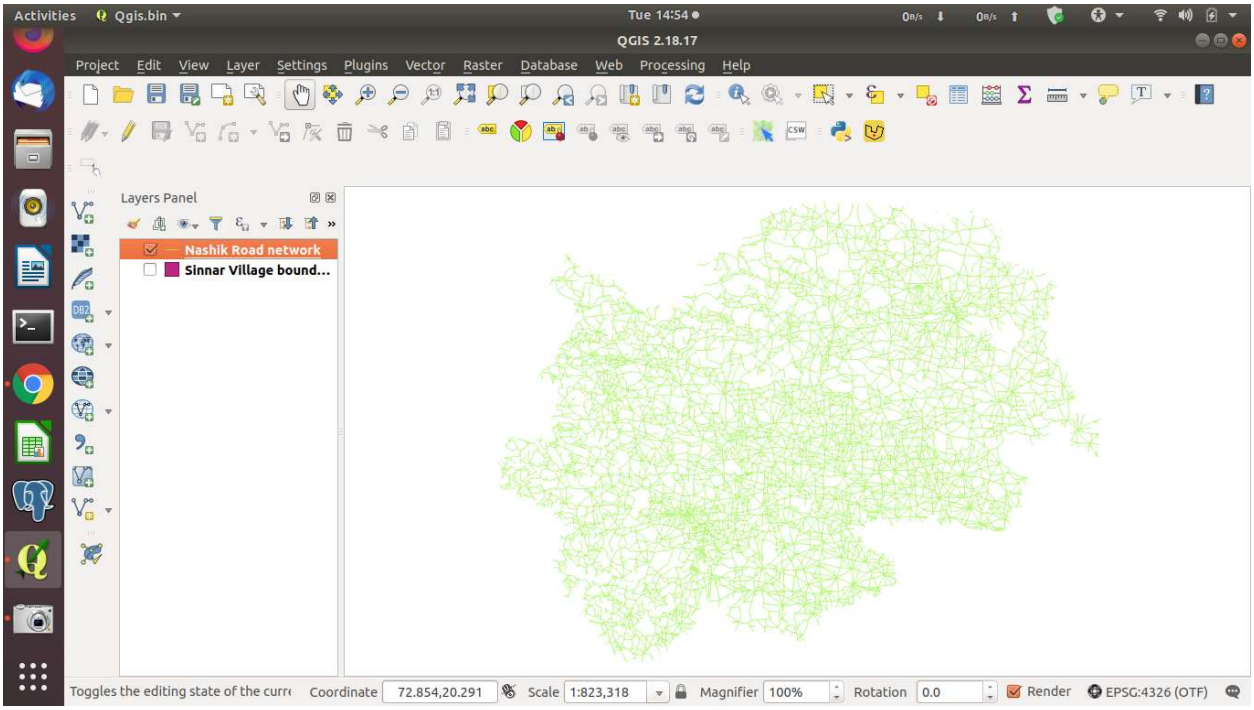


Figure 73. Digital Geography making Process (7)

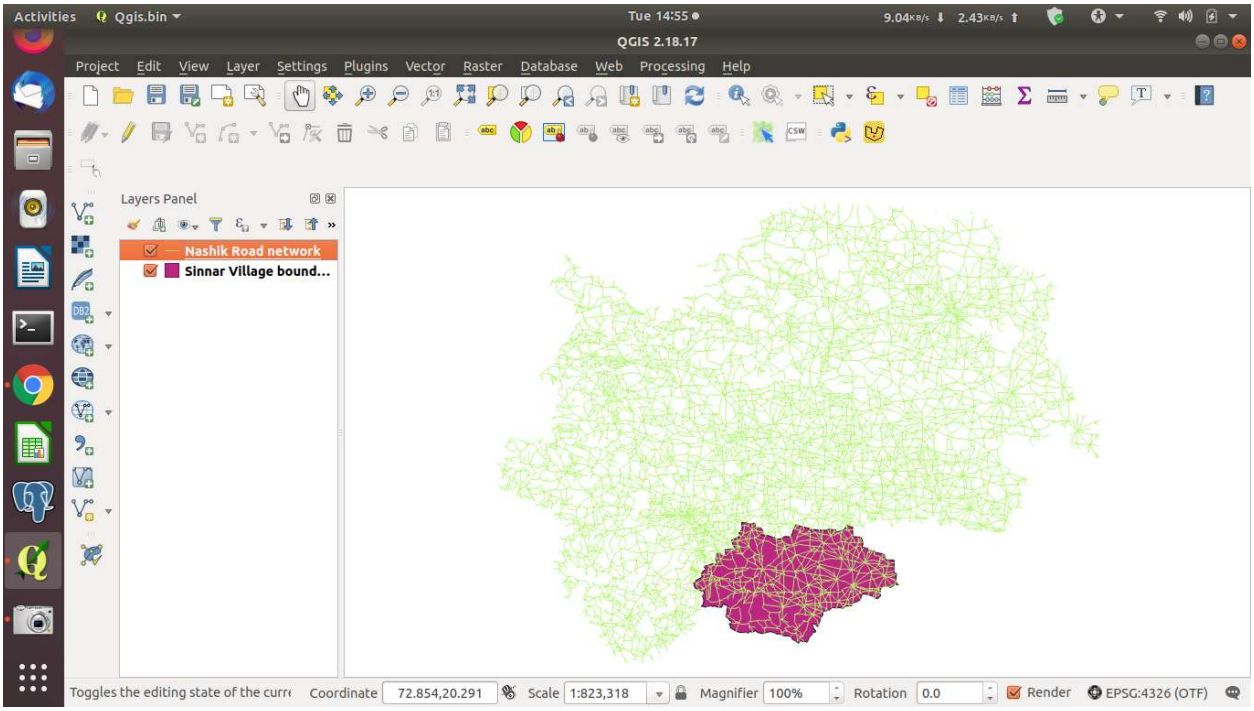


Figure 74. Digital Geography making Process (8)

STEP 7. Make sure all the layers in the layer panel are having the same Coordinate reference system i.e., in our case EPSG 4326: WGS 84. To check go to the Layer Panel, Right-click on the layer, click on the Properties.

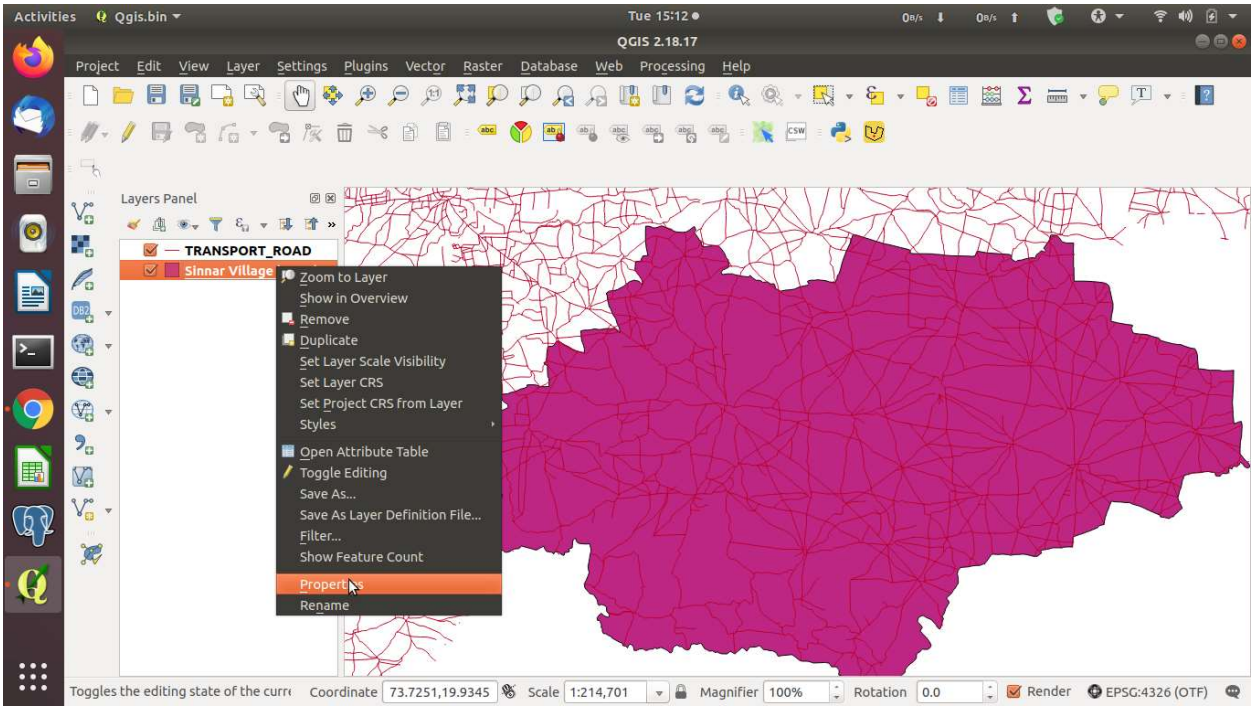


Figure 75. Digital Geography making Process (9)

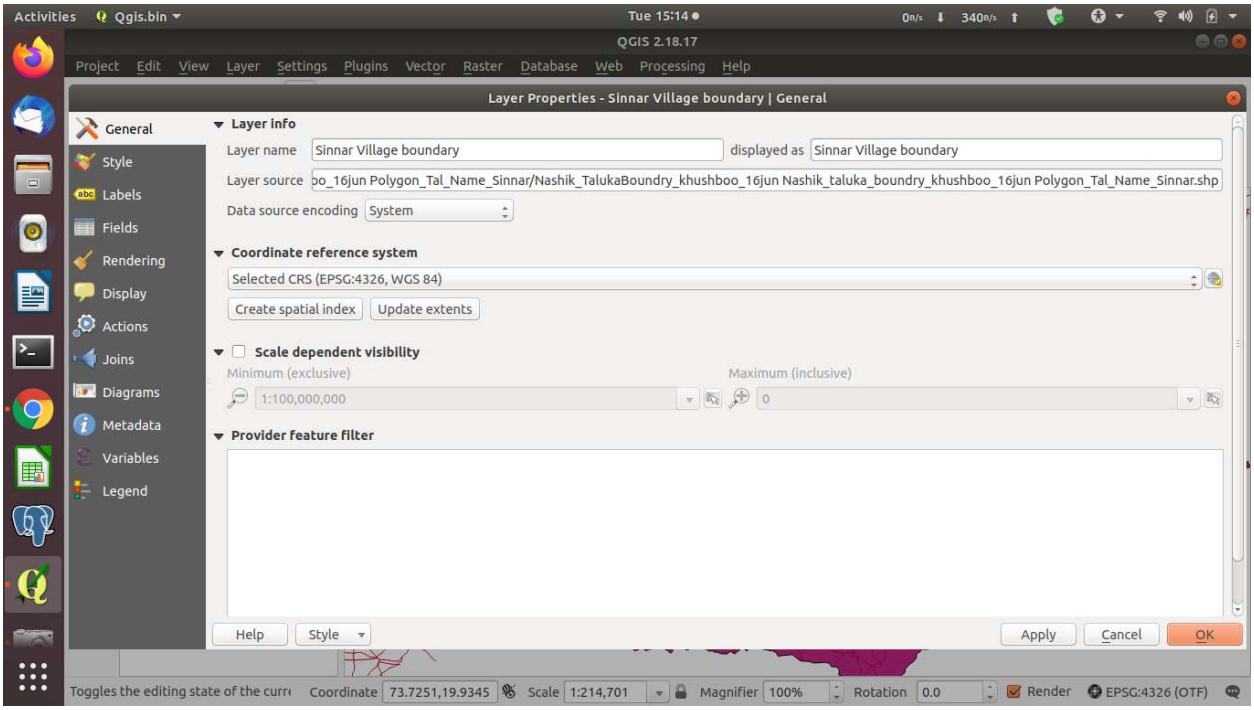


Figure 76. Digital Geography making Process (10)

STEP 8. In the "Coordinate reference system" check whether it is "Selected CRS(EPSG:4326, WGS 84)", if not Click "Cancel". Again Right-click on the layer and select "Save as"

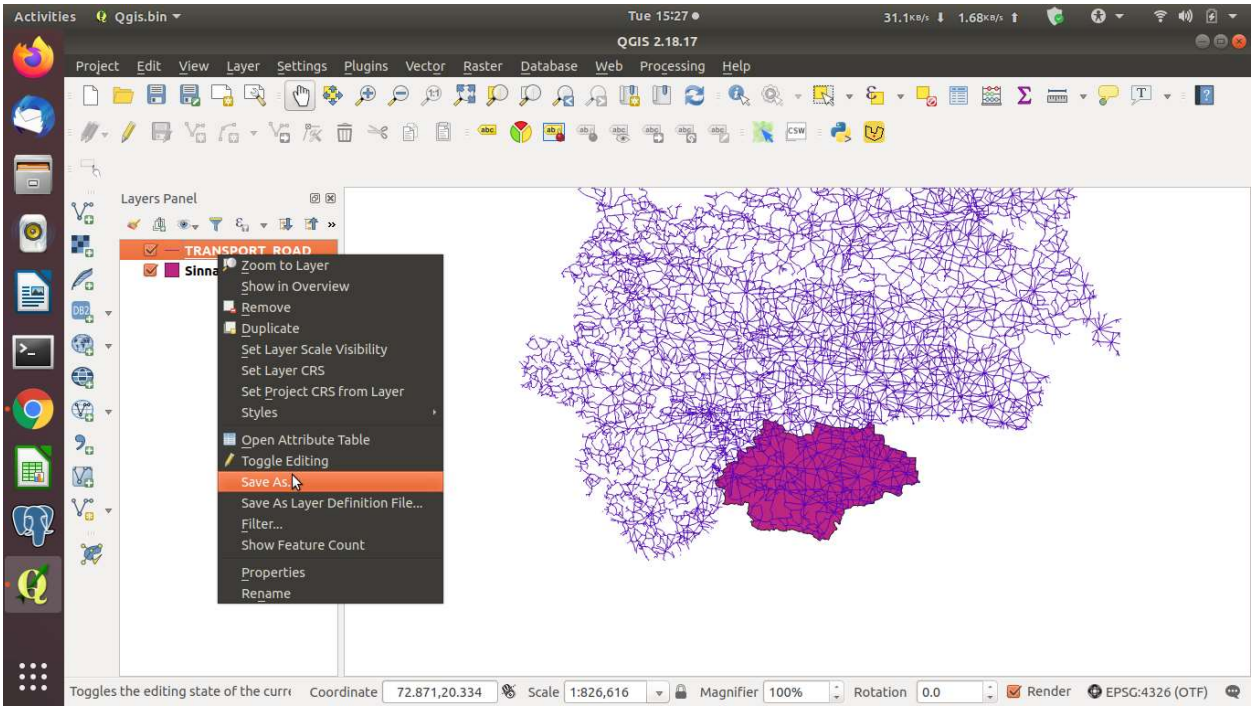


Figure 77. Digital Geography making Process (11)

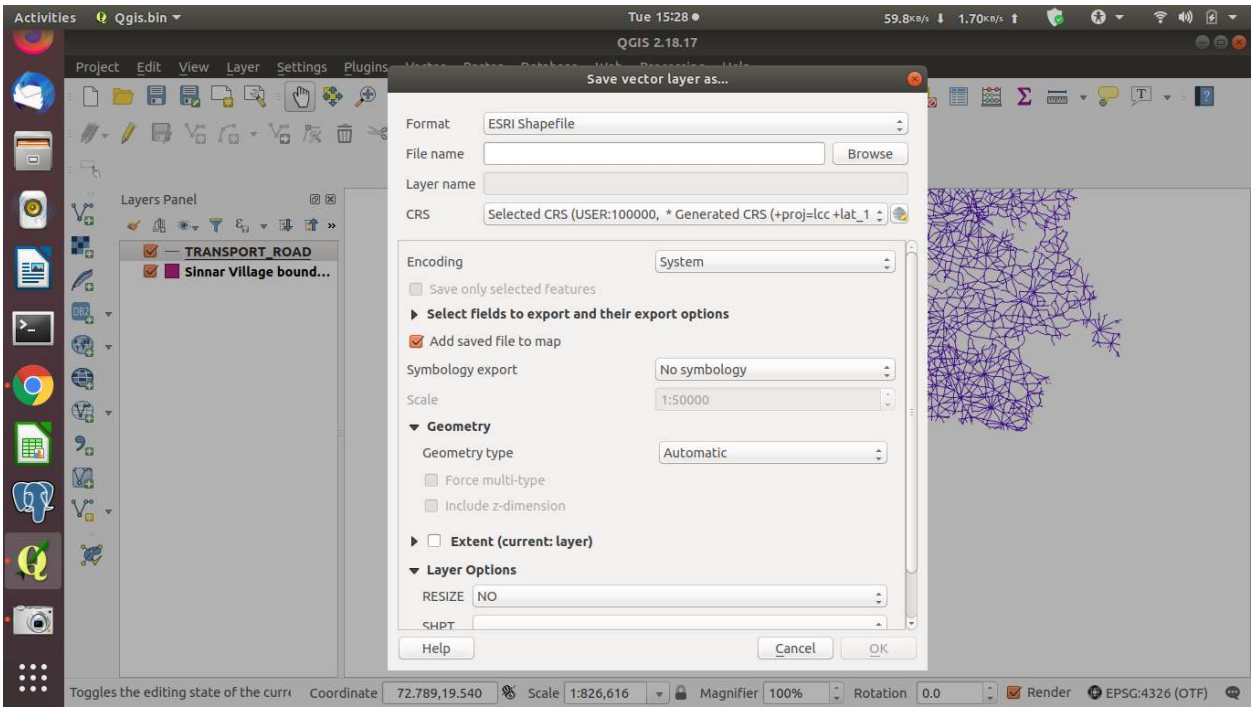


Figure 78. Digital Geography making Process (12)

STEP 9. In the “CRS” drop-down menu, select “Project CRS (EPSG:4326 - WGS 84)” and save to the desired location and click “OK”. Then open that shapefile by seeing the above procedure for opening a shapefile.

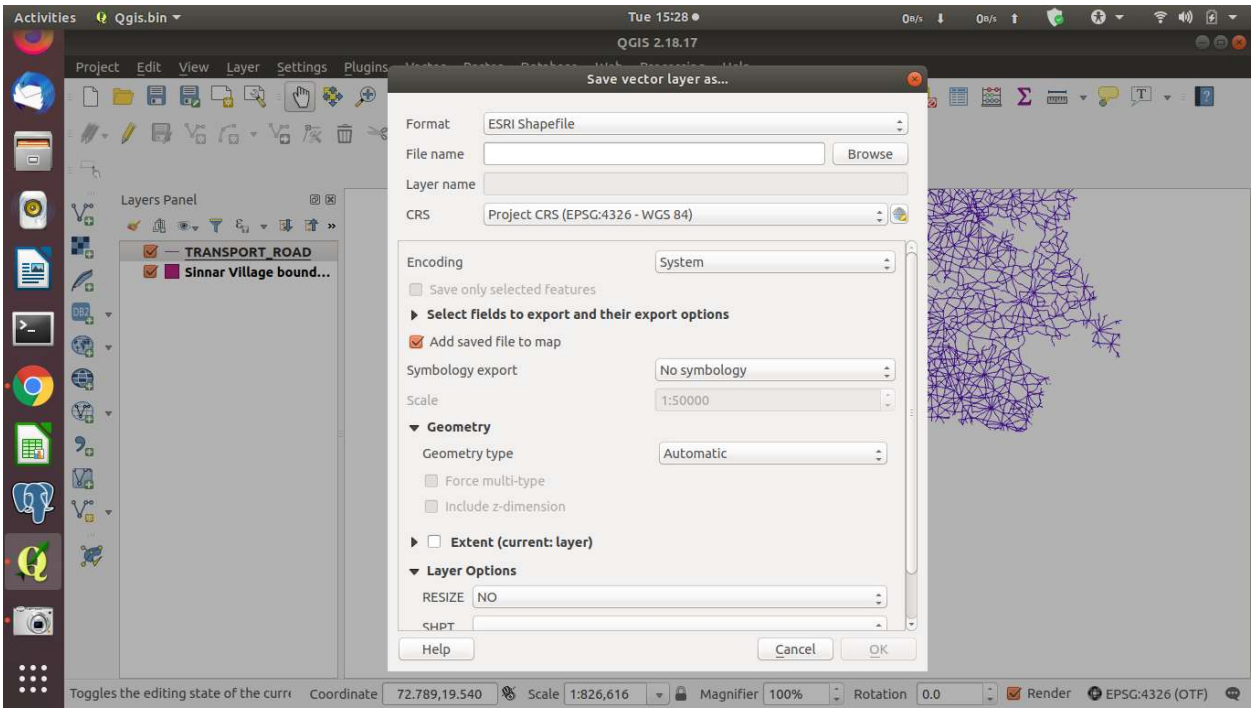


Figure 79. Digital Geography making Process (13)

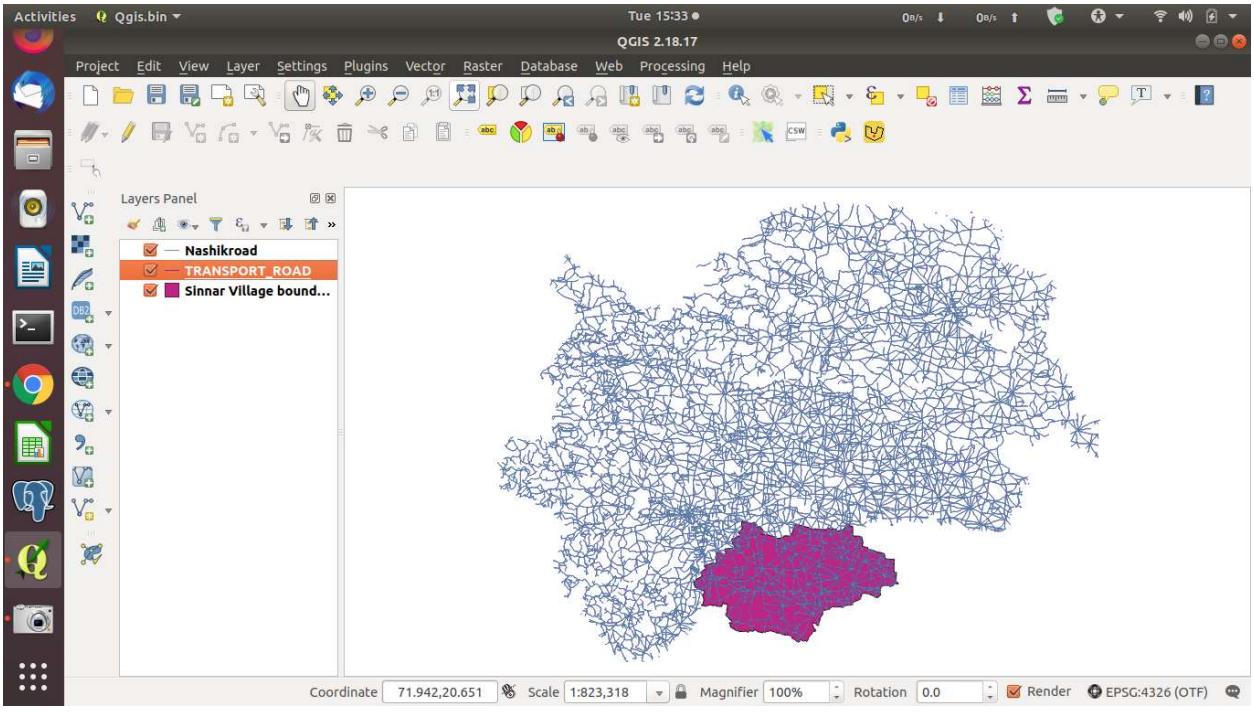


Figure 80. Digital Geography making Process (14)

STEP 10. Now remove the layer which was not having “CRS (EPSG:4326 - WGS 84)” as “Coordinate reference system”

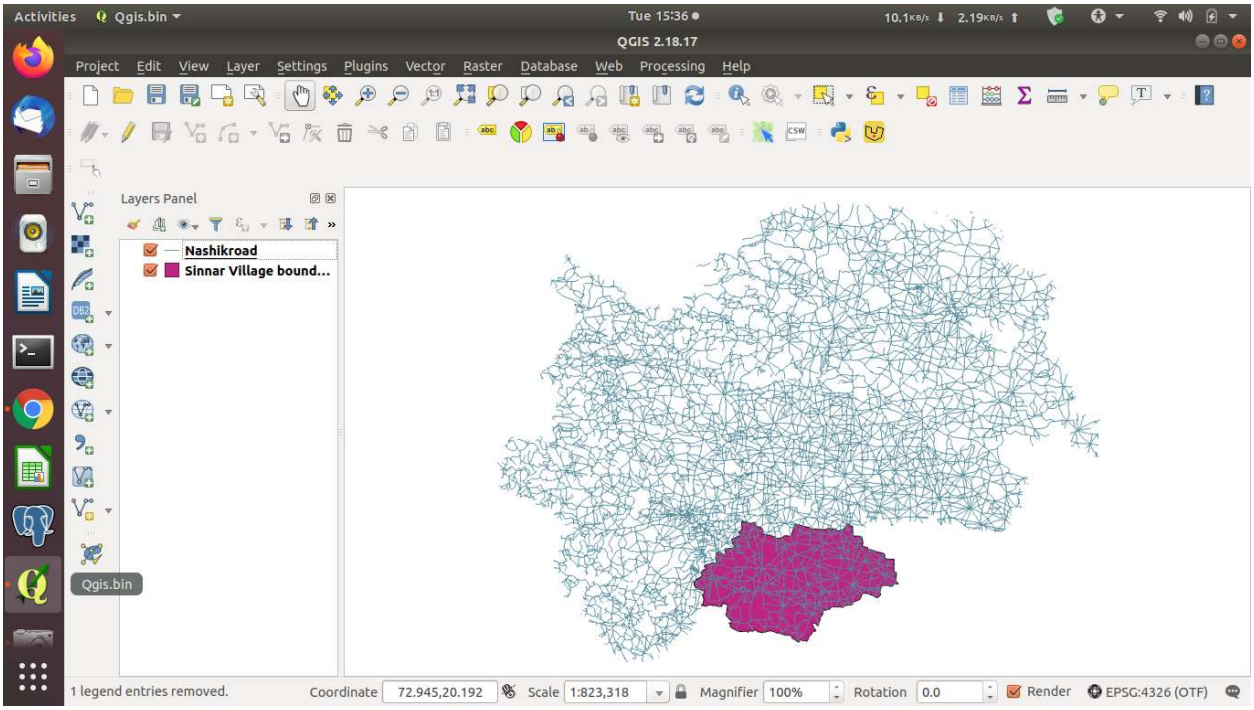


Figure 81. Digital Geography making Process (15)

STEP 11. Use the Clip tool to get the road network of only Sinnar village. Clipping allows you to clip the feature with the defined boundary line. To do that open the tool from Vector > Geoprocessing Tools > Clip. You assign the Input Vector layer that you want to clip and the Clip layer that's boundary line will be used to clip and finally assign the output file name.

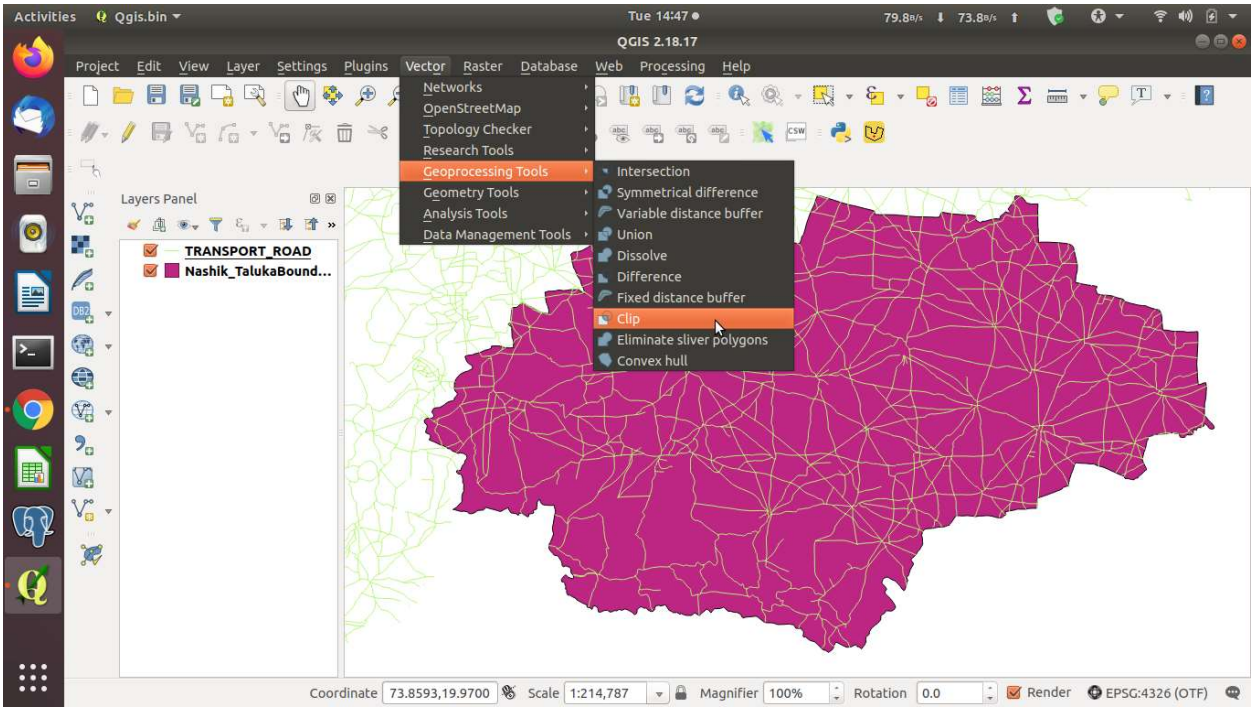


Figure 82. Digital Geography making Process (16)

STEP 12. Now in the "Input layer" choose the layer from which you want to clip the data and in the "Clip layer" Select the layer having boundary of clip layer required and then click "Run".

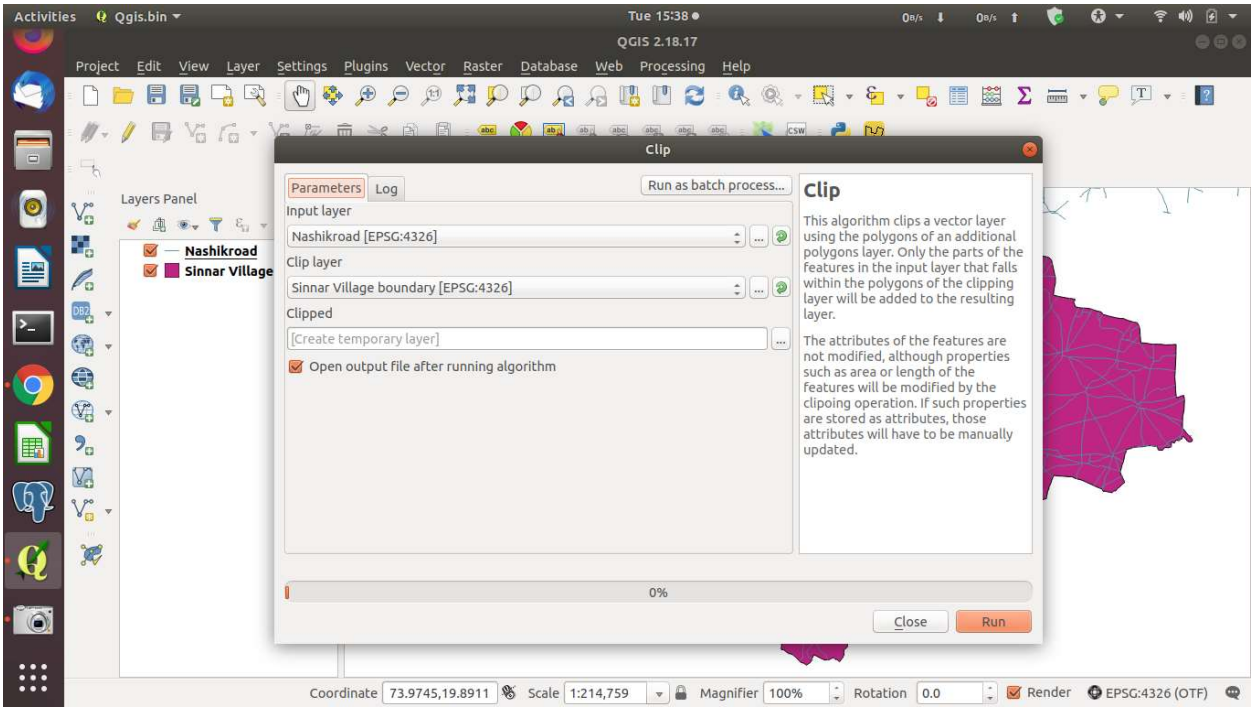


Figure 83. Digital Geography making Process (17)

STEP 13. A new layer will be created as shown in the figure and this is your required road network.

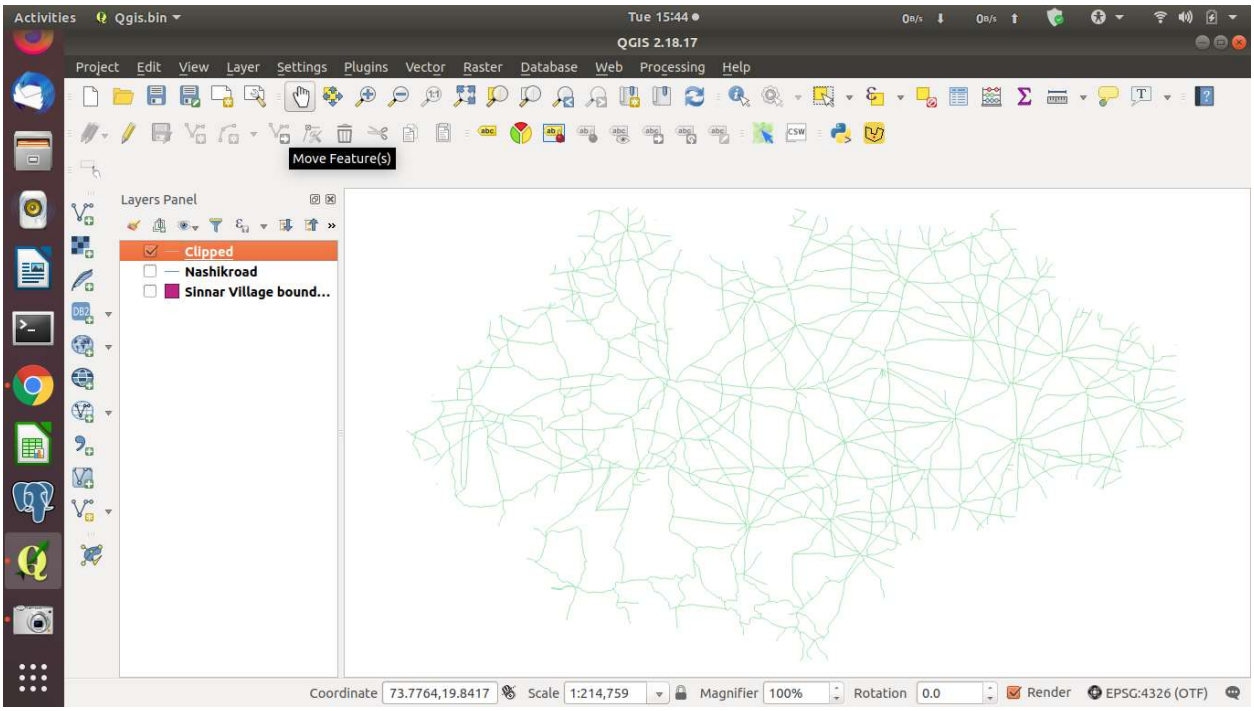


Figure 84. Digital Geography making Process (18)

STEP 14. After Clipping, then right click on the layer "Clipped" in the layer Panel, go to "Open Attribute Table",

STEP 15. Go to "Open field Calculator"

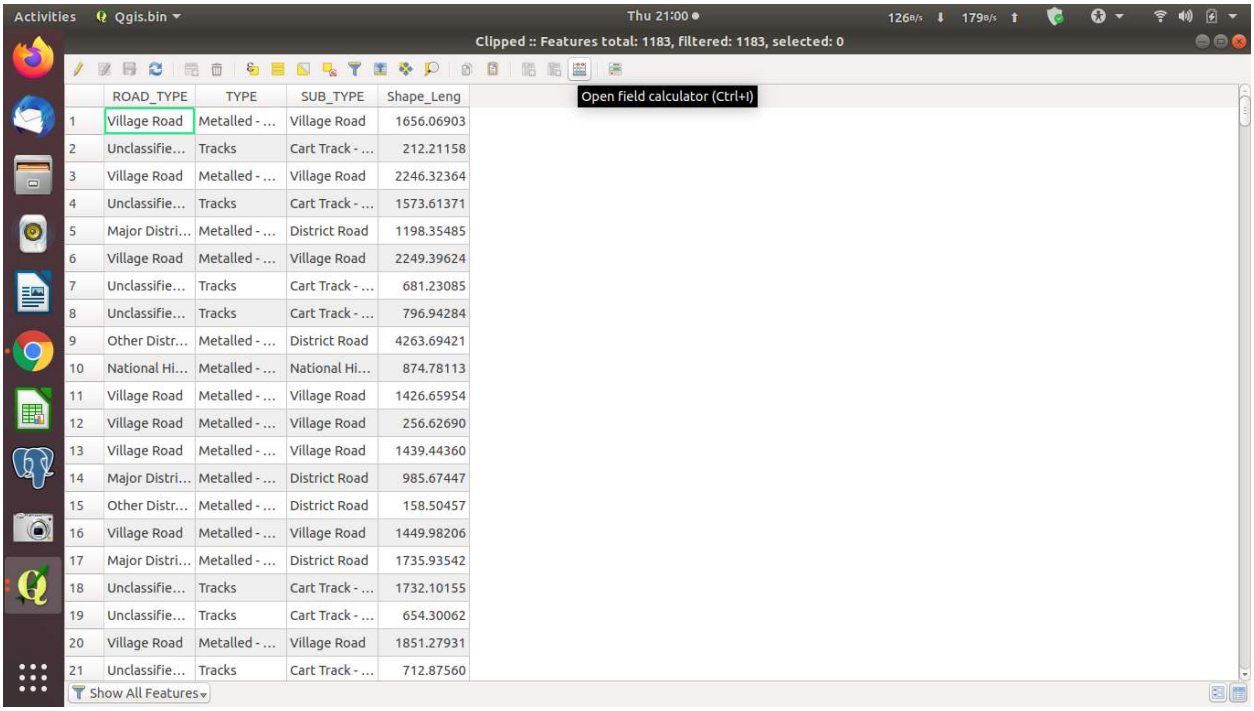


Figure 85. Digital Geography making Process (19)

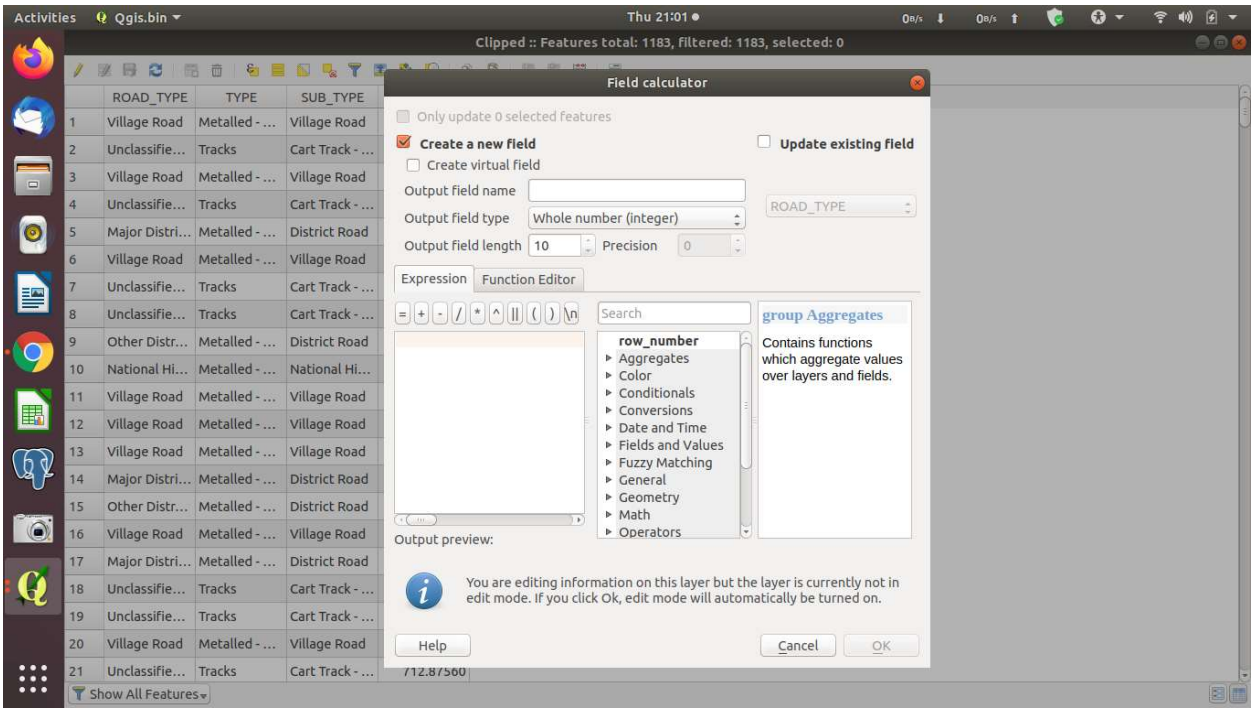


Figure 86. Digital Geography making Process (20)

STEP 16. Tick on the virtual field, In the “Output field name” type “Road_length”, Choose from Drop down menu in Output field type “Decimal number (real) and in the expression field “$length” and click ok

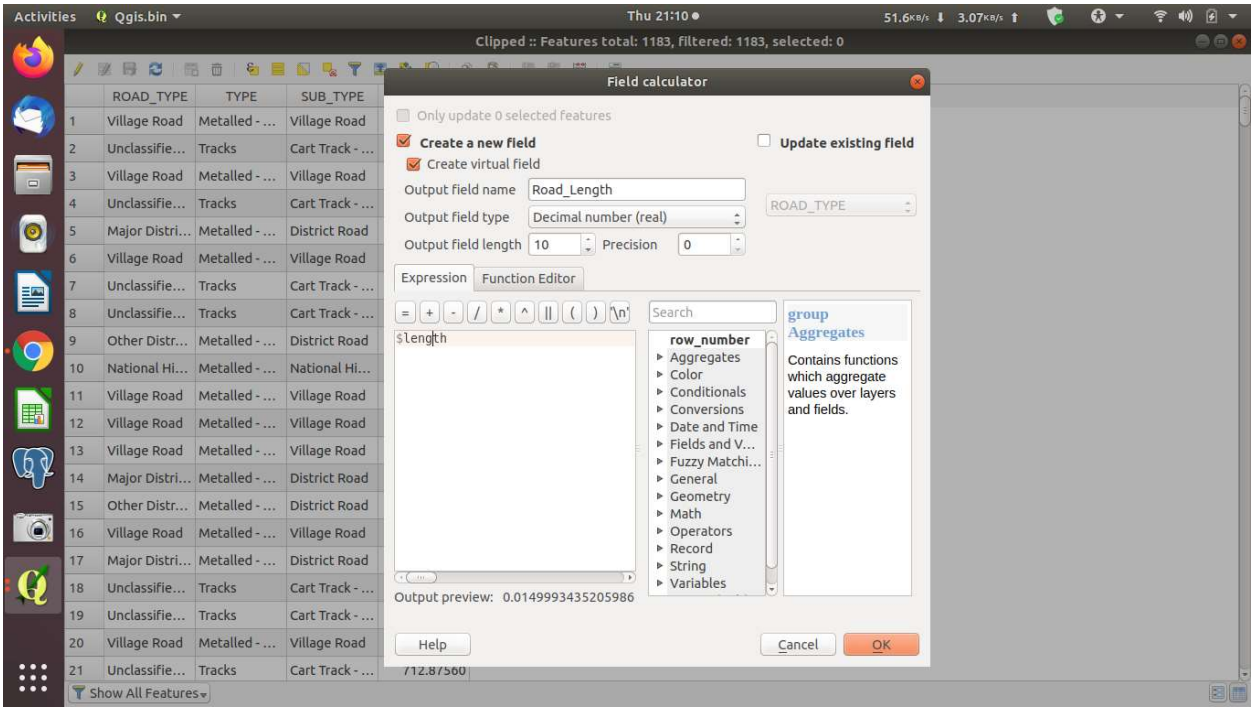
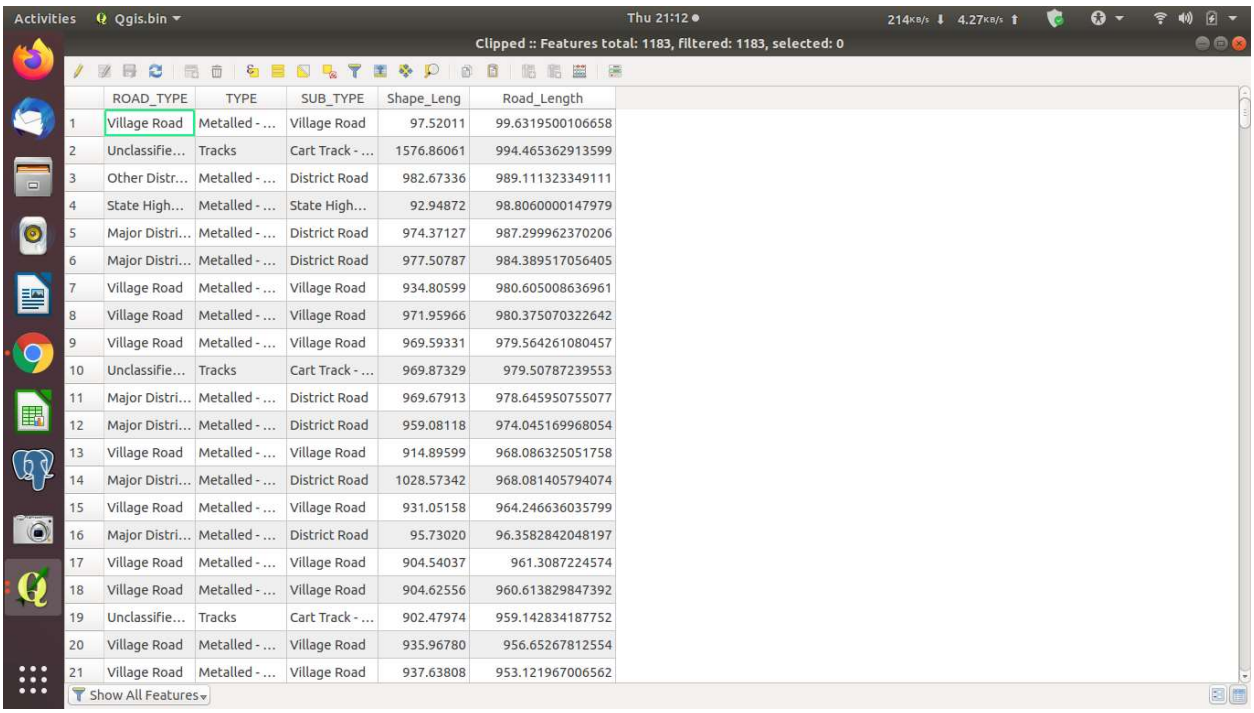


Figure 87. Digital Geography making Process (21)

STEP 17. A new attribute would be created with the name "Road_Length" which denotes the length of Roads.



	ROAD_TYPE	TYPE	SUB_TYPE	Shape_Leng	Road_Length
1	Village Road	Metalled - ...	Village Road	97.52011	99.6319500106658
2	Unclassifie...	Tracks	Cart Track - ...	1576.86061	994.465362913599
3	Other Distr...	Metalled - ...	District Road	982.67336	989.111323349111
4	State High...	Metalled - ...	State High...	92.94872	98.8060000147979
5	Major Distri...	Metalled - ...	District Road	974.37127	987.299962370206
6	Major Distri...	Metalled - ...	District Road	977.50787	984.389517056405
7	Village Road	Metalled - ...	Village Road	934.80599	980.605008636961
8	Village Road	Metalled - ...	Village Road	971.95966	980.375070322642
9	Village Road	Metalled - ...	Village Road	969.59331	979.564261080457
10	Unclassifie...	Tracks	Cart Track - ...	969.87329	979.50787239553
11	Major Distri...	Metalled - ...	District Road	969.67913	978.645950755077
12	Major Distri...	Metalled - ...	District Road	959.08118	974.045169968054
13	Village Road	Metalled - ...	Village Road	914.89599	968.086325051758
14	Major Distri...	Metalled - ...	District Road	1028.57342	968.081405794074
15	Village Road	Metalled - ...	Village Road	931.05158	964.246636035799
16	Major Distri...	Metalled - ...	District Road	95.73020	96.3582842048197
17	Village Road	Metalled - ...	Village Road	904.54037	961.3087224574
18	Village Road	Metalled - ...	Village Road	904.62556	960.613829847392
19	Unclassifie...	Tracks	Cart Track - ...	902.47974	959.142834187752
20	Village Road	Metalled - ...	Village Road	935.96780	956.65267812554
21	Village Road	Metalled - ...	Village Road	937.63808	953.121967006562

Figure 88. Digital Geography making Process (22)

STEP 18. Then close the window.

12.1.3. Creating Fatas-

STEP 1. Go to Processing->Toolbox or Press Ctrl+Alt+T

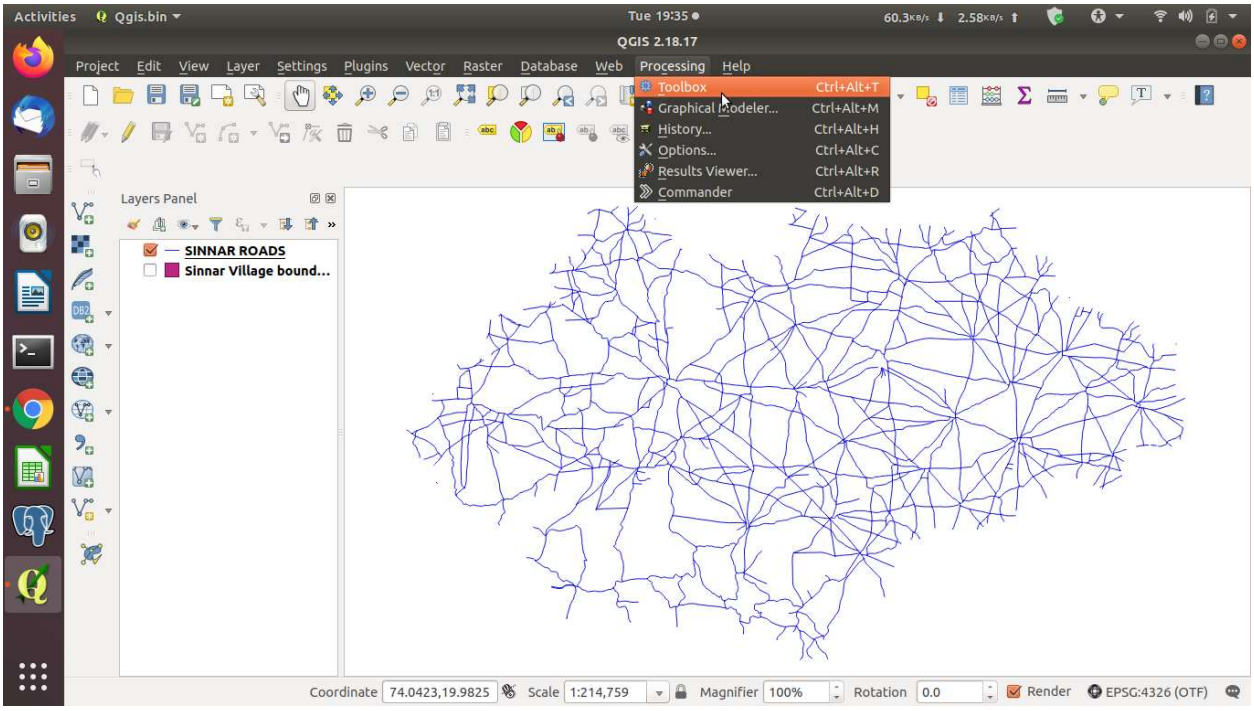


Figure 89. Digital Geography making Process (23)

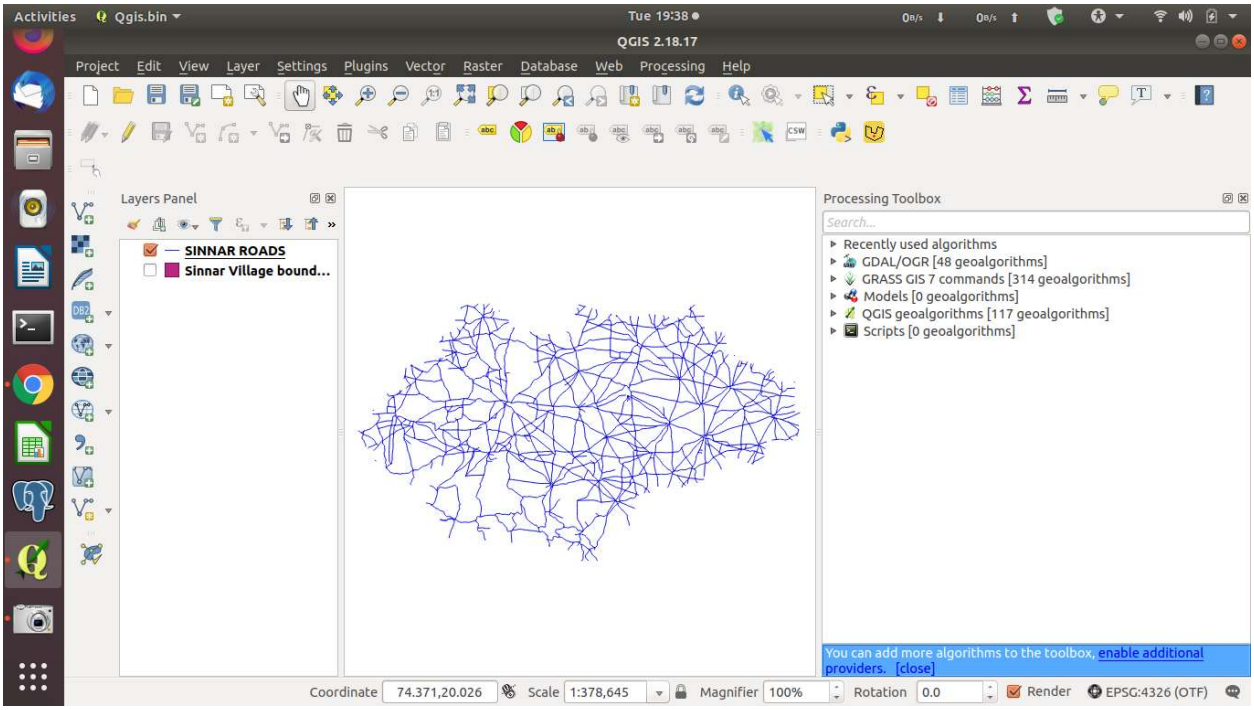


Figure 90. Digital Geography making Process (24)

STEP 2. Search “line intersection” in the Processing toolbox search box and select the “Line Intersections” in “Vector Overlay Tools” in “QGIS geoalgorithms” as shown in figure.

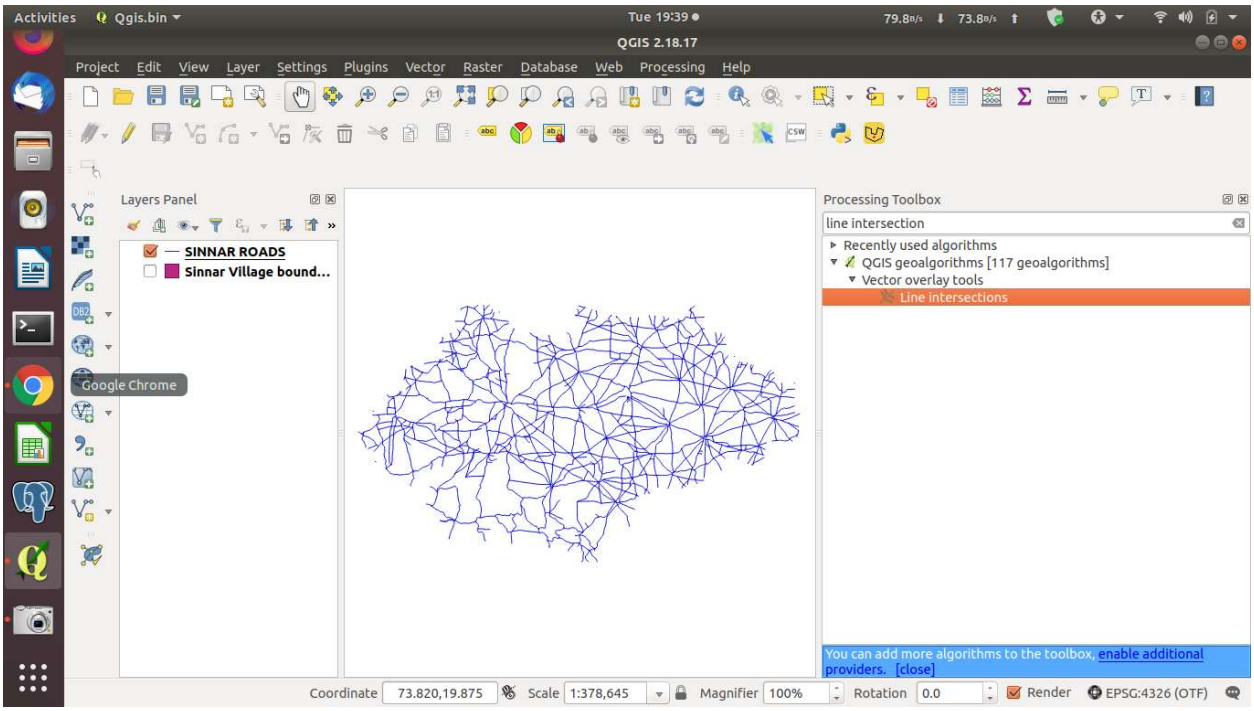


Figure 91. Digital Geography making Process (25)

STEP 3. In the “Input layer”, select the option having a Road network in which we want to find out Fatas. Choose the same road network in the second drop-down menu i.e. “Intersect layer”.

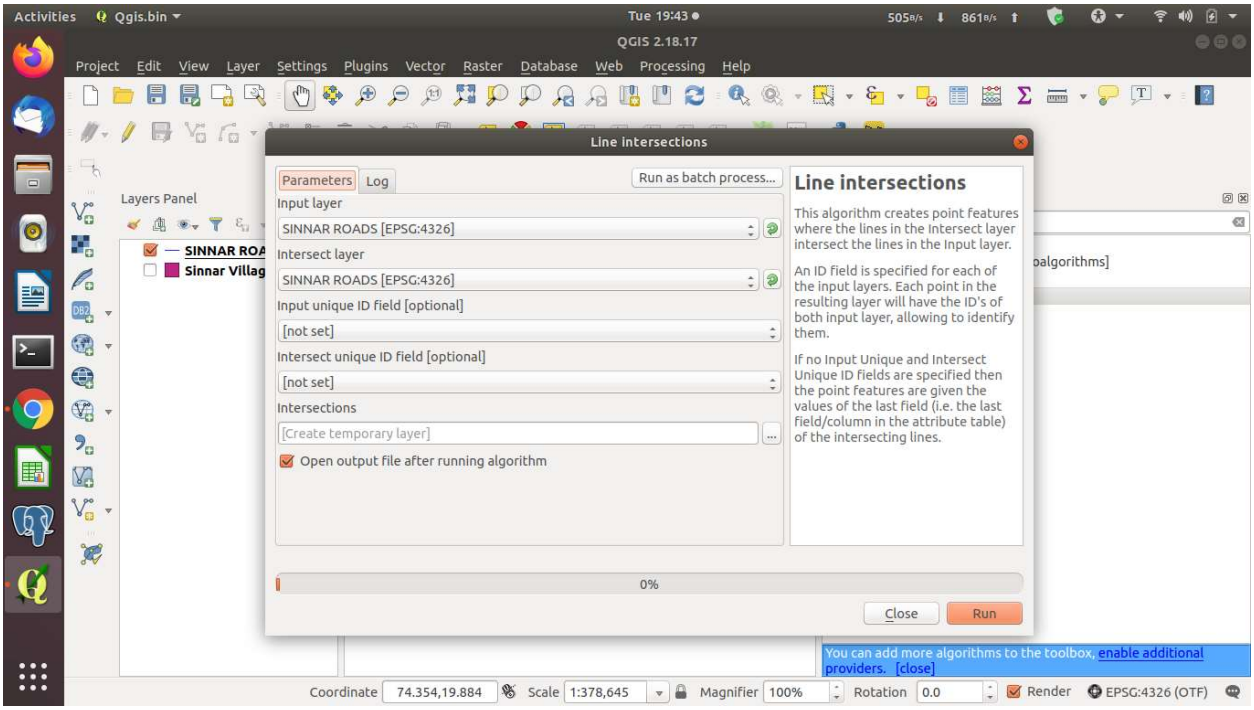


Figure 92. Digital Geography making Process (26)

STEP 4. Click on “Run”. The new output layer named “Intersections” contains the fata

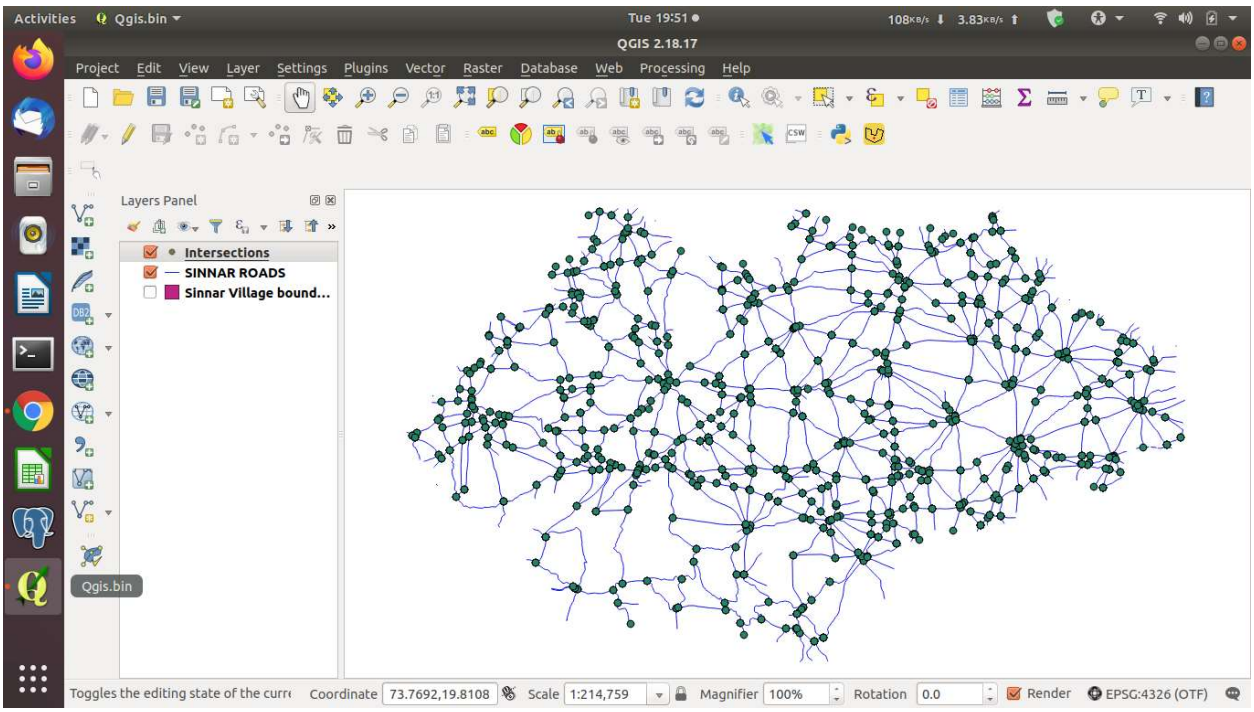


Figure 93. Digital Geography making Process (27)

STEP 5. Rename the layer according to your wish.

STEP 6. Finish.

12.1.4. Creating Centroid-

STEP 1. Download Plugin “RealCentroid”

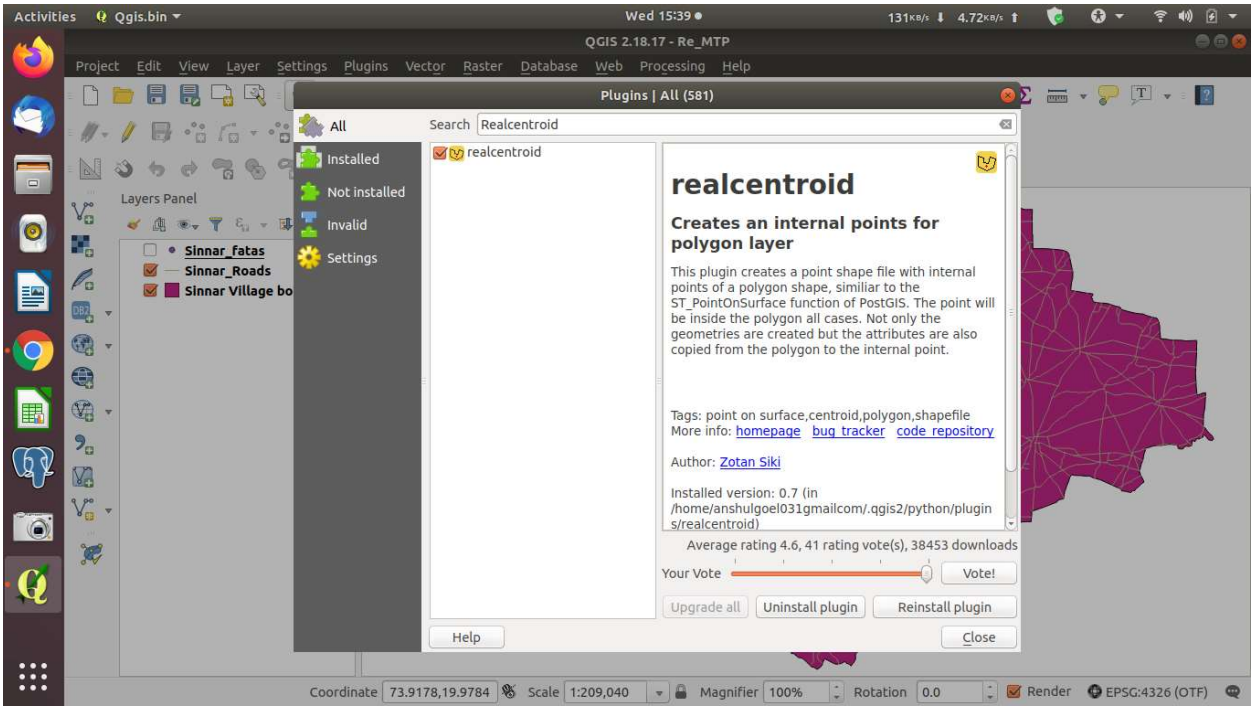


Figure 94. Digital Geography making Process (28)

STEP 2. Load your village shapefile.

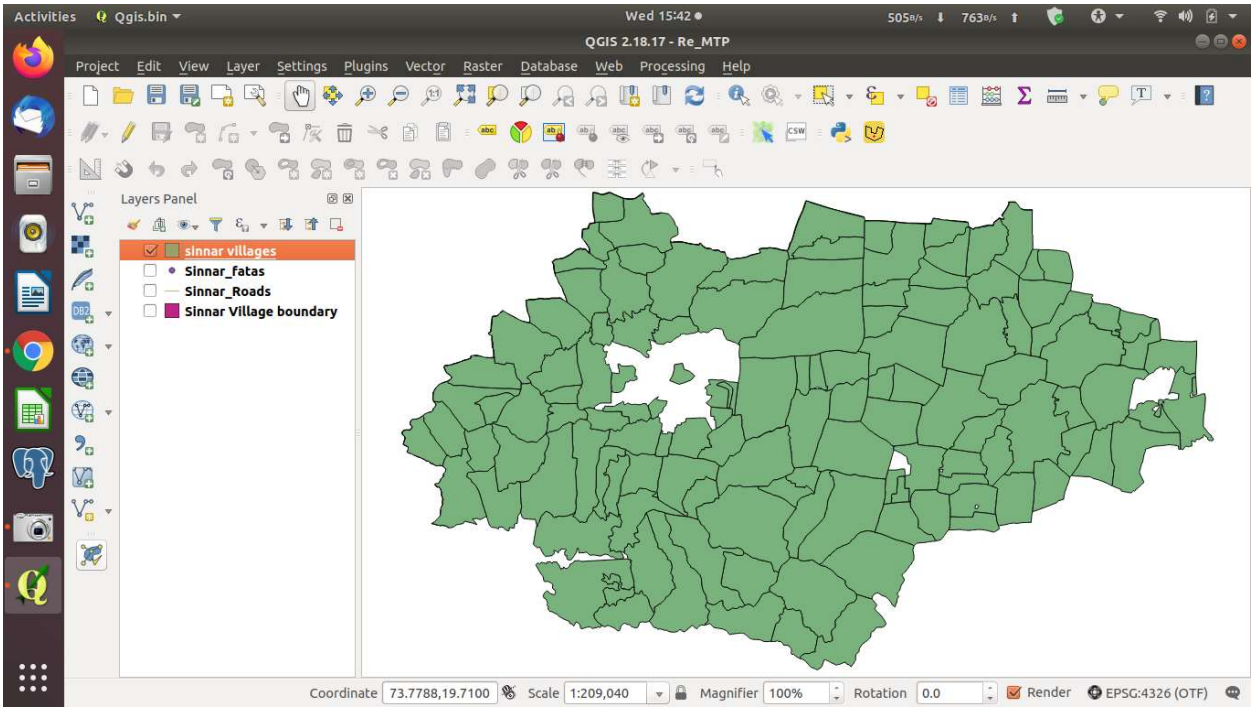


Figure 95. Digital Geography making Process (29)

STEP 3. Go to Plugins->realcentroid->Real centroids.

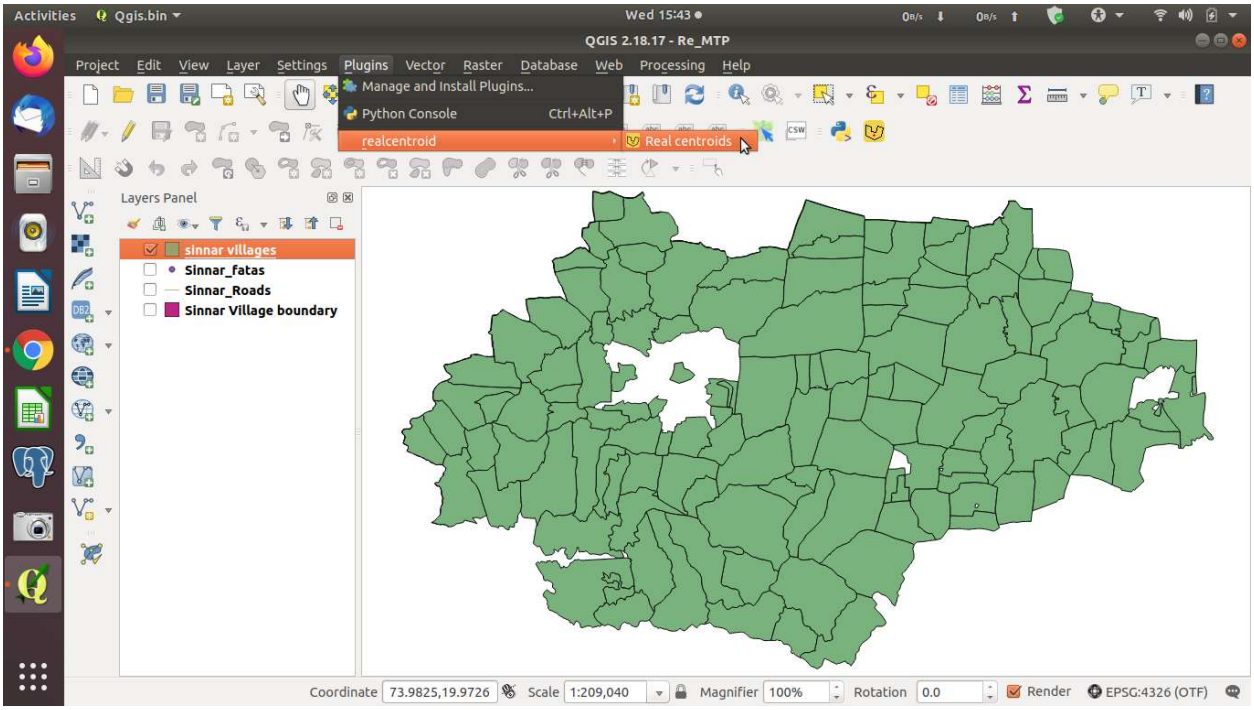


Figure 96. Digital Geography making Process (30)

STEP 4. Select your village Shape layer in “Polygon layer” drop-down menu and Tick on the “Add to map canvas” then click ok,

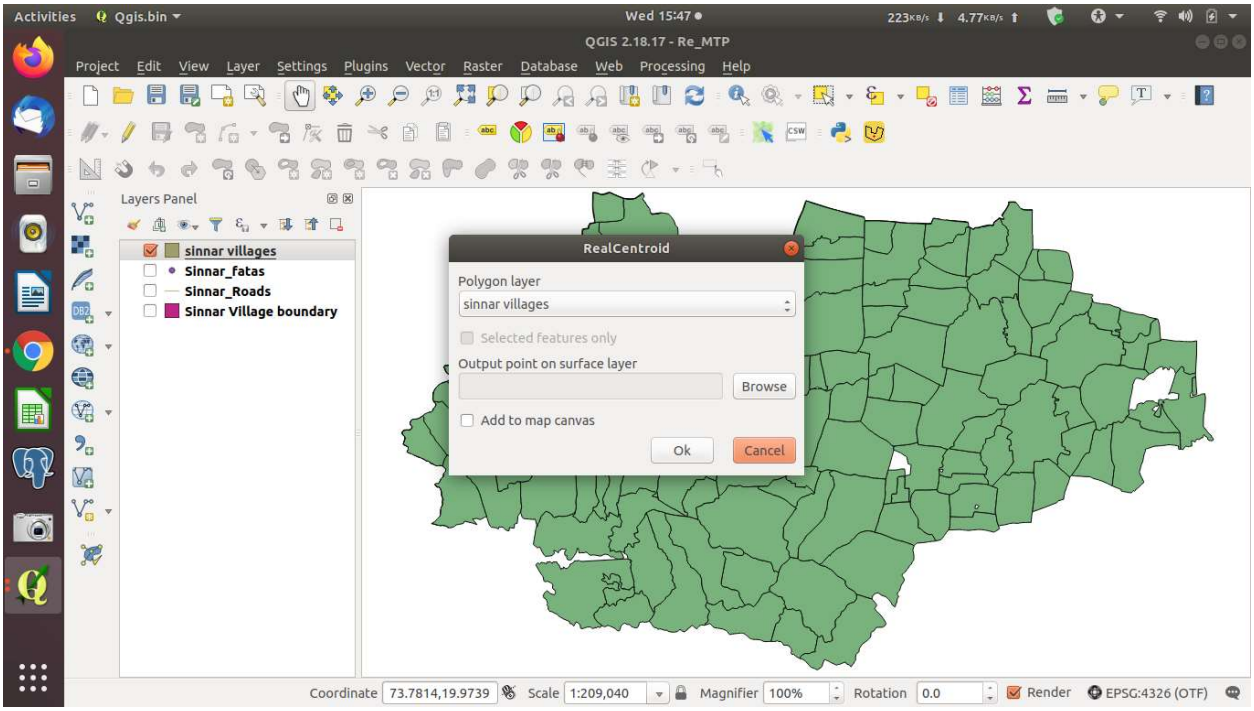


Figure 97. Digital Geography making Process (31)

STEP 5. Output

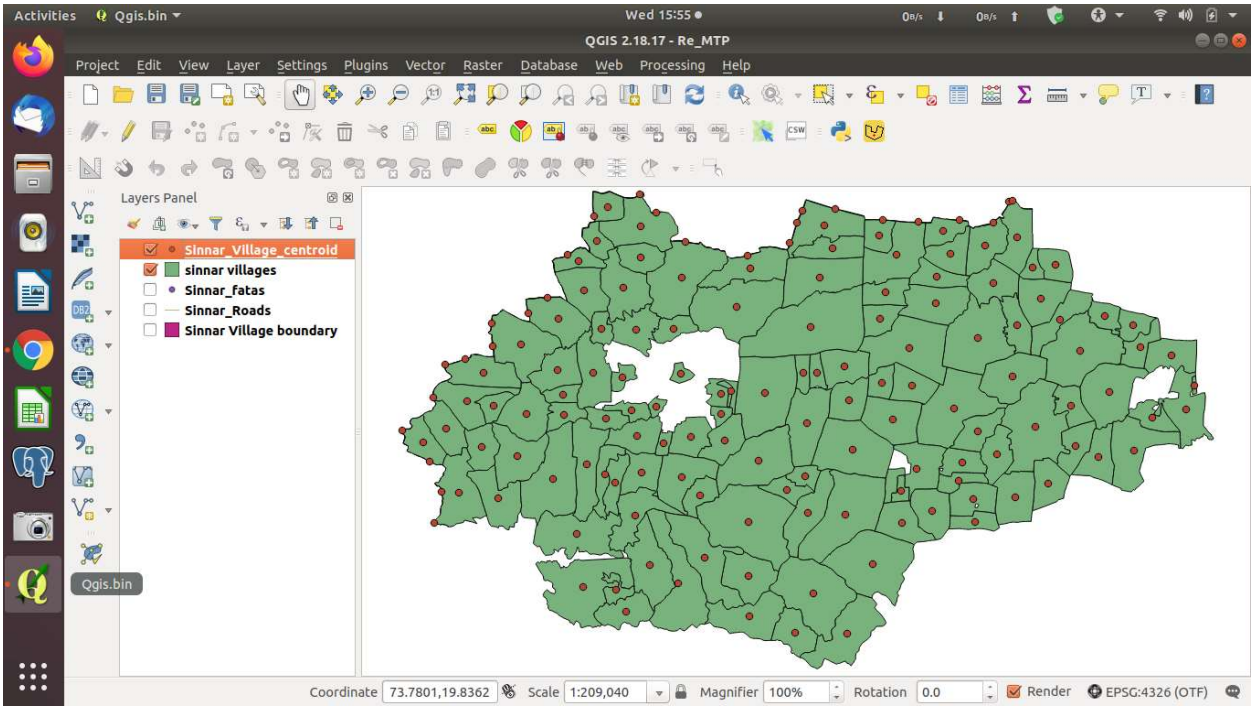


Figure 98. Digital Geography making Process (32)

12.1.5. Creating Road Segment-

STEP 1. Go to Plugins->Manage and install Plugins.

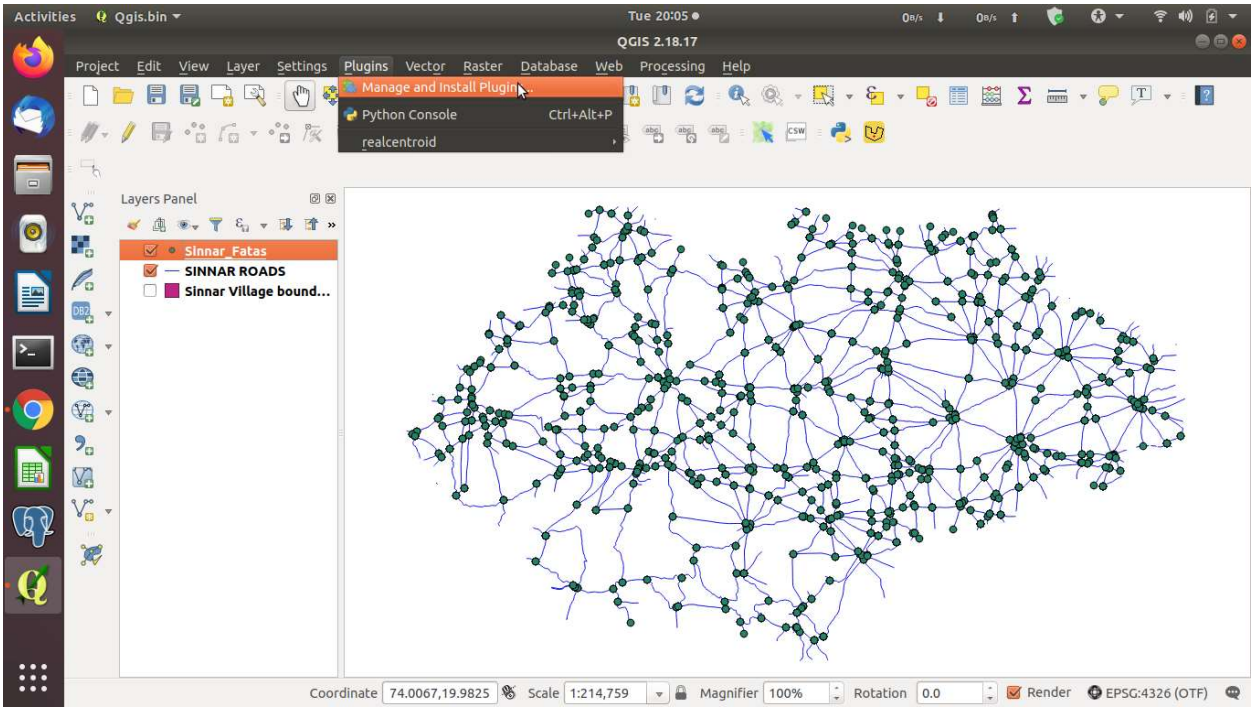


Figure 99. Digital Geography making Process (33)

STEP 2. Go to “ALL”, type “Networks” in the search bar.

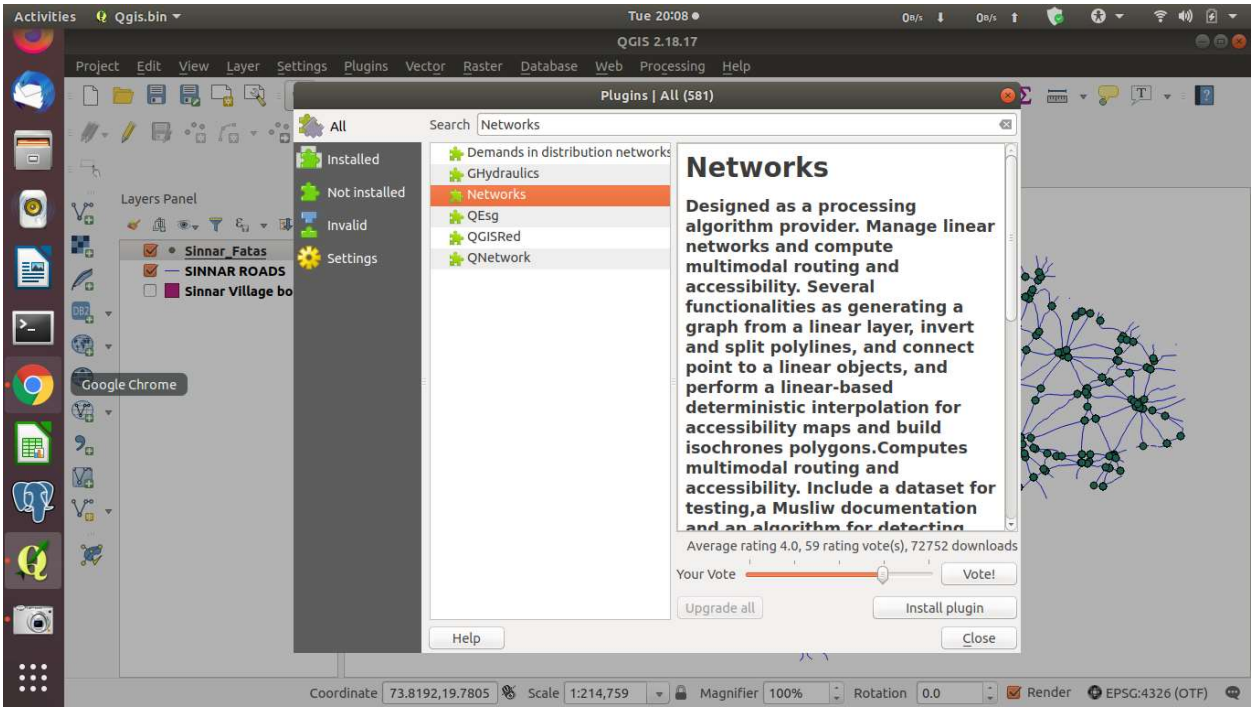


Figure 100. Digital Geography making Process (34)

STEP 3. Select “Networks” and click on “Install Plugins” and then “Close”.

STEP 4. Go to “Vector”->”Networks”->”Connect”.

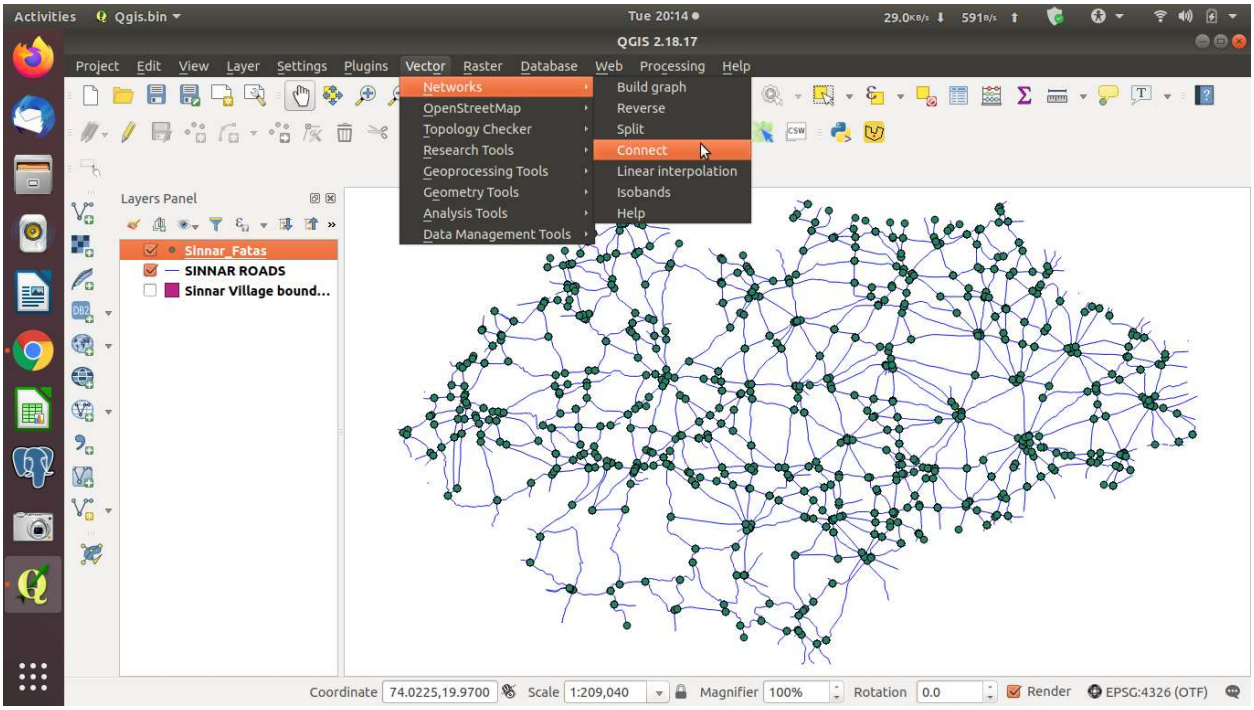


Figure 101. Digital Geography making Process (35)

STEP 5. Make sure you have already saved all your layer files created. Please ensure that in the layer panel only two-layers are ticked, one is the point layer from which you want to cut roads and the second layer is, on which you want to perform operation, all other layers should be unticked. A dialogue box will appear like this

Figure 102. Digital Geography making Process (36)

STEP 6. In the "Point Layer" field, Choose the layer which is having Fatas and input "1" in "Search radius" field. Click on Ok. The process may take time (even 2-3 hours) depending upon your computer speed. If your QGIS asks you to "Force Quit" or "Wait", please have patience and wait.

12.2. Method of Deployment of developed QGIS Plugins-

Plugins developed under the current study works in python 2.x and QGIS 2.x. Hoping both this are already installed in the operating system

STEP 1. Installing Python module 'pb_tool'. Skip this step if this module is already installed. Go to the terminal and type.

sudo pip install pb_tool

STEP 2. Go to Plugin Directory and type

pb_tool deploy

STEP 3. QGIS plugin is installed. Restart QGIS to see the plugin.

13. Bibliography

1. Mr. Sudhanshu Kulkarni (2019), GIS Framework for Taluka Bus Transportation Analysis and Provisioning, Centre for Technology alternatives for rural areas, IIT Bombay.
2. National Transport Development Policy Committee, India Transport Report, Volume I, Executive Summary, vol. II. 2014.
3. "History of MSRTC". msrtc.maharashtra.gov.in. (Accessed on 8 February 2019.)
4. MSRTC Annual Report 2016-17