URBAN ROAD INFORMATION AND MANAGEMENT SYSTEM (RIMS) USING GEOSPATIAL TOOLS

A THESIS

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(Sandeep Gupta)

ABSTRACT

With the development of any road network, the problems associated with the usage of roads arise. Some of the major problems are proper planning and maintenance of road network, including bridges, traffic jams, planning of new parking places and minimize the accidents. Transportation authorities are always challenged by increasing demands for better services under the constrained budgets. Better management systems are urgently needed to support more effective decision making. For improvement of efficiency of the road network with minimum amount and least effort, a proper management of road network is essentially required. This can be achieved through the development of a computer-based Road Information and Management System (RIMS).

Essentially, the RIMS consists of a framework, including both information processing and use of human resources for an integrated management of the road network, including determination and optimization of economically warranted projects, programmes, strategies and budgets, both for development and maintenance. The main purpose of RIMS is to assist the authorities in providing a safe and economical road infrastructure at minimum cost. The goal of RIMS is to plan, identify, quantify and priorities the needs of a road network.

An Integrated Road Management System is required for properly coordinating, evaluating and maintaining the infrastructure systems. Integration of RIMS with a Geographical Information System (GIS) enhances the effectiveness and efficiency of a RIMS manifold due to enormous capabilities of GIS software to analyse the spatial and non-spatial data together. Remote sensing techniques can be used for detailed mapping of roads, rails, water features (e.g. rivers, canals, ponds, lakes and drains etc.), bridges, culverts and public utilities (e.g. parks and tourist spots etc.), as this information is required as input to GIS. Further, high resolution satellite images can provide very detailed information regarding width of road and geometry of roads, space available for road widening, best location for vehicle parking and planning & alignment of new roads. Global Positioning System (GPS) can provide locations of various utilities as required by RIMS, such as bridges or culverts, bus or taxi or tempo stands, parks, police stations, fire stations, government offices, and tourist spots etc. In GIS, a based query system may also be developed. Thus, a GIS based RIMS is

very helpful to decision makers, planners, engineers, administrators, managers and contractors due to its data storage, analysis and decision making capabilities.

The objectives of the study include (i) to create a GIS database of relevant parameters using input from GPS and high resolution satellite images, (i) to develop and integrate various components i.e., RIS, BMS, TIS and AIS, (iii) to develop a suitable query system for the above components and (iv) to develop of a web enabled system for RIMS in order to develop a well integrated and structured GIS based RIMS. Present research work is focused towards the development of a methodology for a RIMS for an urban area, which would be capable of providing the decision making related to maintenance requirements of roads and bridges in order to minimising road accidents and traffic jams, development of new public facilities, such as petrol pumps, fire stations, trauma centres, police stations, fly over bridges/ underpasses etc. The intended customers for the RIMS will include Public Works Department (PWD), public transport system management officials and bus operators, tourist/ traveller seeking information about the features or shortest path, police department, state planning commission and city administration.

To develop a RIMS for fast developing city having complex road network and urban habitation, the city of Dehradun has been taken for the study. There has been a rapid development activity in Dehradun after it became the capital of the state Uttarakhand in November 2001. The study area falls within the jurisdiction of Mussoorie Dehradun Development Authority (MDDA) as envisaged in the master plan 2005-2025. It lies between 30° 13´ 00" N to 30° 29´ 00" N Latitudes and 77° 52´ 00" E to 78° 10´ 00" E Longitudes. The total area covered is approximately 35,867 ha which includes Dehradun Urban Agglomeration Area (9,699 ha) and 172 rural villages (26,168ha).

The spatial data used include Survey of India (SOI) Toposheets 53F-15, 53F-16, 53J-3 & 53J-4, Dehradun guide map, IRS Cartosat -1 data, dated January 24, 2008 and November 20, 2008 respectively, IKONOS data from Google Earth and MDDA Master Plan 2005-2005. The associated non-spatial / attribute data used include road divider and footpath, road top surface, road one way or two way for road layer, bridges/causeways width, length, types of railing, structure, spans, presence of road divider & shoulder and maintenance requirements for bridge layer. Address or locations of the hotels, road intersections, government offices, schools and colleges, professional institutes, tourist place, hospitals, police stations, fire stations, traffic density and pedestrian traffic on important roads or road intersections, religious places, railway crossings, railway stations, petrol pumps, bridges, city bus routes and cinema hall were also collected. Intensive field visits were carried out from November 18-27, 2010, December 13-16, 2010 and January 15-17, 2011 to collect these data as well as mark their locations through GPS survey.

For developing a well structured methodology for the urban RIMS, the followed are collection of relevant data/maps/ satellite images, design of the database (spatial and non-spatial), georeferencing of SOI toposheets with various satellite data, generation of thematic layers and creation of database, field visit for data collection and verification, updation of data with the help of field visits, IRS Cartosat -1 and IKONOS image, development of various components of RIMS i.e., Road Information System (RIS), Bridge Management System (BMS), Accident Information System (AIS) and Traffic Information system (TIS) in GIS environment, spatial analysis of road network, path finding, identifying infrastructure, query etc. and development of web enabled system using Sharpmap as open source GIS software. Geodatabase has been created for the modules RIS, BMS, AIS and TIS. Query formation and network and buffer analysis have been designed to extract desirable information from each module.

The RIS module is capable to provide information of roads, such as road name, type, width, divider, footpath, one way/two way road surface either in single or in combination. Moreover, the module provides information on location & address of police station and sub-police station, fire stations, hospitals, government offices, hotels, petrol pumps, cinema halls, professional institutes and tourist spots etc. Network analysis was carried out to identify shortest route, get the walking/driving directions to reach a particular point, to get nearest public utility, like petrol pump, hospital and hotel etc. It also computes minimum time required to reach a facility from source to destination. Buffer analysis helps in finding out the new locations of the utilities.

The BMS is capable to provide information on several parameters of bridges either singly or in combination. These parameters are mostly collected from field visits, and include bridge type, road name, river name, road type, road width span length, number of spans, total length, divider, shoulders, railing type, bridge top surface, structure type, photo etc. Moreover, with the help of network analysis, alternate route can be found if a particular bridge is under maintenance. The module has the photographs of bridges attached along with the attribute data. By displaying the photos and attributes, the condition of bridges may be assessed for maintenance requirement.

The AIS module provides accident information, like vehicle involved in accidents, jurisdiction of police station, casualties, injured, date & time of accident and hospital information, like name, phone, name of doctors and their specializations. Under AIS module, vulnerable spots on the basis of frequency of accidents are classified as most critical, critical and less critical. In this study, the accident data from 2002 to 2006 was available and used for analysis. To get the vulnerable points, a buffer of 100 m of all accidents spots has been generated. At any location, if 4-5 buffers intersect, then those locations are designated as most critical locations. When 2-3 buffers intersect these are designated as critical locations, and the remaining locations are designated as less critical. These most critical locations are found at the intersection of Rajpur road with East Canal road and on East Canal road at the intersection of Cross road and Amrit Kaur road. The buffers of four years of accidents have intersection points on Rajpur road. Moreover, in case of an accident, network analysis would help to find the shortest route to the hospitals.

With the help of TIS module, analysis was carried out to find out the critical crossings having frequent traffic jam, pedestrian effect on traffic flow, assessment of new bypass route, alternate route during a road closure or traffic diversion for religious or political procession etc. It also helps to decide a route during tourist season so that routine traffic does not affect.

To identify the crossings having frequent traffic jams as an important parameter, road traffic capacity is to be considered. This information is available from IRC-106-1990 Code. In the analysis, first of all a search for all crossings is made from the database, where traffic data are available. Thereafter, it computes the ratio between traffic density and road traffic capacity. Those crossings where ratio is more than one are selected. In this study area, twelve such crossings have been identified, which include Ghantaghar, Darshan Lal intersection, Saharanpur intersection, Prince intersection and Rispana tri-junction etc. This type of analysis helps in identifying the major cause of traffic jam at a given intersection. Traffic jam at

Ghantaghar is due to the narrow width of Chakrata road. Subsequently, the jam spreads upto Darshan Lal intersection. During the field visit, this fact was also verified that if a traffic jam starts from Ghantaghar, it spreads to Darshanlal intersection. The remedial measure to alleviate traffic jam at Ghantaghar is to provide a one way over bridge connecting Gandhi Road to Rajpur road. Pedestrians may also play an important role in the overall management of traffic. Analysis reveals that pedestrian bridges are required at Chakrata road near Krishna palace, Tehsil chowk and Ghantaghar. This will reduce the obstruction caused by the pedestrian. Dehradun is the gateway to Mussoorie, a popular hill station. Tourists/ traffic coming from Haridwar, Saharanpur or Poanta Sahib cities have to go through Dehradun to reach Mussoorie. In order to reduce the traffic congestion it is advisable to have a bye pass. This module is able to support such options.

A web enabled system was also developed using open source Sharpmap software to integrate all the modules. Web GIS based query system accommodates all the layers required for the modules and various queries related to each component at single platform. In Web GIS based query system, a web page for every module has been created, which consists of all the layers and attributes considered in this study. The system also has the capability to make queries.

It may be concluded that the components of the RIMS have the capabilities to identify the shortest route, determine the minimum distance for a utility in RIS, attach photographs in attribute table, sort bridges by their characteristics in BMS, determine critical points, find the hospital in near vicinity of accident in AIS, identify the locations prone to traffic jam, locate pedestrian over-bridges and bye-pass road in TIS along with general queries. The best feature of this study is that road name has been used to create the exhaustive database. The urban RIMS has multi-information presentation in the form of spatial maps and graphs. Use of ancillary information, such as photograph of bridges, can assist in visual inspection for planning maintenance schedules for bridges. Similarly, it provides capability to identify critical accidents locations, provision to pedestrian over bridges for efficient traffic management, alternate routes in case of a special event, such as procession or outbreak of a fire, alignments of bye-pass etc. The urban RIMS is expected be an excellent tool for administrators and planners for road based project formulation and maintenance.

ACRONYMS AND NOTATIONS

AADT	Annual Average Daily Traffic
ACMS	Accident Management System
AGI	Association of Geographic Information
AIS	Accident Information System
ALADIN	The ALpe ADria Initiative Universities' Network
AMS	Asset Management System
AOC	Association of Oregon Counties
AQM	Ad-Hoc Query Module
ASD	Architectural System Design
BAP	Budgeting and Programming
BaTMan	Bridge and Tunnel Management system
BMS	Bridge Management System
C-DAC	Centre for Development of Advanced Computing
CGIS	Canadian Geographical Information System
CIA	Central Intelligence Agency
CMS	Content Management System
CSMS	Cut Slope Management System
CTTP	Comprehensive Traffic & Transportation Plan
DMS	Document Management System
dTIMS	Deighton's Total Infrastructure Management System
DEM	Digital Elevation Model
DFID	Department for International Development
DPWH	Department of Public Works and Highways
EIS	Environment and Social Information system
ERDAS	Earth Resources Data Analysis System
ESRI	Environmental Systems Research Institute
FHWA	Federal Highway Administration
HMS	Highway Management System

GIRAS	Geographical Information Retrieval and Analysis System
GIS	Geographical Information System
GISP	Geographical Information System for Planning
GIT	Geographic Information Technologies
GML	Geographic Markup Language
GMMS	GIS Based Maintenance Management System
GPS	Global Positioning System
GRIMMS	GIS-enabled Road Information Management and Monitoring System
GRMS	Gujarat Road Management System
HDM-4	Highway Development and Management System Version 4
HisMIS	Highways Structures Management Information System
HMS	Highway Management Sysytem
IMCS	Information Management and Control System
IMS	Infrastructure Management System
IRIS 8.0	Integrated Road Information System 8.0
IT	Information Technology
J-BMS	Japan Bridge Management System
LCPC	Laboratoire Centrale des Ponts et Chauss~es
LGII	Lithuanian Geographical Information Infrastructure
LRS	Locational Referencing System
MAAP	Microcomputer Accident Analysis Package
MAP	Map Analysis Package
MDDA	Mussorie Dehradun Development Authroity
MDR	Major District Road
MEDIC	Me´thode d’Evaluation de sce´narios de De´gradation probables d’Investissements Correspondants
MES	Monitoring and Evaluation System
MIMO	Map in – Map out
MIS	Material Information System
MIT	Massachusetts Institute of Technology

MMS	Maintenance Management System
MR&R	Maintenance, Repair and Rehabilitation
NAVSTAR	Navigation Satellite Timing And Ranging
NH	National Highway
NCGIA	National Centre for Geographic Information and Analysis
NHAI	National Highway Authority of India
OECD	Organization for Economic Cooperation and Development
OMMS	Online Management and Monitoring System
ONGC	Oil and Natural Gas Corporation
PCS	Project Control System
PMGSY	Pradhan Mantri Gramin Sadak Yojna
PMS	Pavement Management System
PMTS	Performance Monitoring System
PrMS	Project Management System
RA	Road Authorities
RAMS	Road Asset Management System
RDBMS	Relational Database Management System
RIMS	Road Information and Management System
RIA	Rich Internet Application
RIIMS	Road Information and Inventory Management System
RIMSS	Road Information and Management Support System
RIS	Road Information System
RITES	Rail India Technical and Economic Service
RMS	Road Management System
RMMS	Routine Maintenance and Management System
RRL	Regional Research Laboratory
RRS	Road Referencing System
RTAs	Road Traffic Accidents
RtMMS	Routine Maintenance Management System
SACM	Security & Access Control Module

SH	State Highway
SIG	Special Internet Group
SIM	System Information Module
SOI	Survey of India
SMEC	Snowy Mountains Engineering Corporation
SRA	Swedish Road Administration
SYMAP	Synagraphic Mapping System
TAC	Transport Association of Canada
TIGER	Topologically Integrated Geographic Encoding and Referencing
TIS	Traffic Information System
TMS	Traffic Management System
TOMS	Toll Management System
TRB	Transport Research Board
TRL	Transport Research Laboratory
TRRL	Transport and Road Research Laboratory
TSS	Traffic Surveillance System
UNC-HSRC	University of North Carolina Highway Safety Research Center
URISA	Urban and Regional Information System Association
URMS	Unsealed Road Management System
UPPWD	Uttar Pradesh Public Works Department
USA	United States of America
VOC	Vehicle Operating Cost
VRA	Vietnam Road Administration
VRIS	Village Road Information System
WMS	Web Map Service
WPS	Web Geographic Processing Service
WWW	World Wide Web
XML	eXtensible Markup Language

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CANDIDATE'S DECLARATION

I hereby certify that the work, which is being presented in the thesis entitled **"URBAN ROAD INFORMATION AND MANAGEMENT SYSTEM (RIMS) USING GEOSPATIAL TOOLS"** in fulfilment of the requirements for award of the Degree of Doctor of Philosophy, submitted in the **Department of Civil Engineering** of **Indian Institute of Technology Roorkee, Roorkee** is an authentic record of my own work, carried out during the period from August, 2008 to June, 2014 under the supervision of Dr. P. K. Garg, Professor, Department of Civil Engineering and Dr. S. K. Ghosh Professor, Department of Civil Engineering, Indian Institute of Technology Roorkee, Roorkee.

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

(Sandeep Gupta)

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

(S. K. Ghosh)
Supervisor
Dated:

(P. K. Garg)
Supervisor

The Ph. D. Viva-Voce examination of **Mr Sandeep Gupta**, Research Scholar, has been held on ___________________.

Supervisor (s) Chairman, SRC External Examiner

Head of Dept./Chairman, ODC

CHAPTER 1
INTRODUCTION

1.1 BACKGROUND

Roads have played an important role in the development process of human beings and civilization. These are also important for the economic growth of any nation. A well maintained road network may be considered as an important indicator of the economic development. A good road serves six major functions [83]:

(i) moving vehicles,
(ii) parked vehicles,
(iii) pedestrian and other non-vehicular traffic,
(iv) access to abutting properties,
(v) non-transport functions such as easement for water and power and
(vi) Social intercourse.

For development of roads, every country has constituted a separate and specific department, which is responsible for planning and construction of new roads and maintenance of existing roads.

As every coin has two faces, similarly problems are also associated with the roads and their network. The problems with the road network start with the planning phase. If the planning is not proper, it may not be able to serve its purpose at the later stage. The major and most common problems associated with the road network are maintenance and repair of roads along with bridges and culverts, traffic jams due increased traffic volume, shortage of parking space, road accidents. Roads authorities are always challenged with the limited resources in terms of money for the maintenance of the road network. Hence, the management of roads plays an important role.

After the Second World War, road transport grew rapidly, when countries expanded their road networks considerably and built new roads to open up land for development [38]. By the end of the 1980s there were about 11 million kilometers of roads in developing and transition economies like India, Pakistan, Jordan, Philippines, South Africa, Surinam, and Zambia etc [38].

These roads now carry 60 to 80 percent of all passenger and freight transport. They also provide the only form of access to most rural communities. In terms of assets, employment, and turnover, these roads are truly big business. For some developing and transition countries roads are their largest assets, with replacement costs amounting to well over $500 billion [38].

1.2 DEVELOPMENT OF ROAD MANAGEMENT SYSTEM

The development of a Road Management System (RMS) / Road Information and Management System (RIMS) has started in the early 1960's as a concept, and since then it has been implemented in many countries [120] [121]. Initially it was limited to pavement maintenance, saving in vehicle operating cost (VOC), reduced travel time, decrease in number of accidents and environmental effects. Individual studies on road management were carried out for Uganda [98], [78], Southern Africa [129], Finland [28], Indonesia [16] etc.

As per the World Bank report titled "Road Deterioration in Developing Countries" [36], the World Bank financed 85 countries for the improvements of their road networks. The World Bank wants to properly utilize its funds, so it also provided the technical assistance to these countries. The World bank made tie up with Transport and Road Research Laboratory (TRRL), United Kingdom and the Laboratoire Centrale des Ponts et Chauss~es (LCPC) France. Thereafter, the World Bank commissioned the Massachusetts Institute of Technology (MIT), United States of America [93]. As result of this, the World Bank published a series of technical papers and reports which provides guidance for the development of road management such as Information Systems for Road Management: Draft Guidelines on System Design and Data Issues by Paterson and Scullion in 1990 [106], while Transport Research Laboratory (TRL) provided the guidelines for the design and operation of road management systems [126] were very common. With the help of GIS, decision support system can also be created [94].

With the development in data collection and analysis approaches, scope of the road management system increased. For effective management of roads several, sub systems such as bridge management system, traffic information system, accident information system, pavement management system, budgeting and programming, routine maintenance and management system and environment and social information system etc., have been developed. Many countries have developed a complete road information and management with all sub systems or with few sub systems depending on requirement of the country [81], [121], [131].

Over the last 20 years, almost all road agencies have implemented some form of computerized road management system all over the world. The United States of America, Australia, European countries like United Kingdom, France and Denmark and Asian countries, like Japan, China, Singapore have developed the computer-based road information/management system completely or a part of it for their country/states/cities [89]. The purpose of these systems is to assist the agency in the planning and prioritization of road investments. The World Bank is also helping to 16 different countries on five continents for successful implementation of road management system. Among them, Argentina, Bangladesh, Botswana, Burkina Faso, Cameroon, Chile, China, Costa Rica, India, Indonesia, Mozambique, New Zealand, Papua New Guinea, Tanzania, Uruguay and USA [89].

With the advancement of Geographical Information System (GIS), it can be effectively used in the field of urban growth management and transportation analysis and planning [2]. GIS, together with Global positioning systems (GPS), aerial photography, Remote Sensing techniques, and other spatially related tools for decision making, comprise a larger array of complementary tools that can be grouped together under the more comprehensive rubric of "Geographic Information Technologies" (GIT) [122]. The trio technologies i.e. GIS, RS and GPS have been used for discovering groundwater [125]. RS is used in monitoring grass land health [32]. GIS in combination with RS is used in change detection of land use land cover pattern [111], and protected, non protected forests stands [8] and urban planning [7], GIS is alone is used in road sector [78] and road crashes [104], [105], air pollution monitoring and modeling [102]. The chronological development for GIS was given in [88], [44] while for RS it was given in [124].

Road Information and Management System (RIMS) using GIS has been developed for Namibia [120], and Philippines [81], Philippines [29], United Kingdom [107] while Highway Management System (HMS) has been developed for Korea [131]. Similarly, Road Information System (RIS) has been developed for Lithuania [61], central European countries [87], Germany [57] [112], Teramo Province, Italy [20], Bangladesh [1], Ghana [28], and Mozambique [72]. In India, for Maharashtra State [75] and Karnataka State [65], a Village Road Information System

(VRIS) [109], for rural roads information system [91] [108] [109] has been developed. Bridge Management System (BMS) has been developed for Malaysia [42][113], USA [103], Japan [74], while Accident Information System (AIS) has been developed for Japan [40], Kenya [95], Belgian [117], Afyonkarahisar city, Turkey [25] and London, United Kingdom [5], Malaysia [41] etc. In India, for Kunnur District [19] and Dehradun City [30], AIS has been developed. A report prepared by Federal Highway Administration of US Department of Transportation [116], discussed the ways of integrating Geographic Information System (GIS) with road safety analysis. Transport planning/management using GIS has been carried out for Birkenhead, Auckland [24], Owerri, Nigeria [101], Riyadh [4]. For Indian cities transport planning/management has been done [115].

1.3 NEED OF THE STUDY

In 1994, Dehradun Development Area (in northern India) was demarcated by Mussoorie Dehradun Development Authority (MDDA), which includes Dehradun Urban Area and 172 villages [18] with a gross total area of 7045.13 ha[14]. Prior to 2001, before the declaration as interim capital of the newly formed state Uttarakhand, the people liked to settle in Dehradun city for its salubrious climate and natural beauty and better job opportunities due to several Central govt./ public sector organization, such as Survey of India (SOI) and Oil and Natural Gas Corporation (ONGC) etc. Dehradun is a one of the oldest education hubs and an important tourist destination. It is the gateway to Garhwal Hills and Queen of Hills – Mussoorie. Thus, high growth of population (7,35,420 in 2001 with decadal percentage growth 37.92%) number of vehicles (205569 in 2003-04 with annual growth rate 11%) and tourists (9,28,992 with a 8.29% growth in two years) with marginal road infrastructure, inadequate public transport system aggravated the problem [11]. To manage it, RIMS may prove a better tool. For Dehradun, GIS based decision support system for developmental planning [33] and traffic accident analysis [30] have been done.

1.4 OBJECTIVES OF THE STUDY

The objective of the research work includes the development of a methodology for the management of a road network of an urban area growing at a fast speed. The methodology includes the development of information/management system for road inventory, bridges, accidents and traffic.

The specific objectives of the study are:

1. Identification of a suitable architecture capable of providing spatial and non-spatial data for road network including bridges, accidents, traffic, having capabilities to analyse and present the queries of user and traffic/road network managers with regard to the present infrastructure status.
2. Generation of a GIS database of roads and associated features comprising of spatial and non-spatial data used for information dissemination and analysis.
3. Development and integration of various components of RIMS i.e. RIS, BMS, TIS and AIS
4. Development of a suitable query system for the RIS, BMS, TIS and AIS.
5. Development of a Web-enabled RIMS for varied users.

1.5 SCOPE OF THE STUDY

Present research work is focused towards the development of a methodology for RIMS capable of providing the decision making queries. The study presents the methodology for a fast growing urban area, like Dehradun, the capital city of Utarakhand state. Four modules of RIMS, namely RIS, BMS, AIS and TIS are developed. Some of the decision making queries for the different modules are:

(i) assessing the road condition,
(ii) locating bridges and identifying maintenance requirement of bridges,
(iii) identification of accident prone areas or critical spots,
(iv) identification of shortest route during any emergency such as fire or any natural calamity,
(v) identification of critical traffic congestion areas,
(vi) identification of locations of petrol pumps, government offices, hospitals, police stations, fire stations, tourist spots, cinema halls professional institutes, schools and colleges, and
(vii) finding the location of new facilities

The intended customers for the developed RIMS include:

(a) Public Works Department
(b) Public Transport System Management officials and Bus operators
(c) Tourists/ travellers seeking information about the features or shortest path

(d) Police departments

(e) State planning commissions

(f) City Administration

(g) Disaster Management Agencies etc.

1.6 STRUCTURE OF THE THESIS

Following are the outlines of the thesis:

Chapter 2 discusses about RIMS and its various modules. This chapter also provides chronological development in the field of RIMS using GIS.

Chapter 3 focuses on review of literature regarding RIMS and its modules, RIS, BMS, AIS and TIS, along with their applications in India and abroad.

Chapter 4 discusses the methodology adopted for the development of RIMS and its associated components along with dataflow diagram.

Chapter 5 gives a detailed description of the study area and various data used in the study.

Chapter 6 presents the results obtained from the RIMS modules and their analysis.

Chapter 7 lists the conclusions of the study and provides recommendations for future work

CHAPTER 2
BASICS OF RIMS, GIS AND WEB GIS

2.1 INTRODUCTION

Roads are a major economic asset, and the management of this asset is extremely important for not only economic also for the overall development of any region. The major functions of the road management process can be categorized as (i) planning, (ii) programming and (iii) operations [67]. For the development of road, worldwide every country has a separate department, which is responsible for construction of new roads and maintenance of existing roads.

With the development of road network, the problems associated with the usage of roads arise. The major problems are maintenance of road network, including bridges, traffic jams, shortage of parking place and accidents. Moreover, transportation authorities are always challenged by increasing demands for better services under constrained budgets. Better management systems are urgently needed to support more effective decision making. Road Information and Management System (RIMS), Road Management System (RMS), Asset Management system (ASM), Infrastructure Management (IMS) and Highway Management System (HMS) are essentially components required for properly coordination, evaluation and maintenance of road infrastructure [56]. For improvement in efficiency of the road network with minimum amount and least effort, proper management of road network is required. It leads to the development of RIMS.

2.2 RMS

A Road Management System (RMS) may be defined as a system that is used to store and process road and/or bridge inventory, condition, traffic and related data for planning and management [67]. A RMS is mainly concerned with road monitoring, planning and programming. Major activities of a RMS include

(i) assessment of need,

(ii) strategic planning, including provision of budget for new development and asset preservation,

(iii) development, under budget constraints of multi-year works expenditure programs, and

(iv) collection of data.

All the above activities require large volume of spatial and non-spatial data. Major data items include road inventory, condition and traffic, and socio-economic data. Objectives of a RMS may include operation of a road network with minimum cost and high efficiency, life cycle support to the road network management, accurate information to the managers and management of road assets is important for economic development [67].

A RMS is an all encompassing framework, including both information processing and human resources, for the integrated management of the road network, including the determination and optimization of economically warranted projects, programmes, strategies and budgets, for both development and maintenance. As an essential component of any company or organization dealing with roads, a RMS is inevitable for proper and optimized planning. The purpose of RMS purpose is [67] -

(i) identification of need,
(ii) quantification of needs,
(iii) prioritization of needs and
(iv) assistance in planning and management

Fig 2.1 shows the flow chart of a typical computer based RMS framework while Fig 2.2 shows the flow of activity within a RMS. Not all RMS implementations contain all elements shown in Fig 2.1, however, there is always a minimum requirement to be met for maintaining a central database and some form of reporting [67].

2.2.1 Components of a RMS

The typical components of a RMS are given below:

(i) Road Information/Inventory System (RIS)
(ii) Pavement Management System (PMS)
(iii) Routine Maintenance and Management System (RMMS)
(iv) Bridge Management System (BMS)
(v) Traffic Information/ Monitoring System (TIS)

(vi) Accident Information System (AIS)

(vii) Environment Information System (EIS)

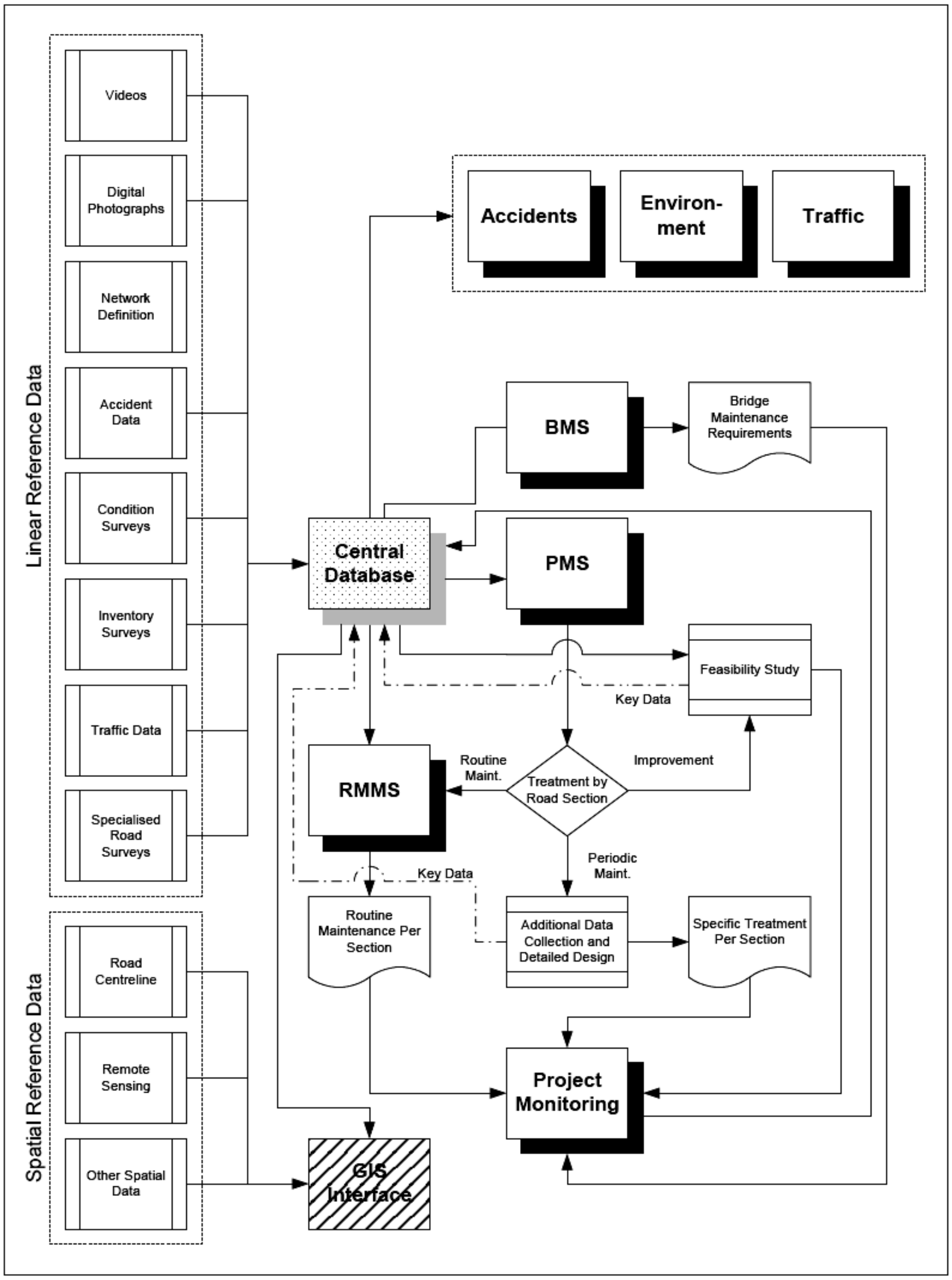


Fig 2.1: Flow Chart of a Typical RMS Framework [67]

All the above mentioned components, except (iii), with their objectives and benefits are discussed here in brief.

2.2.2 `Road Information/Inventory System (RIS)

A RIS may be defined as an integrated system for collection and storage of highway related data in a format compatible to the requirements of various user groups [66]. It is a system to collect and distribute road information so that road managers can manage roads safely and effectively. Since such road information has been broadly provided for general road users too, an even more and reliable system is required. This makes it possible to improve the system's reliability, and provide road information in a real-time manner.

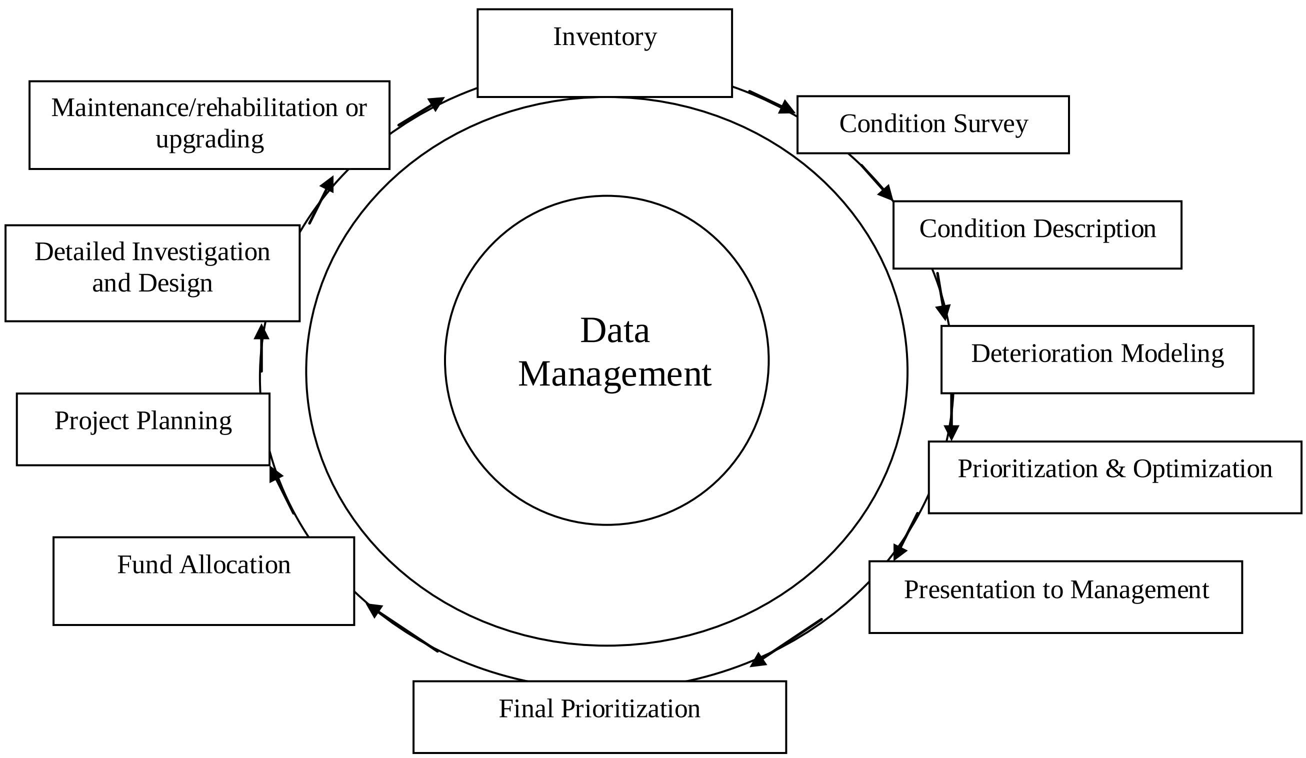


Fig 2.2: Activity Flow Used in RMS [46]

RIS is consolidated, inter-related and analytical information on the highway component characteristics, based on continuously updated data, readily available at the users end. Information would include on all highway components, such as geographical location, asset, traffic, type of pavement, bridges, accidents, operating level of service and costs, environment, etc. RIS would provide information of a road as a whole or by its individual link stretches defined by nodes. RIS helps in rational, quick and on time decision making, optimizing resources, equitable distribution of resources, minimizing costs, maximizing productivity of highway users, prolonging the life of assets, minimizing life cycle costs, measuring level of service and improving environment [66].

Few modules included in a RIS core system performs the primary functions like:

i) Locational Referencing System (LRS): To provide a common locational referencing system for the road network.

ii) Asset Management System (AMS): To setup and maintain asset management data, such as carriageway inventory, off-carriageway features, access and wayside amenities.

iii) Toll Management System (TOMS): To setup and maintain information about toll plazas and their locational referencing within a road network.

iv) Document Management System (DMS): To setup and maintain information about documents stored in the RIS database.

v) Performance Monitoring System (PMTS): To setup and maintain information about performance indicators and standards related to various road authorities performance-based contracts.

2.2.3 PMS

PMS may be defined as an all encompassing process that covers all those activities related to planning, programming, construction, maintenance, rehabilitation and research, involved in providing and maintaining pavements at an adequate level of services [37].

According to the Organization for Economic Cooperation and Development (OECD) [100], PMS may be defined as

"*the process of coordinating and controlling a comprehensive set of activities in order to maintain pavements, so as to make best possible use of the resource available*".

As per the Transport Association of Canada (TAC) [126], PMS may be defined as

"*a wide spectrum of activities, including the planning of programming of investments, design, construction, maintenance and the periodic evaluation of performance. The function of management at all levels involves comparing alternatives, coordinating activities, making decisions and seeing that they are implemented in an efficient and economical manner"*.

The PMS represents a significant tool for Financial Managers, Asset Managers and Road Maintenance Engineers. The system offers asset valuations and depreciation schedules, road inventory management, optimised pavement condition management and maintenance of works scheduling (Fig. 2.3).

PMS is used for predicting the pavement deterioration and road user costs under different maintenance scenarios. The system provides the tools necessary for Road Asset Managers to [79]:

i) analyse, optimize, prioritize and schedule road maintenance and rehabilitation programs, ensuring a rational approach to maintenance and rehabilitation of the road network
ii) provides detailed recommendations for the most cost effective maintenance treatments
iii) optimize benefits to the users of the road network
iv) provide a guide to long term financial planning, and assess the implications of alternative funding levels
v) facilitate planning, and implementing of the maintenance and rehabilitation program, and monitor its effectiveness, and
vi) minimize cost to the agency responsible for the road network

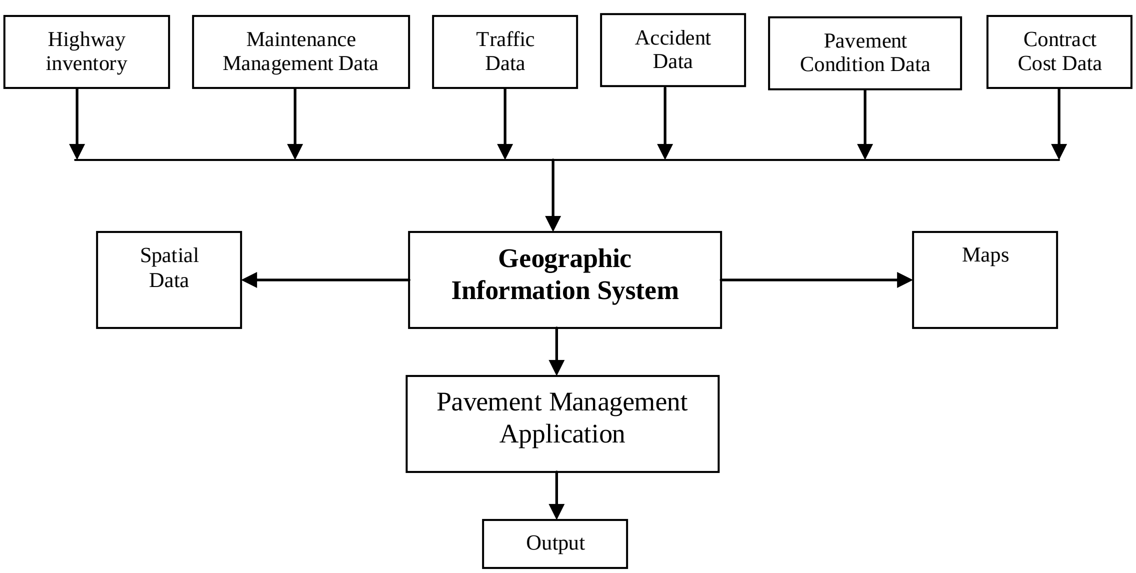


Fig 2.3: Pavement Management System [56]

The following software have been developed for PMS by different countries [79]:

1) CONFIRM Pavement Manager- United Kingdom
2) RoSY Pavement Management System- Denmark
3) Deighton's Total Infrastructure Management System (dTIMS) - Canada

4) dROAD - Canada
5) Visual PMS – United States of America
6) TMS View – United States of America
7) Dynatest - Denmark
8) ROMAN - Australia
9) Snowy Mountains Engineering Corporation (SMEC) Pavement Management System - Australia
10) Micro PAVER - United States of America
11) BELMAN - Denmark
12) Highway Development and Management System (HDM-4)- France

2.2.4 BRIDGE MANAGEMENT SYSTEM (BMS)

A BMS provides a set of tools and procedures for a systematic method of recording inventory and inspection data, assessing maintenance needs, determining optimal use of budget, and improving planning and scheduling of bridge improvements [110].

It is designed to help bridge managers/engineers to perform the basic bridge management functions as follows [110] (Fig. 2.4):

i) to have a clear picture of all the bridges being managed and to prioritize them in terms of importance relative to the overall road infrastructure
ii) to understand the maintenance needs of a particular bridge and by considering a number of intervention strategies to optimize the cost-benefit ratio
iii) to initiate and control the chosen maintenance action, and
iv) to assess the value of the bridge on a periodic basis by the inclusion of performance indicators.

PONTIS is a software tool used to prepare BMS throughout the U.S. and worldwide. This software is a component of AASHTO’s BRIDGEW suite which helps in the following:

i) Recording bridge inventory and inspection data
ii) Developing a preservation policy
iii) Simulating bridge conditions
iv) Generating work candidates, and
v) Developing a bridge program

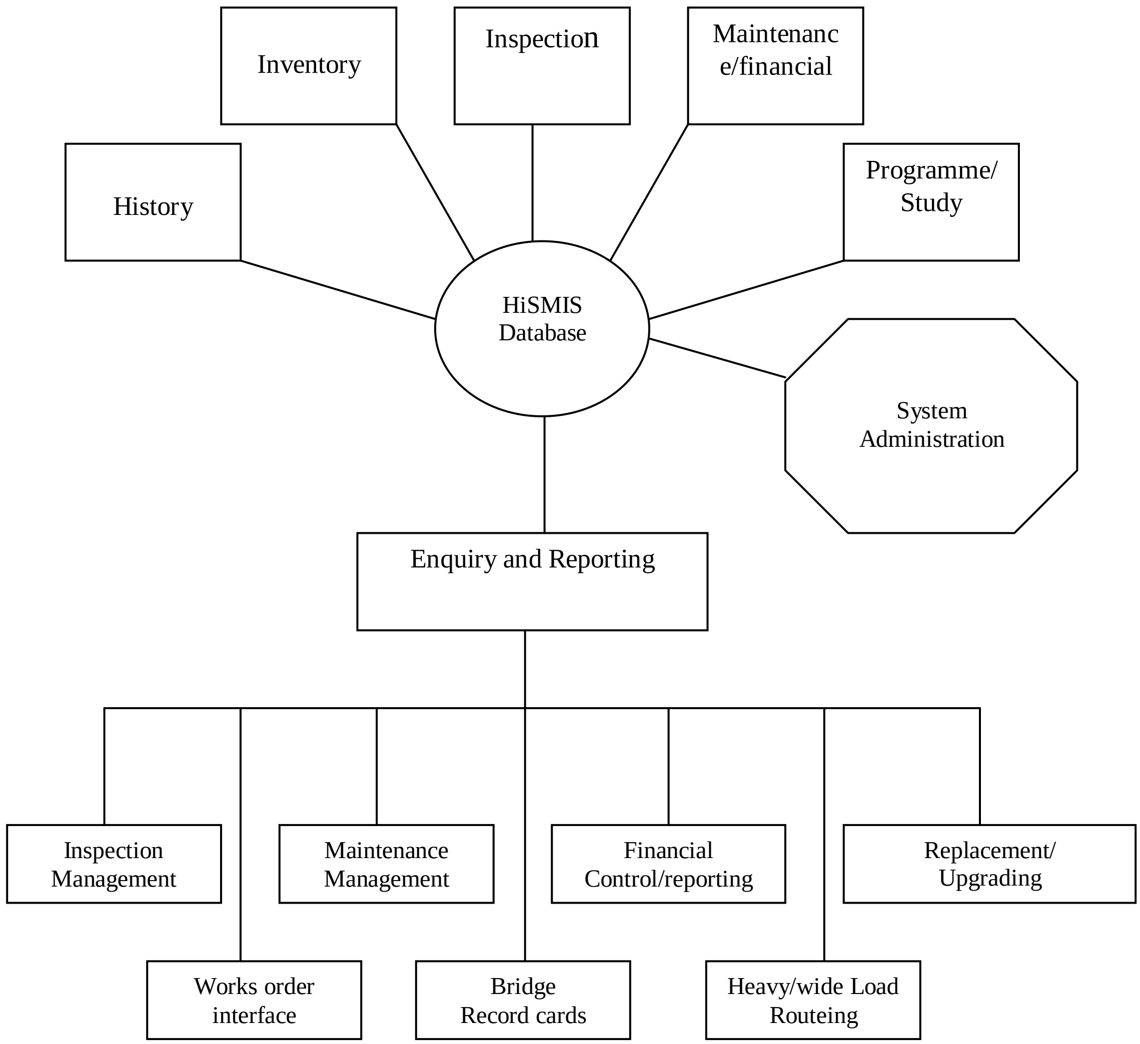


Fig 2.4: Highways Structures Management Information System (HisMIS) BMS for United Kingdom [110]

2.2.5 Traffic Information System (TIS)

A Traffic Information System (TIS) stores traffic volume data as well as data from axle load surveys and origin-destination surveys [35]. This is intended to produce a range of different kinds of analysis/results, including assignment of traffic on the network, estimation of Annual Average Daily Traffic (AADT) and traffic growth forecasts. TIS provide detailed and reliable information about the current traffic state which is hardly obtainable by the road users. The TIS is a design/build/operate scheme for the road authorities. The purpose of this system is to allow the traffic police access to the motorway network cameras for traffic low monitoring from a central location on the other hand to disperse the information to the users. The following are the benefits of a TIS:

i) Contribute to smoother traffic flows by enabling drivers to avoid traffic jams and/or accidents
ii) Increase safety levels to minimise the risks of multiple accidents, and
iii) Increase driving comfort for users

2.2.6 Accident Information System (AIS)

An AIS provides a correlation between traffic accident data with road location, inventory and condition that makes it a powerful tool for road safety analysis including identification of 'Black Spots'. It is defined as the computerization of the accident data to both reduce the cost of the process and increase process execution speed. The objectives can only be met using digital technology to collect and transmit data to a central database, wherein information extraction with a Geographical Information System (GIS) can quickly provide traffic accident information. Cost savings can be made to collate and disseminate information leading to more efficient [50].

The AIS helps road authorities to make roads safe to the users by providing sufficient safety measure at the black spots on the roads. Thus, reducing loss of life, money and traffic jam due to accidents. The benefits of AIS are as follows [50]

i) Better traffic accident investigation procedure (e.g., accident site measurements, reconstruction)
ii) Creation of an integrated traffic accident database system
iii) Geo-referencing of accident occurrences
iv) Utilization of available cost-effective technologies (e.g., GIS, GPS)
v) Utilization of client/server network architecture for better information delivery, and
vi) Training and education of traffic accident investigators in the field of accident investigation and reconstruction

2.2.7 Environment Information System (EIS)

This module is capable of storing comprehensive data related to environment and social information, enabling much wider use to reduce the unprecedented impact on the physical and human environment (Fig. 2.5). The environmental aspects of transportation activities to be considered in any study are as follows [56]

i) Use of resources and raw materials
ii) Waste generation

iii) Fuel consumption
iv) Greenhouse gas emissions
v) Releases to air
vi) Releases to water
vii) Releases to land
viii) Traffic congestion, and
ix) Noise

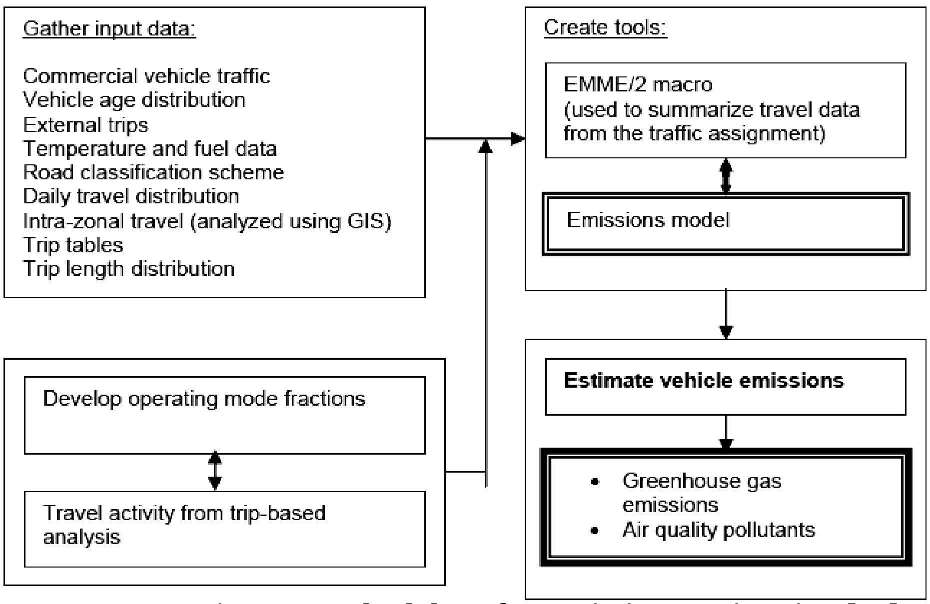


Fig 2.5: Methodology for Emissions Estimation [56]

The following are the environmental impact of transportation activities [56]

i) Depletion/conservation of a natural resource
ii) Global warming
iii) Air pollution
iv) Water pollution
v) Land contamination
vi) Traffic accidents, and
vii) Nuisance

The benefits of following EIS are as follows [56]

i) Cost savings through reduced fuel and other transport costs
ii) Reduced demand for car parking

iii) Reduced business costs associated with congestion
iv) Projecting an improved company image, and
v) Increased productivity

2.2.7 Beneficiaries of RIMS

The beneficiaries will include the following [66]:

i) Ministries of Central and State Governments
ii) Planning Commission
iii) Corporate houses (Public and private sector)
iv) Financial Institutions
v) Investment entrepreneurs
vi) Highway builders and toll companies
vii) Equipment manufacturers
viii) Truck operators
ix) Tour operators
x) Logistics firms
xi) Police
xii) Real estate developers
xiii) City managers
xiv) Academic and research institutes
xv) Consultancy firms
xvi) General public

The following are the likely benefits of implementation of RMS [69]:

i) Web based road inventory information
ii) Traffic and bridge data base
iii) Assessment of budget requirements
iv) Computersied maintenance planning
v) Condition reporting of road network, and
vi) Use of computerised planning tools in selection of projects

The successful implementation of a GIS based RMS depends on the interaction of three fundamental components i.e. Processes, Data and Technology. If any of these components are lacking, the system will not be successful.

2.3 ROLE OF SPATIAL TECHNOLOGY FOR RIMS

By using remote sensing techniques, mapping of roads, rails, water features (e.g. rivers, canals, ponds, lakes and drains etc.), bridges, culverts and public utilities (e.g. parks and tourist spots etc.) can be done easily. With the help of stereoscopic images, topography of the area can be easily known, and Digital Elevation Model (DEM) can be generated. Moreover, with the help of high resolution satellite images, location of construction material, width, geometry of roads, space available for road widening, ideal location for vehicle parking and new roads may be planned.

With the help of Global Positioning System (GPS), location of various utilities required for RMS, such as bridges, culverts, bus taxi tempo stands, parks, police stations, fire stations, government offices and establishments, and tourist spots etc. may be collected. GPS may also be used for generating contours and DEM with higher accuracy. Profiles of the road and terrain may be created from DEM which further may be helpful in developing the drainage system of the area and computing the earthwork for new roads. The only drawback with GPS is that one has to visit the field for data collection.

Geographic Information System (GIS) is helpful in integrating the spatial data as well as non- spatial data. The non-spatial data may be stored during GPS survey in the form of attributes. The parameters required for RMS may be road condition, road/bridge/culvert last repaired, type of road, material used for road construction, density of traffic, width of roads, parking space available on road sides, number of road accidents on a particular location, water logging prone sites on roads, details of bridges/culverts/embankments which may be collected and stored. Moreover, GIS is also helpful in the alignment of new roads, widening of roads, identification of ideal location of bridges/culverts/over bridges, bye pass roads. With the help of GIS, a query system may also be developed. Thus, it is very helpful to decision makers, planners, engineers, administrators, managers and contractors with its data storage, analysis and decision making capabilities.

2.3.1 GIS

The computer based GIS is considered to be started contemporary with the advent of CGIS (Canada Geographic Information system) by Roger Tomlinson, father of GIS, in 1962. Several stages of GIS evolution can be identified [15]:

• The pioneering age, from the early 1960s to about 1975.

• The second phase, approximately from 1973 until the early 1980s.

• The third phase, from about 1982 until the late 1990s.

• The last and current phase.

Few definitions of GIS are as follows:

"*A powerful set of tools for storing and retrieving at will, transforming and displaying spatial data from the real world for a particular set of purposes*" [9].

"GIS a system for capturing, storing, checking, manipulating, analysing and displaying data which are spatially referenced to the Earth" [21]

"A GIS is an application or suite of applications for viewing and creating maps. Generally, geographic information systems contain a viewing system (sometimes allowing users to view maps with a Web browser), an environment for creating maps, and a server for managing maps and data for real- time on-line viewing." [90]

The benefits of this technology are as follows [2]:

i) Integrating geographic information for display and analysis within the framework of a single consist system
ii) Allowing manipulation and display of geographical knowledge in new and exciting way
iii) Automatic geographic information and transferring them from paper to digital format
iv) Linking locations of feature(s) within the one framework of one system
v) Providing the ability to manipulate and analyze geographic information in ways that are not possible manually
vi) Automation of map making, production and updating
vii) Providing a unified database that can be accessed by more than one department or agency
viii) Storing geographic information coinciding and continuous layers (Fig 2. 6)

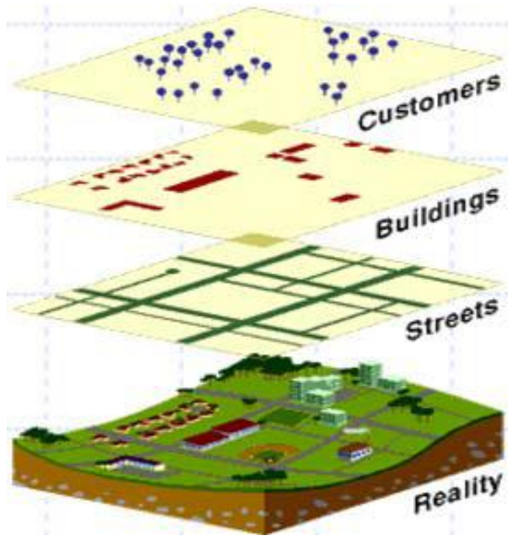


Fig 2.6: GIS representing the Real World coinciding and continuous layers [2]

2.3.2. Web GIS

From the above discussion, it is clear that GIS is capable to show spatial data along with non-spatial data (i.e., attribute data) in a desired standard format. Due to this, its acceptability has increased and moreover, GIS has made it easy to understand and interpret spatial data. Earlier, the information was limited in few hands with in a company or group of companies due existing software. Further, to use these GIS software, prior technical knowledge and hands on training was essential and of course these software were costly. Thus, the information provided by GIS was restricted with in a boundary. Such type of requirements makes it out of reach from a common man. But its application in almost every field attracts common man time and again. This problem was solved with the development of web GIS, an integration of GIS with internet [3].

Web GIS is any GIS that uses web technologies. In a narrower definition, Web GIS is any GIS that use Web Technology to communicate between components [26]. The advantages of Web GIS are

i) global reach,
ii) large number of users,
iii) better cross-platform capability,
iv) low cost as averaged by the number of users,
v) easy to use for end users,
vi) unified update and

vii) diverse application.

The functions of Web GIS are as follows[26]:

(i) mapping and query,
(ii) collection of geospatial information,
(iii) dissemination of geospatial information and
(iv) geospatial analysis.

Due to the development of web GIS, dissemination of spatial information has becomes easy. Moreover, map processing tools are also provided to extract information for a person concerned. Many private/government organizations are interested to spread maps and the processing tools for their expansion or in welfare of society irrespective of location and all around the clock. The internet technology made it possible and permits to all levels of society to get the spatial information [3]. Moreover, due to internet technology more number of people can access the spatial data and it acts as a good interface for GIS when the GIS user is not an experienced one. Making spatial information available to everybody is called “usability of GIS” in comparison to desktop- GIS, which can be used by only one experienced user at a time [73].

Web GIS is a new branch of GIS, which has developed after the development of internet technology. Research on web GIS and its application is extremely popular presently. With the development of advanced computers having large storing capacity and high processing speed, the use of this web GIS technology became more amenable and time saving such as high raster images and Digital Terrain Model (DTM) and other vector data can be processed and downloaded at a much faster rate [80].

In present era, the demand of spatial information and its processing has increased rapidly, therefore require high end computing facility having large storage and processing capacity. Moreover, need for sharing has increased for spatial data by various set of user like departments in public administration, professionals, citizens etc. [128]. With tremendous increase in data from earth and space based sensors, there is growing realization with in geosciences community that technologies like web services and allied technologies need to be leveraged for geospatial data analysis and management [17].

Web GIS has the capability of storing, analyzing and rendering integration of geo spatial data from a wide variety of sources and as it is available on internet, which can be extracted by the user or can get visual response from it [97]. Vector data consume less memory space, therefore, its rate of transmission is more in comparison to raster data. Vector data provide more functionality to uses. For example, single objects can be selected directly or highlighted [3].

Further, standard formats for transferring data over the internet are under development by different organizations. The open GIS consortium, for example, presents Geography Markup Language (GML). GML shall enable the transport and storage of the geographical information in eXtensible Markup Language (XML). Geographic information includes both properties and the geometry of geographic features [23].

To publish map data on web, several technology levels can be employed. It may start from sites that simply publish static web maps to more sophisticated sites which support dynamic maps, interactively customized maps and multiple computer platforms and operating systems. The most challenging map is interactive map in terms of web GIS. Within open GIS consortium, a Special Internet Group (SIG) for world wide web (www) mapping is working on issues of web GIS based publishing. Open GIS model for portrayal at work flow is developed by this group. This group has recently developed an essential model of interactive portrayal, as shown in Fig 2.7.

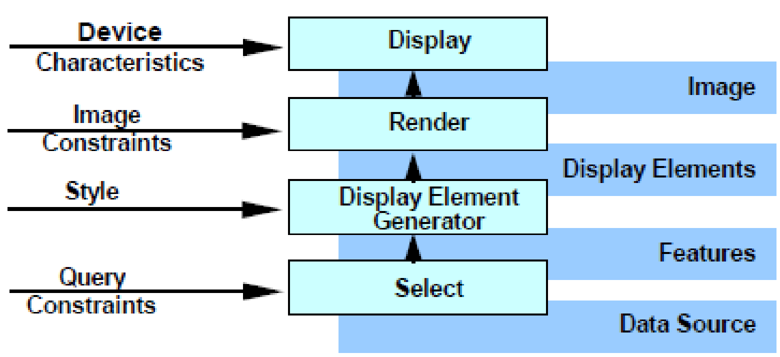


Fig 2.7: Open GIS model of Portrayal Workflow [23]

In performing the GIS analysis tasks, web GIS is similar to the client/server typical three-tier architecture. A client typically is a web browser. The server-side consists of a web server, web GIS software and database as shown in Figure 2.8 [39].

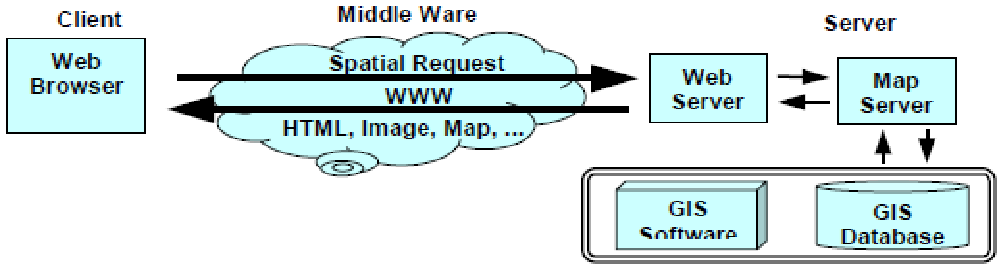


Fig 2.8: Typical Web GIS Model

A typical software architecture for Web-based GIS application can be envisaged to one as proposed by [12] and schematically represented in Fig 2.9. It is clear from the above architecture that the GIS software is an integrated part of the architecture. Fig 2.10 shows the free and open source GIS Software [118]. The desk GIS candidate software (open source GIS) as shown in table 2.2 [13].

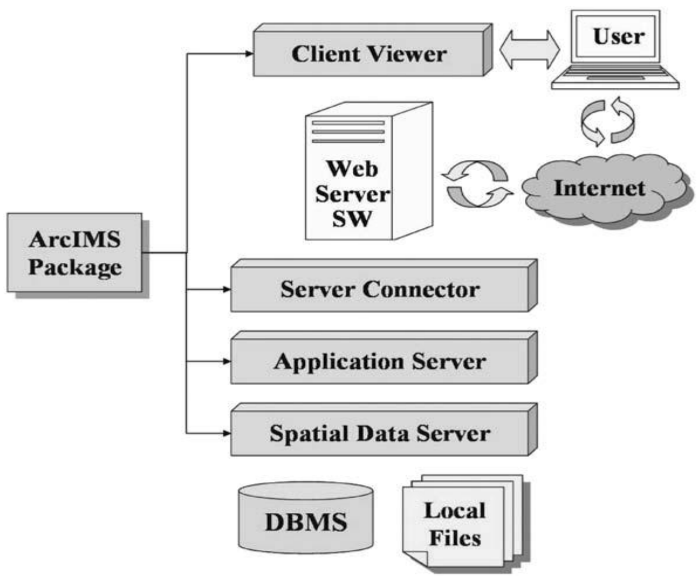


Fig 2.9: Software architecture of Web-based system [12]

Recent development in object oriented programming makes it possible to produce software components, and send them to the client before running it in the client machine, such as Java Classes, Active X components and plug-ins. This comes out to the thick client (client side applications) GIS (Fig 2.11). The thick-client architecture lets the client machine do the most processing works locally. On the other hand, in a thin-client (server side applications) system, the clients only have user interfaces to communicate with the server and display the results (Fig 2.12). Both thin and thick-client systems have some advantages and disadvantages, but they are not the best solution in terms of taking advantages of network resources [3].

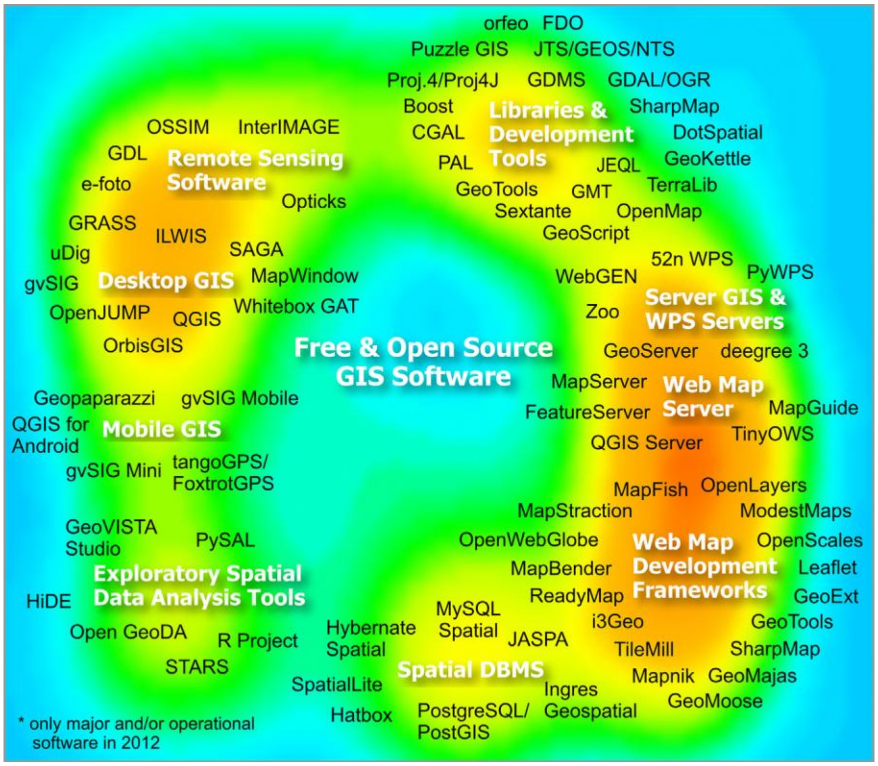


Fig 2.10: Free and open source GIS Software [118]

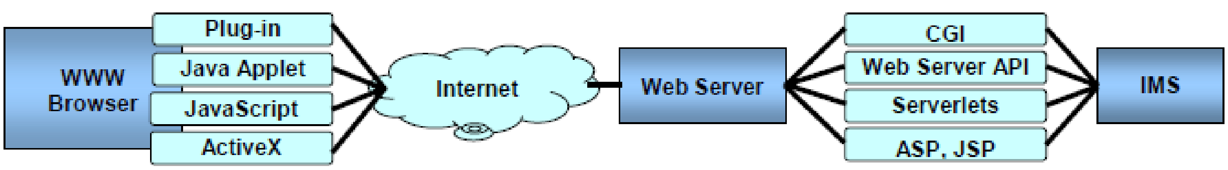


Fig 2.11: Client Side Applications [10]

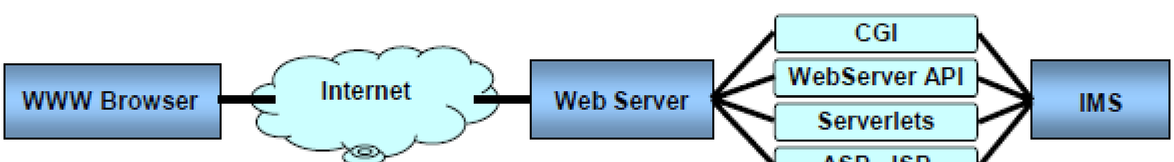


Fig 2.12: Server Side Applications [39]

For avoiding vector data in the client side and reducing problems of above mentioned architectures, Medium client is suggested. By using extensions in both client and server side, client may have more functionality than Thin client architecture. In Fig 2.13, these four components in interactive map are pictured as services, each with interfaces, which can be invoked by clients of that service [3].

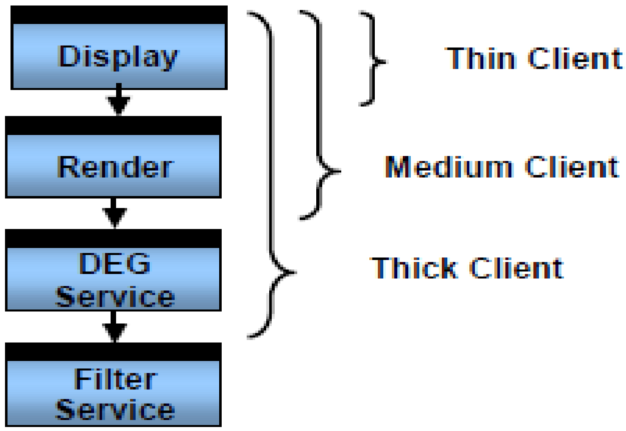


Fig 2.13: Medium Client positions in Open GIS point of view [3]

2.4 CONCLUSION

It is clear from the above discussions that GIS and Web GIS are very important tools for the development of RIMS. A wide variety of open source GIS software are freely available on internet. The linkage of these open source GIS software with World Wide Web is easy and compatible. Integration of an open source GIS software with internet will make it easy and handy to use RIMS, as users do not require much expertise which is normally required to use a traditional GIS software.

CHAPTER 3
LITERATURE REVIEW

Review of literature has been carried out for RIMS and its main modules i.e., RIS, BMS, AIS & TIS. Some salient and important case studies are presented here.

3.1 RIMS

To improve the efficiency of management and operation of more than 17,000 km of national highways and some 4,400 bridges, Vietnam Road Administration (VRA) and its sub-ordinate agency level implemented a RIMS during years 2004 and 2005. The RIMS covers the whole country and locally collected road and bridge data which is merged into one central unified database at VRA [59].

Road Mentor System Development project, funded by the Government of Tanzania and Department for International Development (DFID) of United Kingdom and managed by TANROADS, was developed with the aim of re-organisation of responsibilities within the roads sector. The broad objectives of the project were [71];

(i) to establish local capacity for applying the Road Mentor maintenance management system on a continuing basis for preparing maintenance programmes for paved and unpaved roads, and

(ii) to develop procedures for network and project level data collection, treatment selection and prioritisation and incorporate into updated software and operational guidance.

Philippines developed a Locational Referencing System (LRS) which is a GIS based Road Information and Management Support System (RIMSS). The Department of Public Works and Highways (DPWH) surveyed 29,000 km of national road network of Philippines using GPS, and divided it into 8,000 nodes (points in the road network) and 9,000 sections (the road's centerline between two nodes). During the survey GPS video data of road network and roughness data of the paved roads were also collected [81].

A web-GIS-based road management system known as "Kyoto Michimori-kun" has been developed in Japan. This system adopts Google maps as web-GIS. By the use of web-GIS as the search interface, the road management operation becomes more efficient [96].

Tekie [120] described the progress and development of GIS based Road Management System (RMS) in Namibia. The main requirements for RMS in Namibia are -

(i) to determine a stable funding requirement for the provision and maintenance of road network infrastructure. This information is being used by the Road Fund Administration to determine appropriate road user charges,

(ii) to assist the Road Authorities (RA) in being effective (doing the right things) and efficient (doing things right) in the provision of a safe and cost-effective road network, and

(iii) to ensure accountability towards the Namibian public.

The systems developed in this study include

(i) Architectural System Design (ASD),

(ii) Road Referencing System (RRS),

(iii) Traffic Surveillance System (TSS),

(iv) Information Management and Control System (IMCS),

(v) PMS,

(vi) GIS,

(vii) Unsealed Road Management System (URMS),

(viii) Material Information System (MIS),

(ix) BMS,

(x) Network Integration Module of IMCS,

(xi) Project Control System (PCS),

(xii) Maintenance Management System (MMS), and

(xiii) Network Integration Module.

A GIS–based integrated highway management system (HMS) was developed for Korea [131]. The system is capable of generating and providing comprehensive highway data by introducing and operating a unified location reference system in connection with existing highway-related systems and establishing a linkage between the highway digital maps and a variety of highway-related data. This system is web based and developed to accommodate needs and requirements of computer system engineers, highway decision makers, and highway engineers. The HMS is an operating stage. The sub-systems of HMS include PMS, BMS, traffic monitoring system (TMS), CAD drawings and registers management system (NAHMIS), cut slope management system (CSMS).

A fully integrated Road Asset Management System (RAMS) has been developed for a Government agency of Australia, which manages road infrastructure, safety and traffic management and driver licensing and vehicle registration with the target to design and develop a fully integrated system with thin customer interface for road asset management [60].

The Government of Tamil Nadu has developed a Road Information and Inventory Management System (RIIMS) to provide

(i) a operating road network with minimum cost and high efficiency,
(ii) life cycle support to the road network management,
(iii) accurate information to the managers, and
(iv) managing road asset.

In this work, following modules were developed [68], [69], [70].

(i) Road Inventory Information,
(ii) Road Asset Information,
(iii) Road Condition Information,
(iv) Traffic Information,
(v) Bridge Information, and
(vi) Accident Information

As per the presentation on Gujarat Road Management System (GRMS) by Satyakam Sahu, Senior Transport Planner, LEA Associates South Asia Private Ltd. [47], the primary objective of the GRMS, India was to improve the quality and delivery of services in the provision and management of the road system. The GRMS enhance the capabilities of the department by providing a source of readily accessible, relevant and valid information on the road system as well as improved support for decision-making by providing various modern, analytical tools. The typical components of a GRMS include RIS, PMS, RMMS, BMS, TIS, AIS, EIS, MES and BAP.

The objective of RMIS in Punjab State India is to create a digital base map of roads and bridges in the State of Punjab for 9200 km of national highways, state highways, district roads and other district roads by using the spatial data and non-spatial data. Based on the input, the followings are the common analysis done by the road authorities: [62], [63], [64]

i) Digging historical & current information about Road / Bridge / Junction
ii) Buffering (width along the road / canal / power line / railway line)
iii) Overlay (putting layers on top of each other i.e. Thematic Layer), and
iv) Network Analysis (pipelines, traffic patterns)

As per the “Report on Engagement of IT Expertise to Enhance Computerization and IT Training Action (Final) Report No. 2 (2007)” [50], a Management Information System (MIS) was developed for Uttar Pradesh Public Works Department (UPPWD) India with the main focus to fully computerise the existing manual operations and procedures in PWD. The RIS, PMS, Routine Maintenance Management System (RtMMS), TIS, BMS, Budgeting and Prioritization System (BAP), Project Management System (PrMS), Accident Information System (AIS), EIS, and e-Tendering were developed as sub-modules of the MIS.

National Highway Authority of India (NHAI) India has created a GIS based road management system for the National Highways using modern techniques of remote sensing satellite imagery and GPS based surveys. It is expected to provide the following: [51]

i) Web publishing of project data for project monitoring and Highway asset management
ii) Fast access to project status and other vital project information.
iii) Updation of feature data
iv) Maximizing ease of access through user friendly Graphical User Interface, and
v) Easy scalability for handling large volume of data access

3.2 RIS

Integrated Road Information System 8.0 (IRIS 8.0) has been developed by the Association of Oregon Counties [43] (AOC) consisting of 36 counties. The population varies from under 2000 to over 600000, specifically for use by the counties of Oregon to acquire and maintain data concerning the roads and related objects contained within the counties. IRIS provides a seamless method for any Oregon road department to have a complete computerized road inventory system in a Microsoft Windows environment. This system provides both managerial and technical assistance. The managerial assistance is provided in the large number of reports and graphs. The technical assistance is provided for data entry checking and validation. The goal of IRIS is to provide Oregon counties with the required management systems and tools to allow them to efficiently and effectively manage their road departments. The IRIS consists of the Road Inventory, Pavement Management, Cost accounting, Maintenance Management, Service Request, GIS, Document Management, Accounts Payable, Accounts Receivable, Equipment Management and Vegetation Management modules.

Lithuanian Road Administration has undertaken a Lithuanian Geographical Information Infrastructure (LGII) project. Goal of LGII is to develop an official geographic information source system or infrastructure and information environment allowing the incorporation of geographic information into almost any public sector information services. With this system, it should be possible to combine seamlessly spatial information from different sources across Europe and share it between many users and application [66].

The Central Europe Road Information System for Security and Tourism is a joint project of the Universities of Novi Sad, Trieste and Verona for precise data acquisition on the trans-national road network and the extension to the ALADIN (the ALpe ADria Initiative Universities' Network) Group. This project consists of the application of instruments and methods that are currently available but are to be used in an innovative way. There is also a direct link between this project and the road cadastre prototype (already produced); a project coordinated by the Regional Government itself and concerning the roads in the four provinces of the Friuli- Venezia Giulia region [87].

A Transportation Infrastructure Management, a GIS based Road Information and Management System to manage nearly 0.2 million km of road network in the state of Maharastra, India has developed. The GIS interface of the system is coupled to an attribute information base residing in an RDBMS (Relational Database Management System), thereby providing for extensive database querying in a user-friendly environment. The system has been implemented across the state and is being utilized as an effective decision support tool [75].

Centre for Development of Advanced Computing (C-DAC) has developed GIS-enabled Road Information Management and Monitoring System (GRIMMS), which provides GIS interface to the existing Online Management and Monitoring System (OMMS). The OMMS is the management information system for *Pradhan Mantri Gramin Sadak Yojna* (PMGSY) which is a popular Central Government Scheme. The PMGSY GIS project involved generation of spatial database, customisation of a standalone GIS system (GRIMMS-S) and development of web GIS (GRIMMS-Web) application [45].

National Highway Authority of India (NHAI) has developed a RIS for Golden [66] Quadrilateral for a length of 5,846 km connecting North South East West parts of India, together. RIS comprises of computerised time series database on highways attributes, like traffic analysis, pavement condition, road inventory, asset condition on GIS interface along with economic modeling with HDM – IV software. RIS has two major groups i.e. core system and support modules. RIS core system contains -

(i) Locational Referencing System (LRS),
(ii) Asset Management System (AMS),
(iii) PMS,
(iv) EMS,
(v) Traffic Management System (TMS),
(vi) Accident Management System (ACMS),
(vii) BMS,
(viii) Toll Management System (TOMS), and
(ix) Document Management System (DMS).

RIS support modules has following [66]-

(i) Security & Access Control Module (SACM),
(ii) System Information Module (SIM),
(iii) Ad-Hoc Query Module (AQM),
(iv) HDM-4 Integration Module (HIM), and
(v) GIS.

3.3 BMS

Public Works Department Malaysia (JKR) has developed an in-house computerized BMS in 1989. The system, called JKR BMS, subsequently enhanced to include the incorporation of picture images in early 1992. Despite the popularity of GIS technology, there is no BMS today which is completely GlS-based. JKR is about to embark on an in-house development of a GlS-based BMS [27], [47].

The Swedish Road Administration (SRA) has developed an information technology based Bridge and Tunnel Management system (BaTMan) that is widely implemented by the organisation. It is a tool for operational, tactical and strategic management, but does not include systems and tools for managing optimisation and long-term planning of Maintenance, Repair and Rehabilitation (MR&R) actions due to service life performance aspects. The unique feature of this bridge management system is the need of service life performance analysis for sound optimization and long-term planning of MR&R actions in the bridge management. The service life performance analysis model is based on a Markov Chain model and the MEDIC (Me´thode d'Evaluation de sce´narios de De´gradation probables d'Investissements Correspondants) method. The main activities in the Swedish bridge management include everything from inspection to verification of completed MR&R projects [35].

Orndoff & Vasudevan [103] developed a web-based Bridge Management System (BMS) by combining the GIS and the Internet. The stakeholders, elected officials, and the public need to have access to information, and this Internet-based system is an efficient way to reach a large number of users at a low cost. Arc IMS helps in distributing geographic information over the internet, which allows for real-time integration of data. A web-based system helps departments share data, potentially paving the way for a comprehensive asset management system. A web-based BMS could be a significant step by the agencies in building a comprehensive asset management system encompassing all infrastructures.

The Japan Bridge Management System (J-BMS) was developed for damaged concrete bridges. The J-BMS not only evaluates the performance of bridges, but also offers a rehabilitation strategy based on a combination of maintenance cost minimization and quality maximization and applied to existing concrete bridges is so as to demonstrate the validity of the system [92].

3.4 Traffic Information System

Shinji [114] developed a traffic information systems in Japan using internet technology to build up and confirm effect of original traffic information systems which includes trip time, parking facility situation and video monitoring. This information system can give the driver trip-time by using the information board on the road and world wide web.

A study carried out in United Kingdom discusses traffic management systems in [116] improving the competitive edge of transportation sectors, and traffic divisions in particular. It discusses the process of building an information management system and technology to improve the transportation and traffic units. It highlights the lessons learnt from the experience of building traffic information systems and the steps needed to improve it. These steps will enable traffic managers to adapt their decisions; deliver efficient traffic management; make decisions that suites changing traffic patterns associated with incidents and special events on the road network. Consequently, traffic departments will no longer need to rely on snapshot views of traffic conditions. Traffic planning will be revolutionised because the system will incorporate traffic simulation models that will enable traffic departments to analyse the congested networks.

3.5 Accident Information System (AIS)

The improvement in the efficiency and effectiveness of traffic accident counter-measures by using the GIS in the analysis of traffic accidents in Japan [40]. The system databases contain digital road map, traffic accident, road, traffic volume and weather. Data include road structure (longitudinal grade, horizontal alignment, width) and road accessory facilities (center strip, guard fence, roadway lighting). Weather data are collected from the meteorological authority of each area, which include temperature, rainfall, snowfall, and hours of sunshine. Traffic volume data is linked with 12-hour traffic volume and day-night ratio. Since the system is intended for a wide spectrum of users, a simple graphic user interface is required to be designed that is easy to use. A study carried out by Traffic Engineering Division of the Civil Engineering Research Institute, Hokkaido, Japan, has developed such a system in which digital maps are linked with data of traffic accidents, roads and weather [40].

The rapid urbanization and motorization have resulted in deterioration to environment, traffic congestion and major road safety issues. Road accident is one of the major problems in

Malaysia. In response to this problem, Malaysian Government has adopted Microcomputer Accident Analysis Package (MAAP) in managing and analyzing the accident related information since year 1991. However, MAAP database is inadequate, especially in identifying accident-prone location. The best approach to improve accident location identification is to integrate the GIS and MAAP to form more comprehensive accident analysis systems [41].

Spatial patterns in Honolulu motor vehicle accidents for 1990 were prepared [84] [85]. A method for geo-coding accident locations is utilized with approximately 98% of the crash locations being identified. Spatial software tools are developed for describing the degree of spatial concentration. The spatial patterns of different types of accidents for every hour of the day, weekdays and weekends separately, are analyzed. Accidents spatially fluctuate dynamically, as a response to changing traffic patterns and volume. Generally, most accidents are closer to employment centers than to residential areas. In the suburban and rural areas, however, accidents are more likely to involve fatalities or serious injuries and be related to night-time driving and alcohol. It is shown that these conditions spatially correlate with single-vehicle crashes and crashes with opposite direction vehicles. The spatial patterns point to the limits of "blackspot" analysis.

Mwatelah [95] discussed various measures to reduce the problem of road traffic accidents through the inclusion of new technologies in developing countries, so that proper decisions can be taken precisely to provide remedial solutions to the occurrences of road traffic accidents. GIS is a technology which when incorporated in the analysis of road traffic accidents, can alleviate this menace. An important data base which will allow for the analysis of road traffic accidents on highways using GIS software was created. This approach is argued as feasible since it will facilitate a quick way of data retrieval, in addition to facilitating a means of making precise remedial engineering designs to improve road sections which are prone to road traffic accidents.

Steenberghen [117] described the usefulness of GIS and point pattern techniques for defining road-accident black zones within urban agglomerations. The location of road accidents is based on dynamic segmentation, address geocoding and intersection identification. One-dimensional (line) and two dimensional (area) clustering techniques for road accidents are compared. Advantages and drawbacks are discussed in relation to network and traffic characteristics. Linear spatial clustering techniques appear to be better suited when traffic flows can be clearly identified along certain routes. For dense road networks with diffuse traffic patterns, two-dimensional techniques make it possible to identify accident-prone areas. The operationality of the techniques is illustrated by showing the impact of traffic-calming measures on the location and type of accidents in one Belgian town.

A GIS based traffic accident data collection, referencing and analysis framework for Abu Dhabi municipality was developed [76]. This is part of a strategy to implement a GIS based Transportation Information and Management System comprising of several components including an accident management system. This study revealed the main findings of the initial study, together with the proposed framework of the new system. In particular, the study discussed some of the results of a regional and international review of similar initiatives. The study also explains the method of using GPS to reference an accident location by using a GIS map, since the accurate identification of accident location was a critical element. The study is still underway and the final output is expected to be a workable GIS based accident data collection, referencing, management and analysis system.

Loo [86] did the validation of spatial variables of the crash database in Hong Kong from year 1993 to 2004. The proposed spatial data validation system makes use of three databases (the crash, road network and district board databases) and relies on GIS to carry out most of the validation steps so that the human resource required for manually checking the accuracy of the spatial data can be enormously reduced. With the GIS-based spatial data validation system, it was found that about 65 to 80% of the police crash records from 1993 to 2004 had correct road names and district board information. In 2004, the police crash database contained about 12.7% mistakes for road names and 9.7% mistakes for district boards. The situation was broadly comparable to the United Kingdom. However, the results also suggest that safety researchers should carefully validate spatial data in the crash database before scientific analysis.

A GIS-based traffic accident analysis system for Afyonkarahisar city, Turkey has been developed [25]. They used GIS technology for visualization of accident data and analysis of hot spots in highways. Many traffic agencies have been using GIS for accident analysis. Accident analysis studies aim at the identification of high rate accident locations and safety deficient areas on the highways. So, traffic officials can implement precautionary measures and provisions for traffic safety.

A study by Tiglaco [123] suggests that the success of traffic safety and highway improvement programmes hinge on the analysis of accurate and reliable traffic accident data. This study discussed the present state of traffic accident information in Metro Manila. It also revealed the potentials of developing a traffic accidents information system using GIS. Lastly, this study comes up with some recommendations on the institutionalization of such a system line Metro Manila.

3.6 CONCLUSION

It can be derived from the above discussions that GIS and Web GIS are very helpful tools for the development of RIMS. Generally, RIMS have been devised for developed countries. Very little work has been carried out in India for development and use of RIMS. In particular, no significant has been done to develop RIMS for urban areas in India. Since there is a great need and scope to develop RIMS for urban areas, the propose work has been undertaken in Dehradun urban area using the geospatial tools.

CHAPTER 4
METHODOLOGY

4.1 INTRODUCTION

In order to develop urban RIMS, which consists of RIS, BMS, AIS and TIS modules, a well structured approach has to be adopted. In the present research work of development of urban RIMS, after collecting the data from various sources, basic thematic layers were generated and designed attribute data was entered. Then, the selected modules i.e. RIS, BMS, AIS and TIS are generated to achieve the desired objective within a GIS environment and then in web GIS environment. To get the results in the form of maps, tables and graphs, spatial and attribute based queries and network & buffer analysis were carried out in GIS environment.

4.2 DEVELOPMENT OF METHODOLOGY FOR URBAN RIMS

The following steps were taken to develop the RIMS. Table 4.1 shows the basic data layers generated and their use for development the modules, i.e. RIS, BMS, AIS and TIS.

1. Collection of relevant data/maps/ satellite images
2. Design of the database (spatial and non-spatial)
3. Georeferencing of SOI toposheets with various satellite data
4. Generation of thematic layers and creation of database
5. Field visit for data collection and verification
6. Updation of data with the help of field visits, IRS Cartosat -1 and IKONOS image
7. Development of various components of RIMS i.e., RIS, BMS, AIS and TIS in GIS environment
8. Analysis and query development through GIS software
9. Availability of RIMS on web

4.2.1 Urban RIMS in Arc GIS 9.2 Environment

For development of RIMS in GIS environment, its modules under consideration were developed. The main reason for development of modules in GIS environment is to use the facility of

Table 4.1: Layers Generated for RIMS and their use in Various Module

Layers	RIMS Modules			
	RIS	BMS	AIS	TIS
Point Features				
Bridge		√		
Intersections	√	√	√	√
Cinema Halls	√			√
Colleges	√			√
Fire Stations	√			√
Government Offices	√			√
Hospitals	√			√
Hotels	√			√
Peak Hour Pedestrian Traffic				√
Peak Hour Traffic Volume				√
Petrol Pumps	√			√
Police Stations	√			√
Professional Institutes	√			√
Railway Crossing	√			√
Railway Stations	√			√
Road Accident for the year 2002 - 2006			√	
Schools	√			√
Tourist Spots	√			√
Line Features				
Boundary	√	√	√	√
Bus Route	√	√	√	√
Railway Lines	√			√
Roads	√	√		√
Polygon Features				
Drains	√	√	√	√
Rivers	√	√	√	√
Villages	√			√

network and buffer analysis. For development of modules in GIS environment geo-database has been created for every module and queries and spatial analysis were carried out. The flow diagram and data flow diagram for methodology are shown in Figs 4.1 and 4.2, respectively.

4.2.1.1 Development of RIS Module

The methodology flow diagram to develop RIS in Arc GIS 9.2 environment is shown in Fig 4.3. To start with the module first of all toposheets and maps have been scanned, georeferenced and digitized. All desired attribute information, collected from field, has been stored in the shape file. In RIS, maximum generated data is used. For this basic thematic files like rivers, roads, study area boundary, villages and others files like police and sub police station, schools, colleges, professional institutes, petrol pumps, fire stations, tourist spots, hospitals, hotels and crossing etc have been used and finally geo-database has been created. For RIS module, road shape file has most importance as it provides the information regarding road feature.

4.2.1.2 Development of BMS Module

Fig 4.4 shows the methodology flow diagram for development of BMS module. For development of BMS module, bridge shape file with its attribute data is of utmost important along with the road. The attribute information, for bridge may include name of road and river, length of bridge, number of spans and its span length, type of bridge structure, the loading class, type of railing, road surface and maintenance requirement has been defined. The one of the special feature of this module is inclusion of a photograph of the bridge along with its shapefile. Geo-database is created by using the files of bridge, road, rivers, drains, study area boundary etc.

4.2.1.3 Development of AIS Module

For the development AIS module accident data collected for the period 2002-2006 is used. The attribute information, for accident shape file, like time, vehicle involved in accidents, casualty, and police station information has been used. The methodology flow chart is shown in Fig 4.5.

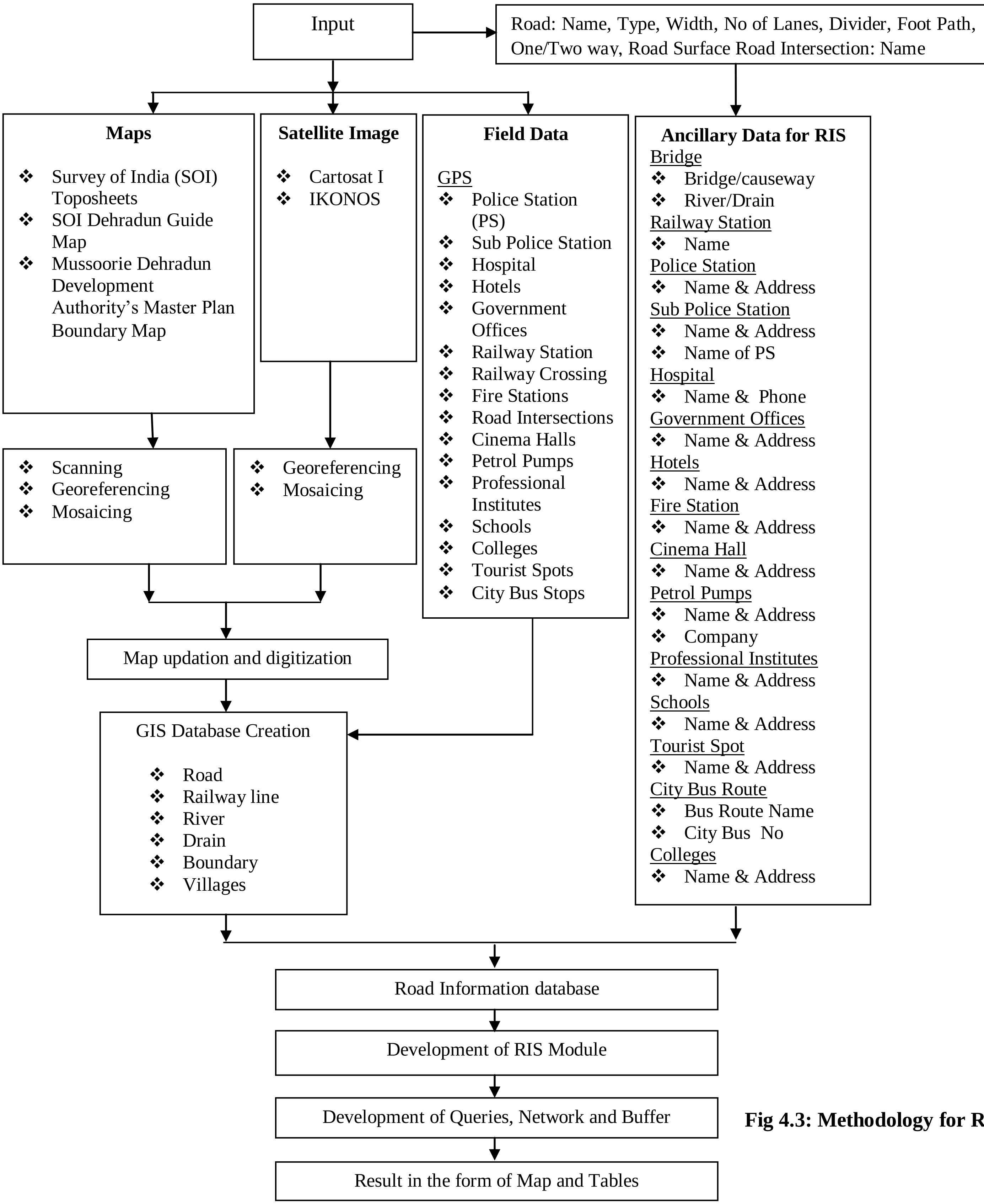


Fig 4.3: Methodology for RIS

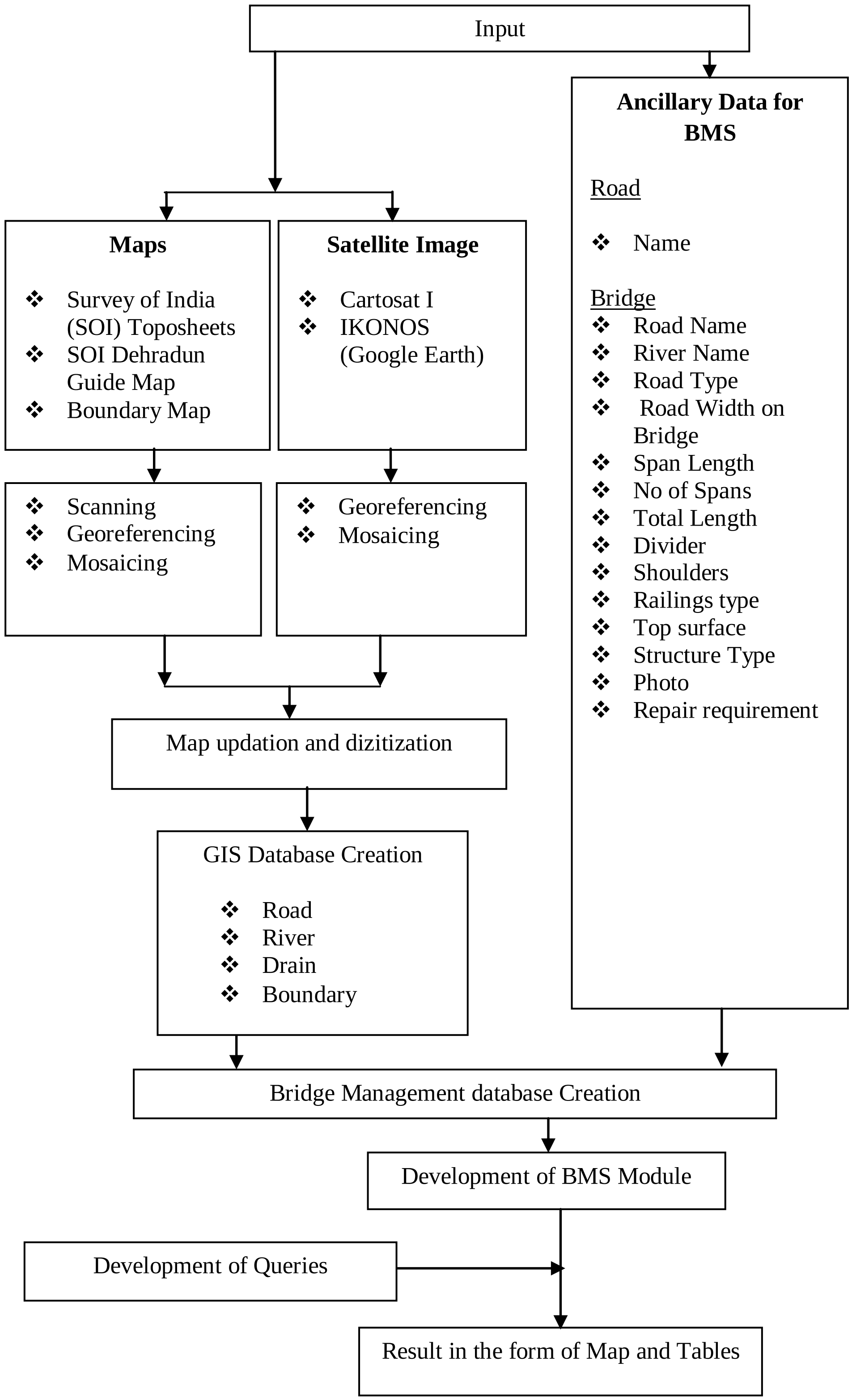


Fig 4.4: Methodology for BMS

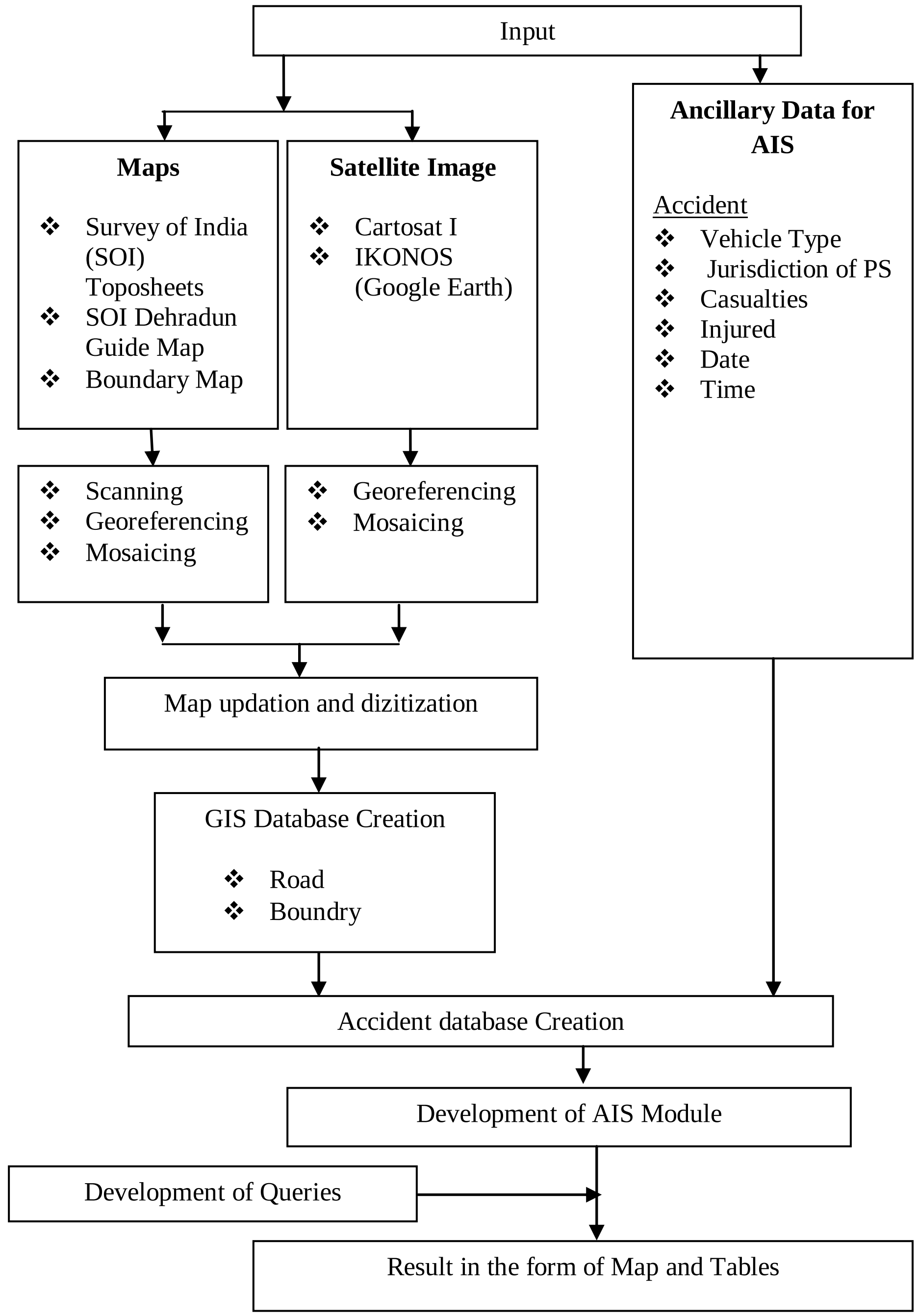


Fig 4.5: Methodology for AIS

4.2.1.4 Development of TIS Module

For the development of TIS module, the used methodology is shown in Fig 4.6. In this traffic volume and pedestrian traffic data has been used along with basic thematic files.

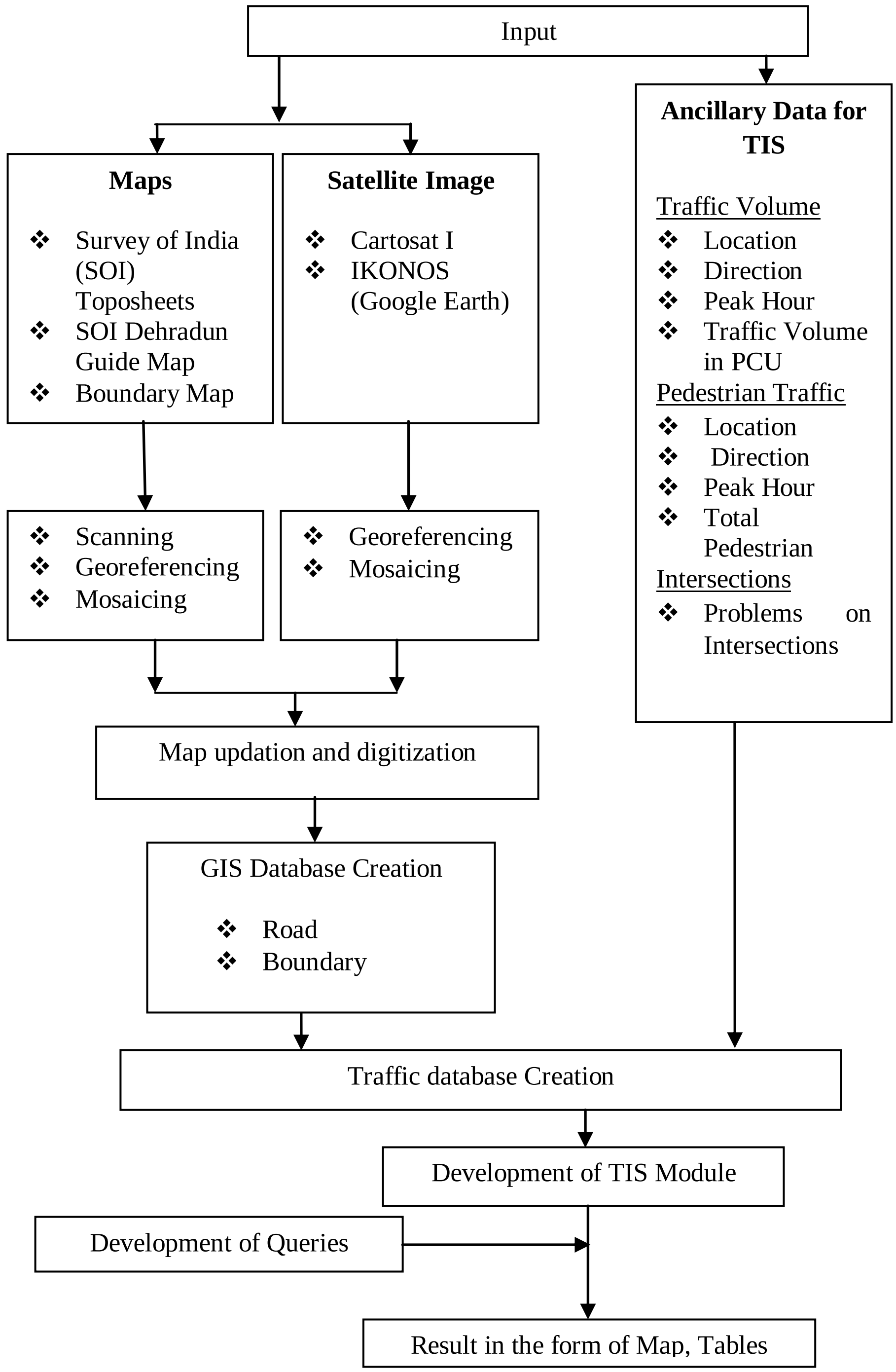


Fig4.6: Methodology for TIS

4.2.2 Urban RIMS in Web GIS Environment

For development of RIMS in web GIS environment open source software Sharp Map 2.0 was used. For development of database SQL server 2008 was used. For web publication C# with

ASP.net was used. The web architecture adopted is shown in Fig 4.7. The entity relationship (E-R) diagram for RIMS with its modules is shown in Fig 4.8. First of all, generated .shp files have been converted to .dbo file, compatible for Sharp Map, with the help of a converter as shown in Fig 4.9. These .dbo files are used for development of web enabled modules.

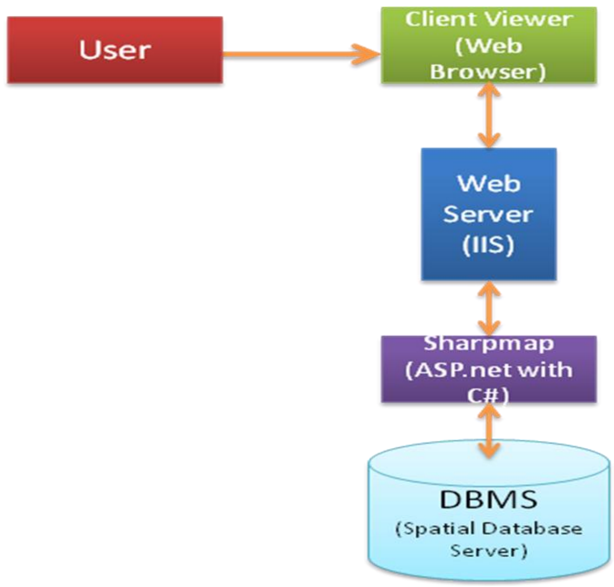


Fig 4.7 Web Architecture for Web Enabled System

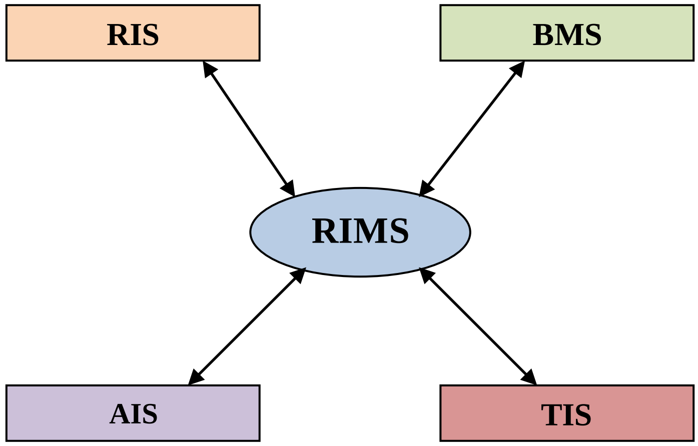


Fig 4.8: E-R diagram for development of Urban RIMS

4.2.2.1 RIS in Web GIS Environment

First of all, RIS module has been developed. The flow chart is similar to RIS in Arc GIS environment except that the step of converting the .shp file in .dbo file, the format is suitable for

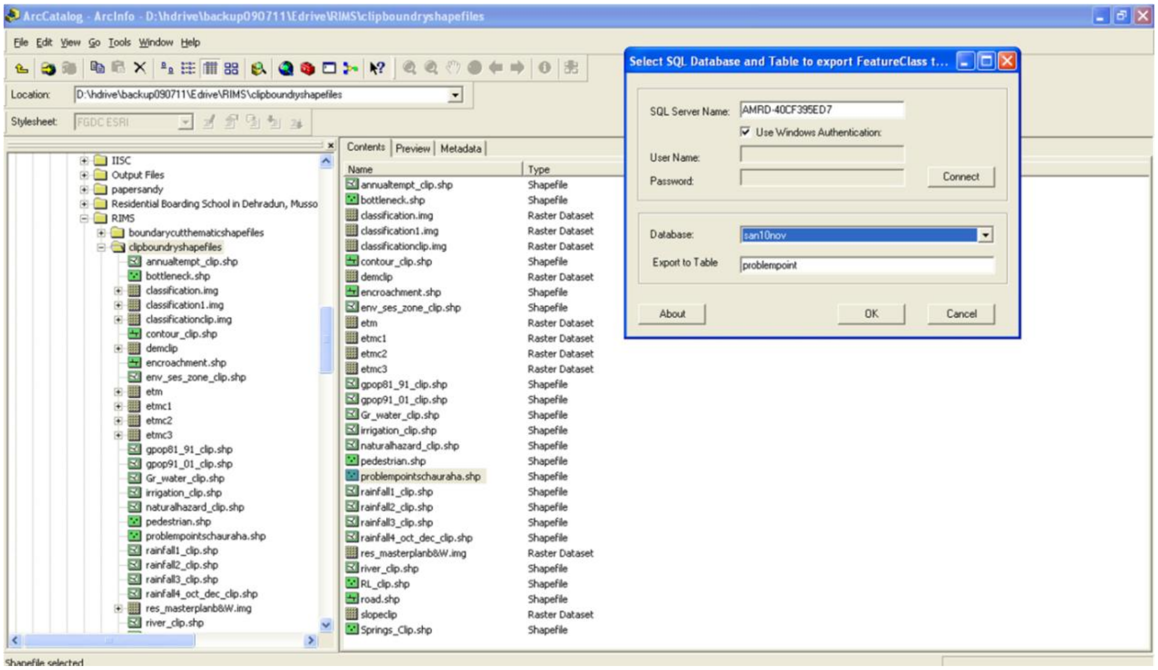


Fig 4.9: Shape file Converter for Use in Sharp Map

Sharp Map. To develop the web page, the coding is done in ASP.net with C#. It is clear from the flow chart (Fig 4.10) that the desired file is selected with the help of a check box. Further, the categorization is done for road as road type (NH, SH, MDR and local roads), presence of footpath and road divider, either one way or two way, road surface type (black top, cement concrete) etc. Schools are categorized by education level i.e. play group, primary, high school, intermediate, by gender of students i.e. boys, girls and coeducation. Professional institutes are classified, like engineering colleges, management colleges, engineering and management colleges, medical colleges, sports colleges etc. For analysis of the data categories can be selected from the drop down menu on the web page and desired result can be obtained. The format of result may be the in form of figure and table. From the table data graph can be prepared. Moreover, for analysis of a complex query many files and their categories may be selected. Moreover, schools can be seen all together or it may search by the name and its location can be seen on the map. Similar queries are also prepared for police and sub police station, fire station, bus routes, colleges, professionals institutes, government offices, hotels and hospitals etc. The E-R diagram which shows the flow of data in the RIS module, is shown by 4.11, while Fig 4.12 shows the files used with the attribute data.

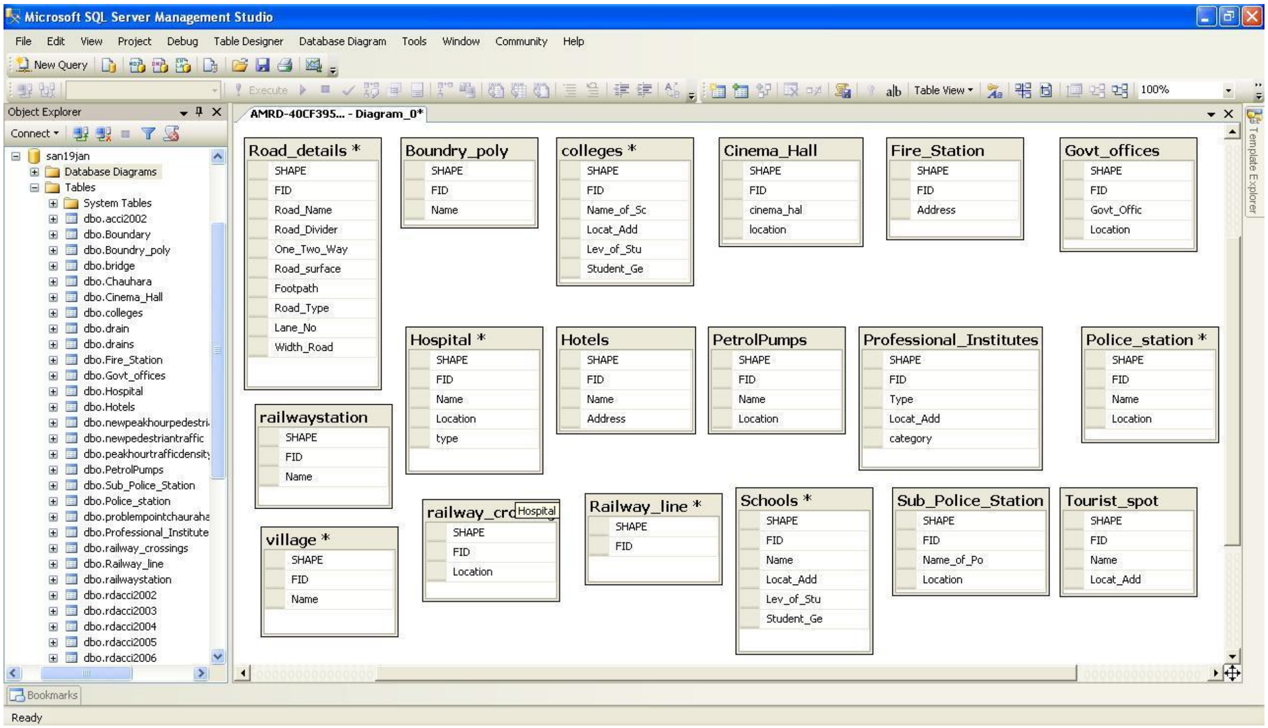


Fig 4.12: Data Diagram for RIS

4.2.2.2 BMS in Web GIS Environment

The BMS module has been developed. Its methodology for development in web GIS starts similar to Fig 4.4 and differ from the place when the .shp file is converted in .dbo file as per converter shown in Fig 4.9. Coding is done for the query system in the same way as in the development of RIS.

The flow chart (Fig 4.13) describe the way in which the BMS web page has been prepared and give the output in the form of figures and tables. The bridge data is categorized as lengthwise widthwise, top surface (i.e., cement concrete or black top), bridge structure, bridge railing type (like aluminum, brick work, precasted cement concrete pipes etc.) river name, road type, maintenance requirement (minor, medium and major), presence of road divider and shoulder and class loading type (Class A and Class AA etc.). In this module the photographs of the bridges are also shown.

The data flow in the BMS, is shown by E-R diagram in Fig 4.14 while data diagram shows the files with their attribute information in Fig 4.15,

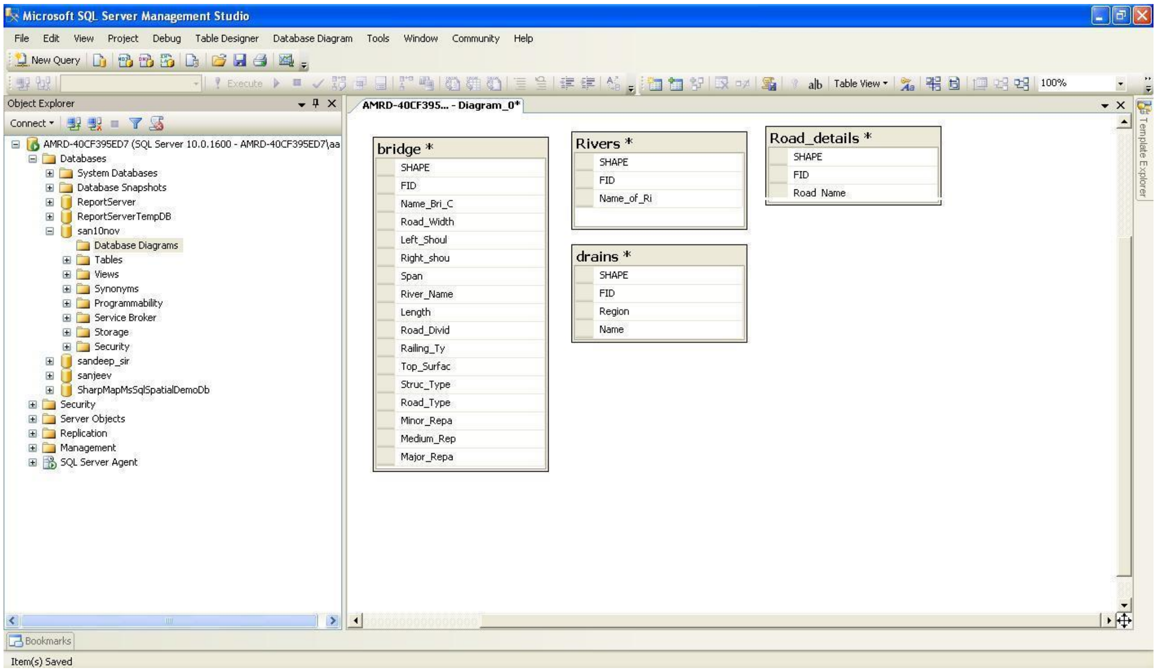


Fig 4.15: Data Diagram for BMS

4.2.2.3 AIS in Web GIS Environment

Similarly, AIS module has been developed as for RIS and BMS, following the methodology mentioned in Fig 4.5. It requires the conversion of .shp file in to .dbo file with the help of converter shown in Fig 4.9. Coding is done to get the output through web based system.

Accident data have been explored for desired information extraction. The data can be categorized police station wise, year time, hours of the day wise, death and injuries wise complex queries can also be formed by including many parameters at the same time. The output is shown in the form of figures and tables. The flow diagram for AIS module is shown in Fig 4.16

The data and its attribute information are shown by E-R diagram in Fig 4.17 and data diagram is shown by Fig 4.18.

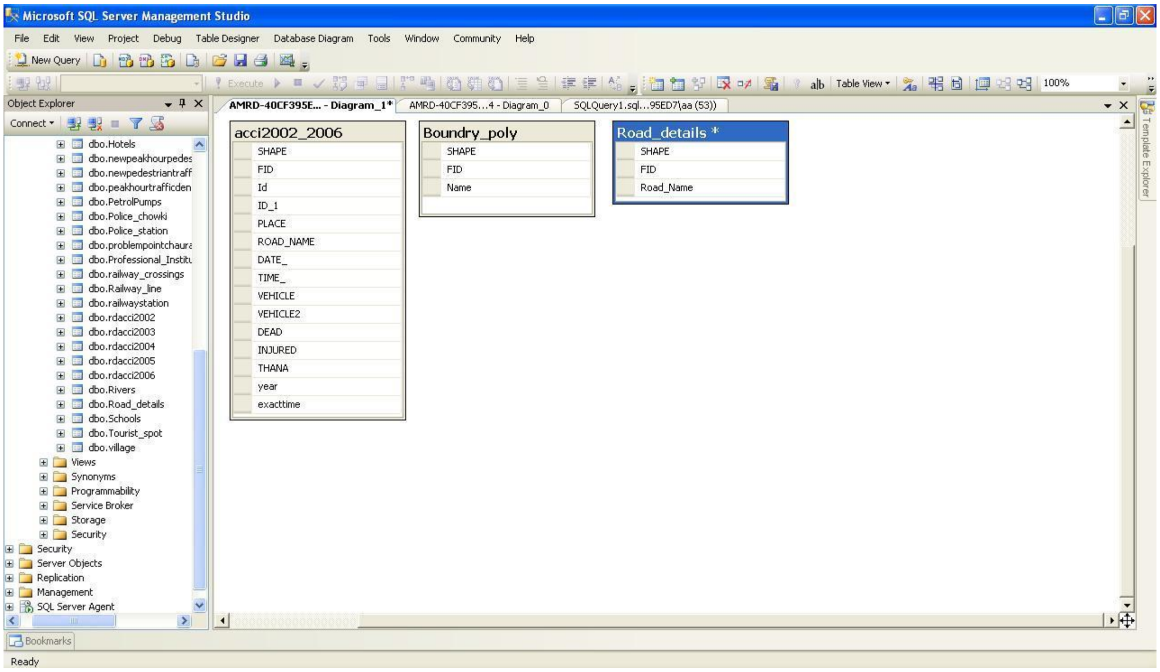


Fig 4.18: Data Diagram for AIS

4.2.2.4 TIS in Web GIS Environment

Similarly, AIS module has been developed, as for RIS, BMS and AIS, following the methodology mentioned in Fig 4.7. It also requires the conversion of .shp file in to .dbo file with the help of converter shown in Fig 4.9. Programming is done to get the output on web based system.

Traffic volume and pedestrian data are explored for desired information extraction. The output is shown in the form of figures and tables. The flow diagram for AIS module is shown in Fig 4.19. The data and its attribute information are shown by E-R diagram in Fig 4.20 and data diagram is shown by Fig 4.21.

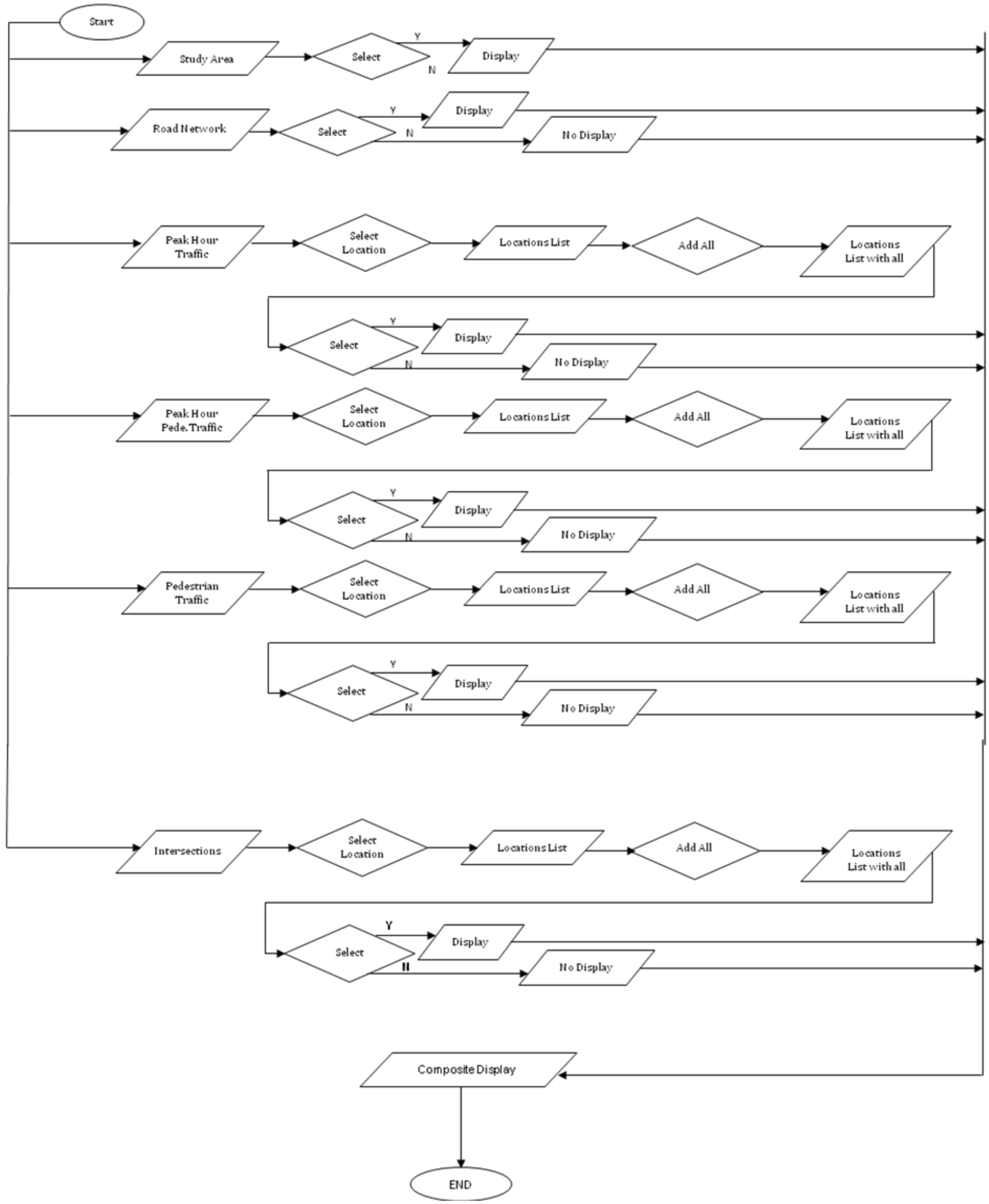


Fig 4.19: Flow Chart for TIS

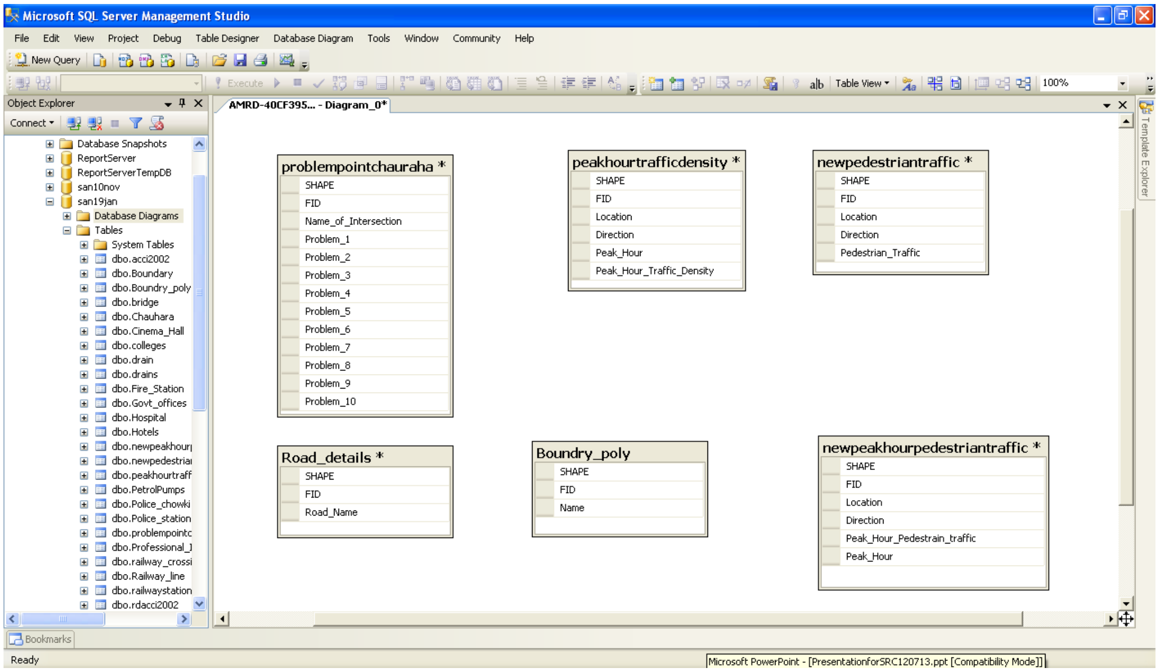


Fig 4.21: Data Diagram for TIS

4.3 CONCLUSION

In this chapter a well structured methodology is discussed to develop various modules of the urban RIMS. The modules were developed in Arc GIS environment and web GIS environment using Sharp Map 2.0. For web GIS modules the flow diagrams, E-R diagrams and data diagrams for each module are given in detail. After the development of urban RIMS, the results obtained and their analysis will be discussed in next chapter.

CHAPTER 5

STUDY AREA AND DATA USED

5.1 INTRODUCTION

The state of Uttarakhand, formerly Uttaranchal, was formed on November 9, 2000, as twenty seventh state of Republic of India. The city of Dehradun was declared as its interim capital. After the declaration of Dehradun as capital, it has become the centre of attraction for people for various reasons. The population has increased at a faster rate in comparison to the road infrastructure and other basic amenities. The traffic volume in terms of vehicles and other road users has increased many folds and it is now a common sight to see congested roads or traffic jams at different locations. The number of accidents is on the rise and so is the death of people due to road accident. This is one of the prime reasons that the city has been selected as the study area. It is proposed to develop a RIMS within a GIS environment and the same is available on web.

The Master plan of Dehradun has been selected as the study area for the development of RIMS using geospatial techniques. It covers the Dehradun Urban Agglomerate and 172 villages. Fig 5.1 shows the study area, while basic geographical and demographical profile of study area is given in Table 5.1.

5.2 STUDY AREA PROFILE

Dehradun is the administrative centre and the interim capital of the new state of Uttarakhand formed on November 2001. Dehradun is situated at the Himalayan foothills in the fertile Doon Valley. The valley is well known for its salubrious climate and natural beauty. It is due to this reason Dehradun has been one of the preferred residential cities. It is not only one of the most beautiful resort centers in India, it is well known for its scenic natural beauty, dense forests, waterfalls and natural surroundings. It is also one of the important educational hub of the country, where some of the best public and convent schools are located here. Further, Indian Military Academy (IMA), Forest Research Institute (FRI), ONGC, Indian Institute of Petroleum, Indian Institute of Remote Sensing, Zoological Survey of India, Wadia Institute of Himalyan

Geology, Survey of India, National Institute of Visually Handicapped, Wildlife Institute of India etc are located in Dehradun. It is well linked with rail, road and air routes to all the parts of the state and the country.

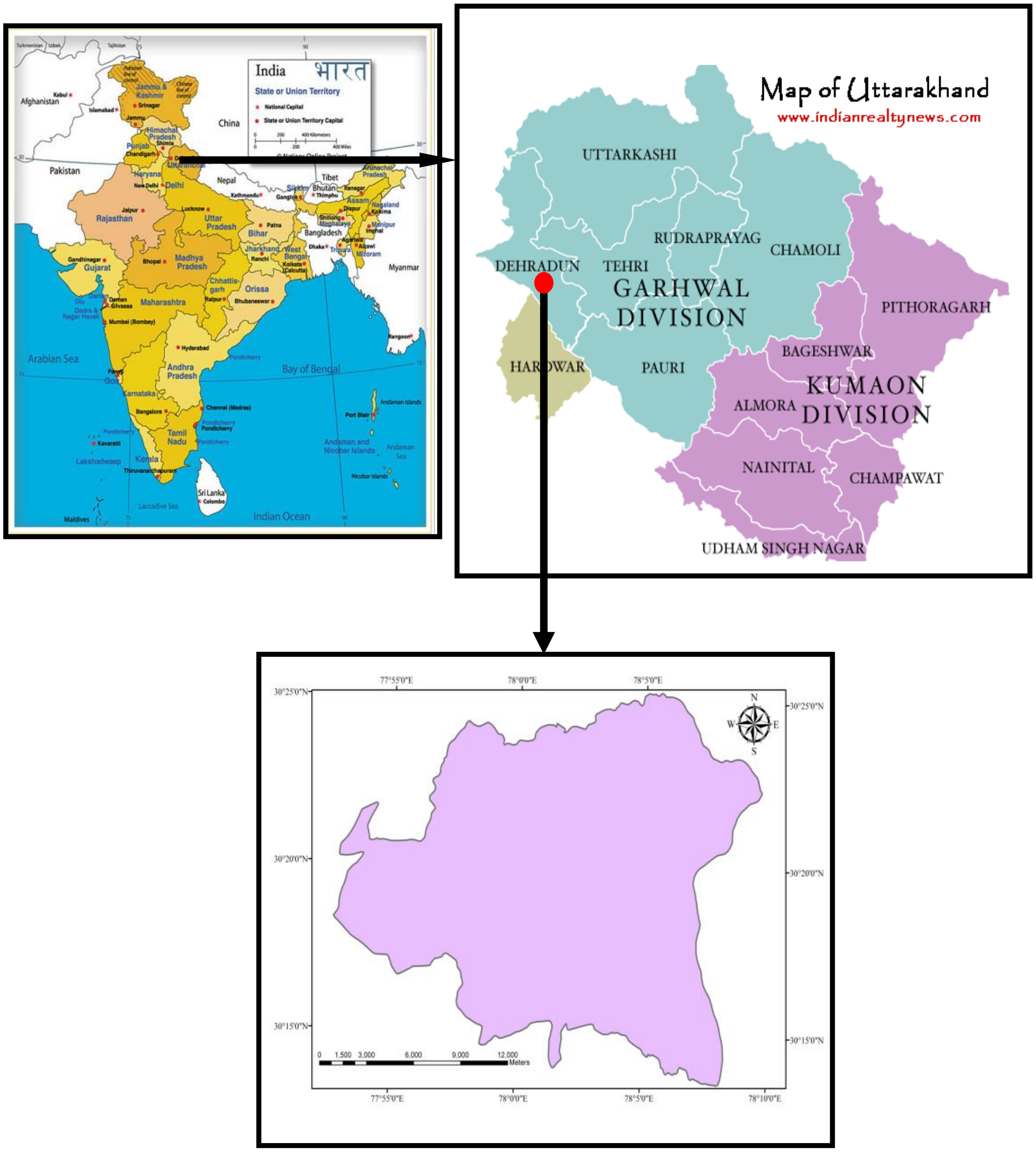


Fig 5.1: The Study Area

5.2.1 Demographic Profile

Table 5.2 shows the population growth of urban agglomerate since 1901. The decadal population growth is very high except in 1931 and 1961, in which the decadal population growth was +4.17%

and +8.41%, respectively. The highest decadal population growth was in 1951, 2001, 1941 and the value is + 78.97%, +52.45% and 52.25%, respectively. For future planning work the population for the years 2021 and 2025 was forecasted by Urban and Rural Planning Department, Uttarakhand and is given in Table 5.3. This will be very helpful for proper planning and execution of the policies [18].

Table 5.1 Basic Geographical and Demographical Profile of Study Area

Area	Total of 35867.20 ha Urban : 9698.87 ha and Rural: 26168.33 ha
Longitude	77° 52′ 0" E to 78° 10′ 0" E
Latitude	30° 13′ 0" N to 30° 29′ 0" N
Altitude	Avg 640 m to 1000m
Slope	15-20° (for 75% of the urban Agglomerate)
Annual Rainfall	1900-2000 mm
Monsoon	June to September
Temperature	Max 36°C and min 5.2°C
Total Villages	172
Population (2011 Census)	7,53,420 (Urban: 5,60,120 and Rural: 1,93,300)
Population Density	Urban: 64 persons/ha and Rural: 7 persons/ ha

Table 5.2: Decadal Population Growth in Dehradun Urban Agglomerate

Year	Total Population	Increase	Decadal Percentage Growth
1901	30995	-	-
1911	42568	+ 11573	+37.34
1921	50858	+ 8290	+19.47
1931	52927	+2069	+4.17
1941	80580	+27653	+52.25
1951	144216	+63636	+78.97
1961	156341	+12125	+8.41
1971	220571	+64230	+41.08
1981	293010	+72439	+32.84
1991	367411	+74401	+25.39
2001	560120	+192709	+52.45

Table 5.3: Dehradun Master Plan Decadal Population: Present and Projected – Year 2025

Year	Description of Total decadal Population of Dehradun Master Plan			Decadal Population of Dehradun Urban area			Decadal Population of Dehradun Rural area		
	Decadal Population	Decadal Population Increase	Increase in %	Decadal Population	Decadal Population Increase	Increase in %	Decadal Population	Decadal Population Increase	Increase in %
1991	5,46,288	1,44,324	35.90	3,67,411	74,401	25.39	1,78,877	69923	64.17
2001	7,53,420	2,07,132	37.92	5,60,120	1,92,709	52.45	1,93,300	14,423	10.80
2011	10,41,268	2,27,848	38.20	7,84,168	2,24,048	40.00	2,57,100	63,800	33.00
2021	13,64,000	3,22,732	31.00	10,43,000	2,58,775	33.00	3,21,000	63,900	25.00
2025	15,30,000	1,66,000	12.17	11,76,500	1,33,500	12.80	3,53,500	32,500	10.12

5.2.2 Tourism Potential

Tourism is an economic activity of great importance as the inflow of tourists creates economic and social benefits. Dehradun is one of the most beautiful cities in Northern India. The entire Doon Valley is full of places with scenic beauty and picnic spots. A number of tourism attractions such as Gurudwara, Sahastradhara, Robbers Cave, Ajabpur Kalan, Tapkeshwar Mahadeo, Laxman Sidh, Malsi Deer Park, Wildlife Sanctuary etc., are located in the nearby or close vicinity of the city. Apart from being a tourist destination in its own right a majority of tourists use the City for onward journey to other prominent tourism destinations in region, i.e. Mussoorie, Tehri, Uttarkashi etc.

It is clear from Table 5.4 that the number of visitors, both Indians and foreigners, are increasing every year. The total number of tourists in year 2003 was 9.29 lakh, and it is projected that by the year 2025, it is expected to increase to 2.09 [18].

5.2.3 Vehicle Growth

Table 5.5 shows the growth of vehicles registered in Dehradun for the years 1994-2004. It can be clearly observed that the number of 2-wheelers is highest among all the different categories in a particular year and constitutes 81% of the total vehicle registered in 2003-2004[18].

After that, amongst four wheeler category, the cars constitute maximum weightage of 12% of total vehicles registered in 2003-2004. This shows that public transport system is not good and people like to travel by own vehicle i.e., scooter, motor cycle, moped and cars. Due to excessive growth in these two categories, the annual average growth in total registered vehicle for the period, i.e., from 1994-2004, is 17%.The annual growth rate for registered vehicles is 17%, while the percentage growth for 2-wheelers is only 15%, in spite of its highest numbers in the vehicle [18]. The 3-wheeler category, consisting of auto or tempo, the percentage growth is very high i.e. 108% because of its wide adoption as public transport [18]. .

Table 5.4: Number of Tourists: Present and Projected

Year	Indian	Foreigners	Total	Percentage Increase
1997	8,69,919	4,355	8,74,274	-
1999	5,62,151	10,693	5,72,844	(-) 34.47
2001	8,45,175	12,667	8,57,838	(+) 49.75
2003	9,17,070.	11,922	9,28,992	(+) 8.29
2011	11,55,510	13,490	11,69,000	(+) 25.83
2021	16,83,000	17,000	17,00,000	(+) 45.42
2025	20,68,300	21,000	20,89,300	(+) 22.90

5.2.4 Existing Public Transport System

Bus transport system is being operated by Uttarakhand Transport Corporation for intercity travel. About 10 main city bus routes are operating in the city to cover the length and breadth of the City by the private operators. The route and fare structure is fixed by Road Transport Authority. The city bus routes are presented in Table 5.6.

5.3DATA REQUIREMENT FOR THE DEVELOPMENT OF RIMS

One of the important characteristic of GIS is that it can combine the spatial data with non spatial data i.e., attribute data. For any RIMS, one of the most important data is information regarding road and its associated data. For spatial data of roads, Survey of India (SOI) toposheets have been geo-referenced and all roads have been digitized. Since the SOI maps used in this study,

Table 5.5: Growth of Registered Vehicles in Dehradun

Year	Car/Jeep/ Van	2-Wheeler (Scooter/ M. Cycle/ Moped)	Taxi /Maxi	3-Wheeler (Auto /Tempo)	Bus /Minibus /Omnibus	Goods Vehicle	Others	Total
(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**
1994-95	4852	66104	348	211	1028	1948	552	**75043**
1995-96	5690	72716	591	281	1105	2186	617	**83186**
1996-97	7419	80415	875	375	1146	2602	708	**93540**
1997-98	8879	88557	1140	500	1249	2892	806	**104023**
1998-99	10426	98566	1337	666	1300	3163	934	**116392**
1999-00	12972	109498	1678	905	1405	3502	1207	**131167**
2000-01	15262	121678	2135	1567	1461	3835	1427	**147365**
2001-02	17479	135202	2620	1956	1546	4155	1612	**164570**
2002-03	20214	150296	3041	2187	1621	4658	1754	**183771**
2003-04	23859	166399	3370	2484	1991	5479	1987	**205569**
Growth Rate (p.a. average)	39%	15%	77%	108%	9%	18%	26%	17%

have been printed in the year 1969, 1988 and 2004, so for updating of road network, Cartosat -1 data and IKONOS data from Google Earth has been used. Further, Dehradun Guide Map (scale 1:20,000) has been used to extract information regarding the road and subsequently create database for roads. For collection of road attribute data (like road width, divider, footpath), road category (like National Highway (NH), State Highway (SH), Major District Road (MDR) etc), road surface types and one way or two way roads etc., field survey was conducted.

For RIS, important information, like tourist place, government offices, police stations, schools and colleges, petrol pumps etc., was collected through field survey, Google Earth Images, Dehradun Guide Map etc. For bridge database, crossings and rivers/drains were obtained from

Table 5.6 City Bus Routes

Route No.	Route Structure
1	**Rajpur Road – Clement Town** via Clement Town, Majra, Saharanpur Intersection, Gandhi Road, Parade, Subash Road, Dillaram Balar, (Shahanshai Ashram)
2	**D. L. Road – Defence Colony** via Police Chauki, Dillaram Bazar, Clock Tower, Prince Intersection, Haridwar Road, Defence Colony
3	**Parade – Sahastradhara** via Parade Ground
4	**Prem Nagar - Gular Ghati** via Bhaliwala Intersection., Prince Intersection, Jogiwala, Harawala, Baller Wala, Gular Ghati.
5	**Banjara Wala – Gular Ghati** via Kargi, Guru Ram Rai Degree College, Saharanpur Intersection, Prince Intersection, Darshan Lal Intersection, Parade, Survey Intersection, Sahastradhara Jn., Raipur, Ranjha Wala, Nathu Wala, Balwali, Gular Ghati,
6	**Parade Ground – Parwal** via Darshan Lal Intersection, Cannaught Place, Prem Nagar Parwal
7	**Purkal Gaon – Mathura Wala** via Chand Roti, Anarwala (Surdly Depot), Hathi Badkala, Dilram Bazar, Globe Intersection, Pavillion, Subash Depot, harampur, Azabpur, Mathura Wala.
8	**Thana Central – Ballupur** via, GMS Road, Sabzi Mandi, Majra, By Pass – Rispana Rao – Subash Road – Pande
9	**Nabada Majra – Rispanapur** via, Subhash Marg, Parade ground, Majra, By Pass – Rispanapur
10	**Prem Nagar – Dhonlas Ki Chakki** via Nanda Intersection, Phulsoni, Amwala.

toposheets, IRS Cartosat-1 and IKONOS data of Google Earth Images. Its attribute data with photograph was collected by field survey. For AIS, data was collected from Disaster Mitigation and Management Centre (DMMC) from 2002-2006. It was digitized and database was created in Arc GIS. In attribute data time, time, vehicle involved, persons died and injured was included. For TIS, data was collected from various reports and field survey.

To make RIMS available on web, open source GIS software Sharpmap, for browsing GIS data and to create geographic image maps, Sharp Map is used and for sharing the information on net Internet Information Service 7.0 (IIS7) is used.

Data can be categorized in two categories i.e., spatial data and non-spatial data, which are described below.

5.3.1 Spatial Data

The following spatial data have used in the development of RIMS:

(a) SOI Toposheet No. 53F-15, 53F-16, 53J-3 & 53J-4 (Fig 5.2),

(b) Dehradun Guide Map scale of 1:20,000 (Fig 5.3),

(c) IRS Cartosat -1 data of the study area path/row number 526/258 and 527/258 January 24, 2008 and November 20, 2008 respectively, Fig 5.4

(d) IKONOS images from Google Earth, Fig 5.5

(e) MDDA Master Plan 2005-2025, Fig 5.6

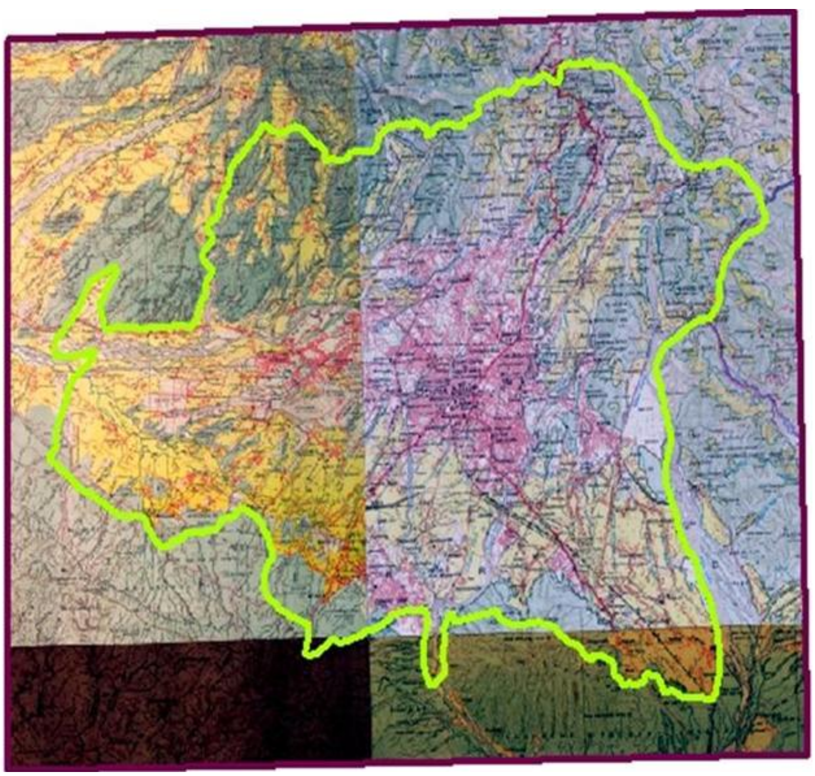


Figure 5.2: Mosaic of SOI Toposheets of the Study Area

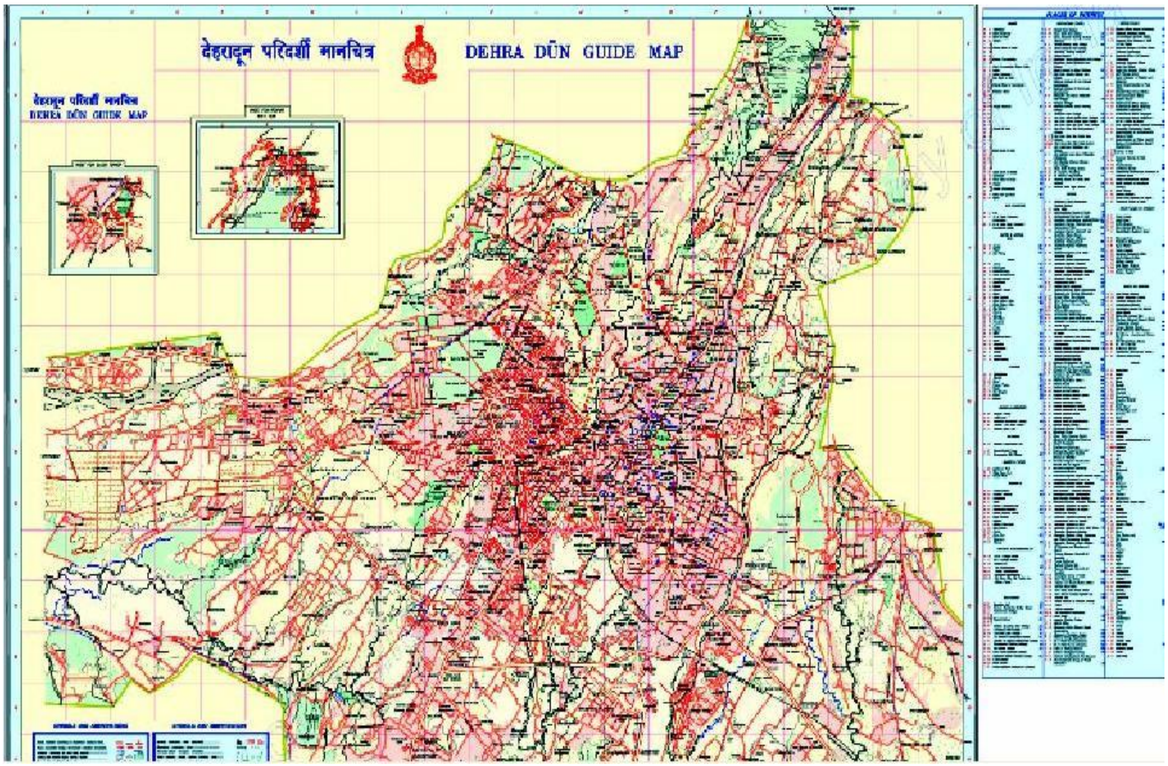


Fig 5.3: Dehradun Guide Map

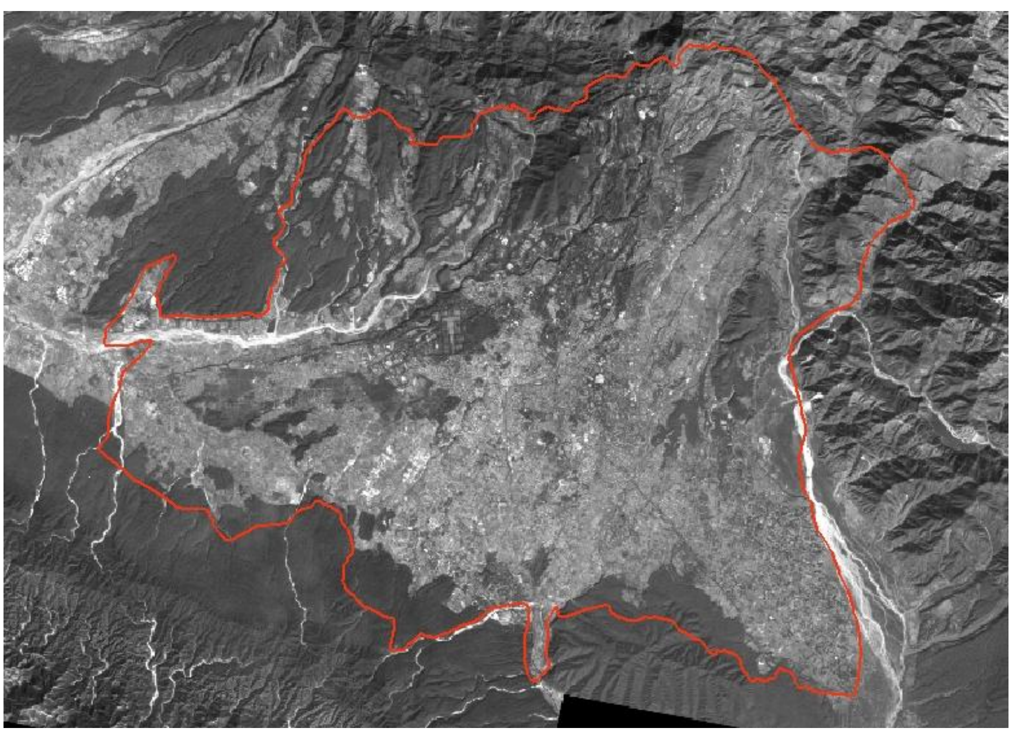


Fig 5.4: Mosaic of IRS Cartosat – 1 Image, Dated January 24, 2008 and November 20, 2008

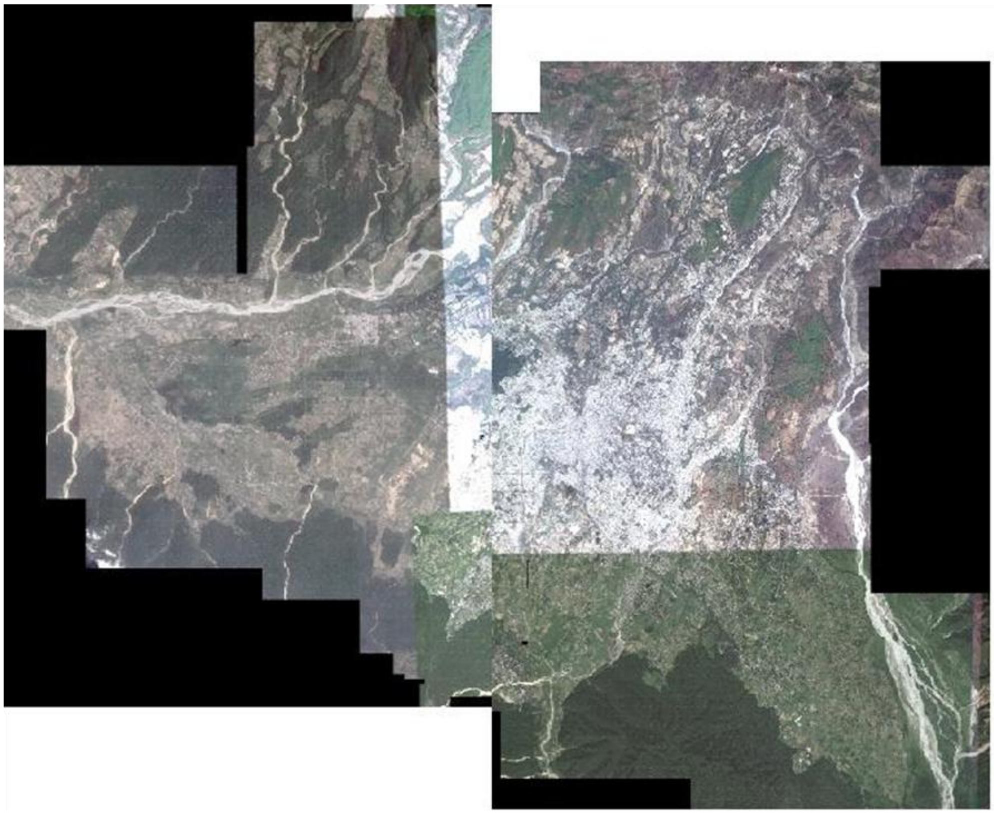


Fig 5.5: The IKONOS Image (2007)

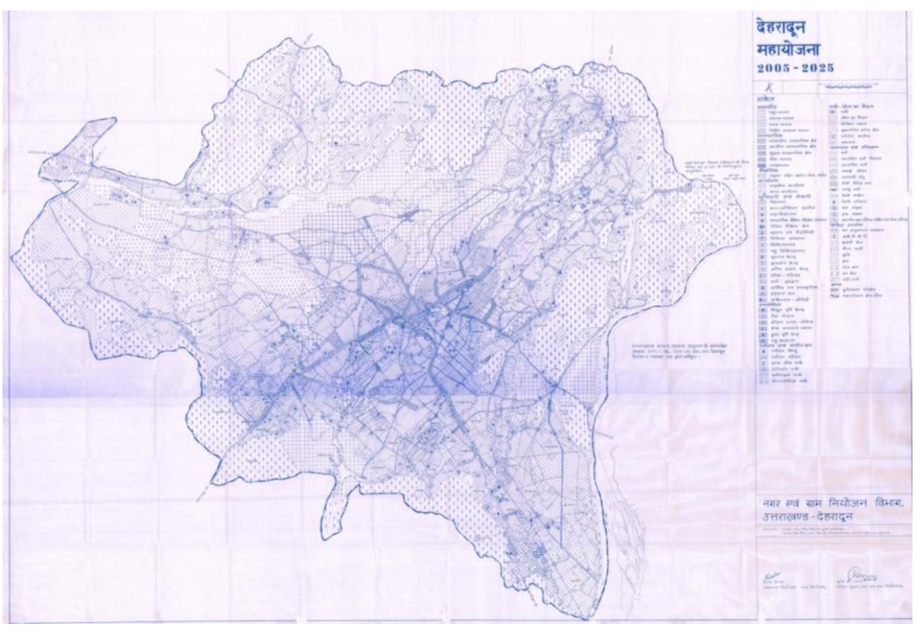


Fig 5.6: MDDA Master Plan 2005-2025

5.3.2 Non-Spatial Data

Along with these information, attribute data, such as presence of road divider and footpath, type of road top surface, one way or two way road, details of bridges/causeways like width, length, type of railing, structure, number of spans, span width, presence of road divider and shoulder and maintenance requirements. Address or locations of hotels, road intersections, government offices, schools and colleges, professional institutes, tourist place, hospitals, police stations, fire stations, traffic density and pedestrian traffic on important roads or road intersections, religious places, railway crossings, railway stations, petrol pumps, bridges, 12 city bus routes and cinema hall have been added to the database. Intensive field visits were carried out during the period of November 18-27, 2010, December 13-16, 2010 and January 15-17, 2011, to collect these data. All the above information have been converted into shape file developed for RIMS, are listed in Table 5.7, mentioning its data source.

5.4 SOFTWARE USED

(a) **Spatial Database Generation:** ERDAS IMAGINE 8.5 and Desktop GIS Software Arc GIS 9.2 have been used to carry out basic spatial data for spatial and associated attribute data generation.

(b) **Tools Used:** Microsoft SQL Server 2008, Microsoft Visual Studio 2010, Sharp Map 2.0 and C# with asp.net

5.5 CONCLUSION

In this chapter, the justification for the selection of study area is given with the help of necessary data, like its geographical and demographical information, employment opportunity, tourist attraction and public transport. First of all, its salubrious climate condition and many institutes of national level attract the people to settle down here. Moreover, due to the declaration of this city as interim capital of the state Uttarakhand, the influx of the population increases. With the increase in population the travel needs have also increased which has created congestion on all the major roads of the city. In Chapter 6, outcomes of the modules are shown and analysed.

Table 5.7: Layers Generated for RIMS along with Data Source

Layers	Data Source
Point Features	
Bridge	Field Visits, Google Earth Image, Cartosat -1
Crossings	Field Visits, Google Earth, Traffic Police Report, Cartosat -1
Cinema Halls	Field Visits, Google Earth Image
Colleges	SOI Toposheets, Field Visits, Google Earth Image
Fire Stations	Field Visits
Government Offices	Field Visits, Google Earth Image
Hospitals	Field Visits, Google Earth, Disaster Mitigation and Management Centre (DMMC)
Hotels	Field Visits, Google Earth Image
Peak Hour Pedestrian Traffic	Mussoorie Dehradun Development Authority (MDDA) Report
Peak Hour Traffic Volume	MDDA Report
Petrol Pumps	Field Visits, Google Earth Image
Police Stations	Field Visits, Google Earth Image
Professional Institutes	Field Visits, Google Earth Image
Railway Crossing	SOI Toposheets, Field Visits, Google Earth Image
Railway Stations	SOI Toposheets, Field Visits, Google Earth Image
Road Accident data (2002 – 2006)	DMMC
Schools	SOI Toposheets, Field Visits, Google Earth Image
Tourist Spots	SOI Toposheets, Field Visits, Google Earth Image
Line Features	
Study Area Boundary	MDDA Report
Bus Route	Field Visit and City bus operator office
Railway Lines	SOI Toposheets, Field Visits, Google Earth Image, Cartosat -1
Roads	SOI Toposheets, Field Visits, Google Earth Image, Cartosat -1
Polygon Features	
Drains	SOI Toposheets, Field Visits, Google Earth Image, Cartosat -1
Rivers	SOI Toposheets, Google Earth Image, Cartosat -1
Villages	SOI Toposheets, Google Earth Image, Cartosat -1

CHAPTER 7

CONCLUSIONS AND RECOMMENDATIONS

7.1 INTRODUCTION

In this study, ERDAS IMAGINE 8.5 and Desktop GIS Software Arc GIS 9.2 software have been used to generate a GIS database of spatial and associated attribute data for roads in urban environment. To develop Web GIS module, tools like Microsoft SQL Server 2008, Microsoft Visual Studio 2010, Sharp Map 2.0 and C# with asp.net have been used. A Web GIS based RIMS with four modules, viz., RIS, BMS, AIS and TIS has been developed for roads in Dehradun, the interim capital of the state Uttarakhand. The total area covered is approximately 35,867 ha which includes Dehradun Urban Agglomeration Area (9,699 ha) and 172 rural villages (26,168ha).

The spatial data used include Survey of India (SOI) Toposheets 53F-15, 53F-16, 53J-3 & 53J-4, Dehradun guide map, IRS Cartosat -1 data, dated January 24 and November 20, 2008, respectively. In addition, IKONOS images from Google Earth and MDDA Master Plan 2005-2005 have been used. The associated non-spatial / attribute data used include road divider and footpath, road top surface, road one way or two way for road layer, bridges/causeways width, length, types of railing, structure, spans, presence of road divider & shoulder and maintenance requirements for bridge layer. Address or locations of the hotels, road intersections, government offices, schools and colleges, professional institutes, tourist place, hospitals, police stations, fire stations, traffic density and pedestrian traffic on important roads or road intersections, religious places, railway crossings, railway stations, petrol pumps, bridges, city bus routes and cinema hall were also collected. All the attribute information were collected from Traffic Police Report, City bus operator office and field visits undertaken from November 18-27, 2010, December 13-16, 2010 and January 15-17, 2011.

The RIS module produced results of queries regarding roads, such as road name, type, width, divider, footpath, one way/two way road, road surface, either in single or in combination. This module also provides information on location & address of police station and sub-police station, fire stations, hospitals, government offices, hotels, petrol pumps, cinema halls, professional institutes and tourist spots etc. Network analysis was carried out to identify shortest route, get the walking/driving directions to reach a particular point, to get nearest public utility, like petrol pump, hospital and hotel etc. It also computes minimum time required to reach a facility from source to destination. Buffer analysis helps in finding out the new locations of the utilities.

The BMS is capable to provide information on several parameters of bridges, either singly or in combination. These parameters are mostly collected from field visits, and include bridge type, road name, river name, road type, road width span length, number of spans, total length, divider, shoulders, railing type, bridge top surface, structure type etc. This module has the photographs of bridges attached along with the attribute data. By displaying the photos and attributes, the condition of bridges at the time of data collection may be assessed for maintenance requirement. Moreover, with the help of network analysis, alternate route can be found if a particular bridge is under maintenance.

The AIS module provides information about accidents on the roads, like vehicle involved in accidents, jurisdiction of police station, casualties, injured, date & time of accident and hospital information (like name, phone, name of doctors and their specializations) etc. In this study, the accident data from year 2002 to 2006 was available, which was used for analysis. Under AIS module, vulnerable spots on the basis of frequency of accidents have been classified as most critical, critical and less critical. These most critical locations are found at the intersection of Rajpur road with East Canal road and on East Canal road at the intersection of Cross road and Amrit Kaur road. A visit to these places was done on September 12, 2011, and it was found that a large number of streets/roads are open to major roads, and due to lack of proper rotary, traffic light and road divider etc road accidents occur. Therefore, it is felt that the street/minor roads require to be connected to the major roads with proper rotary. In case of an accident, network analysis helps to find the shortest route to the hospitals.

With the help of TIS module, an analysis was carried out to find out the critical crossings having frequent traffic jam, pedestrian affecting traffic flow etc. Alternate route during a road closure or traffic diversion for religious or political procession or during tourist seasons etc. can also be determined from this module.

7.2 CONCLUSIONS

The following conclusions can be drawn:

a. This research provides a well structured methodology for development of a RIMS for urban areas and through internet it can be used by wide variety of users.

b. The developed methodology demonstrates the working of four important modules of RIMS i.e., RIS, BMS, AIS and TIS.

c. Presently, no software is available for the development of urban RIMS. This research is an effort to develop a web GIS based approach for RIMS

d. It is a query based system. Road planners, administrators and users can develop specific query from the system. An administrator/manager can find the answers of the queries, such as new location to put "Drive Slow" sign board, to find out the shortest route followed by a facility, such as fire brigade/police to reach at the accident location, locations to have new schools/colleges, police sub stations, about bridge repair, critical points where frequent accidents take place, locating intersections prone to traffic jam etc. The users can easily find the answer of the queries, like location of tourist spots, hospitals, petrol pumps, schools, colleges, professional institutes, city buses, government institutes etc.

e. The advantage of web technology has also been derived i.e. through internet it can be used simultaneously by a large number of users as the knowledge of basic software is not necessary to handle web GIS based module. The software to develop Web GIS module are also available free of cost which is a great advantage in a developing country like India.

7.3 RECOMMENDATIONS

The development of RIMS for urban areas is a dynamic process which requires lots of data and its continuous upgradation. In present research work, the RIMS for urban environment has been developed using data upto year 2011 in RIS, BMS and TIS while in AIS the data from 2002 to 2006 has been used. The effective development and use of various modules of RIMS, and specifically the AIS and TIS modules require long time series data.

For future works the module can be enhanced by incorporating the surface condition of the road, location and the size of the potholes on the road, road geometry, road drainage condition, cost estimation required to repair the roads and bridges, which will be quite useful to road engineers/ administrator/planner.

CHAPTER 6

RESULTS & ANALYSIS

6.1 INTRODUCTION

This chapter discusses the results obtained from each module of RIMS. By developing a well structured methodology, the extraction of desired information from thematic layers can be explored and analysed easily in the forms of maps and tables. From the data available in tabular format, graphs can easily be prepared. From the RIS module, the information regarding the roads related features and other data, like schools, colleges, professional institutes, government offices, tourist spots and hospitals can be extracted. The information regarding the bridge infrastructure can be obtained from the BMS. From the AIS, locations of multiple accidents can be analysed and suitable remedy can be suggested. From TIS, locations which are prone to frequent traffic jam can be identified and remedial measures proposed.

6.2 DEVELOPMENT OF WEB ENABLED SYSTEM

A web enabled system is developed for urban RIMS using open source software Sharpmap. Fig 6.1 shows the home page of the web enabled GIS while Fig 6.2 presents the screen shots of details of study area.

Fig 6.1: Home Page of the Web Enabled GIS System

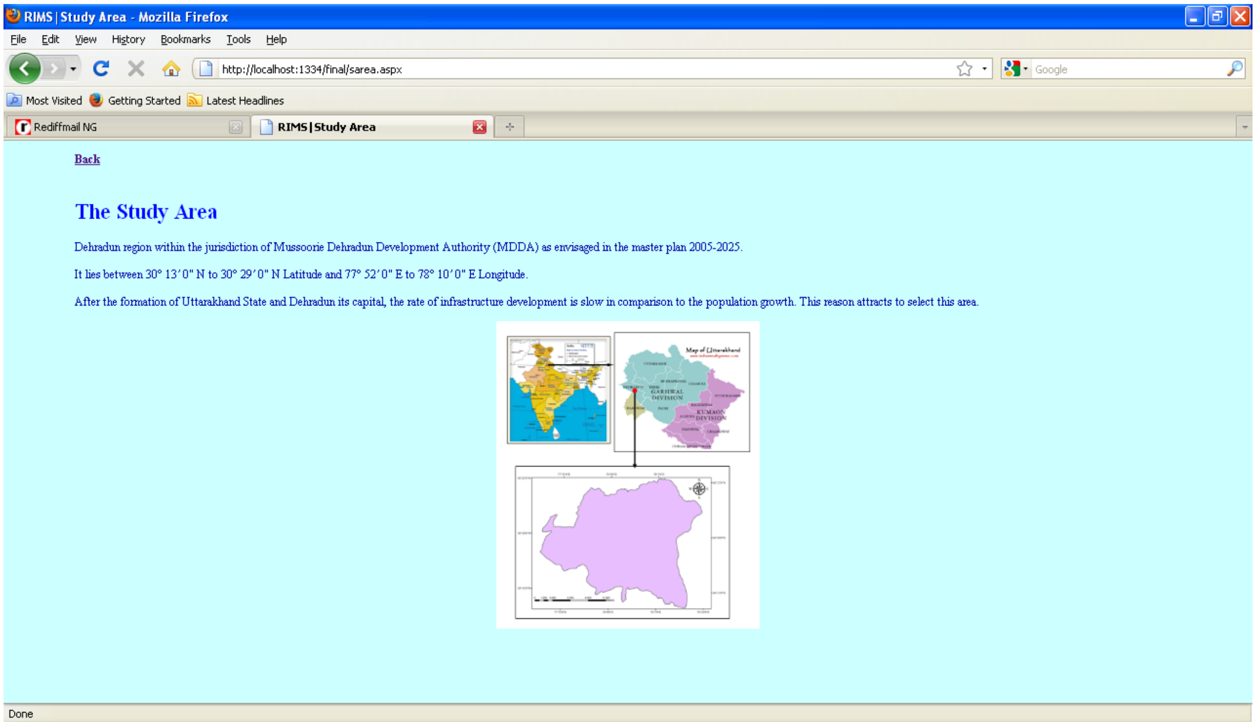


Fig 6.2: Details of Study Area on Web Enabled GIS System

Fig 6.3 shows the components of RIMS on web page, while Fig 6.4 presents the web page of RIS.

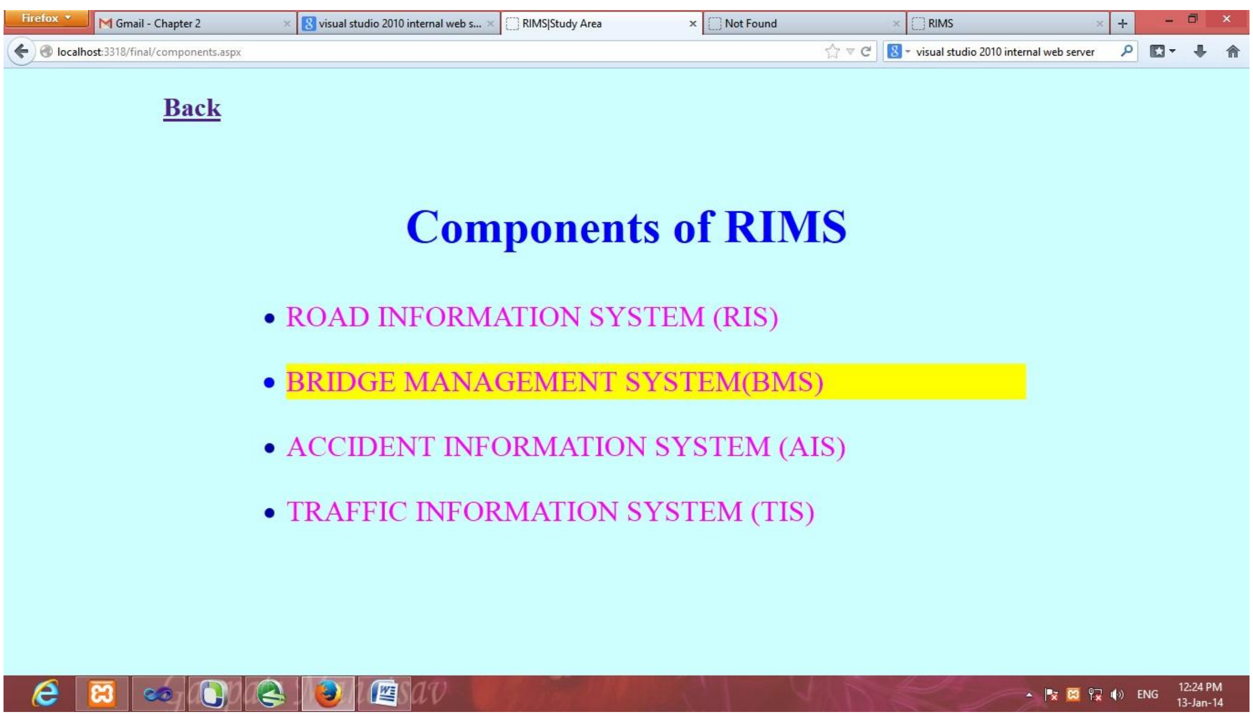


Fig 6.3: Components of RIMS on Web Enabled GIS System

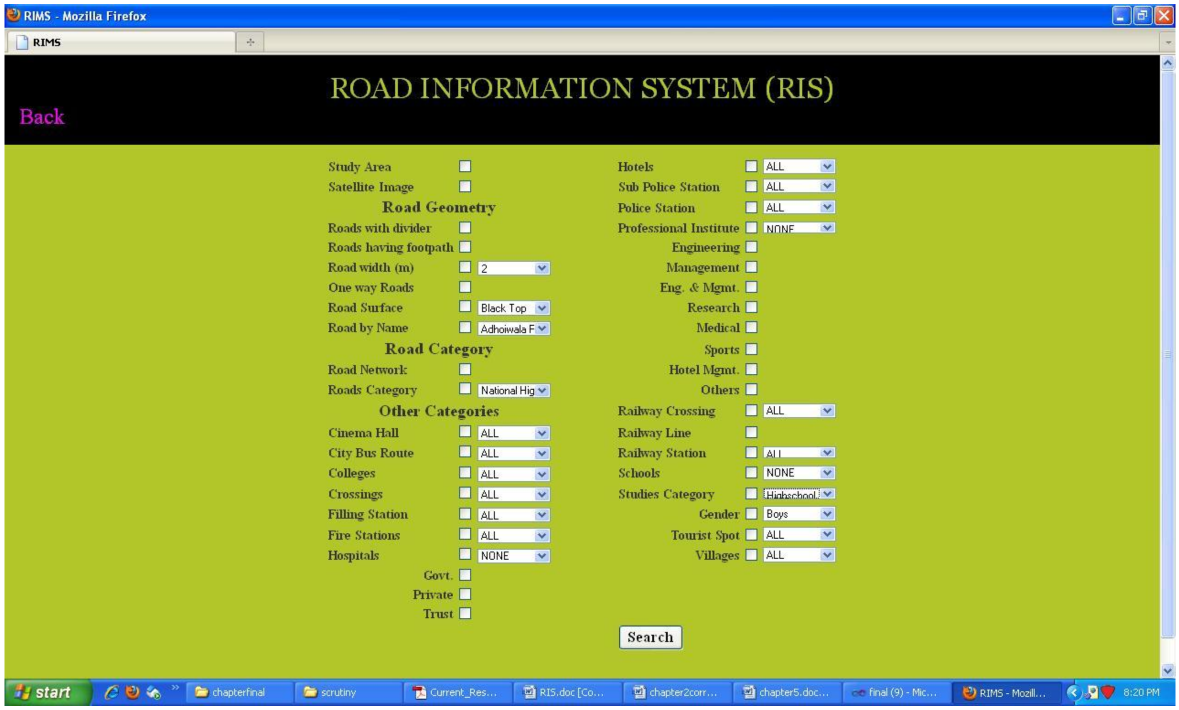


Fig 6.4: RIS on Web Enabled GIS System

Fig 6.5 shows the BMS on web page, while Fig 6.6 presents the AIS on web page. Fig 6.7 shows the TIS on web page.

Fig 6.5: BMS on Web Enabled GIS System

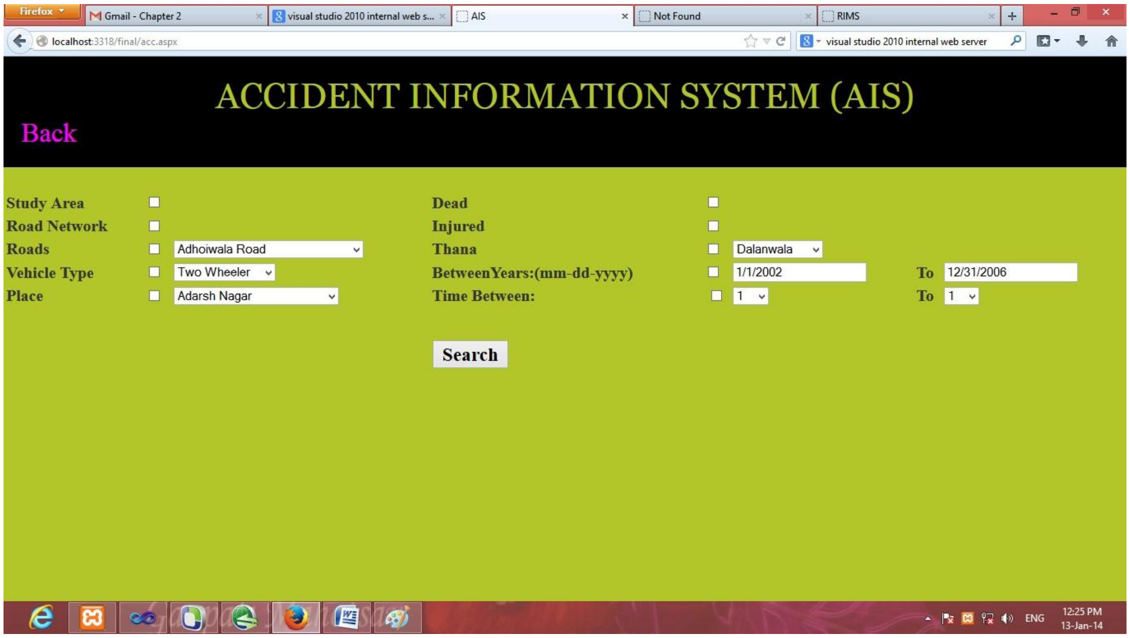


Fig 6.6: AIS on Web Enabled GIS System

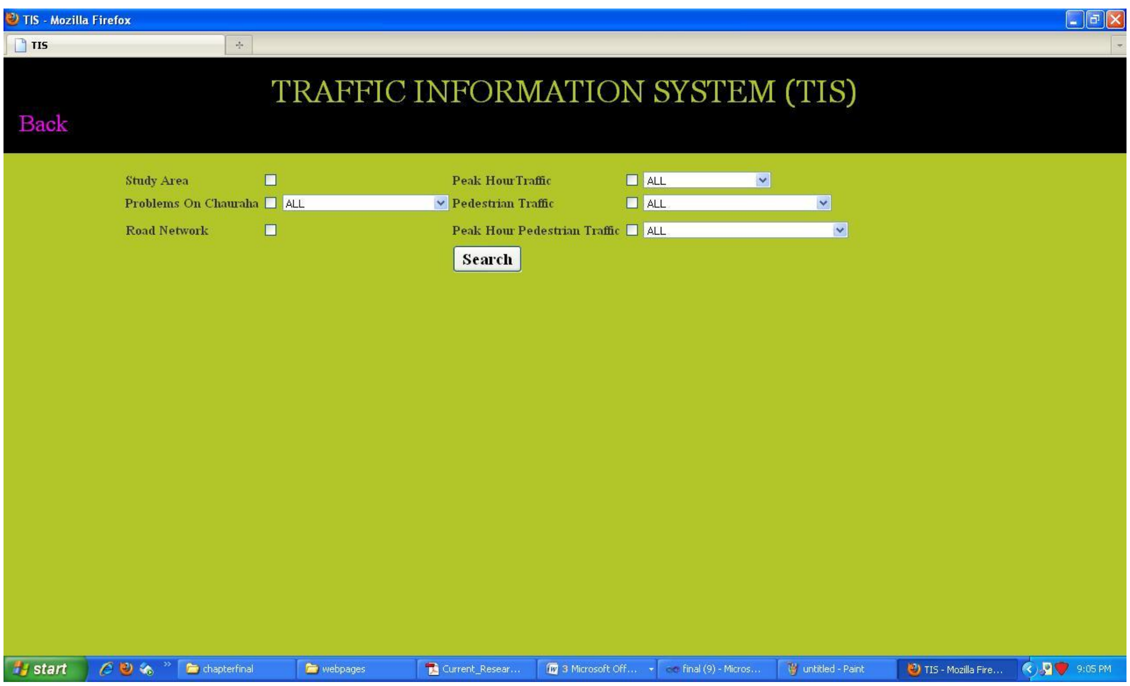


Fig 6.7: TIS on Web Enabled GIS System

6.3 RESULTS AND ANALYSIS

The results obtained from each module are presented below.

6.3.1 RIS

The data are analysed in the following manner:

(i) Road Infrastructure wise

(ii) Queries for facilities, like schools, colleges, professional institutes, government offices, tourist spots and city bus route etc.

(iii) Buffering, and

(iv) Networking

For the first two categories as above, the results can be obtained from both i.e. the Arc GIS and web enabled GIS module, while the results for the remaining two categories can be obtained only from Arc GIS version of the module.

6.3.1.1 Analysis of Road Infrastructure

From the GIS database, a number of queries can be generated to derive new maps and useful information. The result of a query of the roads having road divider is given in Fig 6.8 by highlighting the General Mahadev Singh (GMS) road, Saharanpur road, Haridwar byepass from railway crossing to Haridwar road, Rajpur road, Shaeed Kashmira Singh road, Ghandhi road and Chakrata road form Darshan Lal crossing to Ballupur crossing.

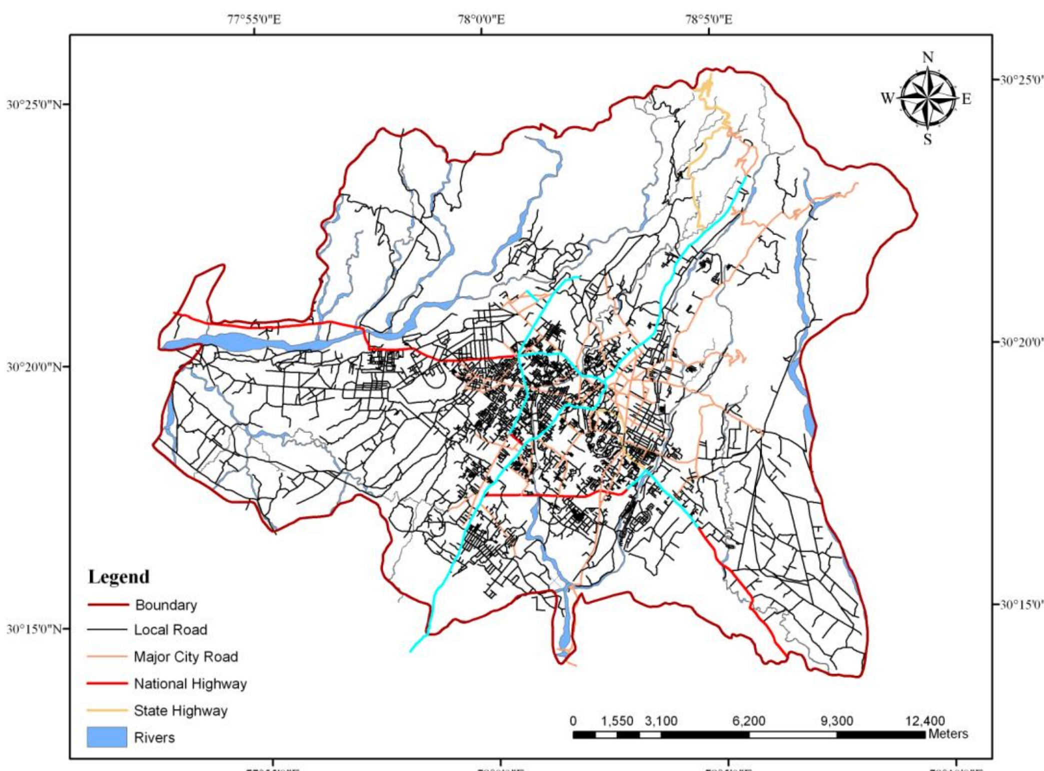


Fig 6.8: Roads with Divider

On running the query for roads of 10 m width, the results are produced in Fig. 6.9 showing Haridwar road, Haridwar byepass road, GMS road, Race Course road, Patel Nagar road, EC Road, Sahastradhara road, Shaeed Durgamal road etc. On running the query for one way roads in Dehradun, the roads selected by the software are Pant road and part of Subhash and EC road (Fig 6.10).

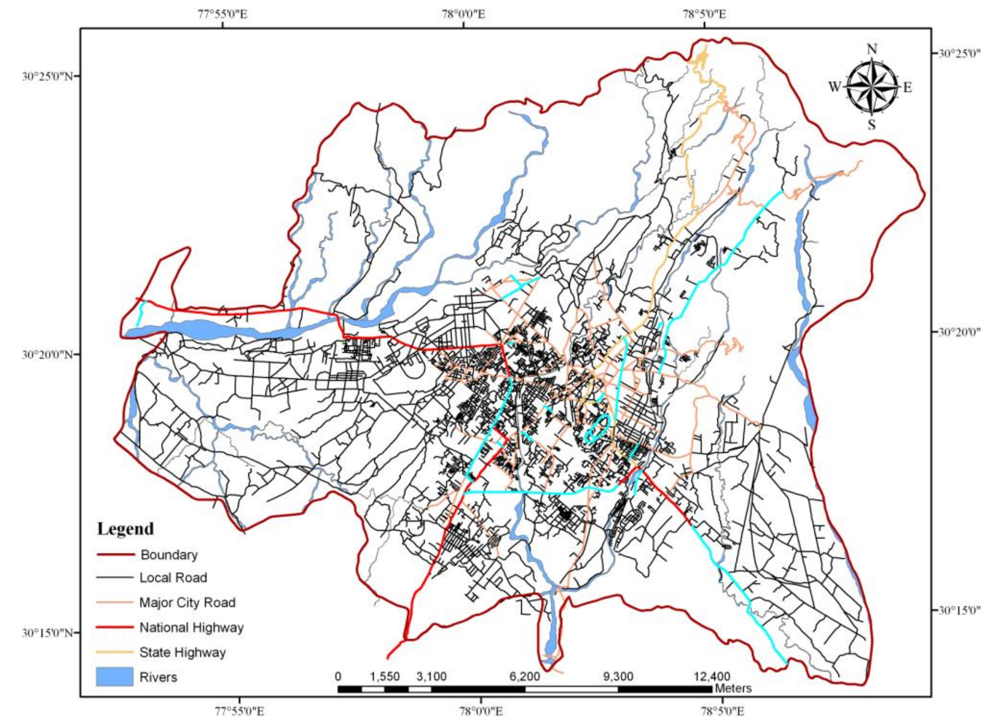


Fig 6.9: Roads of 10 m width

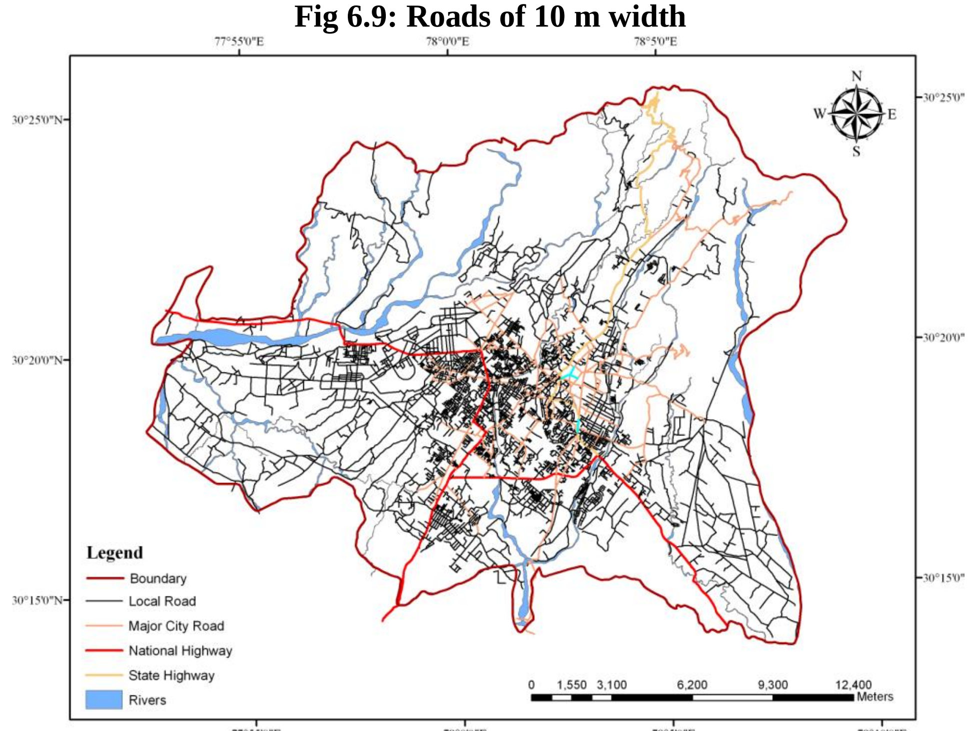


Fig 6.10: One way Roads

While running the queries for having concrete road surface, various local roads are highlighted in Fig 6.11.

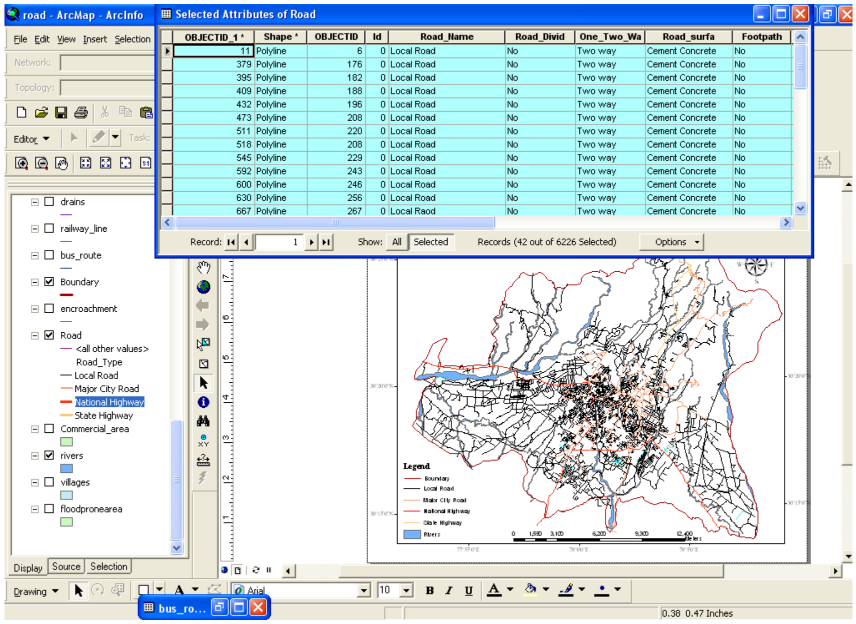


Fig. 6.11: Roads by their Surface

The module has the capability to select the road by their name or by their type, such as National Highway, State highway, major district roads or local roads. The queries were made with the road name and road type, and the roads thus selected are shown in Figs. 6.12 & 6.13. In Fig 6.12, GMS road is selected, while in Fig 6.13 State Highway has been selected.

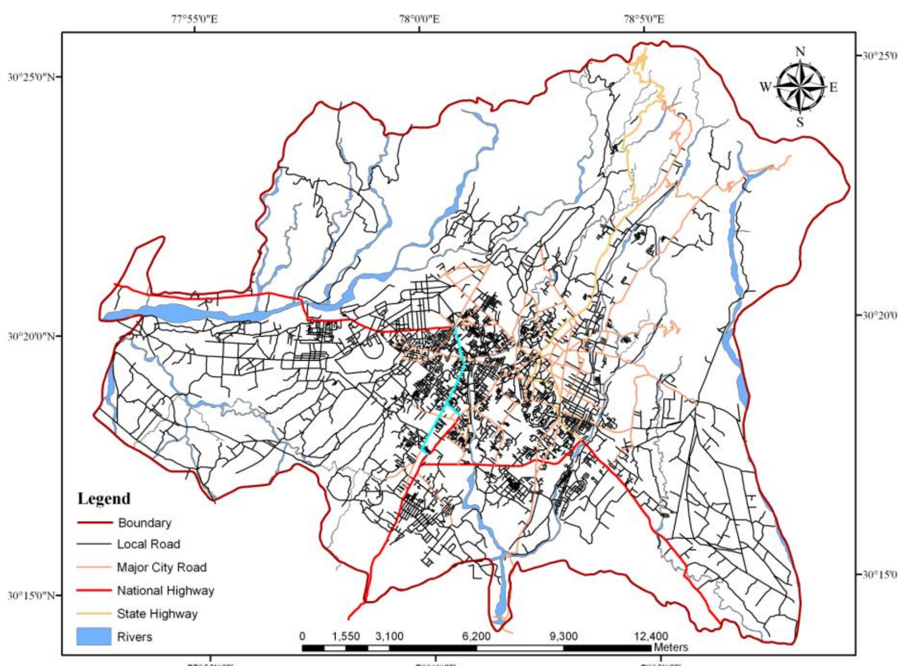


Fig 6.12: Roads by their Name

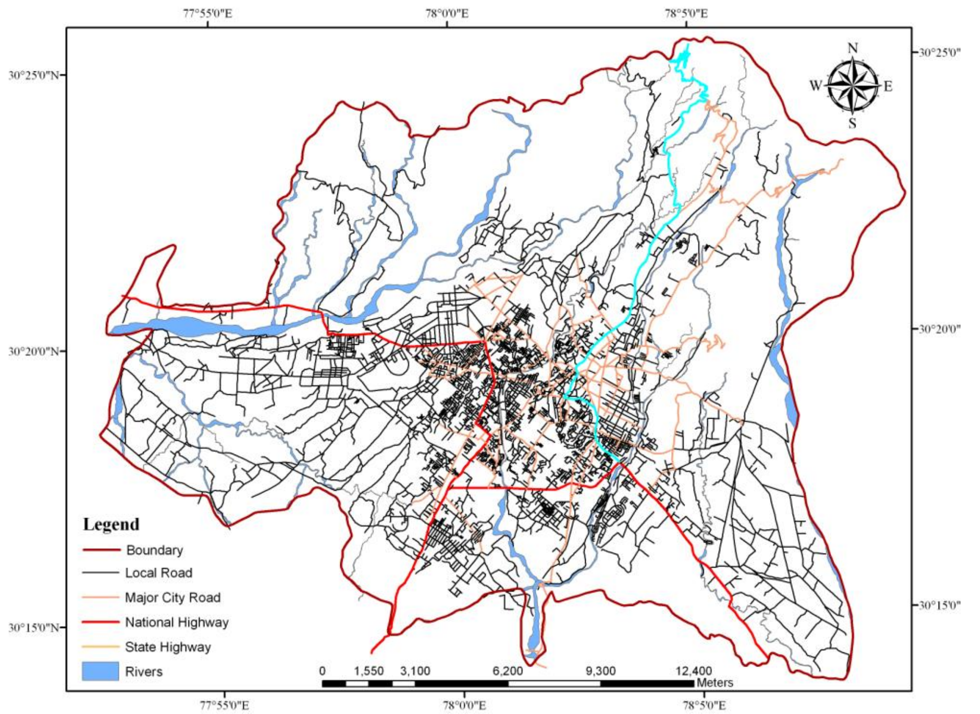


Fig 6.13: Roads by their Types

Fig 6.14 shows the answer of a query that the National Highway has 9.0 m width from Premnagar to Chakrata. Similar type of query can be answered by the web enabled RIS module. For example, a road with 6 m width, having black top and road divider is to be searched. The process of query formation is shown in Fig 6.15.

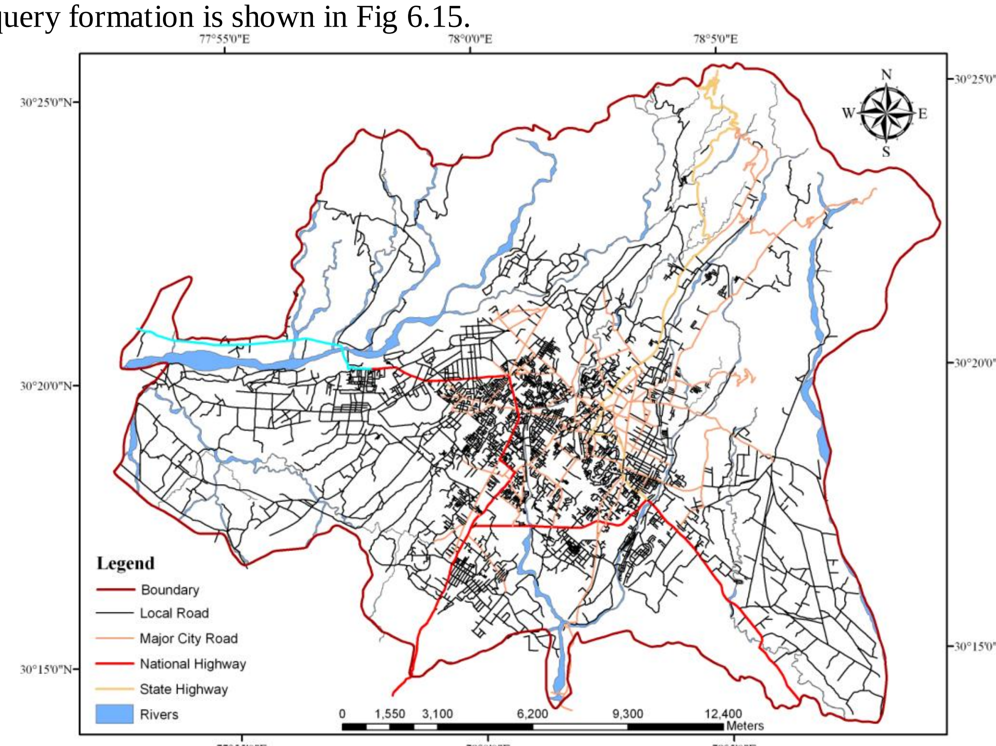


Fig 6.14: Roads by their Width and Types

Fig 6.15: Formation of Query to Select a Road of 6 m Width, with Road Divider and Black Top surface

The answers from the module are given in Figs 6.16 & 6.17.

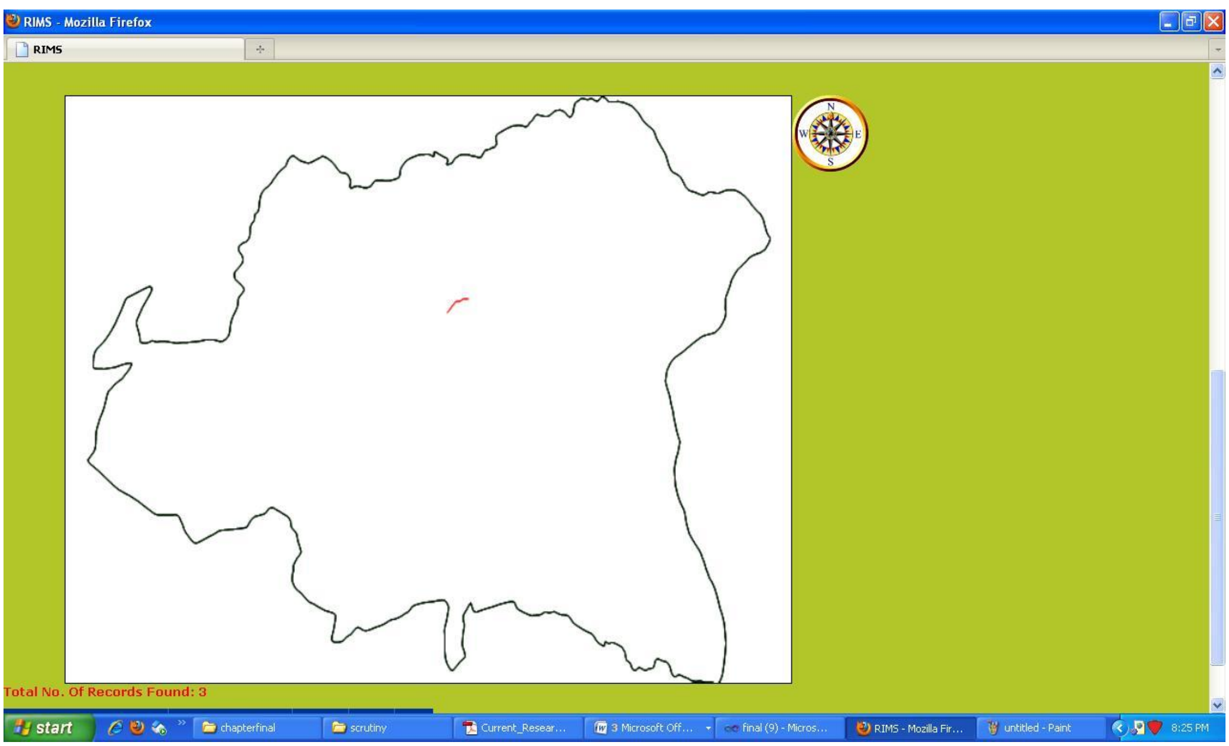


Fig 6.16: Road of 6 m Width, with Road Divider and Black Top Surface

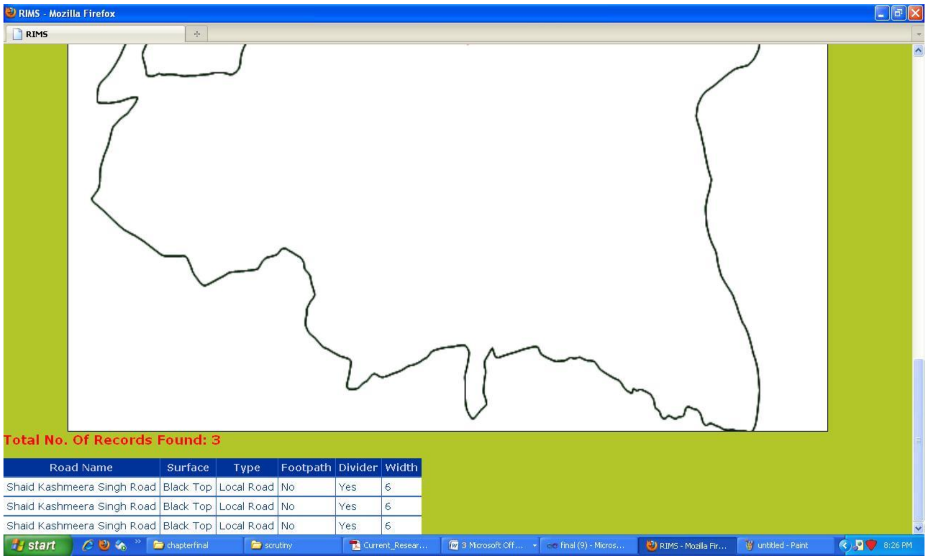


Fig 6.17: Tabular Details of Road of 6 m Width with Road Divider and Black Top Surface

6.3.1.2 Queries Other than Road Infrastructure

Fig 6.18 shows the route of city bus number 10 from Seema Dwar to Nalapani via Ghantaghar. The developed system can provide information about the city buses routes and their origins & destinations on a particular road (Fig 6.19). Through this query, travelers would know about the city buses passing through Gandhi road and their origins & destinations. In this example, the travelers would know that city buses of route no 1, 2, 3, 4, 5, 6, 10, 11, 13 and 14 passes through Gandhi road. In the attribute box (Fig 6.19), the origins and destinations of these buses are also listed.

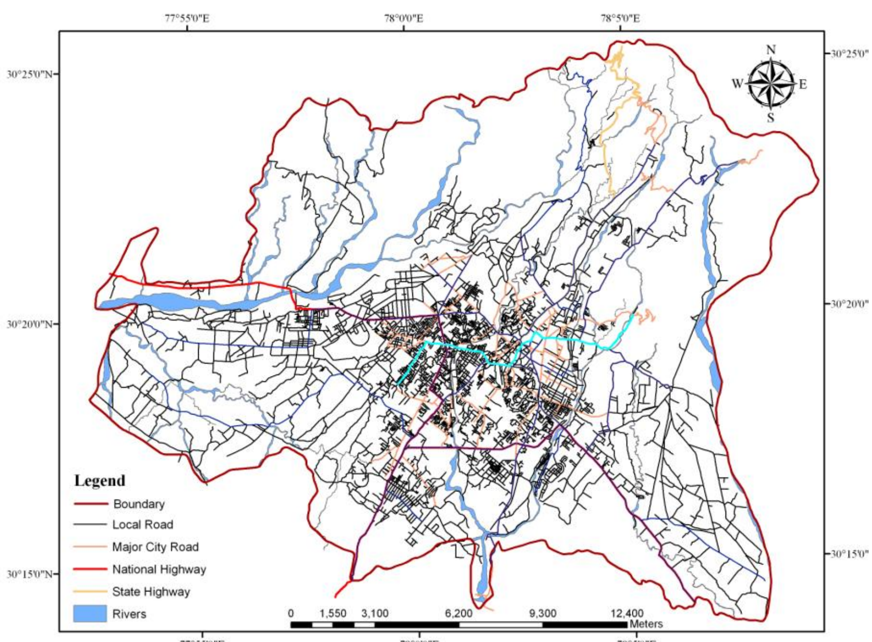


Fig 6.18: Selection of City Bus Route by Bus route number

Similarly, city bus related query can be handled by the web enabled system. Suppose, a student studying at the Royal Ashoka Institute of Engineering and Management wants to know the city bus number going to a particular place. Fig 6.20 shows the formation of a query in which the student selects check boxes of city bus with all city buses route option, professional institutes and engineering and management institutes, on RIS web page. Fig 6.21 shows the results of the query formed in Fig 6.20.

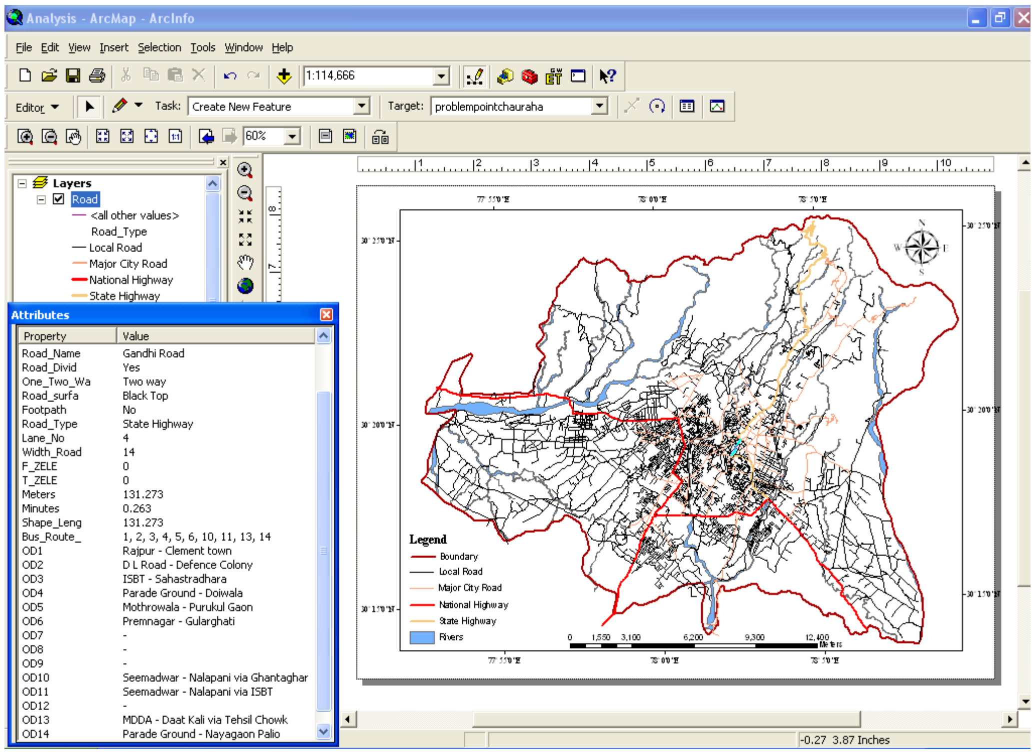


Fig 6.19: City Buses and their Origins and Destinations on a Particular Road

Fig 6.20: Formation of a Query to Select the City Bus Routes from Engineering and Management Institute

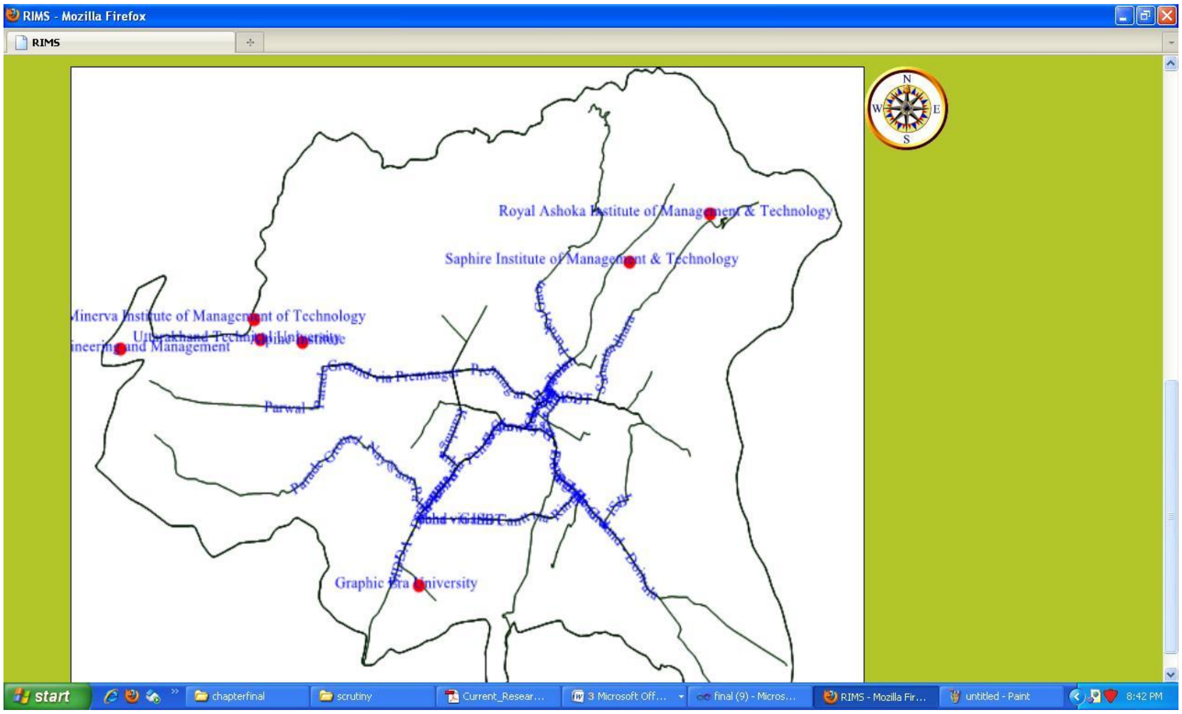


Fig 6.21: City Bus Routes and Engineering and Management Institute

Similarly, Fig 6.22 shows the distribution of government hospitals and major city roads, while Fig 6.23 shows all the engineering and management institutes. Fig 6.24 shows the location of all engineering institutes.

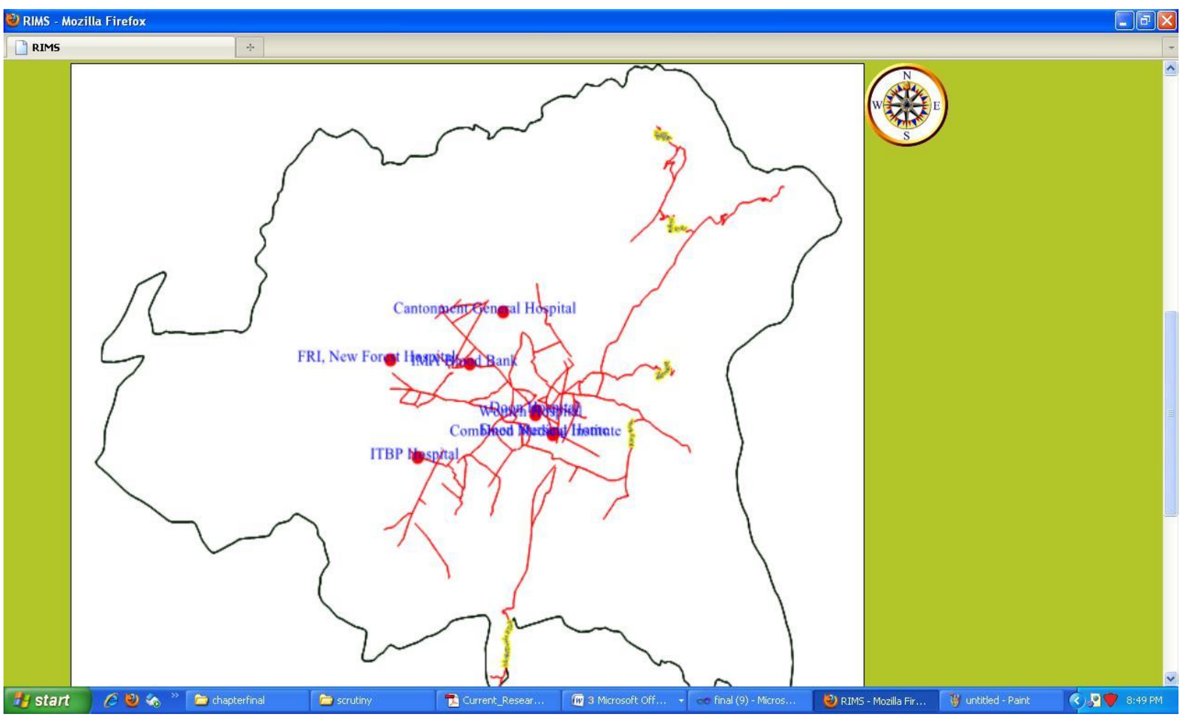


Fig 6.22: Major City Roads and Government Hospitals

Fig 6.23: Engineering and Management Institutes

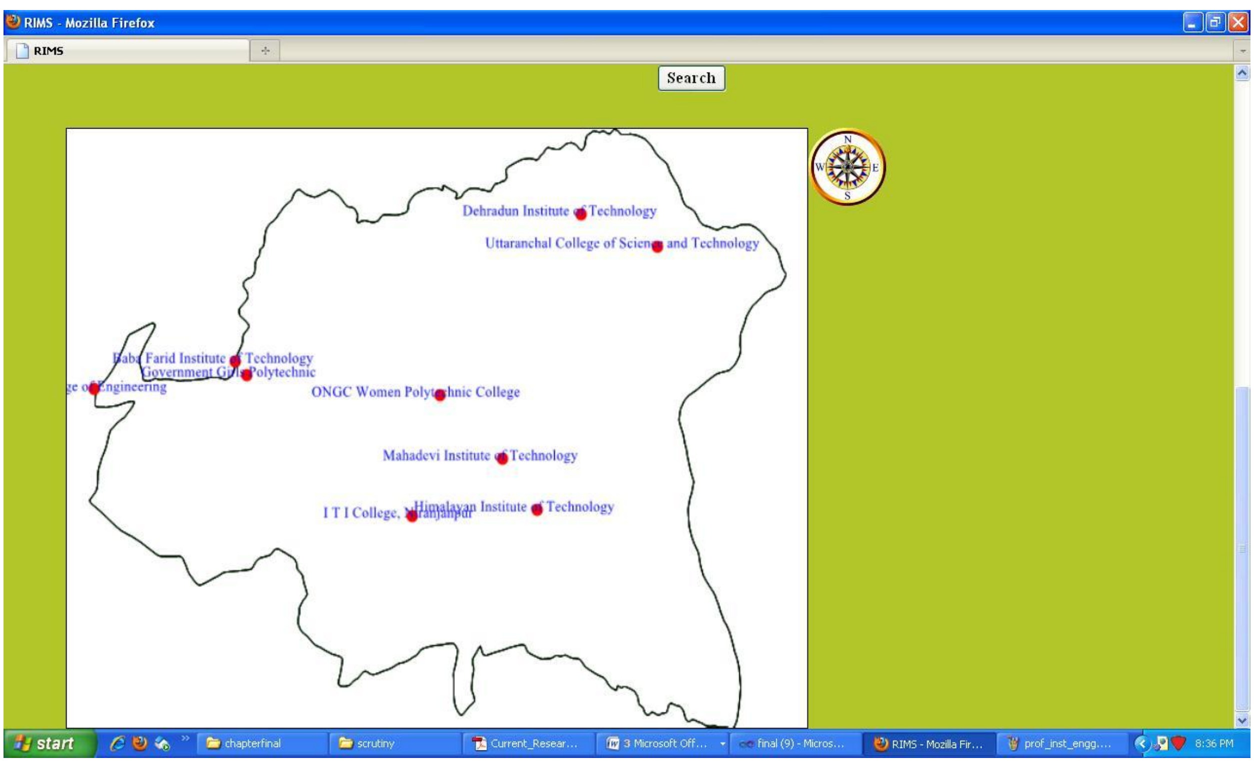


Fig 6.24: Engineering Institutes

Fig 6.25 shows the locations of all major tourist places in the study area, while Fig 6.26 presents the railway line and all the railway crossings. Fig 6.27 shows all the distribution of villages in the study area.

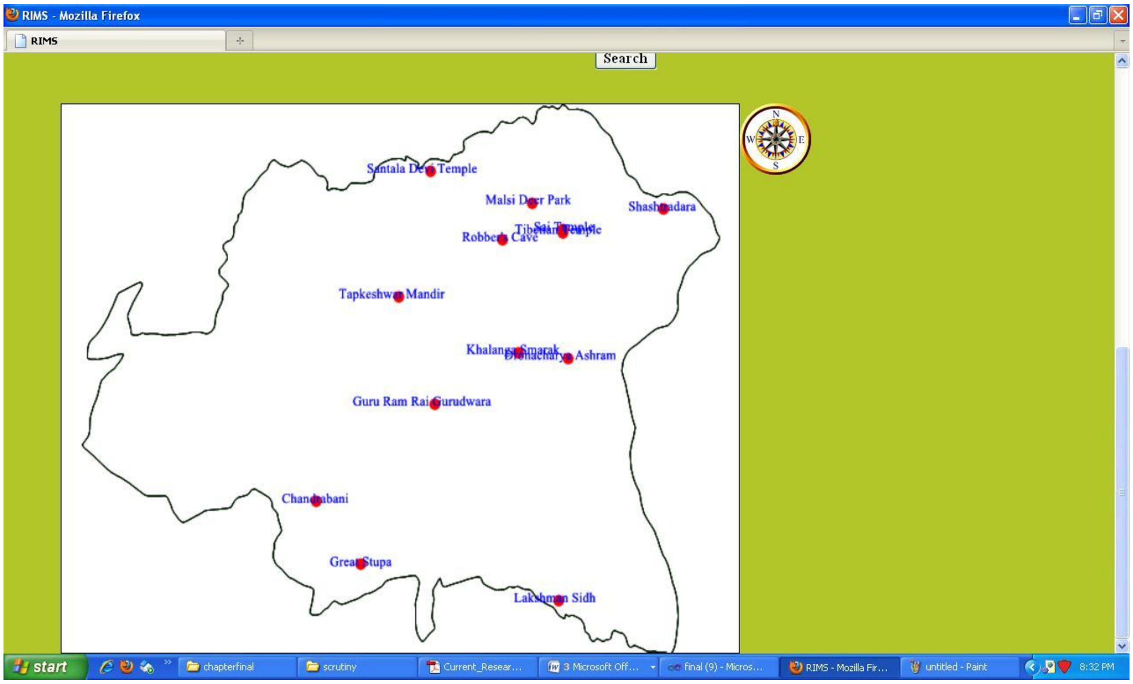


Fig 6.25: Tourist Places

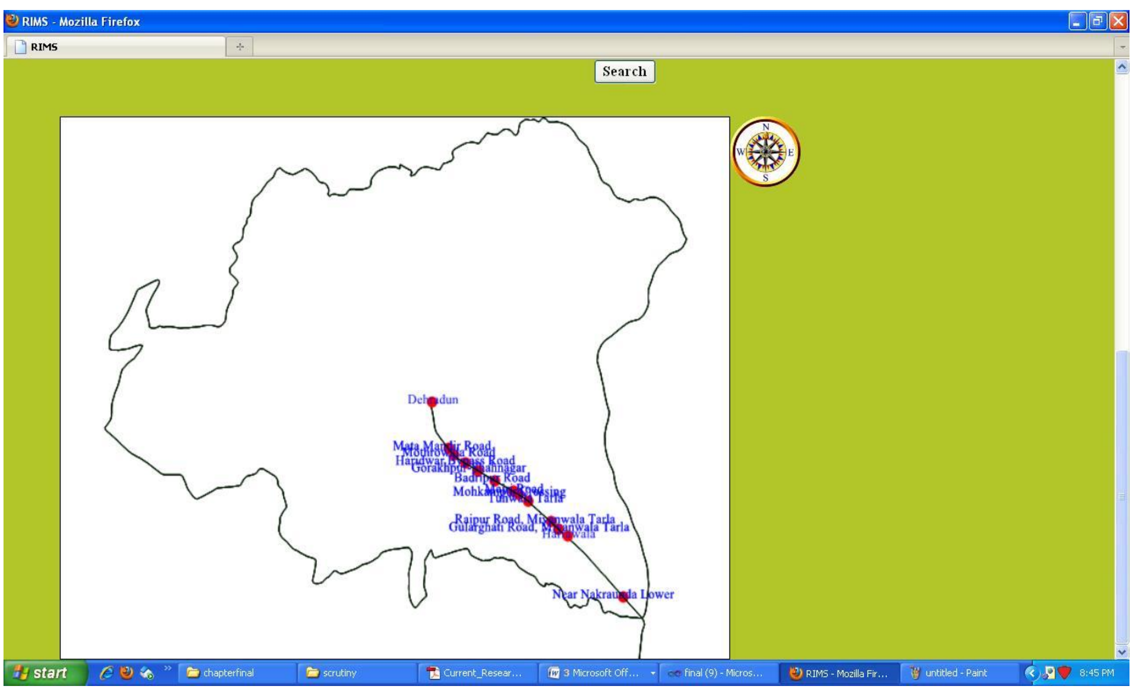


Fig 6.26: Railway Line and Railway Crossings

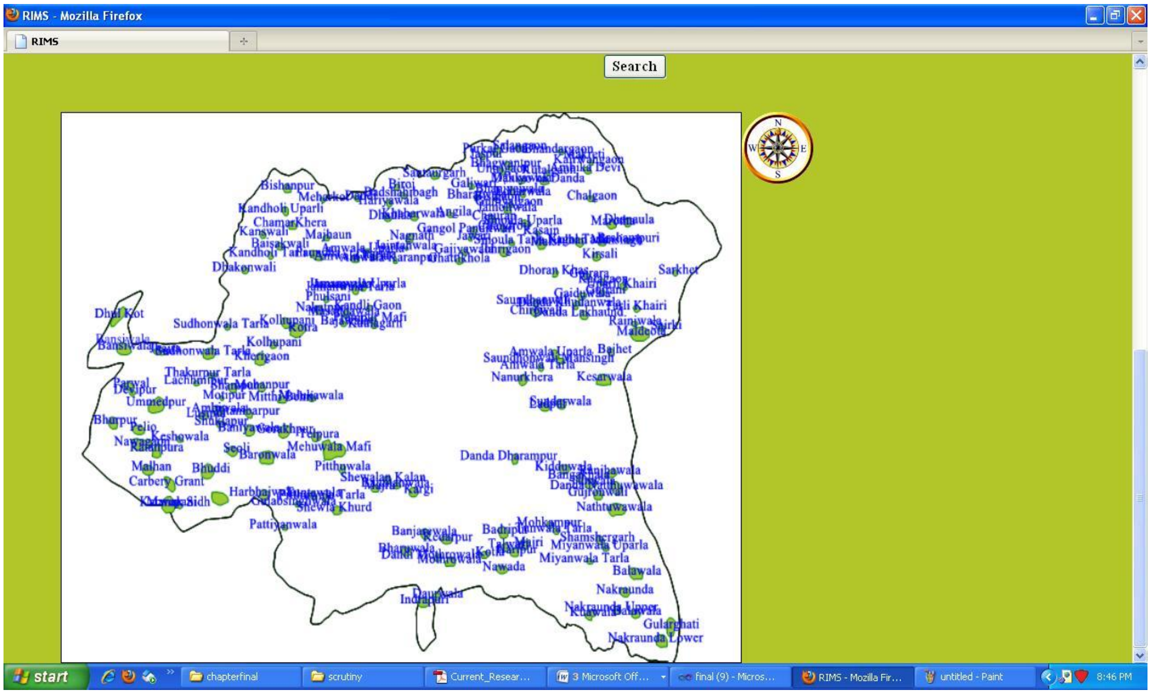


Fig 6.27: Distribution of Villages

This module would also beneficial for traffic police or traffic administrator, as one can get the idea about the sign board to be placed near a place, such as near school or Hospital a sign board would be required to caution the driver to drive slowly. The number of sign boards and their location can be fixed with the help of this system (Fig 6.28). Similarly, the count and locations of the signboards can be calculated for hospitals, professional institutes etc.

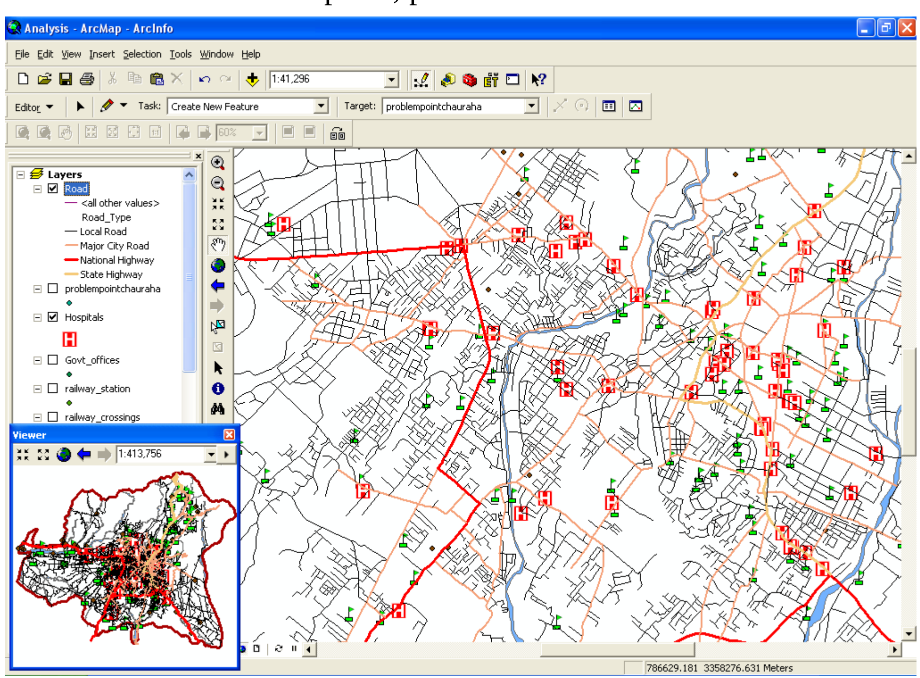


Fig 6.28: Locations of Sign Boards

6.3.1.3 Buffer Analysis

To check the connectivity of picnic spots with all weather roads, a road buffer of 500 m is created and overlaid with all the picnic spots lying within the buffer area. It provides information about the picnic spots which are well connected with the all weather roads (Fig 6.29). Similar analysis can also be performed to check the connectivity of villages in the study area.

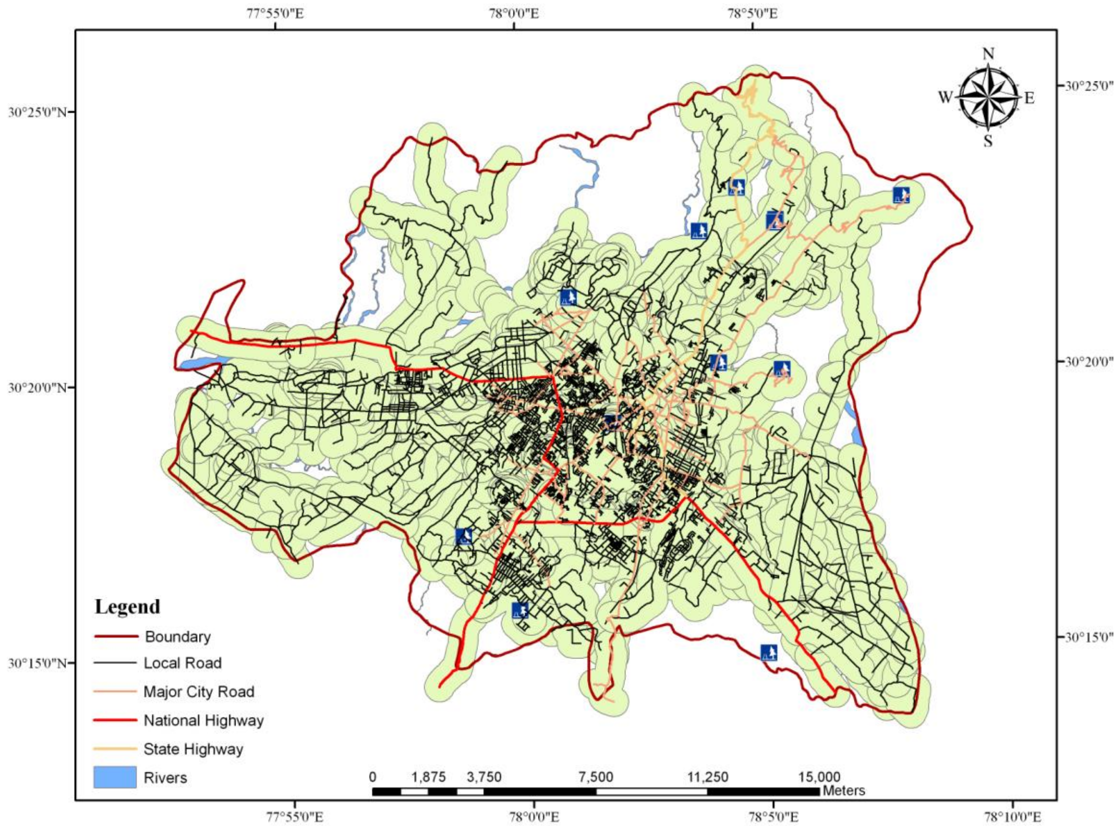


Fig 6.29: Well Connectivity of All Tourist Place from Road

Buffer analysis was carried out for schools, fire stations, police stations and police substation. A ring buffer of 2000 m is prepared for police stations (Fig 6.30). It is observed that the police help is more than 2000 m from the villages such as Balawala, Gularghati, Nakraunda, Miyanwala, Ranjhawala, Thakurpur, Shudhowala and many more villages. A ring buffer of 3000 m is created for schools, and it was observed that east-south and north-west areas require new schools (Fig 6.31).

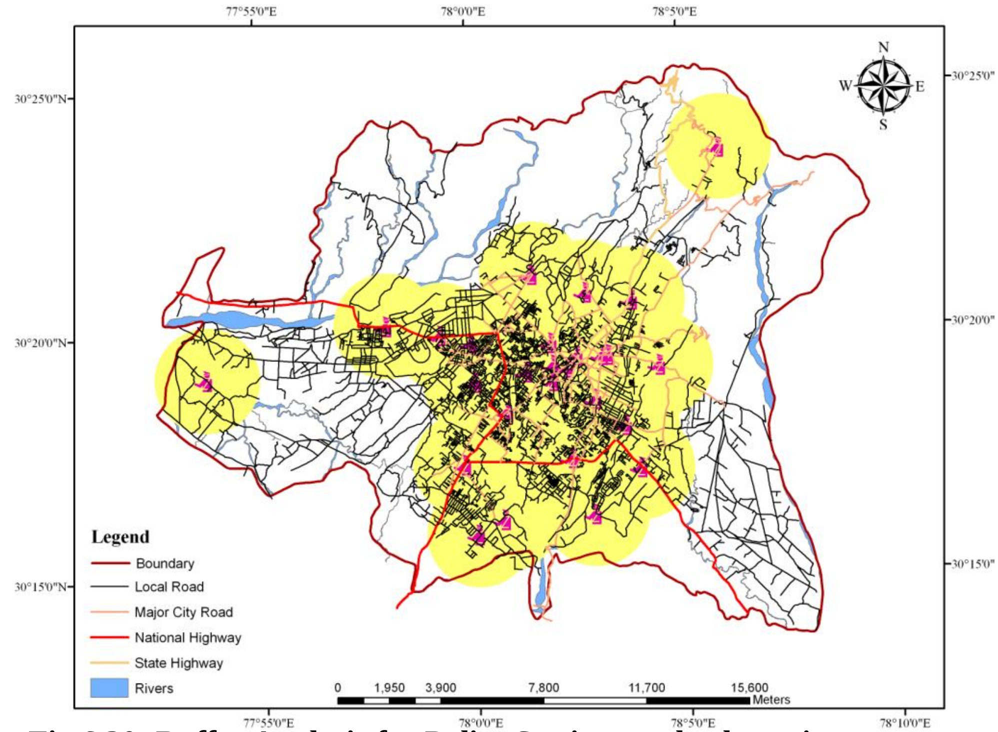


Fig 6.30: Buffer Analysis for Police Stations and sub-stations

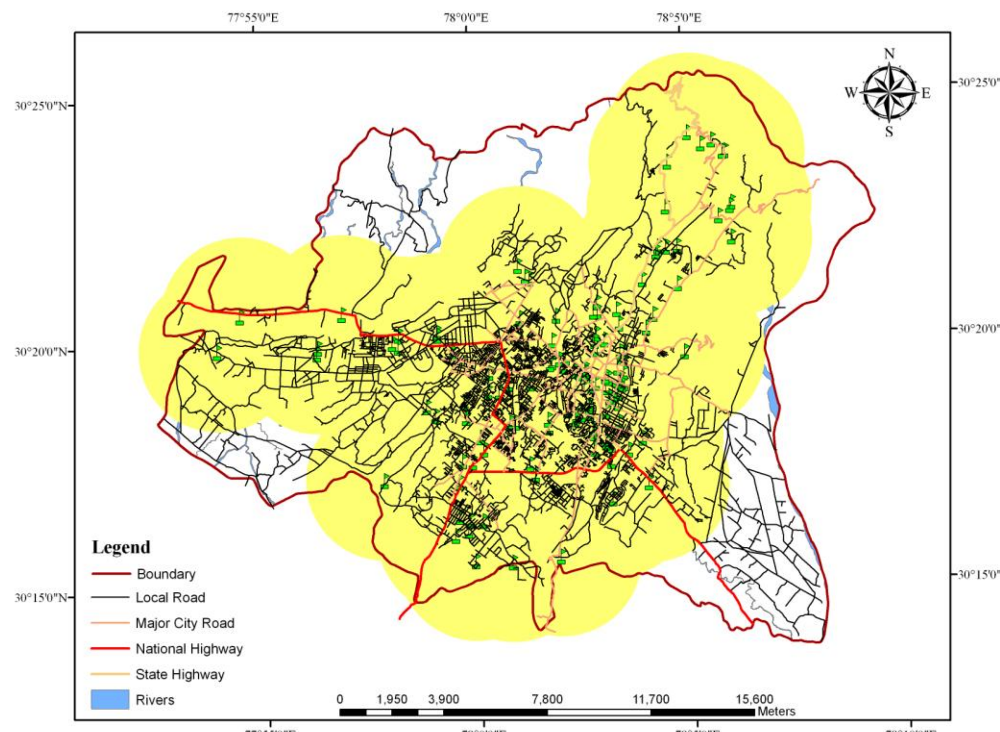


Fig 6.31: Buffer Analysis of Schools

There are only two fire stations in the city; one at Gandhi road and the other one at Shaeed Kashmira Singh Road. A ring buffer of 5000 m is prepared around fire station, and it was observed that only Dehradun municipal area is covered within the buffer. Almost all the villages are 5 km away for the fire stations (Fig 6.32). It clearly indicates that more number of fire stations is required in the area outside the buffer and having proximity to larger settlement.

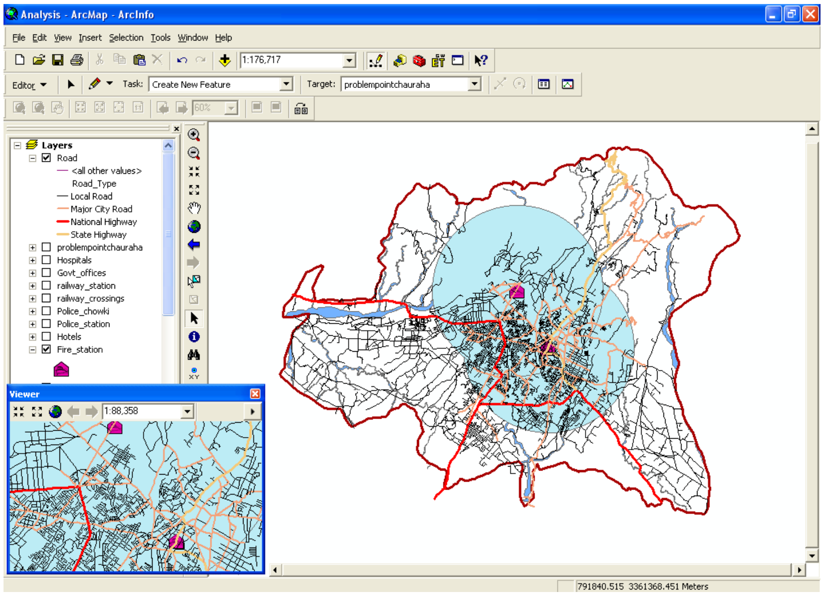


Fig 6.32: Buffer Analysis for Fire Station

6.3.1.4 Road Network Analysis

The network analysis was carried out for the road network of study area. The shortest route covering all the tourist points, starting from a hotel at Gandhi road and ending at the same point, is shown in Fig 6.33. The results on the basis of shortest time are shown in Fig 6.34.

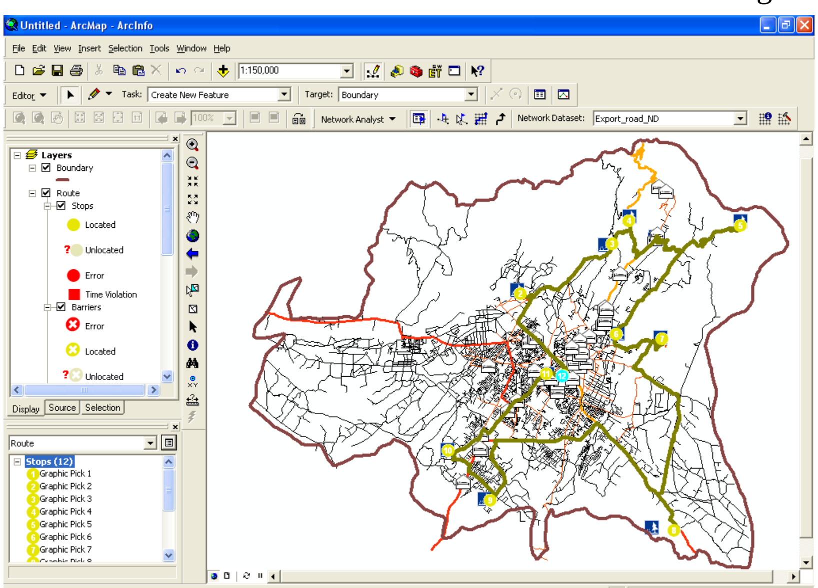


Fig 6.33: The Shortest Route Covering All the Tourist Points Starting and Ending from a Hotel at Gandhi Road

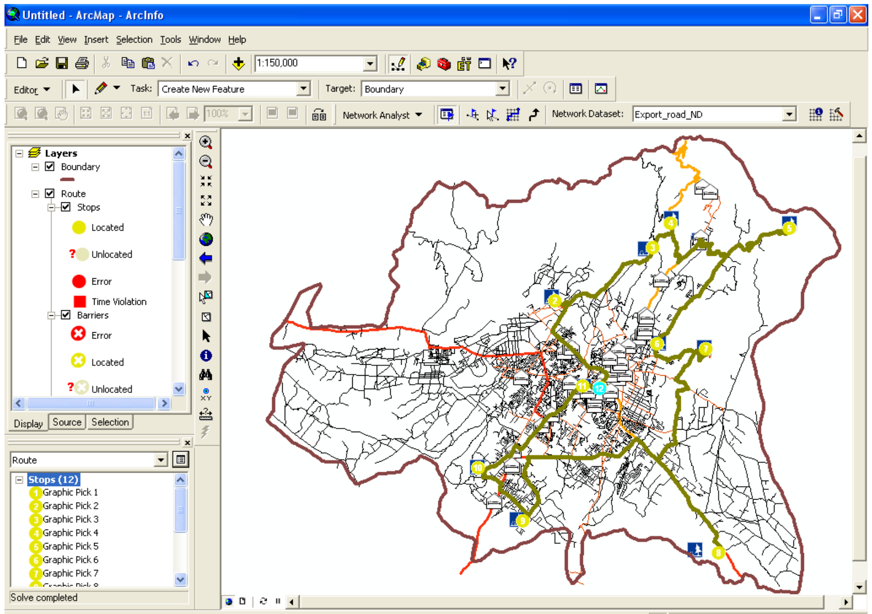


Fig 6.34: Route Covering All the Tourist Points Starting and Ending from a Hotel at Gandhi Road in Shortest Time

The network analysis also facilitates the users to find out minimum travel time from a facility to reach at the point of incident. It is presumed that fire breaks out in Race Course Colony. After analysis, it was observed the fire brigade will take at least 5 minutes to reach there whereas it will take 18 minutes to reach fire brigade from another fire station (Figs. 6.35 & 6.36).

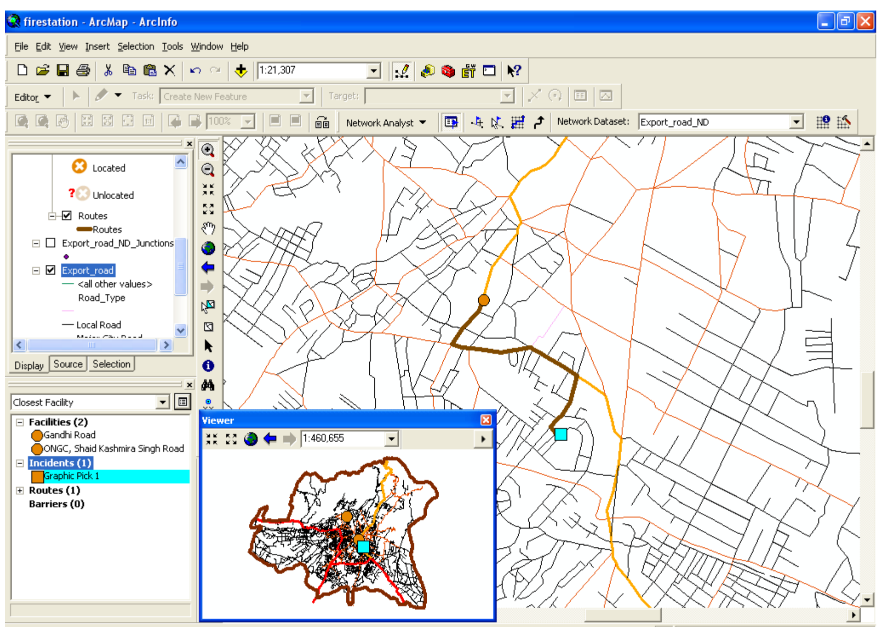


Fig 6.35: Minimum Travel Time Requirement to a Fire Brigade Reaching to the Point of Incident

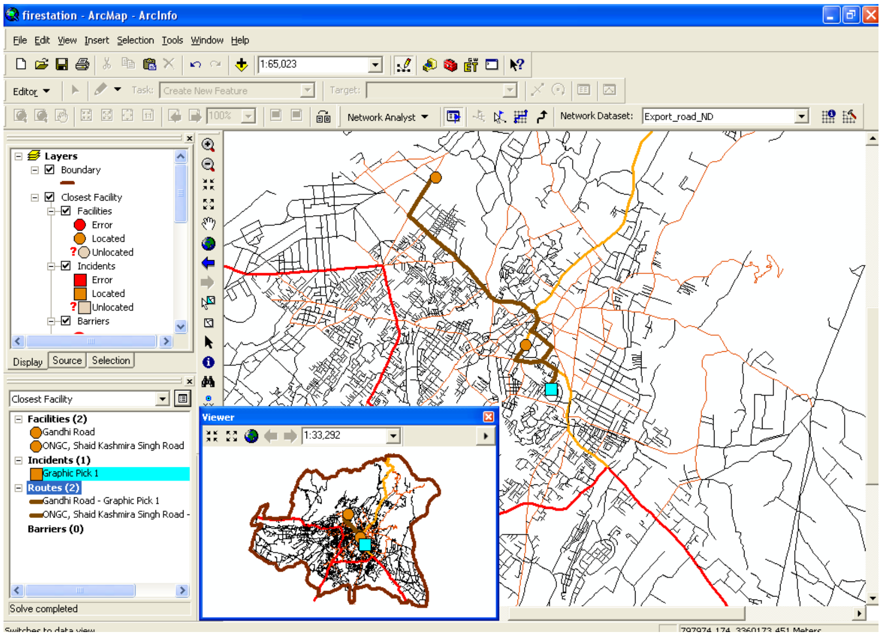


Fig 6.36: Minimum Travel Time Requirement from a Facility Situated at Different Place to the Point of Incident

In another case, it is presumed that some incident happened at Race Course Colony. By network analysis, it is found that Police will take about 10 minutes to reach at the point of incident from the nearest police stations/police sub-station (Fig 6.37).

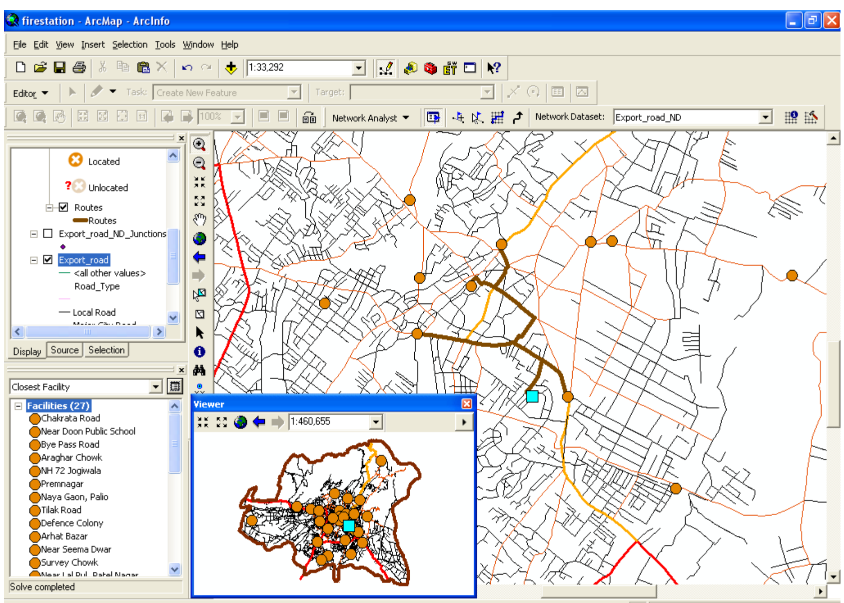


Fig 6.37: Minimum Time Requirement of a Facility Situated at Four Different Places to the Point of Incident

Suppose, a vehicle is heading towards Dehradun, and near Mehuwala Mafi the driver requires fuel in the vehicle. With the help of network analysis, all the petrol stations in 5 km area along the road can easily be found (Fig 6.38).

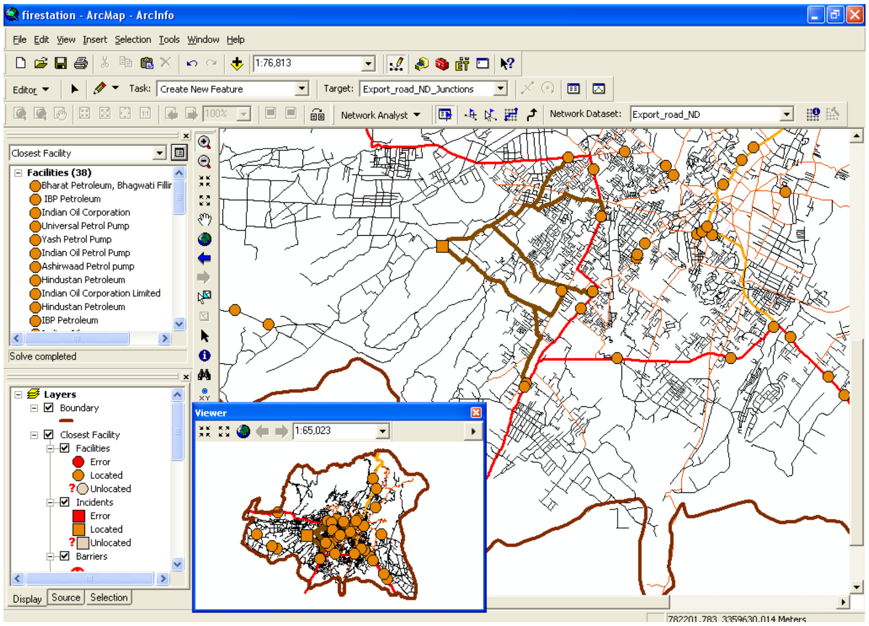


Fig 6.38: Locations of Petrol Stations within 5 km Reach

Further, suppose a person residing at Saharanpur Road would like to go to Income Tax office. From analyses, it is found that the minimum distance is about 8 km, and therefore it will take 22 minute to cover the distance if he/she travels by own vehicle (Fig 6.39). Fig 6.40 shows the locations of hotels within 3 km from the Guru Ram Rai Gurudwara, the worship place of the Sikh religion.

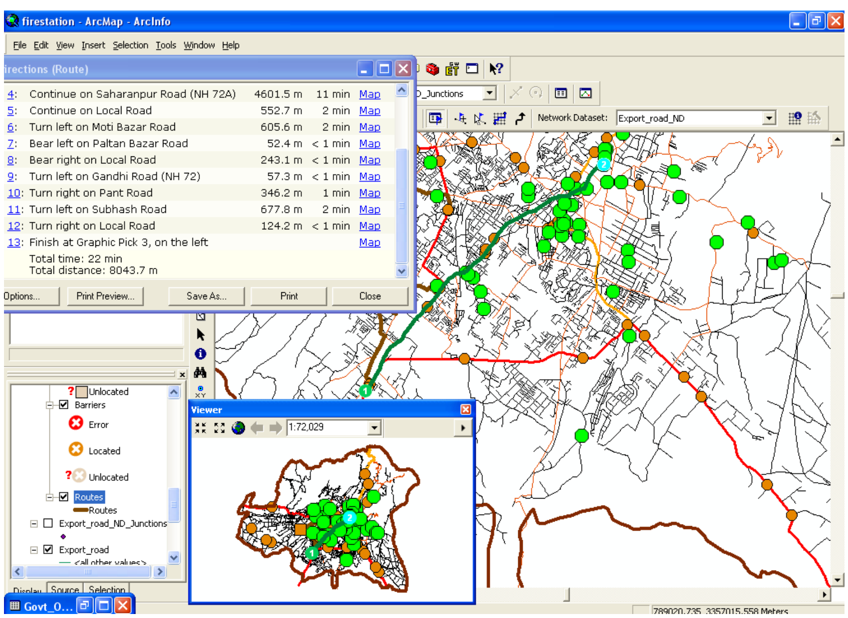


Fig 6.39: Minimum Distance to Reach a Govt. Office

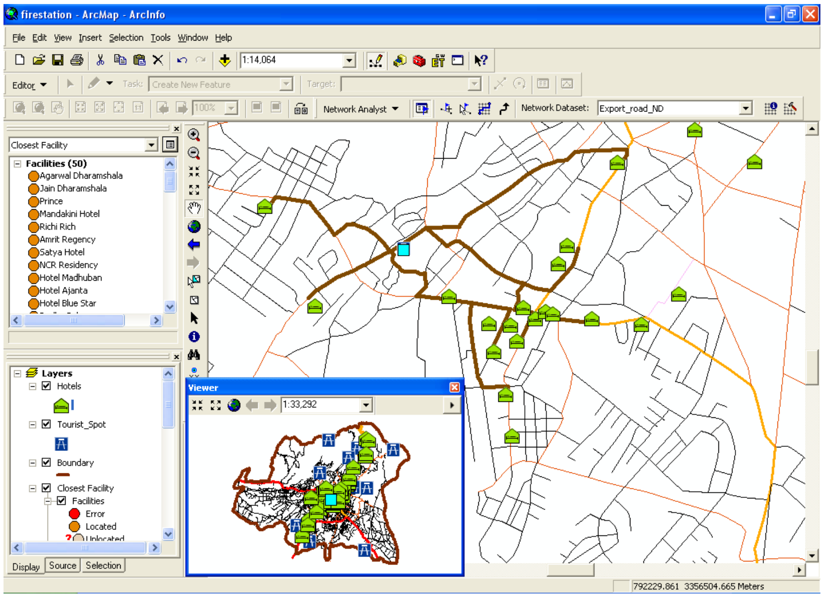


Fig 6.40: Hotels near Guru Ram Rai Gurudwara

6.3.2 BMS

From the database, a number of queries can be generated to derive the new maps and useful information. Fig 6.41 shows all the bridges in through this module.

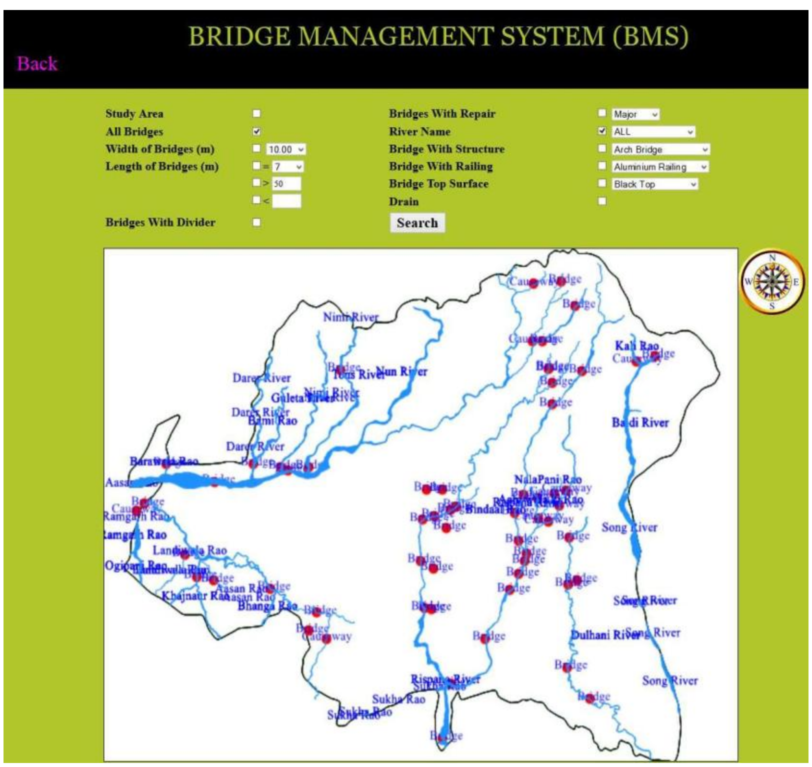


Fig 6.41: All Bridges/Causeways in the Study Area

As an example, a query was made to know as to how many bridges are constructed on Rispana River within the study area. Fig 6.42 shows a total 12 number bridges as the result, while tabular data in Fig 6.43 shows the details of bridges on River Rispana.

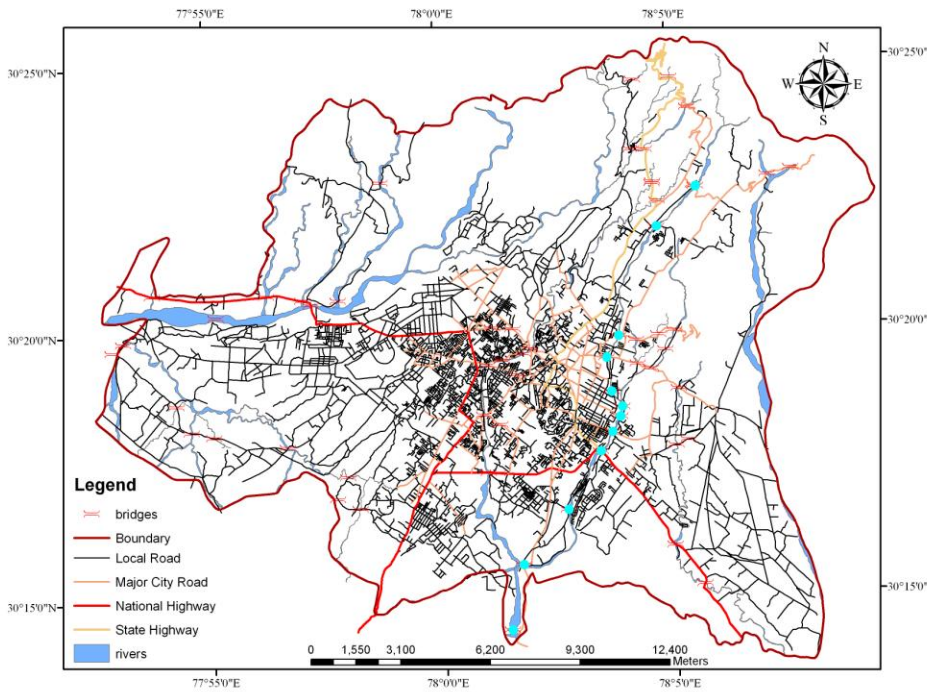


Fig 6.42: Bridges on River Rispana

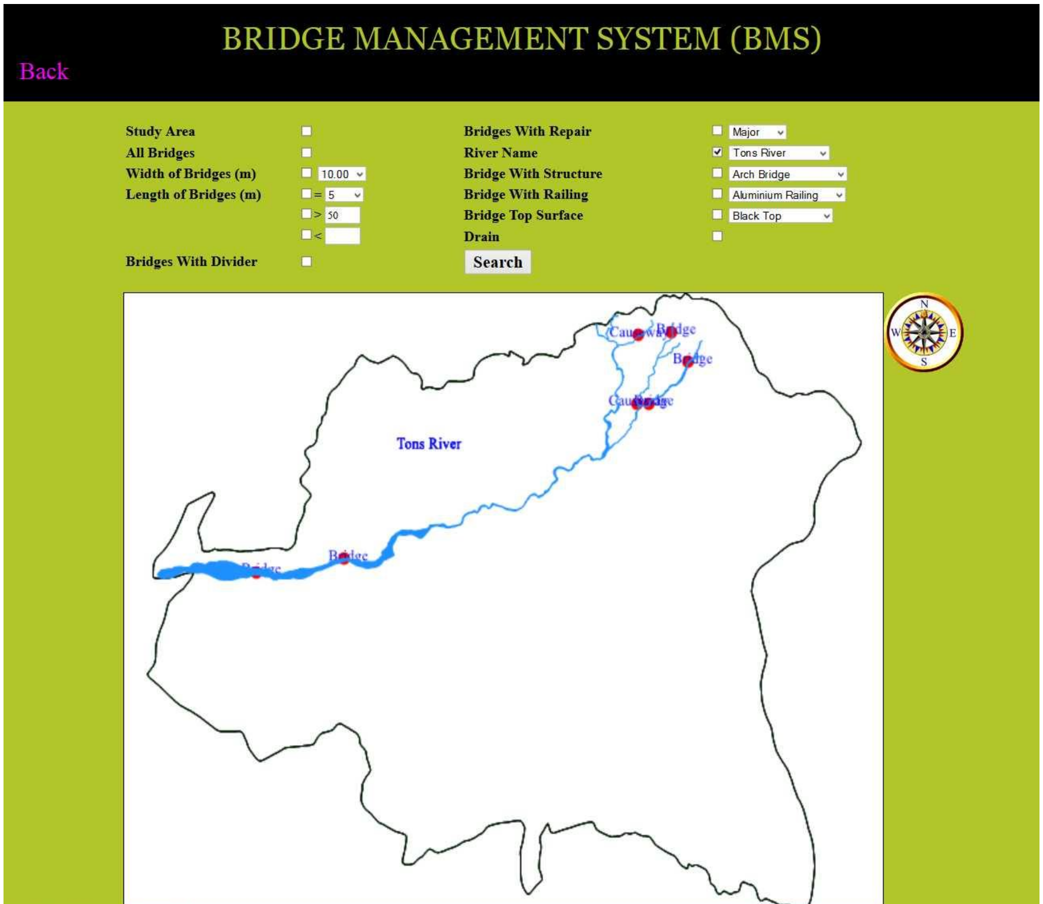
Selected Attributes of Bridge

FID	Shape	OBJECTID	Id	Name_Bri_C	Road_Width	Left_Shoul	Right_shou	Span	comment	River_Name	Length	Road_Divid	Railing_Ty	To
24	Point	25	0	Bridge	7.50	1.20	0.90	3 @ 18.7		Rispana River	56.099998	No	Steel Railing	Black Top
25	Point	26	0	Bridge	7.50	0	0	12 @ 5.85 m	Photo 32, 33	Rispana River	70.199997	No	Steel Railing	Concrete
32	Point	33	0	Bridge	4.00	0	0	33.0 m	Chander Road	Rispana River	33	No	Steel Railing	Concrete
33	Point	34	0	Bridge	7.00	0	0	8 @ 10.0 m	Cement Concrete Top	Rispana River	80	No	Steel Railing	Concrete
34	Point	35	0	Bridge	7.00	0	0	8 @ 10.0 m	Cement Concrete Top	Rispana River	80	No	Steel Railing	Concrete
36	Point	37	0	Bridge	7.50	1.50	1.50	2 @ 20.6 m	Black top	Rispana River	41.200001	No	Casted Concrete	Black Top
37	Point	38	0	Bridge	7.50	1.50	1.50	2 @ 10.0 m,	Cement Concrete Top	Rispana River	65	No	Casted Concrete	Black Top
38	Point	39	0	Bridge	7.80	0.90	0	photo se	cement Concrete Top	Rispana River	30	No	Pipe Railing	Concrete
39	Point	40	0	Bridge	4.00	0	0	35.0 m	Truss Bridge	Rispana River	35	No	Pipe Railing	Black Top
50	Point	51	0	Bridge	5.75	0	0	5 @ 9.00	cement concrete top	Rispana River	45	No	Steel Railing	Concrete
55	Point	56	0	Bridge	21.00	0.60	0.60			Rispana River	72	Yes	Steel Railing	Black Top
59	Point	60	0	Bridge	6.00	0	0			Rispana River	36	No	Steel Railing	Concrete

Record: 1 Show: All Selected Records (12 out of 60 Selected) Options

Fig 6.43: Details of the Bridges on River Rispana

Similar type of query in web GIS module related to bridges/causeways on River Tons was made. Fig 6.44 shows the formation of a query and its results in pictorial as well as tabular form. Results in the second last column in the table in Fig 6.44 are with title “show”. If “show” button is clicked, the picture(s) of the concerned bridge is shown in new web page as given in Fig 6.45.



Total No. Of Records Found: 7

Bridge	Road Width	Left Shoulder	Right Shoulder	Span	River	Length	Divider	Railing	Surface	Structure	Type	Show	id
Bridge	9.00	0	0	8.8	Tons River	9	No	Brick Parapet Wall	Black Top	Arch Bridge	State Highway	Show	6
Bridge	7.50	1.00	1.00	30.0 m x 9	Tons River	270	under construction	Casted Parapet wall	under construction	RCC Girder	Local Road	Show	11
Bridge	7.50	0	0	4 @ 20.0m	Tons River	80	No	Steel Railing	Black Top	RCC Girder	National Highway	Show	17
Causeway	8.00	0	0	35.00	Tons River	35	No	No	Concrete	RCC	Local Road	Show	24
Bridge	6.75	0	0	25.0 m	Tons River	25	No	Steel Railing	Black Top	Arch Bridge	Major City Road	Show	21
Causeway	7.50	0	0	18.0	Tons River	18	No	No	Concrete	RCC	Local Road	Show	44
Bridge	**4.20**	**0.30**	**0.30**		**Tons River**	**30**	**No**	**Casted Concrete**	**Black Top**	**Arch Bridge**	**Major City Road**	**Show**	**55**

Fig 6.44: Details of the Bridges/Causeways on River Tons

Fig6.45: Photos of a bridge on River Tons

Fig 6.46 shows the presence of 11 causeways in study area as an answer of a query about the total number of causeways within the study area, while tabular data in Fig 6.47 shows the details of these causeways.

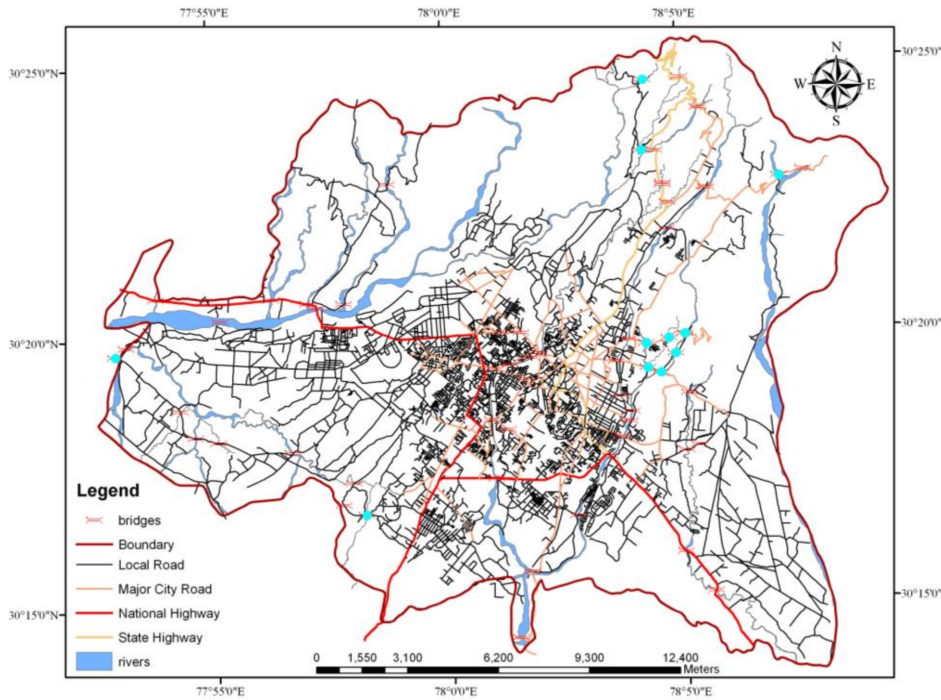


Fig 6.46: Location of Causeways

Selected Attributes of Bridge

FID	Shape	OBJECTID	Id	Name_Bri_C	Road_Width	Left_Shoul	Right_shou	Span	comment	River_Name	Length	Road_Divid	Railing_T
3	Point	4	0	Causeway	10.00	0	0	75 m	21 km mile stone, no photo	Ramgarh Rao	75	No	No
9	Point	10	0	Causeway	6.00	0	0	30.0 m	Causeway, no photo	Nalapani Rao	30	No	No
12	Point	13	0	Causeway	4.00	0	0	20.0 m	Causeway, No photo	Laldhang Rao	20	No	No
18	Point	19	0	Causeway	8.25	0	0	34.5 m	photo 31	Kali Rao	34.5	No	No
23	Point	24	0	Causeway	8.00	0	0	35.00		Local Drain	35	No	No
29	Point	30	0	Causeway	6.00	0	0	40.0 m	Nalapani Rao, No photo	Nalapani Rao	40	No	Aluminium Railing
43	Point	44	0	Causeway	7.50	0	0	18.0		Local Drain	18	No	No
51	Point	52	0	Causeway	4.50	0	0	5.00	cement concrete top	Aam wala ki Rao	5	No	No
52	Point	53	0	Causeway	5.50	0	0	35.0	cement concrete top	Nalapani Rao	35	No	No
53	Point	54	0	Causeway	4.00	0	0	40.0	cement concrete top	Nalapani Rao	40	No	No
58	Point	59	0	Causeway	8.00	0	0	50.0		Aam wala ki Rao	50	No	Aluminium Railing

Record: 1 Show: All Selected Records (11 out of 60 Selected) Options

Fig 6.47: Details of the Causeways in the Study Area

As an another example, Fig 6.48 shows the location of four bridges with 7.0 m road width on them. These bridges are located on Mussoorie Diversion Road, near Sahastradhara and two near Mothrowala village. Another query was made as to how many bridges out of these four have cemented concrete surface; the software selected three such bridges (Fig 6.49).

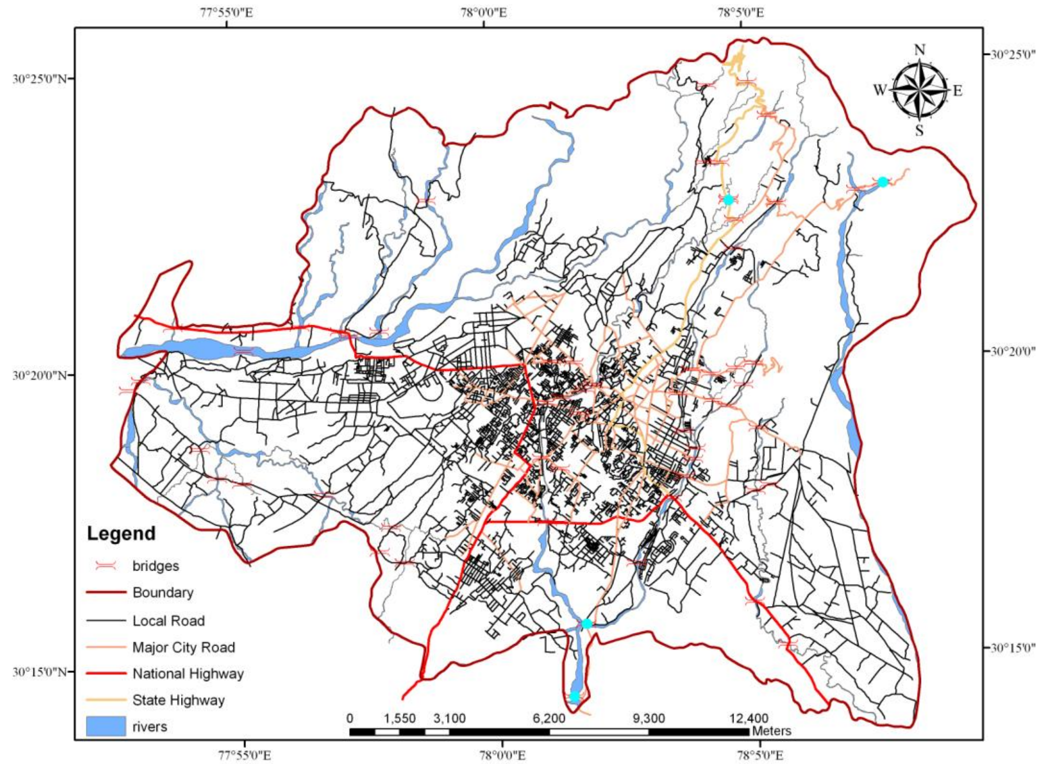


Fig 6.48: Bridges of 7.0 m Road Width

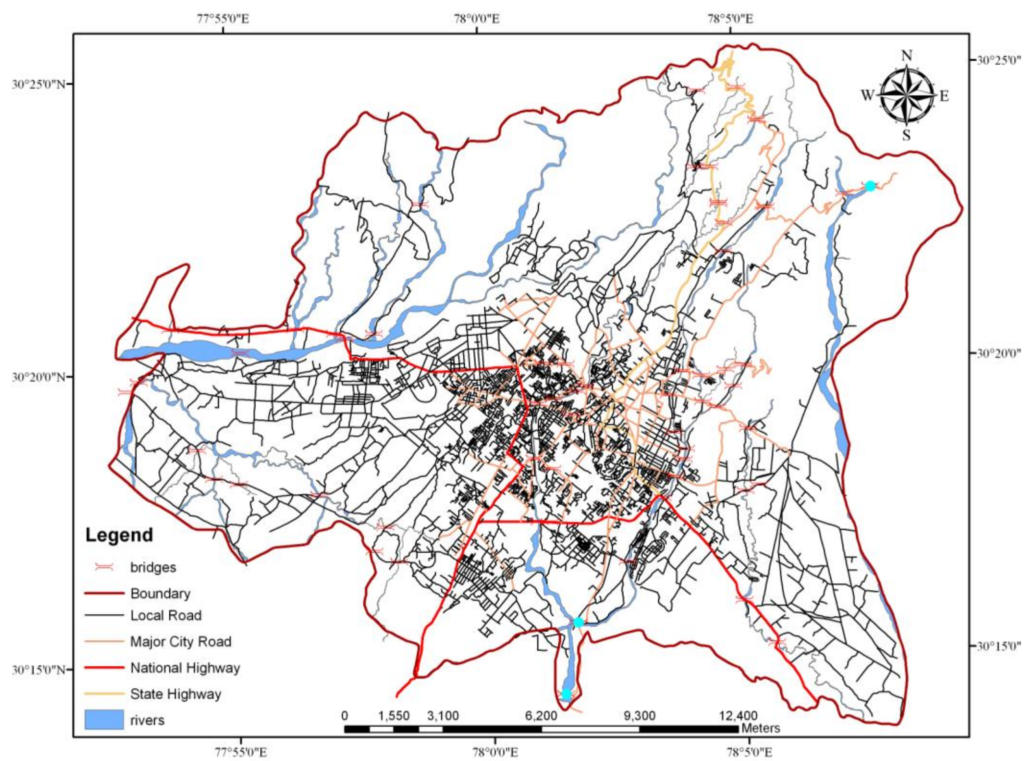
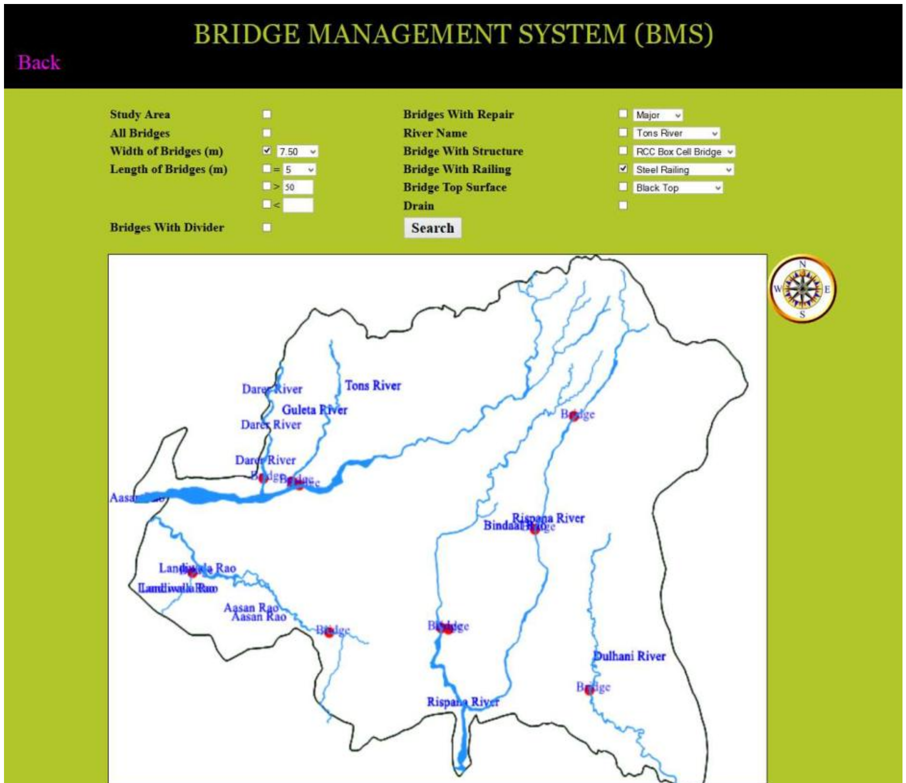


Fig 6.49: Bridges having 7.0 m Road Width and Cement Concrete Top Surface

Similarly in web GIS module, Fig 6.50 shows bridges with 7.5 m width and steel railings. Fig 6.51 shows the photographs of one such bridge. A query was made regarding the presence of left and right shoulders along the bridges, and it was found that 44 bridges do not have both right and left shoulders on them (Fig 6.52).



Total No. Of Records Found: 10

Bridge	Road Width	Left Shoulder	Right Shoulder	Span	River	Length	Divider	Railing	Surface	Structure	Type	Show	id
Bridge	7.50	0	0	40	Aasan Rao	40	No	Steel Railing	Concrete	RCC Box Cell Bridge	Local Road	Show	1
Bridge	7.50	0	0	60.0 m	Darer River	60	No	Steel Railing	Black Top	RCC Box Cell Bridge	National Highway	Show	9
Bridge	7.50	1.50	1.50	2 @ 20.3m and 3@ 19.95 m	Guleta River	100	No	Steel Railing	Black Top	RCC Girder	National Highway	Show	15
Bridge	**7.50**	**0**	**0**	**4 @ 20.0m**	**Tons River**	**80**	**No**	**Steel Railing**	**Black Top**	**RCC Girder**	**National Highway**	**Show**	**17**
Bridge	7.50	0	0	2 @ 9.0 m	Dulhani River	18	No	Steel Railing	Black Top	RCC Girder	National Highway	Show	18
Bridge	7.50	0	0		Landiwala Rao	18	No	Steel Railing	Black Top	RCC Box Cell Bridge	Local Road	Show	22
Bridge	7.50	1.20	0.90	3 @ 18.7	Rispana River	56	No	Steel Railing	Black Top	RCC Girder	Major City Road	Show	25
Bridge	7.50	0	0	12 @ 5.85 m	Rispana River	70	No	Steel Railing	Concrete	RCC Box Cell Bridge	Local Road	Show	26
Bridge	7.50	0.45	0.45	10.0	Local Drain	10	No	Steel Railing	Black Top	RCC Slab	National Highway	Show	57
Bridge	7.50	0.30	0.30	5 @ 9.0	Bindaal Rao	45	No	Steel Railing	Black Top	RCC Girder	National Highway	Show	58

Fig 6.50: Bridges of 7.5 m Road Width and Steel Railing

Fig 6.51: Photographs of Bridges of 7.5 m Road Width and Steel Railing

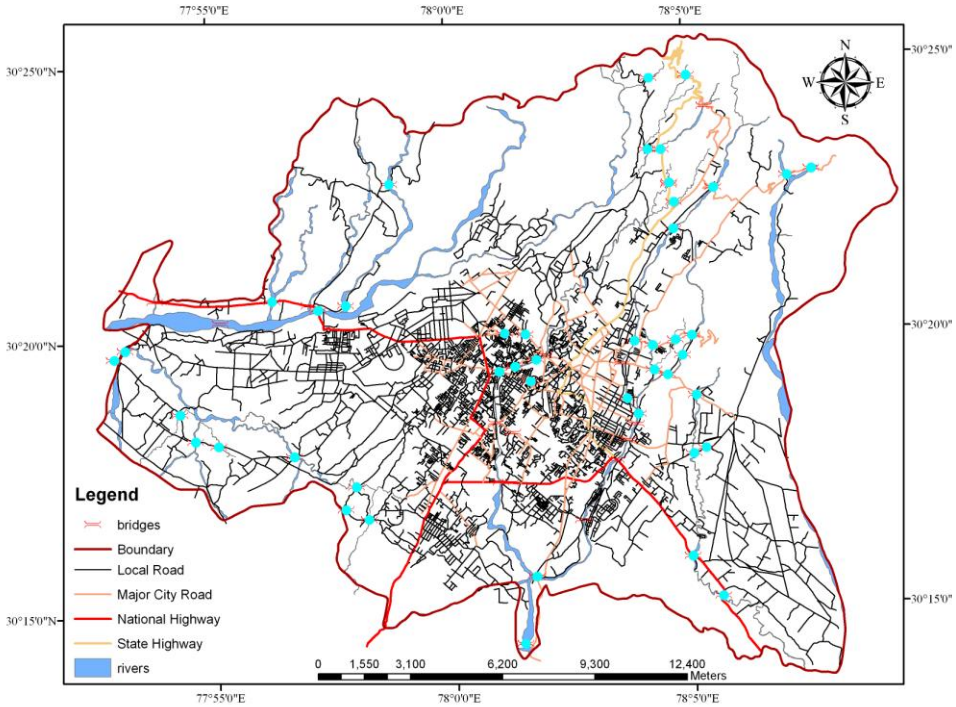


Fig 6.52: Bridges without Shoulders

A query was made to find out the bridges which have greater than or equal to 35 m bridge length. A total of 29 bridges were selected (Fig 6.53) by the software. However, in another query, 17 bridges out of 29 were found having length equal to or more than 35 m length with steel railings (Fig 6.54).

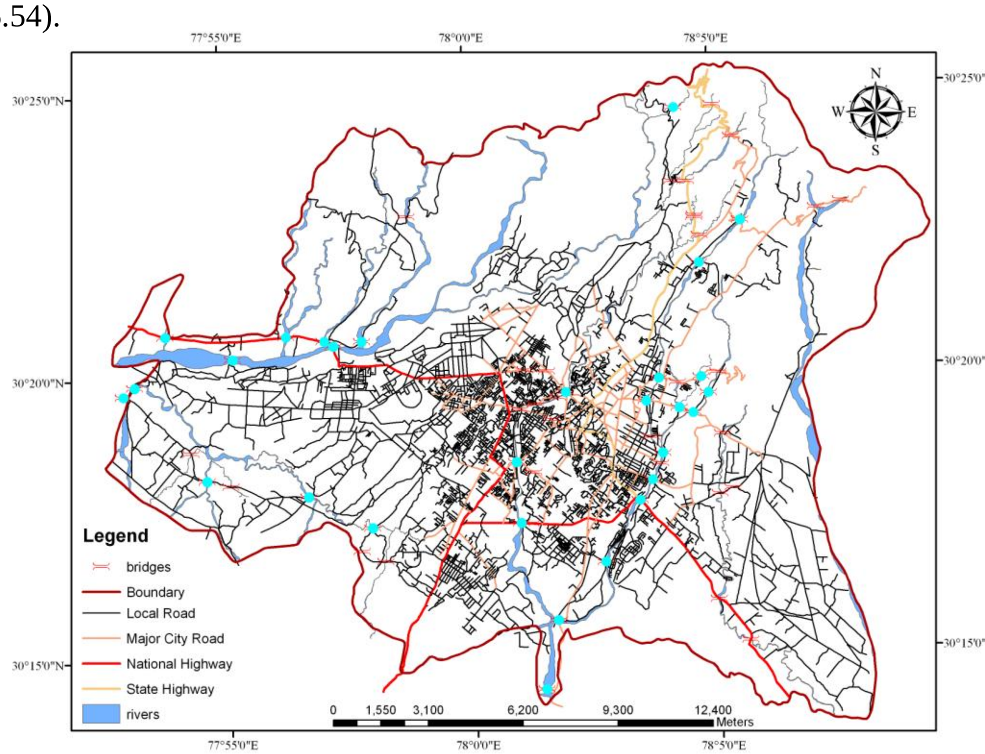


Fig 6.53: Bridges of Length Greater than or Equal to 35.0 m

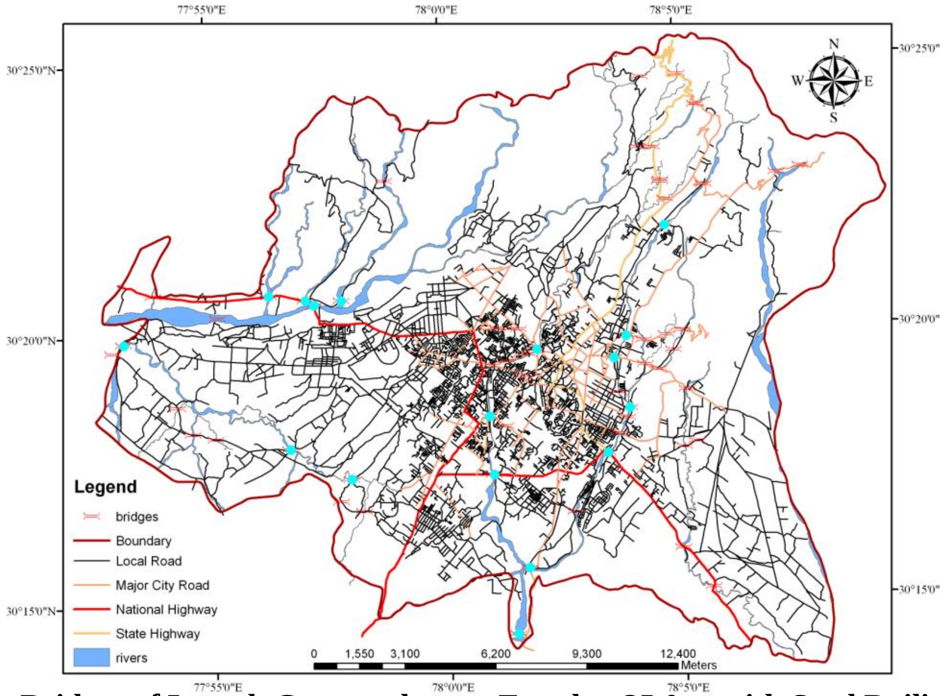


Fig 6.54: Bridges of Length Greater than or Equal to 35.0 m with Steel Railing

Similar query can be made in web GIS module. As an example, Fig 6.55 shows the bridges with more than 10 m length and having divider. Fig 6.56 shows the photographs of one of the bridges with more than 10 m length and having divider.

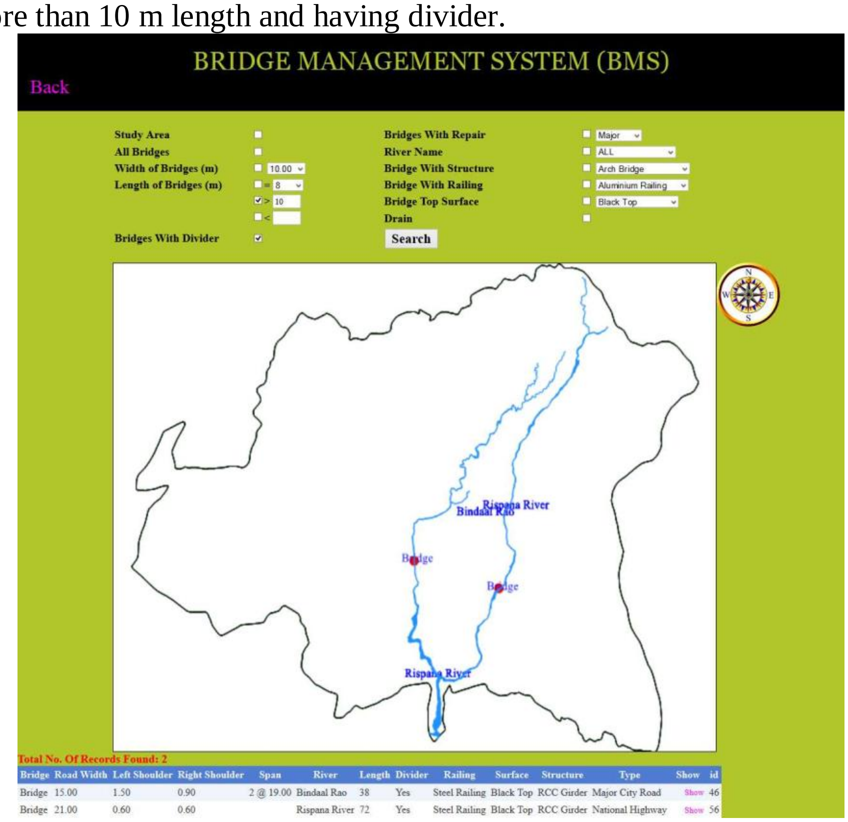


Fig 6.55: Bridge of More than 10 m Length and with Divider

Fig 6.56: Photos of Bridge of More than 10 m Length and with Divider

Fig 6.57 shows location of four bridges having road divider on them. Fig 6.58 shows the same results with web GIS module alongwith details of all the bridges. From Fig 6.58 and data, it can be observed that out of these four bridges one bridge is over-bridge type.

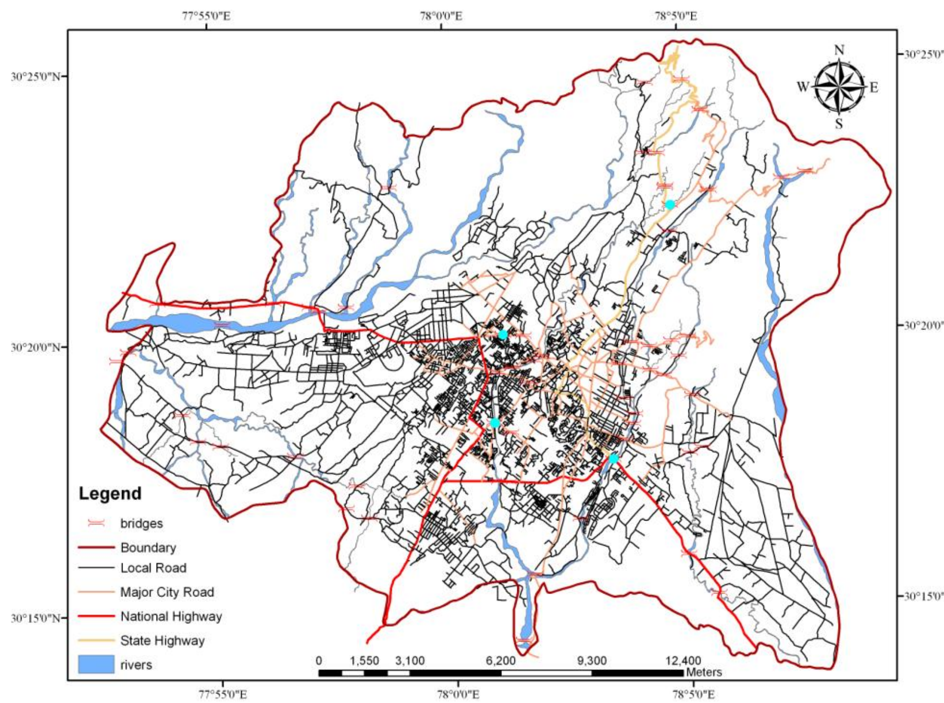
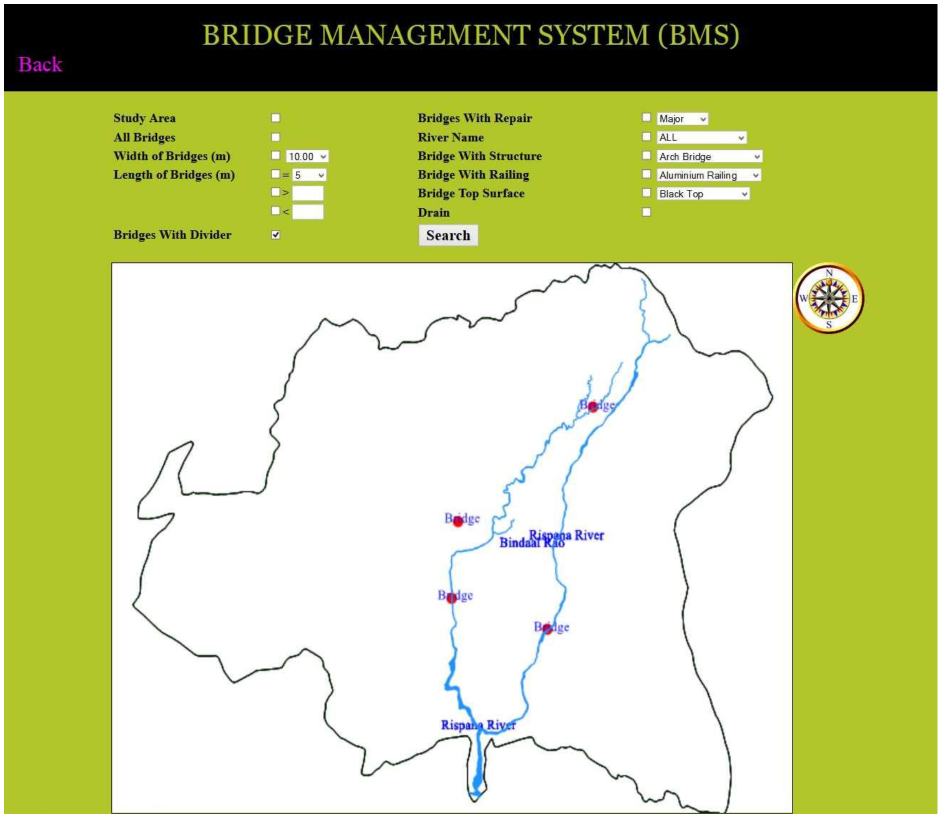


Fig 6.57: Bridges with Road Divider



Bridge	Road Width	Left Shoulder	Right Shoulder	Span	River	Length	Divider	Railing	Surface	Structure	Type	Show	id
Bridge	14.00	0	1.30	8.00	Bindaal Rao	8	Yes	Casted Concrete	Black Top	Arch Bridge	State Highway	Show	41
Bridge	15.00	1.50	0.90	2 @ 19.00	Bindaal Rao	38	Yes	Steel Railing	Black Top	RCC Girder	Major City Road	Show	46
Bridge	15.00	0	0	7.70	Over Bridge	8	Yes	Steel Railing	Black Top	Arch Bridge	Major City Road	Show	47
Bridge	21.00	0.60	0.60		Rispana River	72	Yes	Steel Railing	Black Top	RCC Girder	National Highway	Show	56

Fig 6.58: Bridges with Road divider in Web GIS Module

In the above mentioned query of bridges with road divider, a modification was made to select only those bridges which have 15 m road width. Only two bridges are selected by the software (Fig 6.59). In continuation of the same query, one more characteristic, like structure type of the bridge is included. Only one bridge on Chakrata road was found with road divider, 15m road width and arch structure type (Fig 6.60).

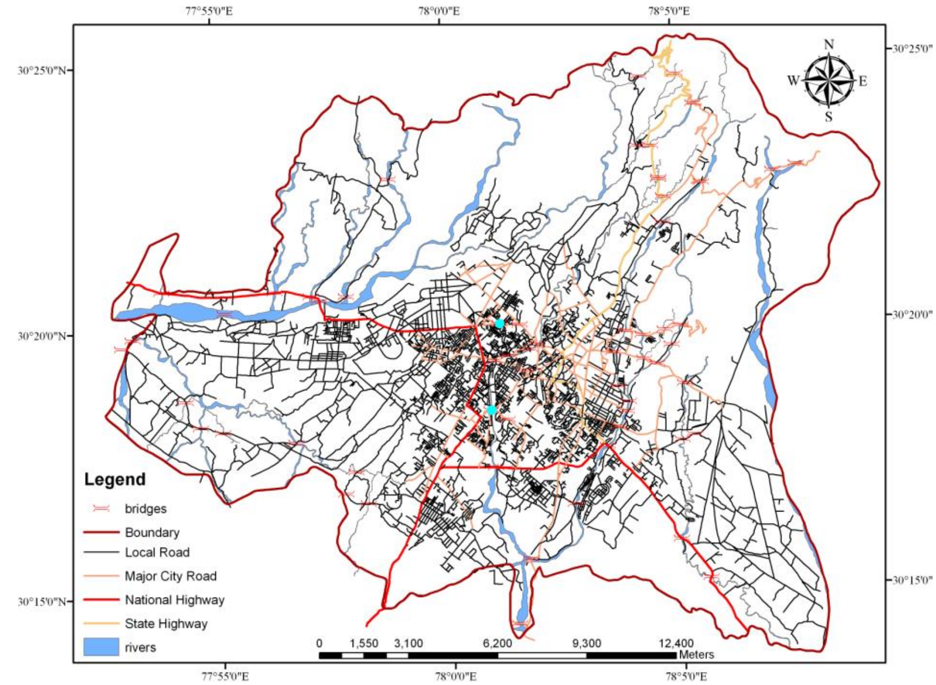


Fig 6.59: Bridges with Road Divider and 15.0 m Road Width

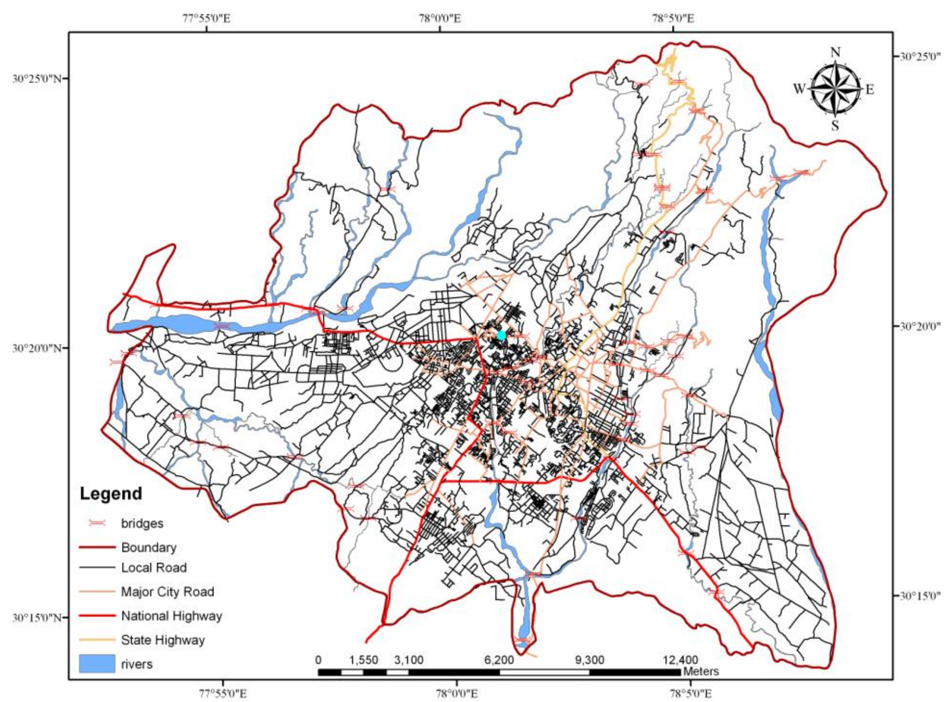


Fig 6.60: Bridges with Road Divider, 15.0 m Road Width and Arch Structure Type

Bridges are classified on the basis of their length and loading class. The categories are culvert, minor bridge and major bridge. Queries were made for major bridges. Fig 6.61 shows 10 major bridges. The categories for class loading are Class AA, and Class A. Query results are shown in Fig 6.62 which displays 47 bridges of Class A loading.

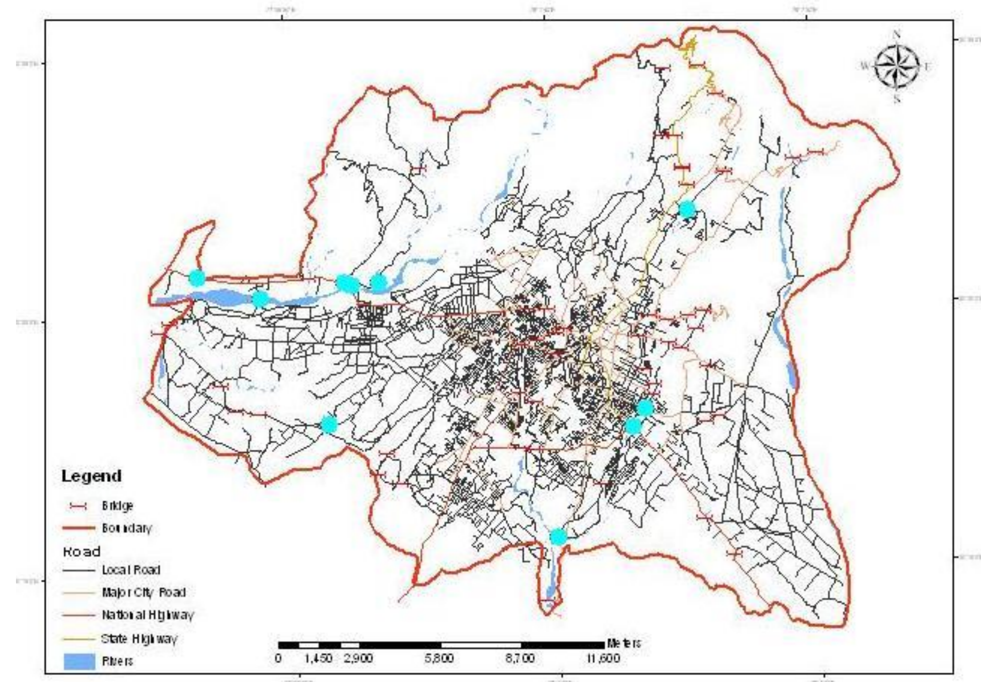


Fig 6.61: Major Bridges

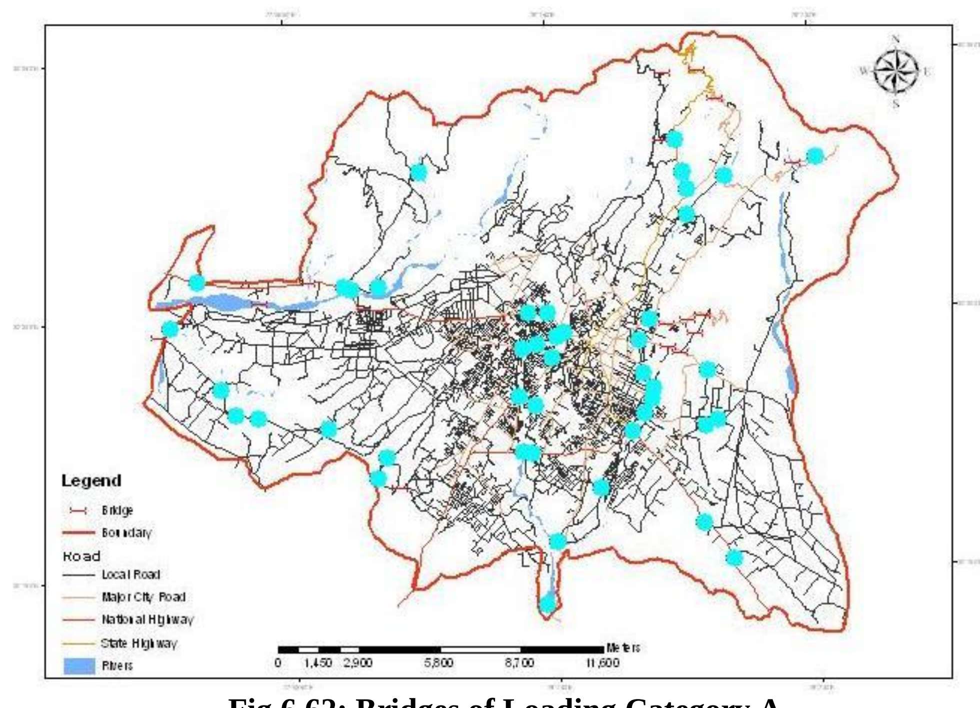


Fig 6.62: Bridges of Loading Category A

The module has the facility to identify the bridges as per their importance; whether these are constructed on national highway, state highway, major city roads or on local roads. After a query, it was found (Fig 6.63) that 9 bridges are situated along national highway in the study area.

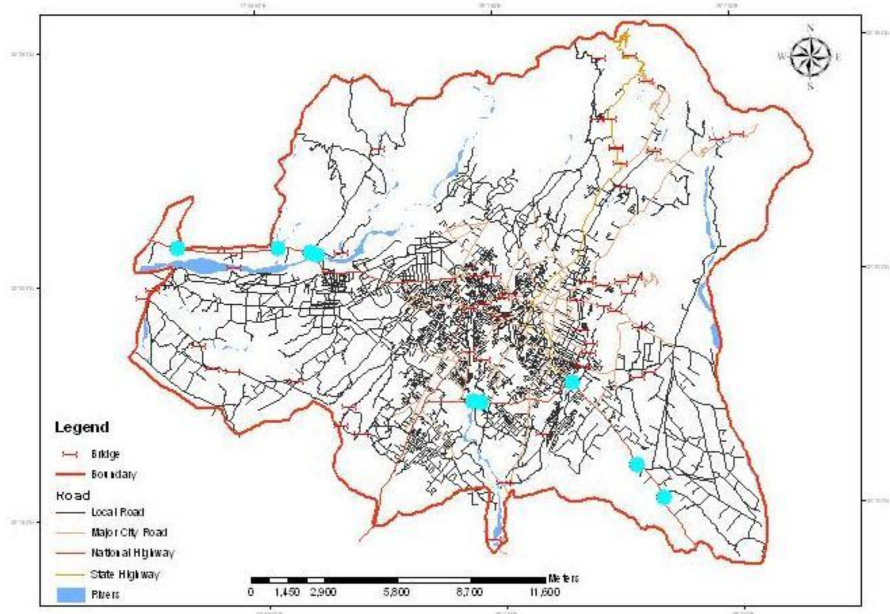


Fig 6.63: Bridges on National Highway

Further, bridges with box cell structure are selected from the database. Fig 6.64 shows there are 14 such bridges. Further, a query was developed that how many bridges (out of 14) have 7.5 m road width. Fig 6.65 shows that 5 such bridges have box cell structure with 7.5 m width.

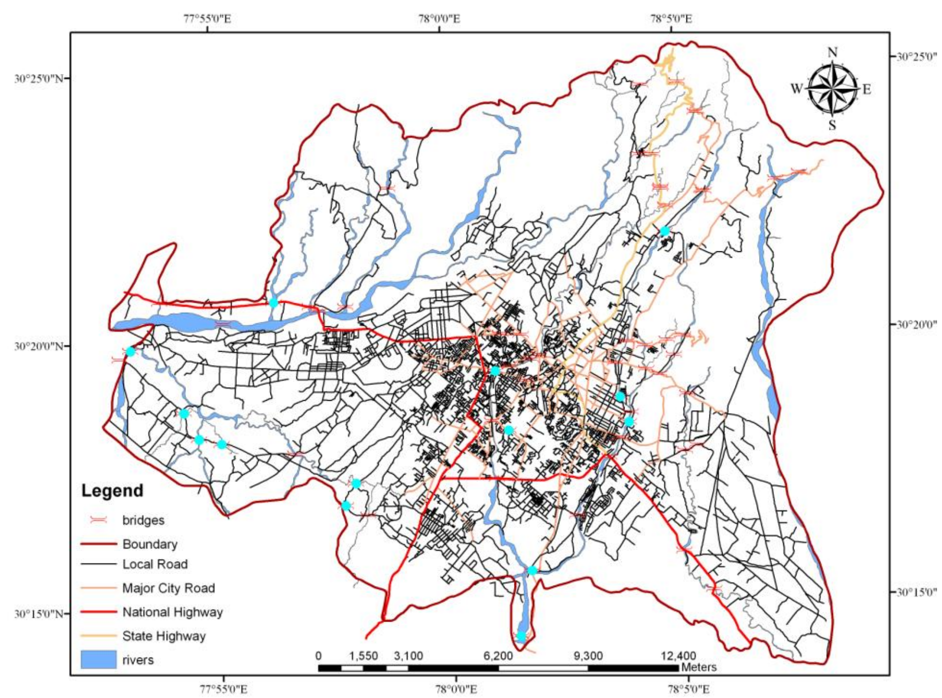


Fig 6.64: Bridges having Box Cell Structure

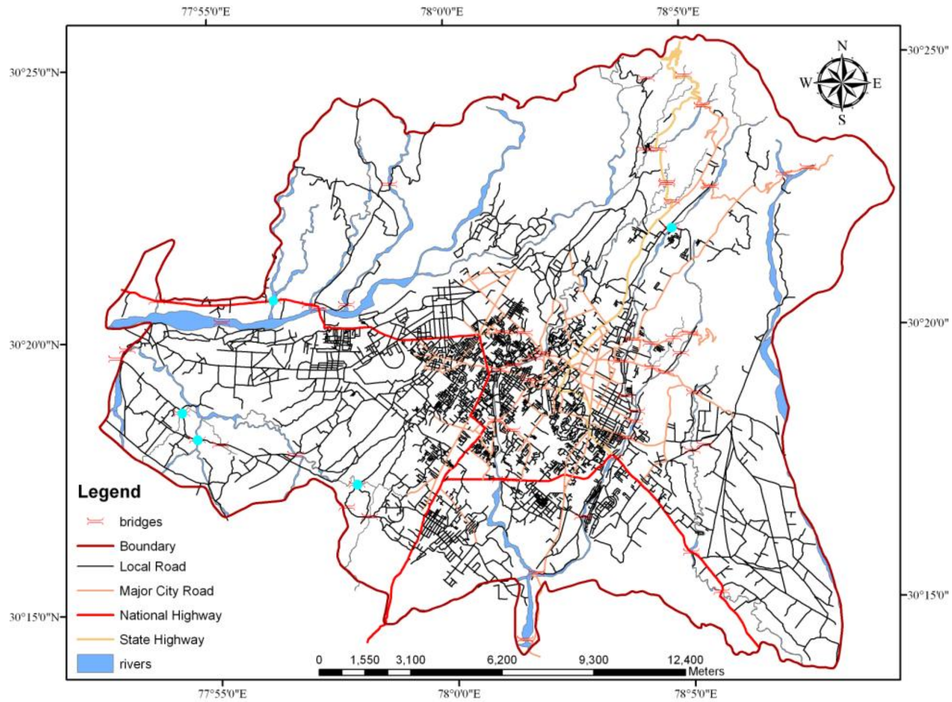


Fig 6.65: Bridges having Box Cell Structure and 7.5 m Road Width

Further, the users may like to know as to how many bridges out of these 5 bridges have black top surface. The software highlights the presence of only 2 bridges (Fig 6.66).

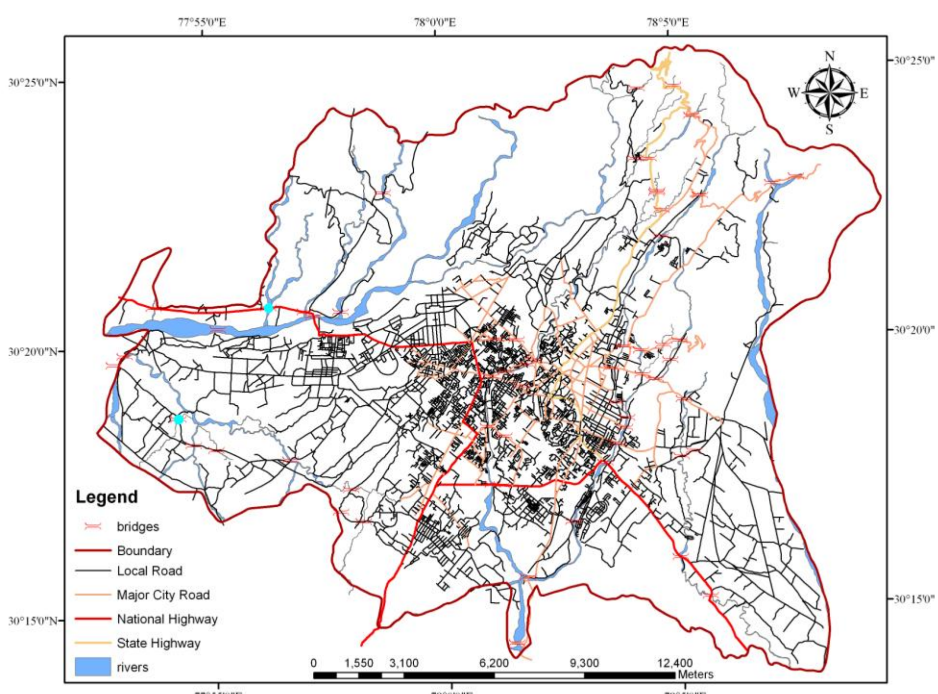
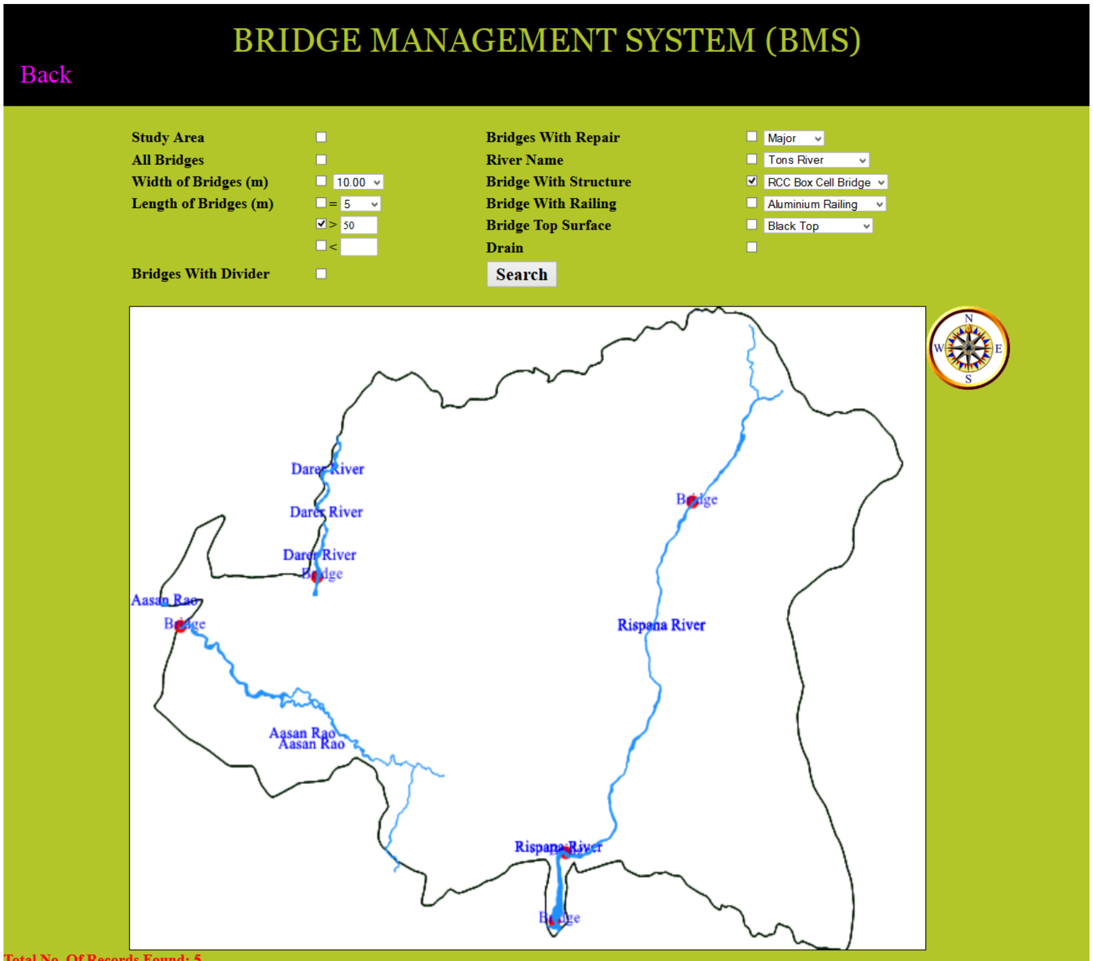


Fig 6.66: Bridges having Box Cell Structure, 7.5 m Road Width and Black Top Surface

Similarly with web GIS module, the bridges with box cell structure and length more than 50 m were identified (Fig 6.67), while Fig 6.68 shows the photographs of one such bridge.



Bridge	Road Width	Left Shoulder	Right Shoulder	Span	River	Length	Divider	Railing	Surface	Structure	Type	Show	id
Bridge	7.45	0	0	10 m x 5	Aasan Rao	50	No	Steel Railing	Concrete	RCC Box Cell Bridge	Local Road	Show	5
Bridge	7.50	0	0	60.0 m	Darer River	60	No	Steel Railing	Black Top	RCC Box Cell Bridge	National Highway	Show	9
Bridge	7.50	0	0	12 @ 5.85 m	Rispana River	70	No	Steel Railing	Concrete	RCC Box Cell Bridge	Local Road	Show	26
Bridge	7.00	0	0	8 @ 10.0 m	Rispana River	80	No	Steel Railing	Concrete	RCC Box Cell Bridge	Major City Road	Show	34
Bridge	7.00	0	0	8 @ 10.0 m	Rispana River	80	No	Steel Railing	Concrete	RCC Box Cell Bridge	Major City Road	Show	35

Fig 6.67: Bridges of Box Cell Structure and More than 50 m Length

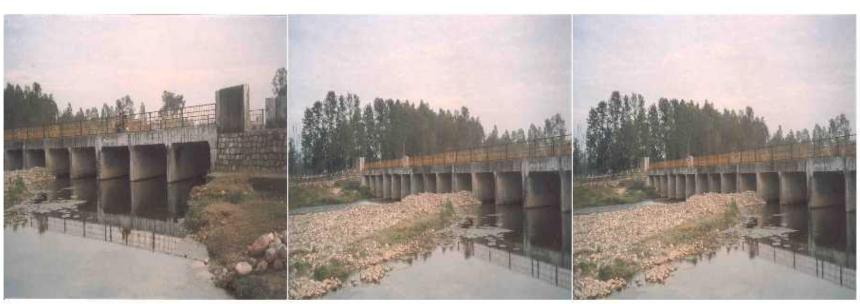


Fig 6.68: Photograph of a Bridge of Box Cell Structure and More than 50 m Length

The photos of the bridges are also attached in the database, which can be accessed through the query (Fig 6.69).

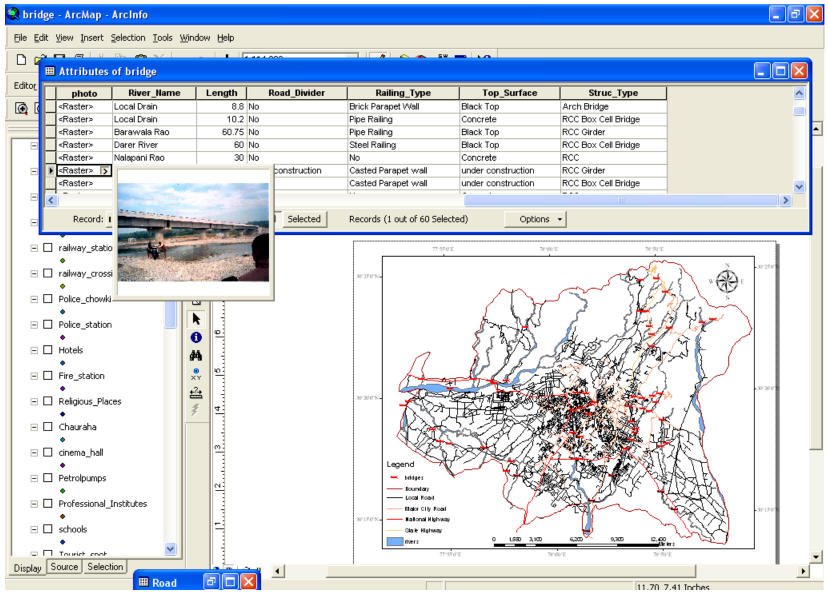


Fig 6.69: Bridge Photo is Added in the Attribute Table

By observation/visual inspection, repair & maintenance requirement of the bridges can also be assessed. The repairing requirement was divided in three categories; major, medium and minor repair and maintenance. As an example, a query was made to select the bridges/causeways which required minor repair, the module selected nine such bridges from the database (Fig. 6.70). While Fig 6.71 shows all the bridges which required major repair.

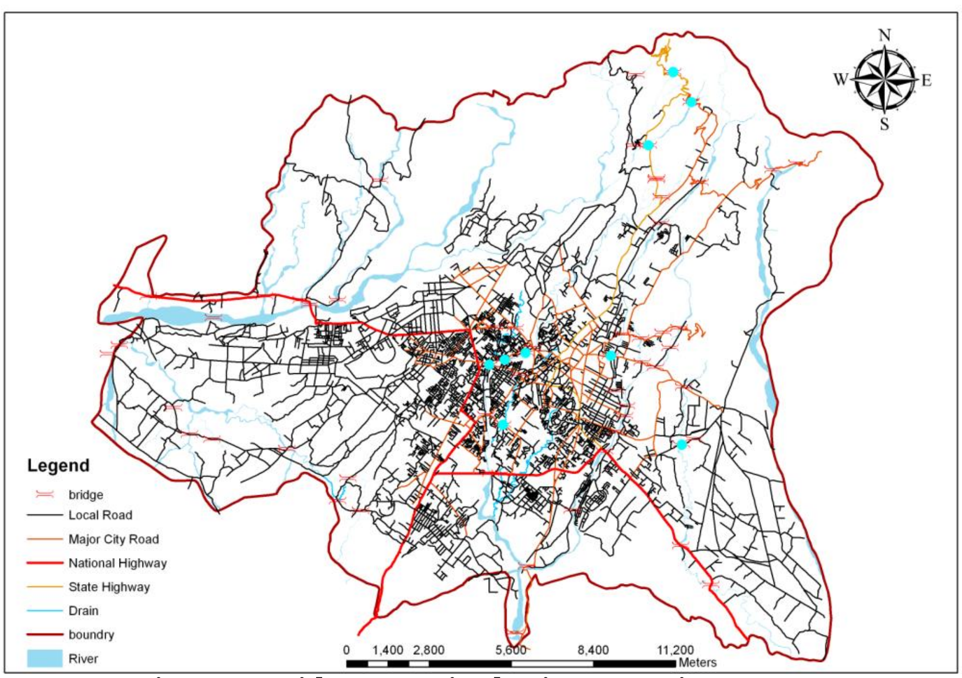
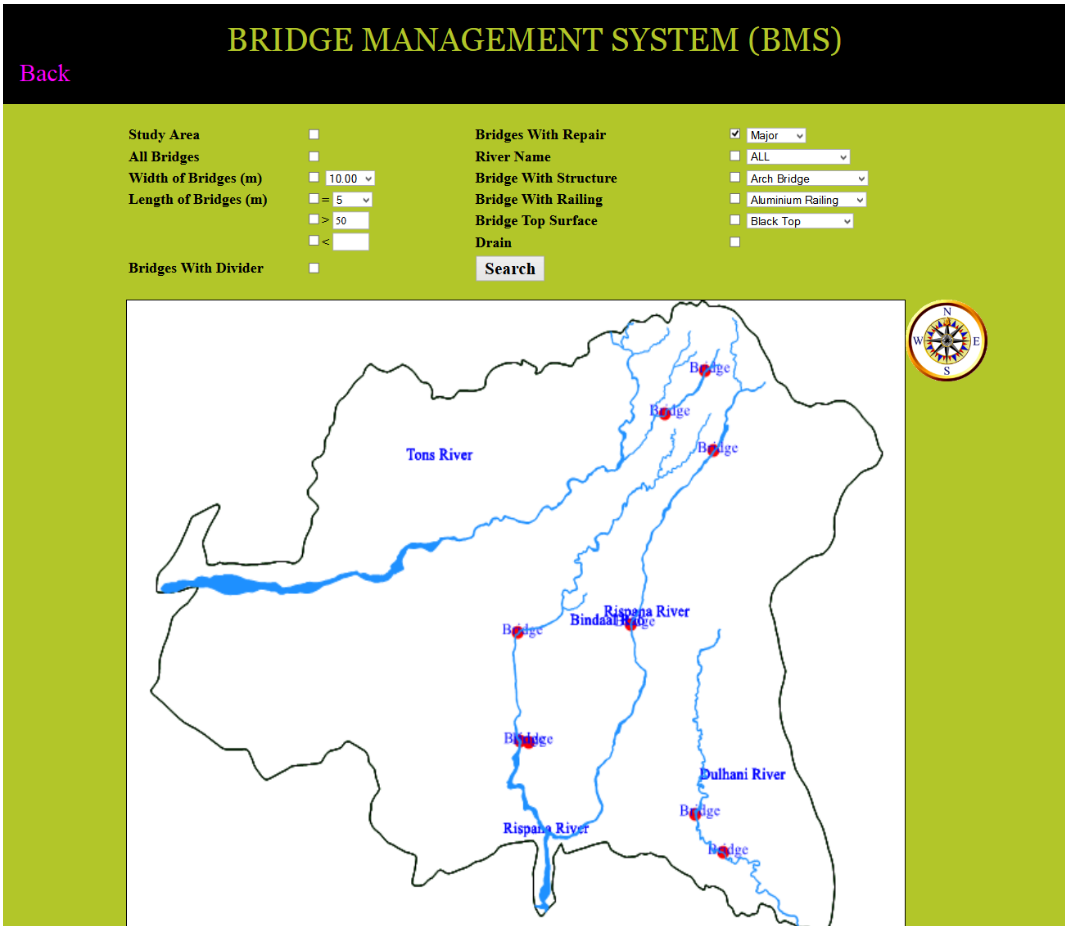


Fig 6.70: Bridges Required Minor Repair



Total No. Of Records Found: 9

Bridge	Road Width	Left Shoulder	Right Shoulder	Span	River	Length	Divider	Railing	Surface	Structure	Type	Show	id
Bridge	5.75	0	0	2 @ 11.3 m	Dulhani River	23	No	Casted Parapet wall	Concrete	RCC Girder	National Highway	Show	14
Bridge	7.50	0	0	2 @ 9.0 m	Dulhani River	18	No	Steel Railing	Black Top	RCC Girder	National Highway	Show	18
Bridge	6.75	0	0	25.0 m	Tons River	25	No	Steel Railing	Black Top	Arch Bridge	Major City Road	Show	21
Bridge	7.50	1.20	0.90	3 @ 18.7	Rispana River	56	No	Steel Railing	Black Top	RCC Girder	Major City Road	Show	25
Bridge	4.00	0	0	35.0 m	Rispana River	35	No	Pipe Railing	Black Top	Truss Bridge	Major City Road	Show	40
Bridge	6.00	0	0	8 @ 3.20	Bindaal Rao	26	No	Steel Railing	Black Top	RCC Box Cell Bridge	Major City Road	Show	45
Bridge	**4.20**	**0.30**	**0.30**		**Tons River**	**30**	**No**	**Casted Concrete**	**Black Top**	**Arch Bridge**	**Major City Road**	**Show**	**55**
Bridge	7.50	0.45	0.45	10.0	Local Drain	10	No	Steel Railing	Black Top	RCC Slab	National Highway	Show	57
Bridge	7.50	0.30	0.30	5 @ 9.0	Bindaal Rao	45	No	Steel Railing	Black Top	RCC Girder	National Highway	Show	58

Fig 6.71: Bridges Required Major Repair

6.3.3 AIS

The data is analysed in the following manner:

(i) Police Station wise　　(ii) Vehicle type

(iii) Temporal analysis (a) Monthly　　(iv) Road wise

(v) Identification of most Critical and critical points

6.3.3.1 Police Station Wise

To analyse the data, a GIS query on the database was performed to get the number of accidents under a police station in year 2002 (Fig 6.72).

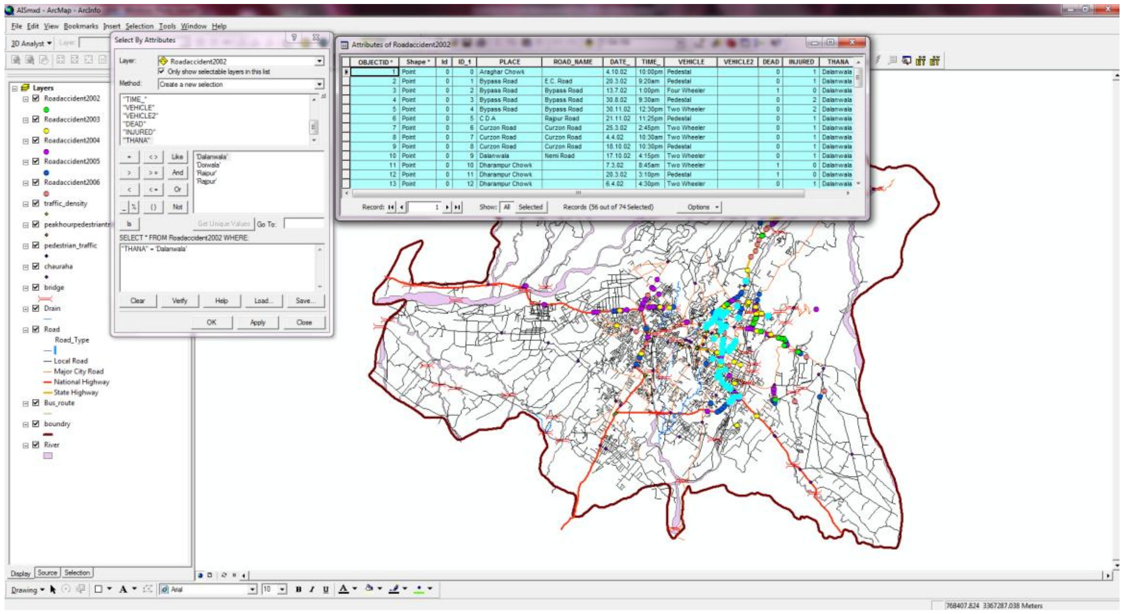


Fig 6.72: Derive Number of Accidents under a Police Station in Year 2002

Figs 6.73 & 6.74 show the use of software to get the information about the persons died and injured in road accident in a particular year.

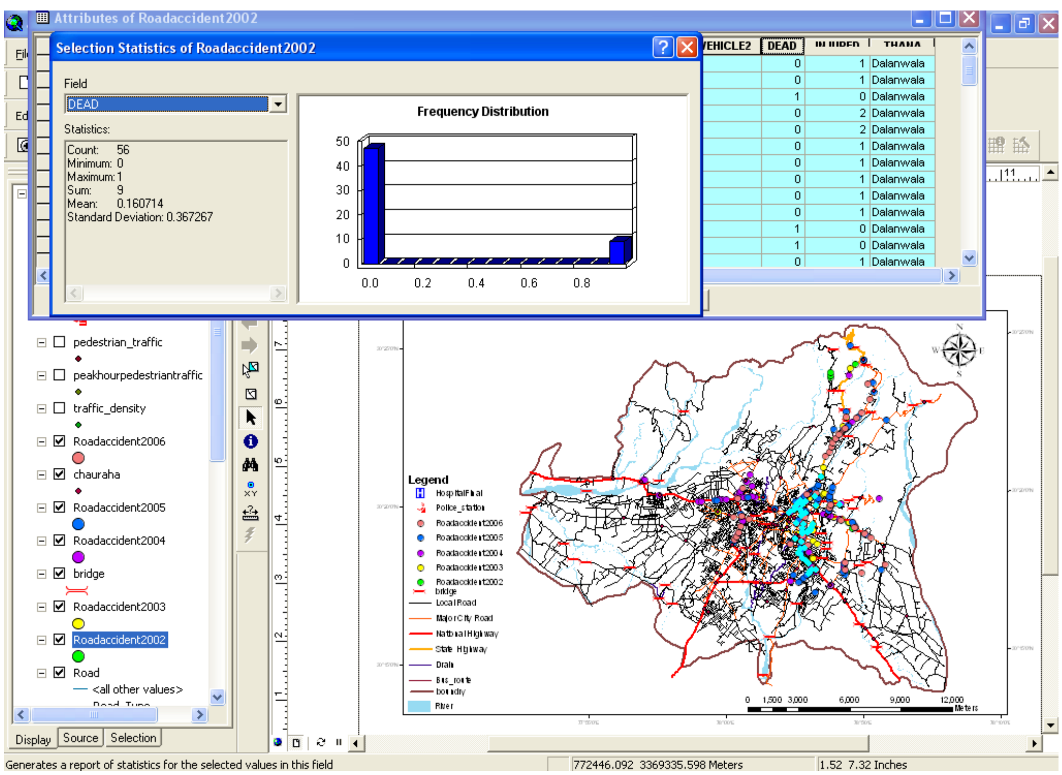


Fig 6.73: Persons Died in Accidents under Dalanwala Police Station in 2002

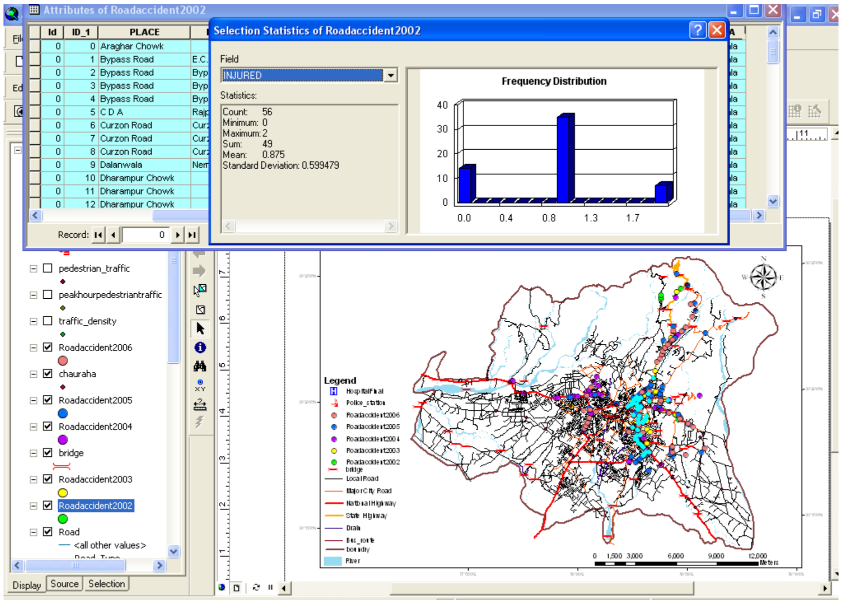


Fig 6.74: Persons Injured in Accidents under Dalanwala Police Station in 2002

Similar queries were formed in web GIS module for Doiwala police station for year 2002, and results obtained are shown in Figs 6.75, 6.76, and 6.77. Figs 6.75 shows the formation of a query. Figs 6.76 shows the results in pictorial form and Fig 6.77 shows the results in tabular format with other relevant information. In the pictorial form, the road network is not shown for the accident spots. In this connection, in tabular form the last column is titled "Road" and the rows are highlighted with option "Show". On clicking this option, the road will be displayed on the screen.

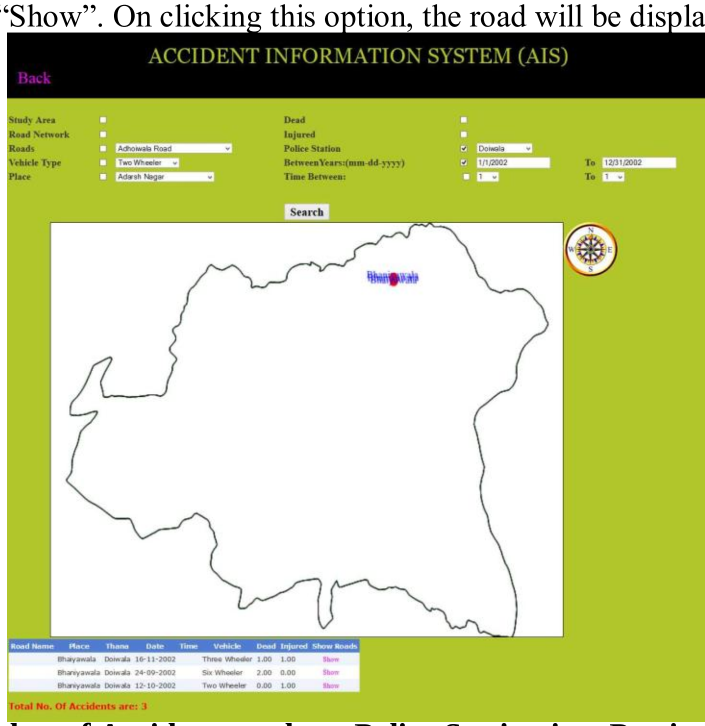


Fig 6.75: Derive Number of Accidents under a Police Station in a Particular Year and its Results in Pictorial and Tabular Format

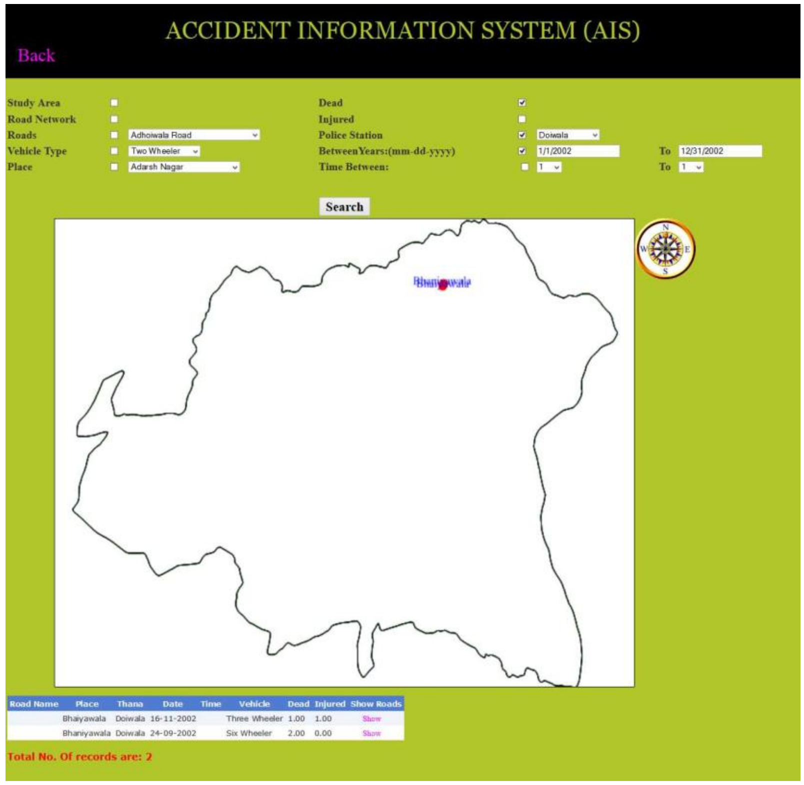


Fig 6.76: Persons Died in Accidents under Doiwala Police Station in 2002

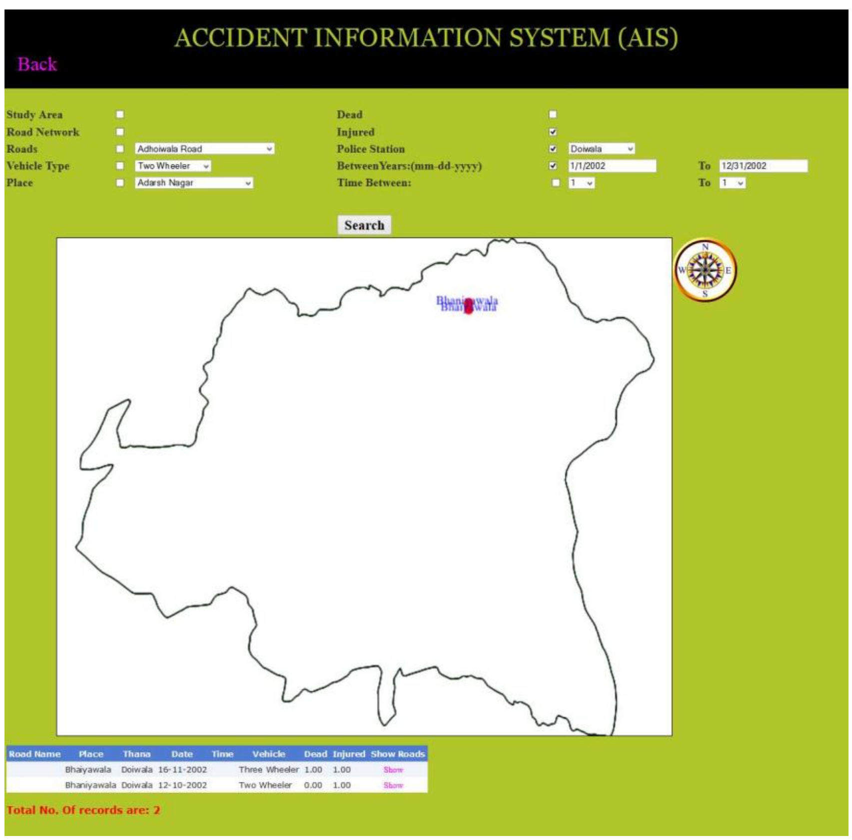


Fig 6.77: Persons Injured in Accidents under Doiwala Police Station in 2002

On the basis of process shown in above figures, Table 6.1 and Fig 6.78 have been prepared which show the accident record available with the police station and persons injured or died. It is observed that maximum accidents took place under the jurisdiction of Dalanwala police station.

Table 6.1: Police Station Wise Total Accidents and Persons Injured and Dead

Police Station	2002			2003			2004			2005			2006		
	TA[1]	Inj[2]	Dead	TA	Inj	Dead	TA	Inj	Dead	TA	Inj	Dead	TA	Inj	Dead
Dalanwala	56	49	9	60	56	17	40	33	11	43	47	10	13	12	2
Doiwala	3	2	3	2	2	2	1	1	0	0	0	0	0	0	0
Raipur	10	5	5	11	9	4	16	8	9	15	18	2	11	3	8
Rajpur	5	5	0	6	5	0	9	7	7	13	28	24	14	16	5
Vasant Vihar	0	0	0	5	3	2	6	5	2	6	3	3	7	14	2
Garhi Cantt.	0	0	0	0	0	0	18	26	9	3	1	2	2	2	0
Total	74	61	17	84	75	25	90	80	38	80	97	41	47	47	17

1. Total Accidents, 2. Persons Injured

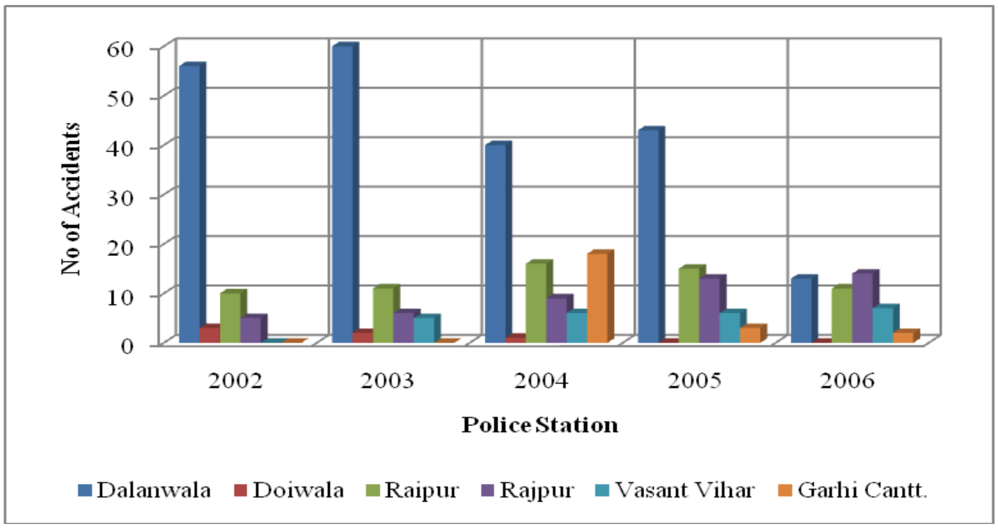


Fig 6.78: Accidents Police Station Wise

On the basis of data given in Table 6.1, Fig 6.79 has been prepared which shows the total accidents, persons injured or died, year-wise. Maximum accidents took place in 2004 and then in 2003, while maximum casualties and person injured occurred in 2005.

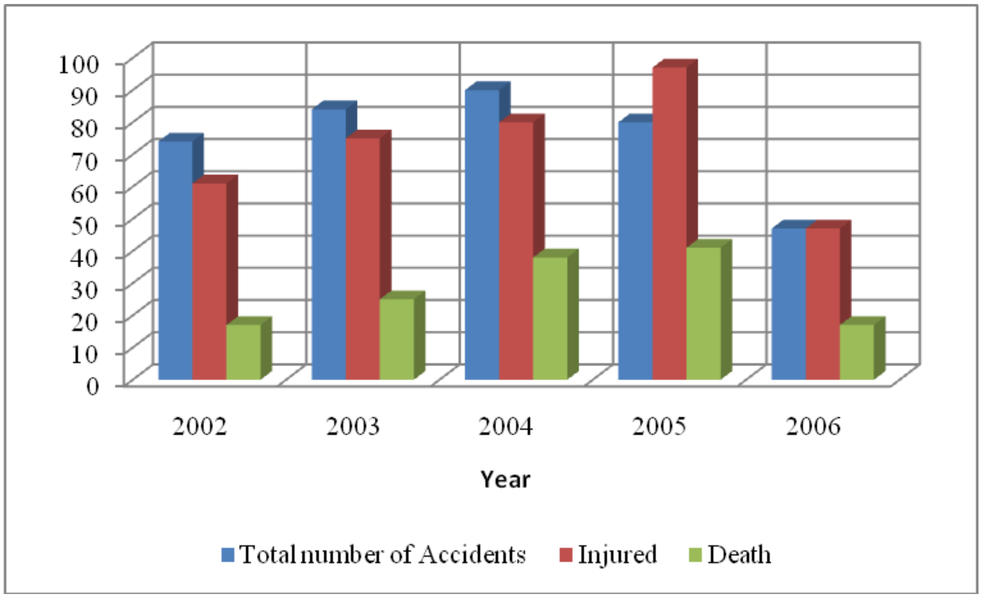


Fig 6.79: Number of Accidents and Persons Died and Injured

6.3.3.2 Vehicle Wise Analysis

Figs 6.80 & 6.81 show the process to get the information about the persons died and injured by a particular type of vehicle in a particular year. Similar query from web GIS module was made, and results are shown in Figs. 6.82, & 6.83.

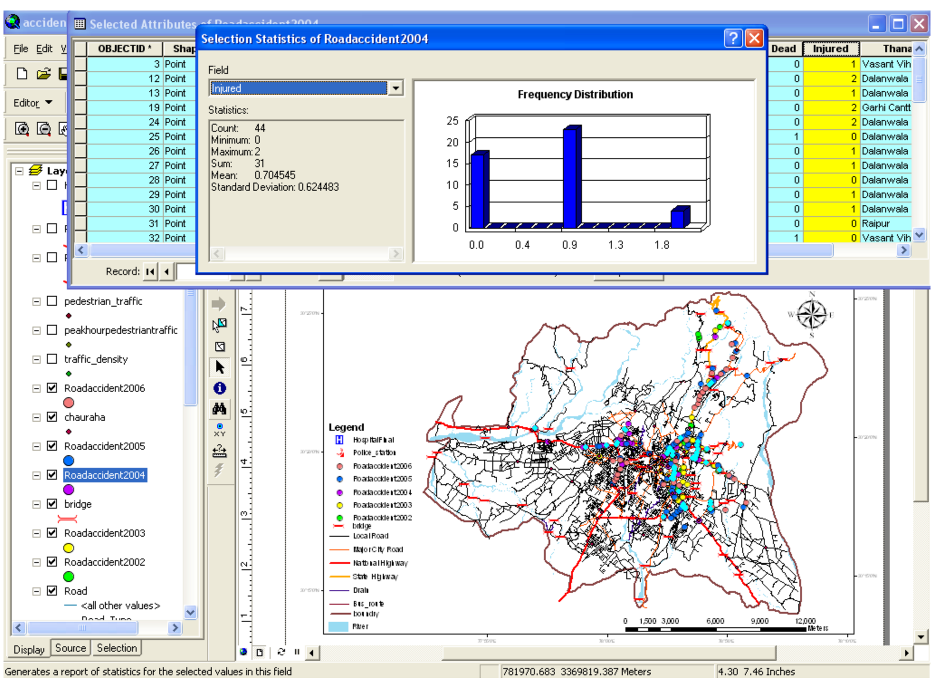


Fig 6.80: Persons Injured in Accidents with Two wheeler in 2004

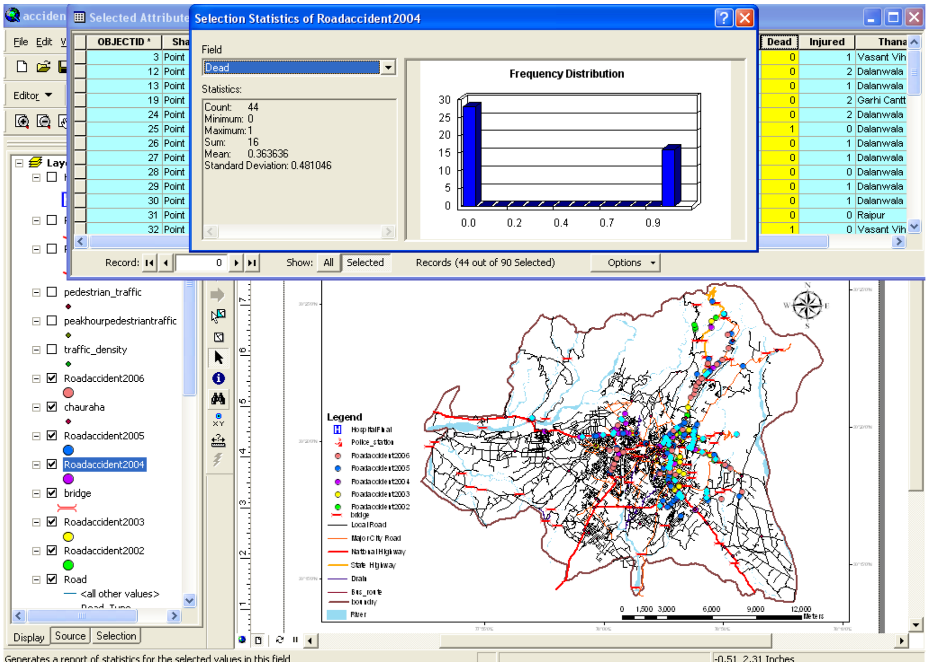


Fig 81: Number of Persons Died in Accidents with Two wheeler in 2004

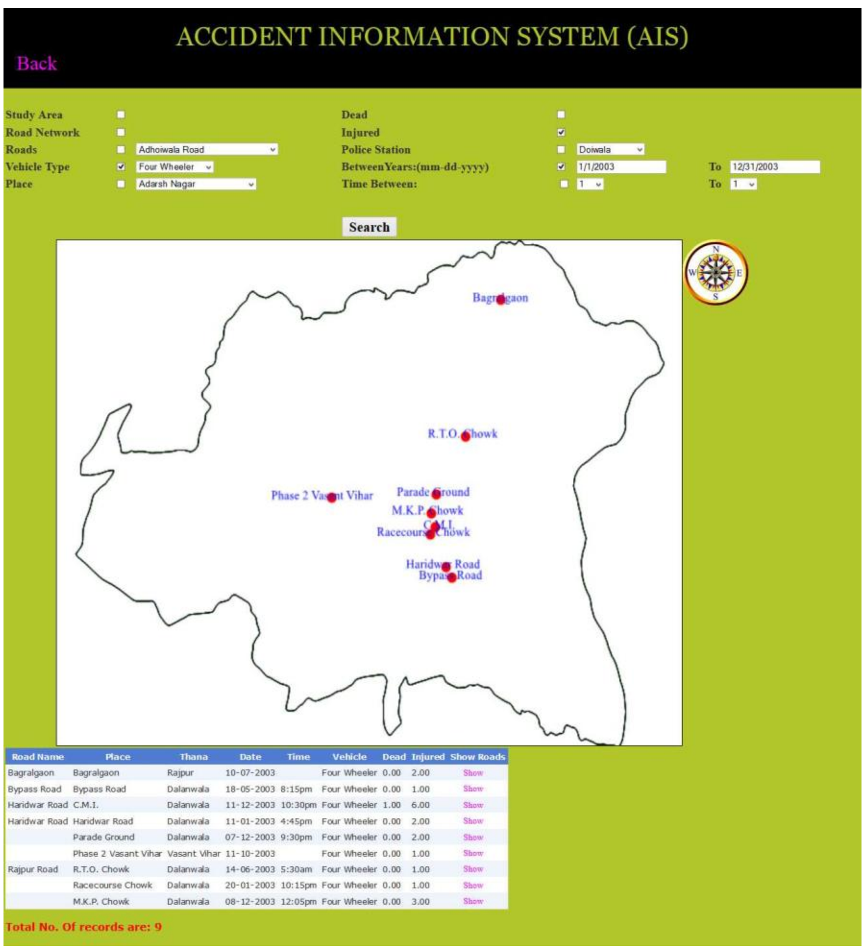


Fig 6.82: Persons Injured in Accidents with Four Wheelers in 2003

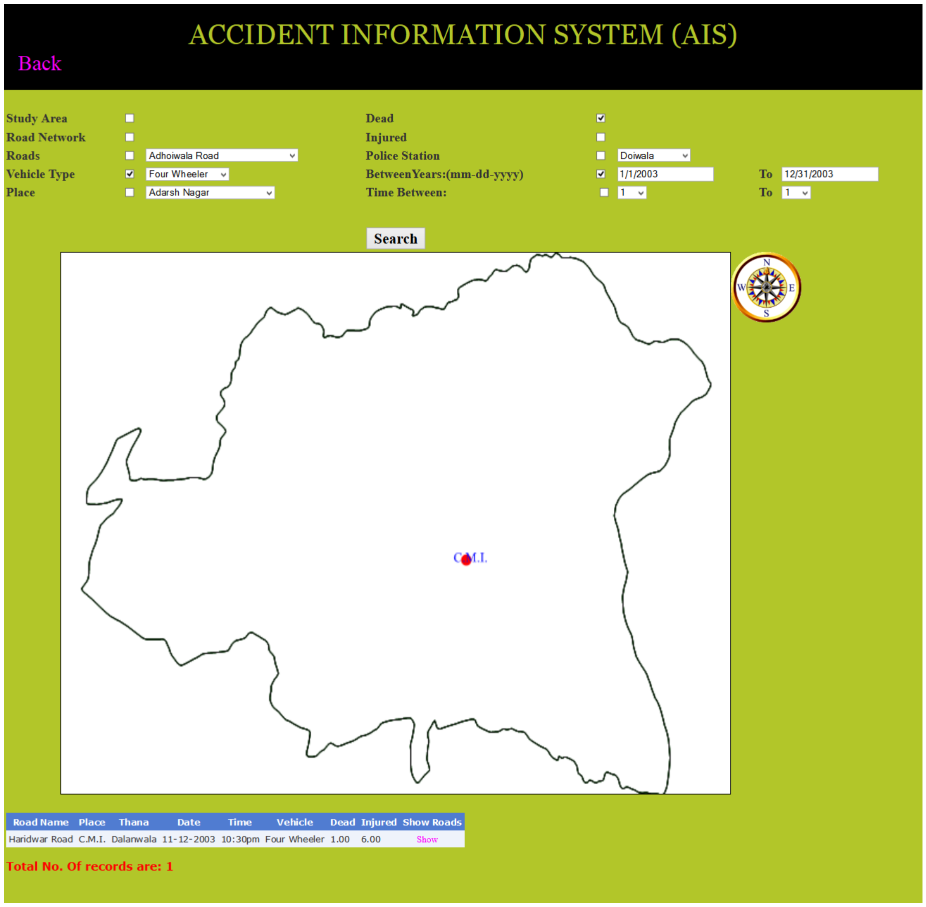


Fig 6.83: Persons Died in Accidents with Four Wheelers in 2003

Table 6.2 and Figs 6.84, 6.85 and 6.86 show the vehicle involved and persons injured or dead. It is clear from this table that two wheelers are the most vulnerable to accidents. Every year, on an average, two wheelers are involved in 50% of accidents. Pedestrian covers the second largest, and at third place four wheelers are involved. In 2004, maximum accidents occurred with six wheelers. It is clear from this table that maximum number of injuries or death occurred with accidents of two wheelers.

Table 6.2: Vehicle Wise Total Accidents and Persons Injured and Dead

Police Station	**2002**			**2003**			**2004**			**2005**			**2006**		
	TA[1]	Inj[2]	Dead	TA	Inj	Dead	TA	Inj	Dead	TA	Inj	Dead	TA	Inj	Dead
Pedestrian	22	2	4	18	9	10	15	9	7	21	22	4	2	2	0
Two wheeler	35	31	9	45	42	10	44	31	16	34	36	9	24	11	12
Three wheeler	2	2	1	3	4	1	6	12	3	2	1	1	3	5	1
Four wheeler	14	9	1	14	19	1	14	13	2	18	22	4	16	29	2
Six wheeler	1	0	2	3	1	2	11	9	7	4	22	4	2	2	0

1. Total Accidents, 2. Persons Injured

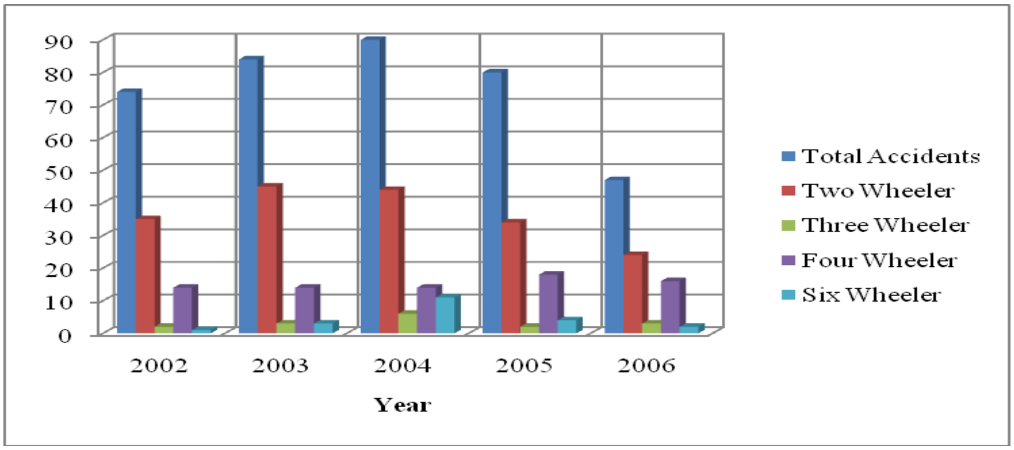


Fig 6.84: Vehicle Wise Accident

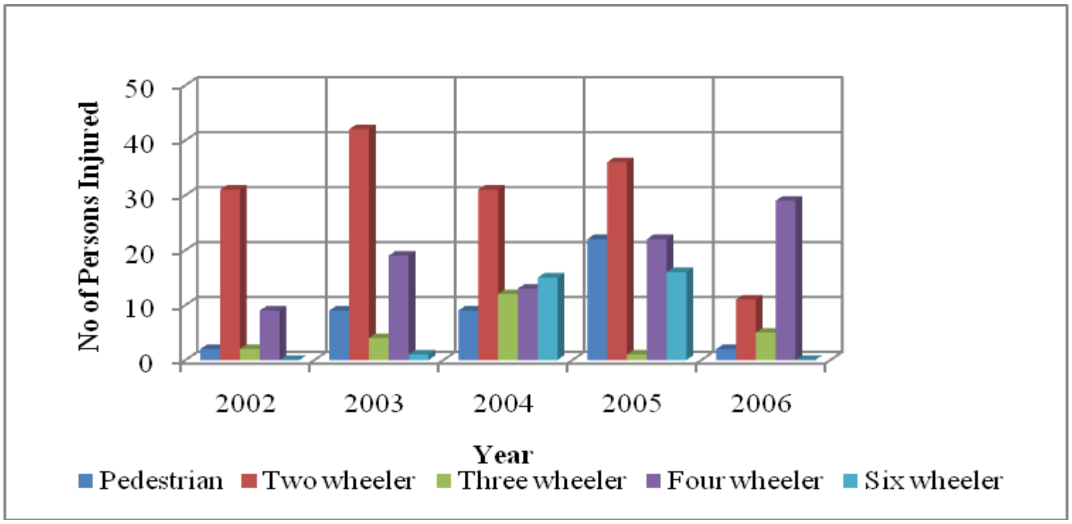


Fig 6.85: Vehicle and Year Wise Injured Persons

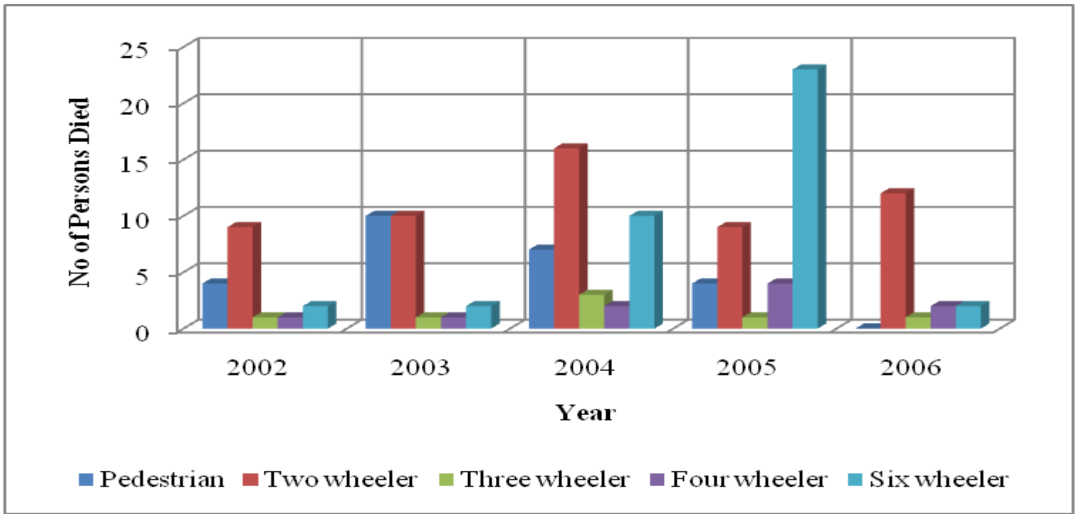


Fig 6.86: Vehicle and Year Wise Dead Persons

6.3.3.3 Temporal Analysis

Fig 6.87 shows the process to get the information on accidents and results in pictorial & tabular form for January 2003 using web GIS module. On this basis, Table 6.3 and Fig 6.88 have been prepared.

Fig 6.87: Accidents in January 2003

Table 6.3: Month Wise Accident

	2002	2003	2004	2005	2006	Total
January	5	7	8	8	8	36
February	4	7	8	6	6	31
March	7	1	5	9	6	28
April	8	3	8	5	2	26
May	9	7	12	8	2	38
June	6	4	8	4	3	25
July	3	12	6	5	2	28
August	5	9	4	3	6	27
September	6	6	10	9	6	37
October	10	8	8	7	2	35
November	8	9	6	6	2	31
December	3	11	7	5	2	28

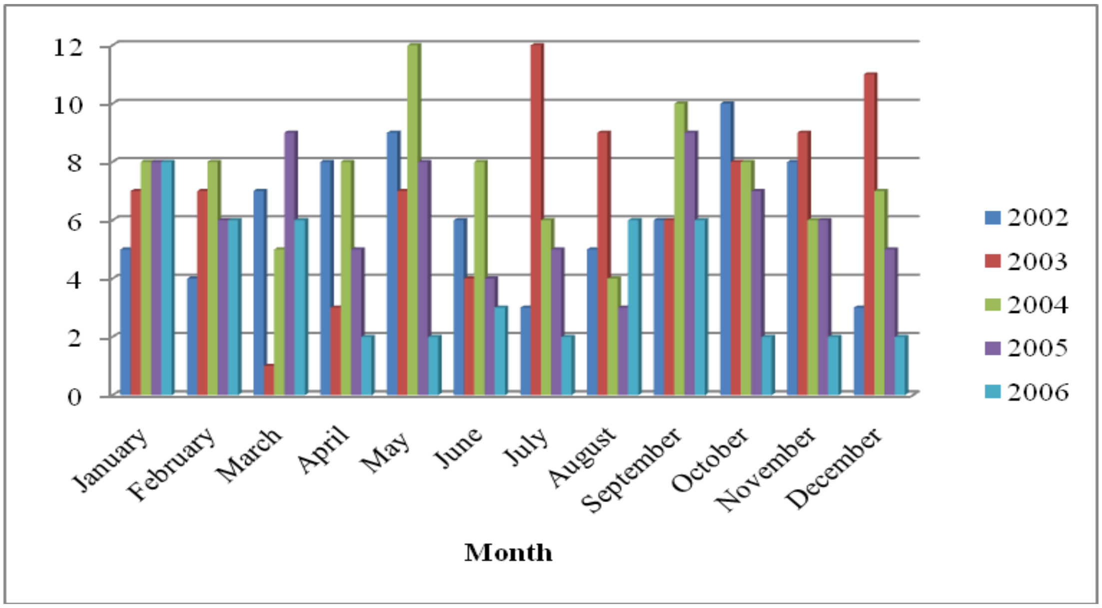


Fig 6.88: Month Wise Accident Pattern

Fig 6.89 & Fig 6.90 shows the persons injured and died in a particular year on or before 12 in the noon.

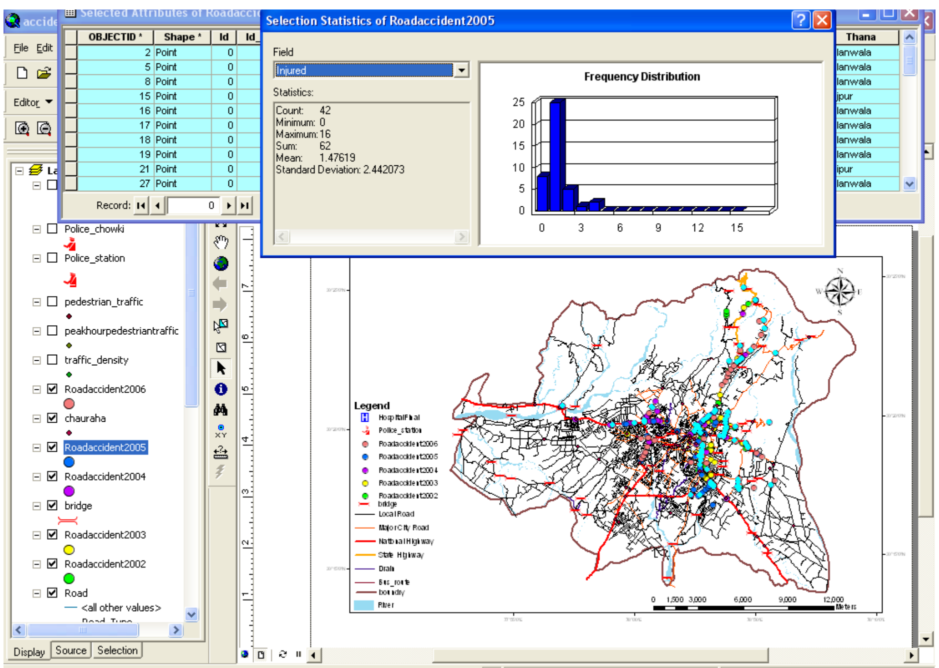


Fig 6.89: Persons Injured in Accidents on or Before 12 noon in 2005

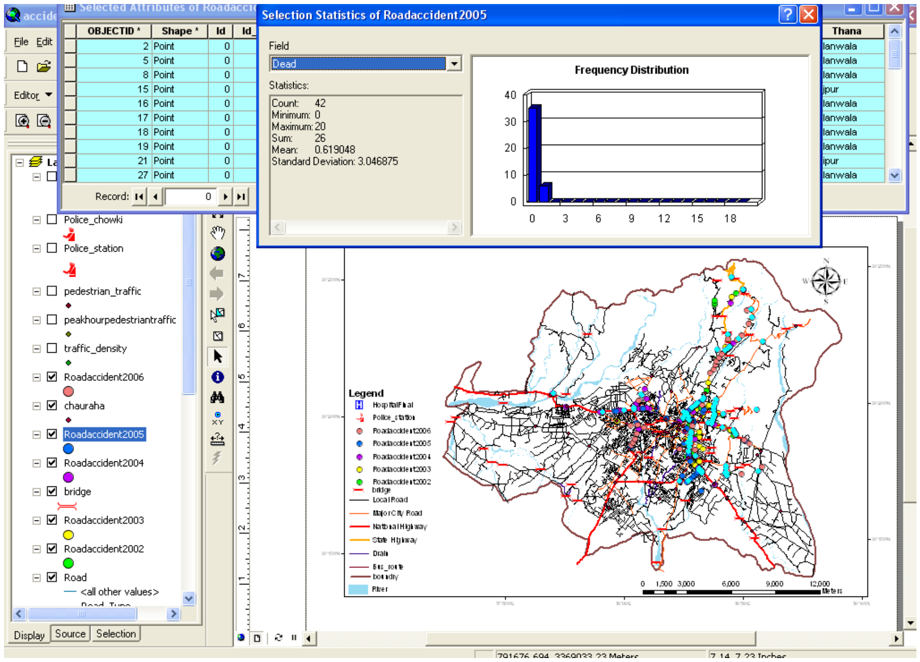
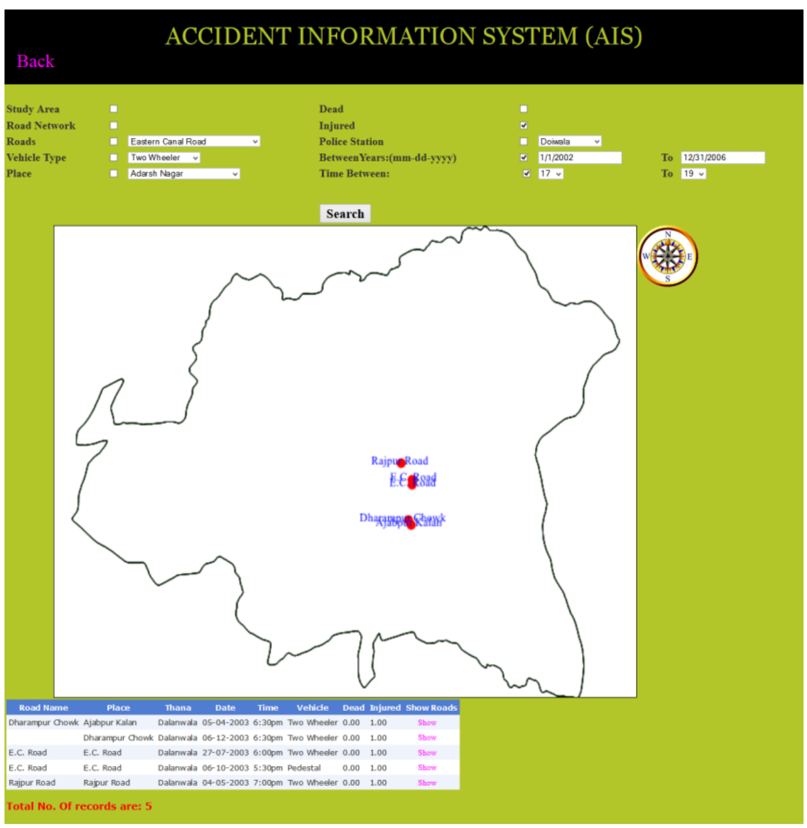


Fig 6.90: Persons Died in Accidents on or Before 12 noon in 2005

Similar queries are also formed in web GIS module, and results are shown in Figs. 6.91 and 6.92.



Road Name	Place	Thana	Date	Time	Vehicle	Dead	Injured	Show Roads
Dharampur Chowk	Ajabpur Kalan	Dalanwala	05-04-2003	6:30pm	Two Wheeler	0.00	1.00	Show
	Dharampur Chowk	Dalanwala	06-12-2003	6:30pm	Two Wheeler	0.00	1.00	Show
E.C. Road	E.C. Road	Dalanwala	27-07-2003	6:00pm	Two Wheeler	0.00	1.00	Show
E.C. Road	E.C. Road	Dalanwala	06-10-2003	5:30pm	Pedestal	0.00	1.00	Show
Rajpur Road	Rajpur Road	Dalanwala	04-05-2003	7:00pm	Two Wheeler	0.00	1.00	Show

Fig 6.91: Persons Injured in Accidents from 5 pm to 7 pm in 2003

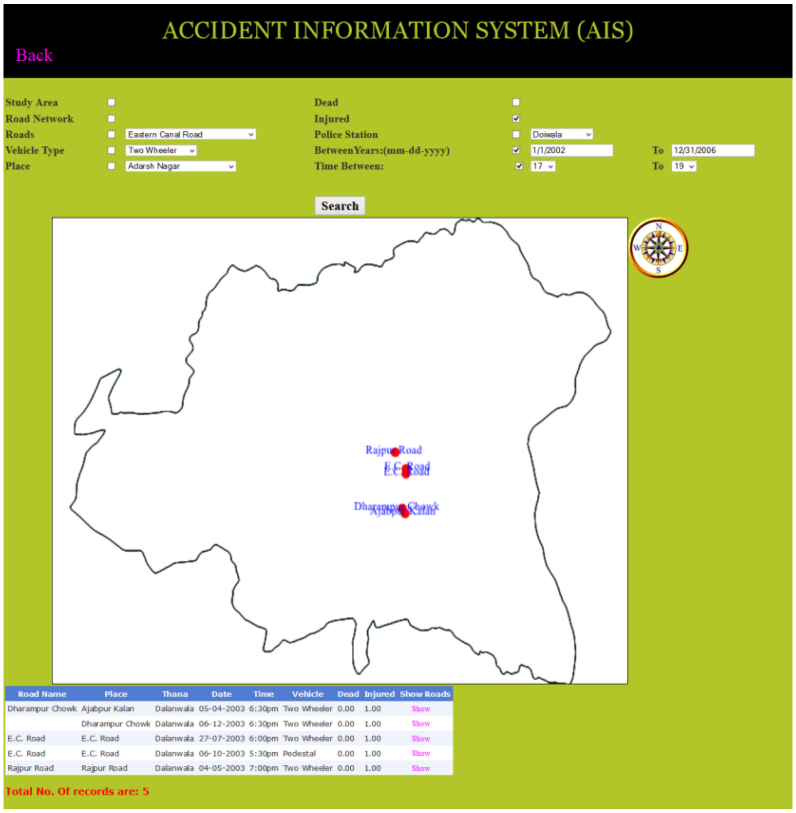


Fig 6.92: Persons Died in Accidents from 5 pm to 7 pm in 2003

6.3.3.4 Road Wise Accidents

Figs. 6.93 & 6.94 show the process to derive information on persons injured and died in a particular year on a particular road. Similar queries can also be developed from web GIS module.

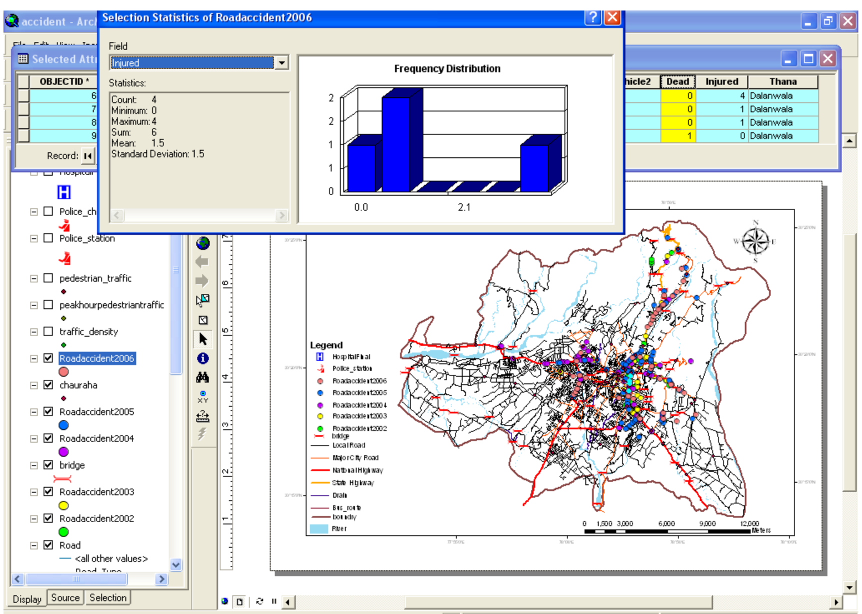


Fig 6.93: Persons Injured in Accidents on East Canal Road in 2006

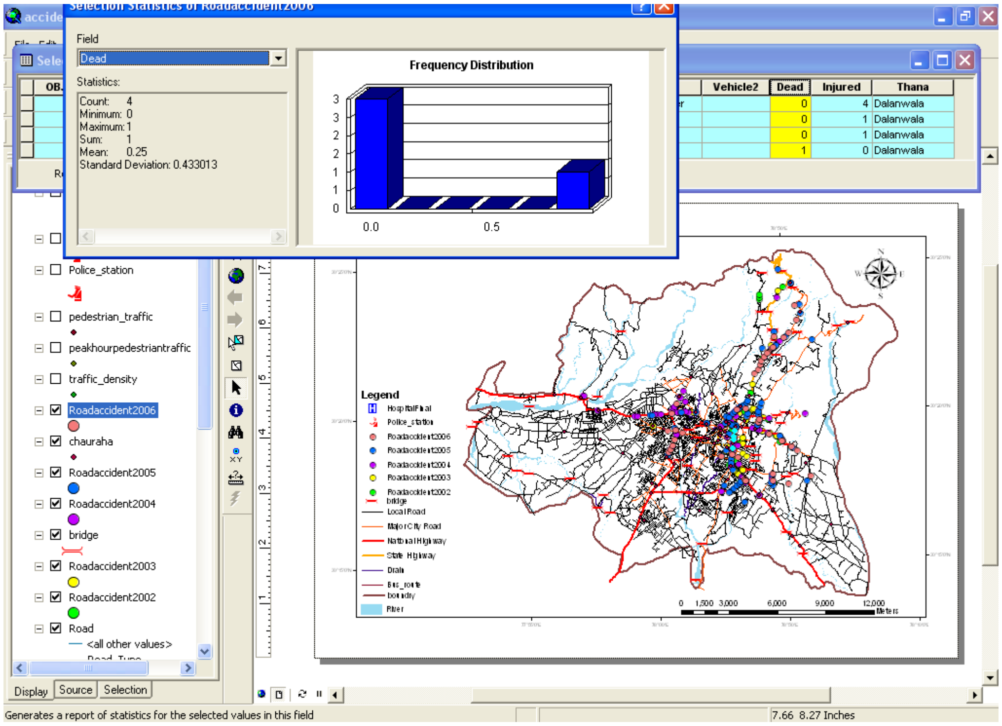


Fig 6.94: Persons Died in Accidents on East Canal Road in 2006

Similarly, Fig 6.95 shows the accidents that took place between year 2002-2006, while Fig 6.96 shows the location of police stations/police sub-station and hospitals. The accident spots on the basis of their frequency of accidents are classified as most critical, critical and not critical spots. In this study, the accident data from 2002 to 2006 were used. First of all, 100 m buffer of all accidents spots was prepared. Intersection of these buffers of different years was carried out. All the locations where 4 to 5 buffers intersect have been designated as most critical. Similarly, if 2 to 3 buffers intersect at a location, then this location is designated as critical and the remaining as not critical.

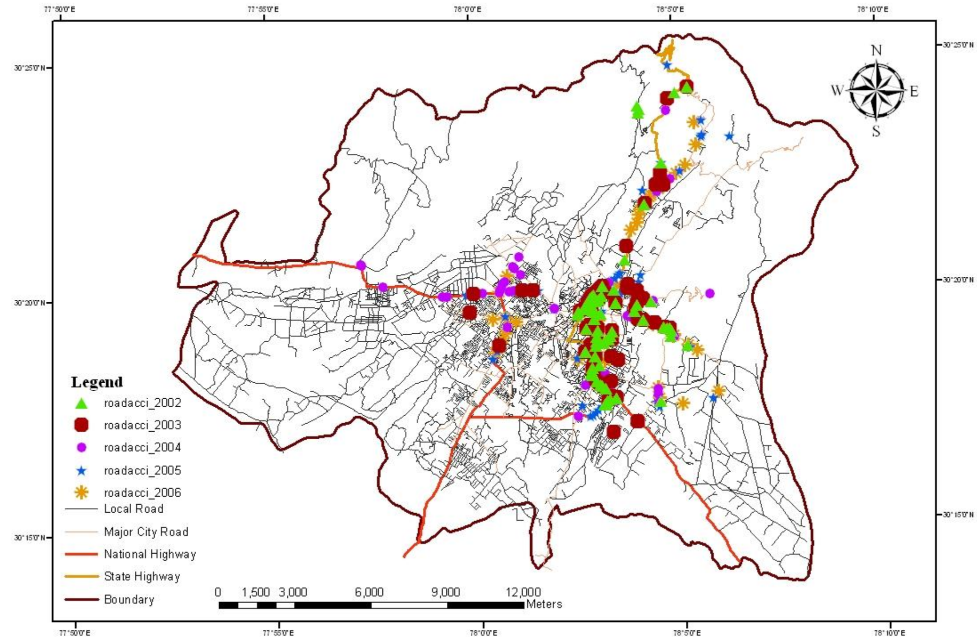


Fig 6.95: Road Accidents Between 2002-2006

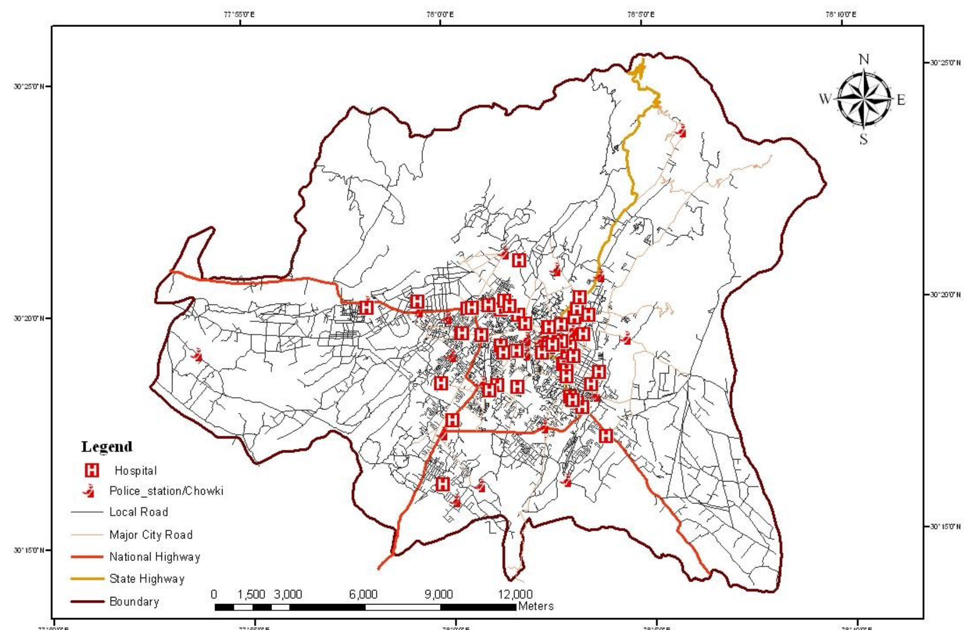


Fig 6.96: Locations of Police Stations and Hospitals

Fig 6.97 shows the intersection of all five buffers. These points are situated either on Rajpur road where East Canal road intersects or on East Canal road in between the intersection of Cross road and Amrit Kaur road. The buffers of four years of accidents have intersection points on Rajpur road, East Canal road, Haridwar road, Haridwar bye pass, and Shahastradhara road etc.

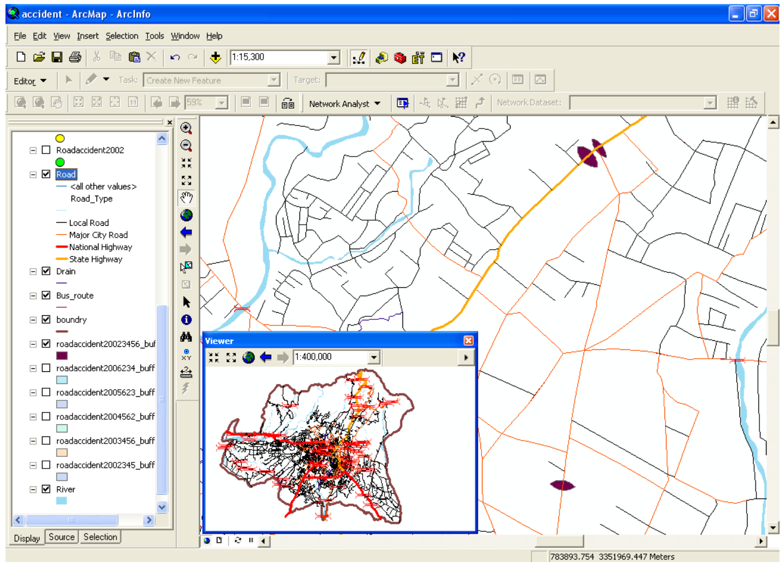


Fig 6.97: Most Critical Spots Inviting Accidents

Fig 6.98 shows the critical points, intersection of any three buffers. These points lie on Rajpur road, East Canal road, Subhas road, Haridwar road, Haridwar bye pass, Ring road, Raipur road and Shahastradhara road etc. The intersection of three years of buffer lies on Chakrata road, Race Course Road, General Mahadev Singh road, Rajpur road, East Canal road, Subhas road, Haridwar road, Haridwar bye pass, Ring road, Raipur road, and Shahastradhara road etc.

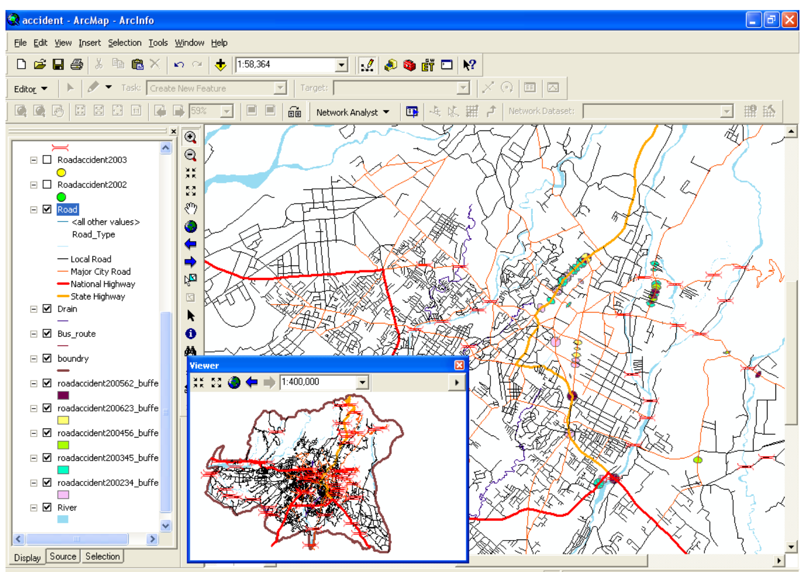


Fig 6.98: Critical Spots Where any Three Buffers Meet

With the help of network analysis, the AIS can provide the information on path to reach a hospital, in case of injury/emergency. For example, if an accident occurs on Ring road, nearest hospitals with the travel time of within 15 minutes can be determined through the query. Fig 6.99 shows the results of such a query. Five hospitals were found nearer to the accident spot on Ring road, such as Samadhan, Vaish Nursing home, Drishti eye hospital, S K Memorial and Rawal Nursing home. Out of these five hospitals Samadhan, Rawal and S K Memorial will be much closer to the accident spot.

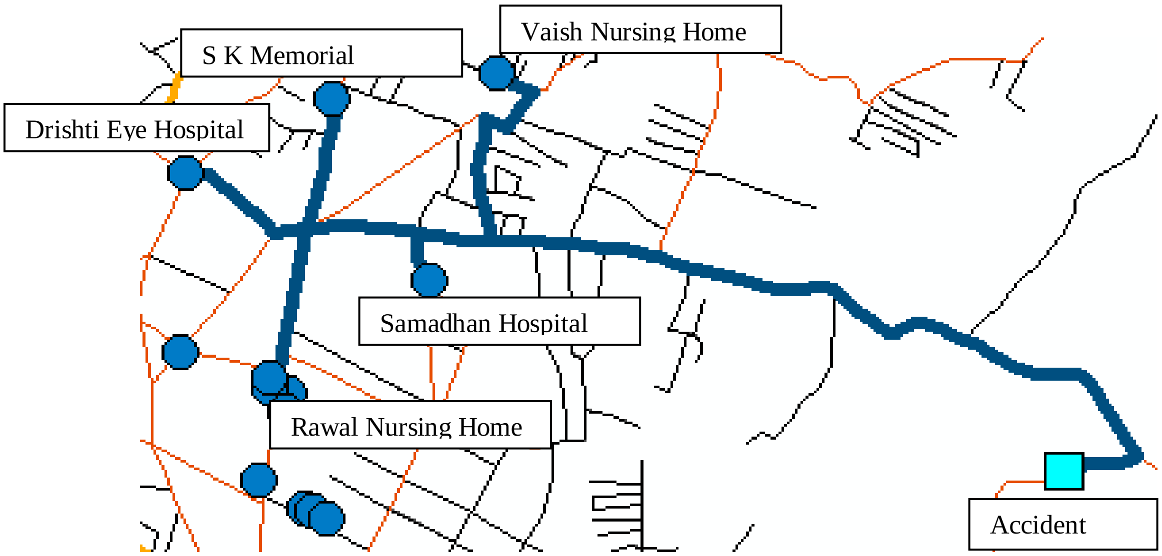


Fig 6.99: Network Analysis Showing the Accident Spot and Five Nearest Hospitals within a Travel Time of 15 Minutes

6.3.4 TIS

The data was analysed in the following manner:

- Determination of intersections prone to traffic Jam
- Identification of locations of overbridges for pedestrian movement
- Identification of bye pass road

6.3.4.1 Determination of Intersections prone to Traffic Jam

To identify the intersections prone to traffic jams an important parameter, road traffic capacity is to be considered, which is available in IRC-106-1990. In the analysis, first of all a search for all crossings is made in the database, where traffic data is available. Thereafter, it computes the ratio between traffic density and road traffic capacity. For those crossings where ratio is more than one is selected. For analysis, first of all a search for all intersections is made from the database, where traffic data are available. It then computes the ratio between traffic density and road traffic capacity. Those intersections where ratio is more than one are selected.

In study area, twelve such intersections have been identified, such as Ghantaghar, Darshan Lal intersection, Saharanpur intersection, Prince intersection and Rispana tri-junction etc. (Fig 6.100). This type of analysis would help in identifying the major cause of traffic jam at a given intersection. It was found that the traffic jam at Ghantaghar is due to the narrow width of Chakrata road. Subsequently, the jam spreads upto Darshan Lal intersection. During the field visit, this fact was also verified that if a traffic jam starts from Ghantaghar, it spreads to Darshanlal intersection. The measure to minimise traffic jam at Ghantaghar is to provide an over bridge connecting Gandhi road and Rajpur road.

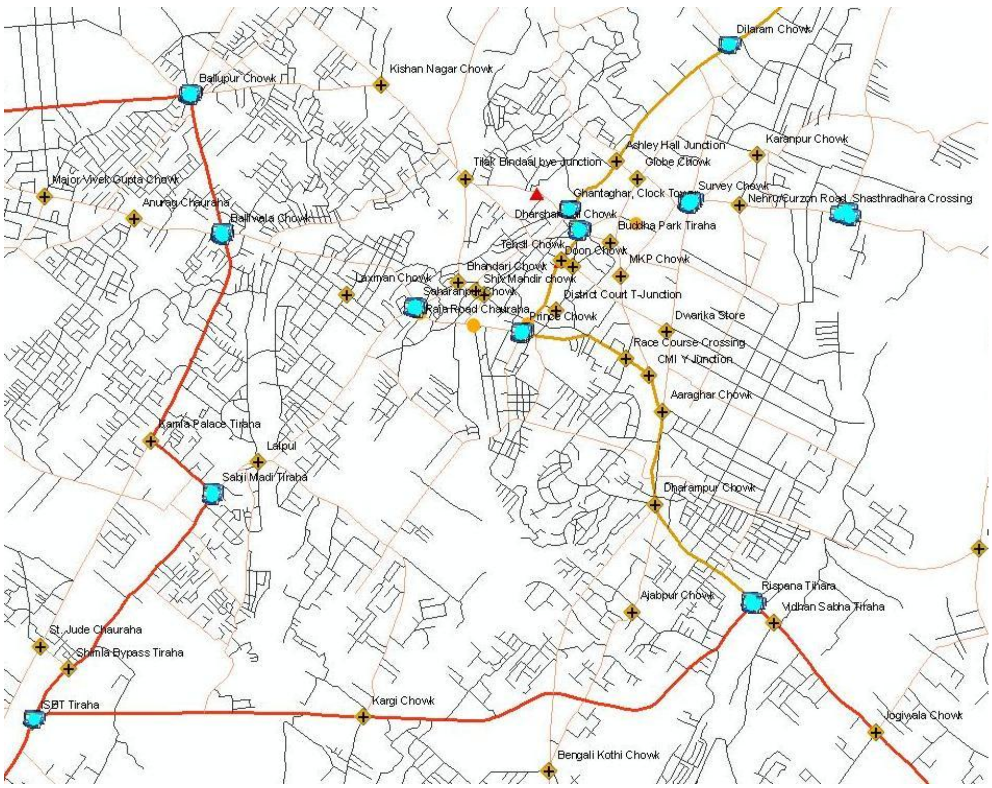


Fig 6.100: Intersections Prone to Traffic Jam

To remove traffic jam at Ghantaghar intersection, the city administration has already started a new initiative, and is providing a shop and a residence at some other location in lieu of the business property acquired near Ghantaghar, which will be used for road widening. On the Prince/Agrasen intersection, the road heading towards Haridwar is also having frequent jam. Saharanpur/Mahavir intersection is one of the most critical intersections. All the roads meeting at the Saharanpur intersection have regular traffic jam. Saharanpur intersection lies in the heart of city, and is one the oldest commercial areas. It is the wholesale market of food grains and wood commonly known as Arhat bazaar. Railway station is also situated nearby. Roads have been widened to their full extent, and there is no scope of further widening. Approach similar to Ghantaghar may be adopted by the administration at this place and new place may be provided for this wholesale market to remove congestion from here. For Rispana tri-junction, road has been widened towards Haridwar, so it will help in minimising the traffic jam.

6.3.4.2 Identification of Locations for Overbridges for Pedestrian Movement

Pedestrians also play an important role in the overall management of traffic. Analysis reveals that pedestrian bridges are required at Chakrata road near Krishna palace, Tehsil chowk and Ghantaghar (Fig 6.101). This will reduce the obstruction caused by pedestrian on the road where there is a heavy vehicular traffic.

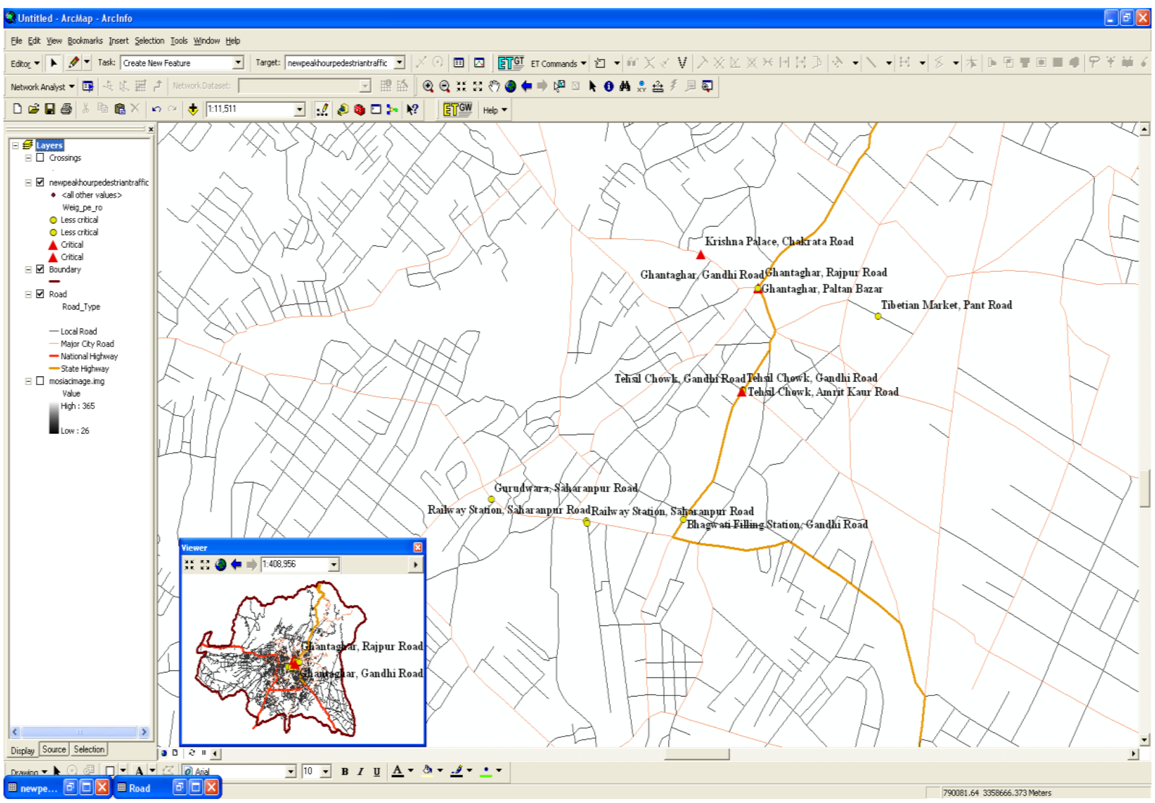


Fig 6.101: Location of Pedestrian Bridges

6.3.4.3 Identification of Byepass Road

Dehradun is the gateway to Mussoorie, a hill station. Tourists/ traffic from Haridwar, Saharanpur or Poanta Sahib have to go through the city. In order to reduce congestion, it is advisable to have appropriate bye pass route. This Fig 6.102 shows the existing byepasses. Tourists from Saharanpur green color road can easily

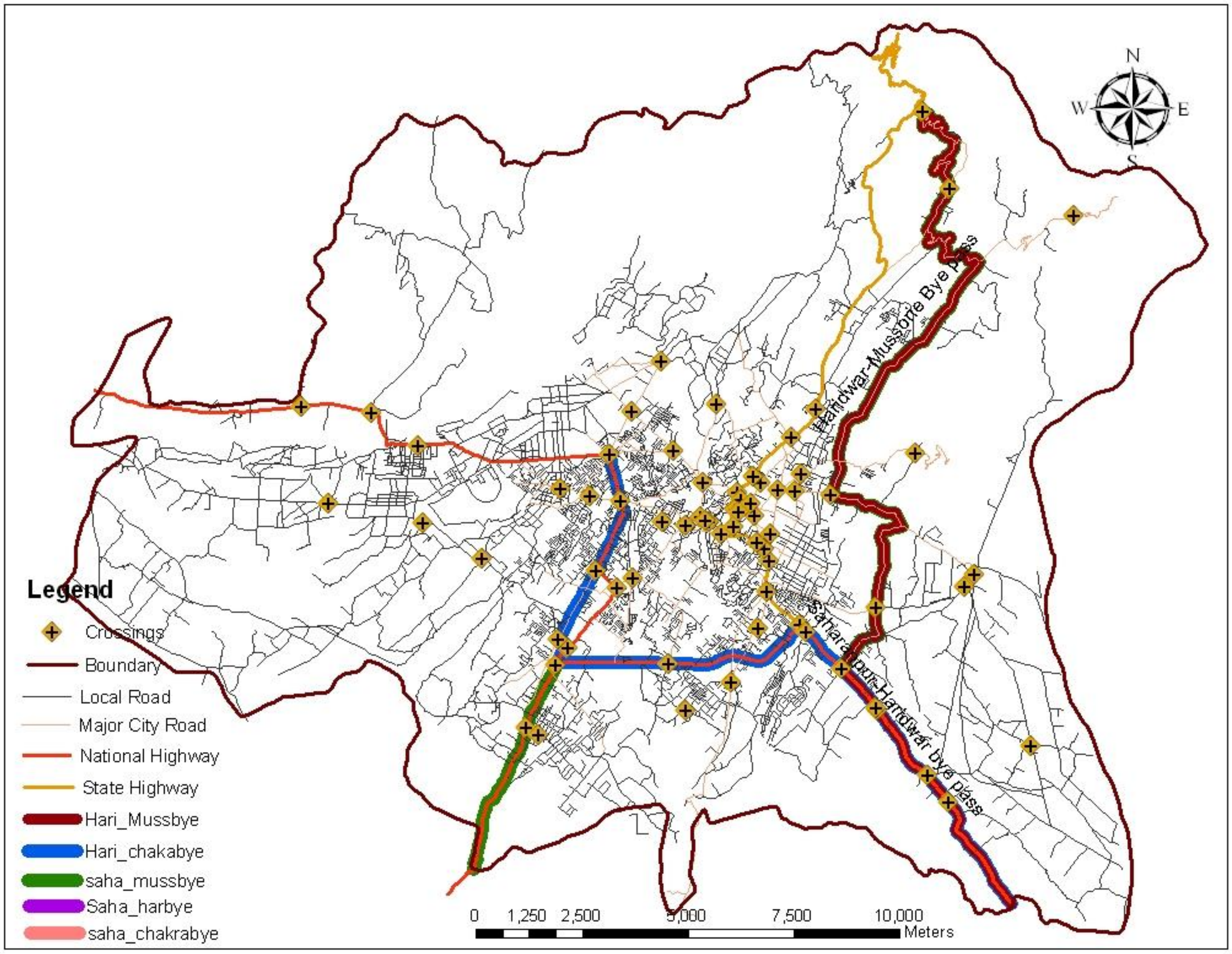


Fig 6.102: Existing Byepass

go to Chakrata following the General Mahadev Singh Road (blue). They may also go to Haridwar following Haridwar byepass road without entering in to the city, and to Mussoorie following the Haridwar Mussoorie byepass (first blue then brown color). Similarly, tourists coming from Haridwar can easily go to Mussoorie, Saharanpur and Chakrata following the bye pass. The tourists from Chakrata can go to Saharanpur, Haridwar easily. If they want to go to Mussoorie then they have to pass through the city. Therefore, one bye pass route is needed which connects Chakrata road to Mussoorie road. Fig 6.103 shows one possible alignment of the bye pass. In this alignment, existing road is followed. The width of this road is approx 3.5 m which may be widened.

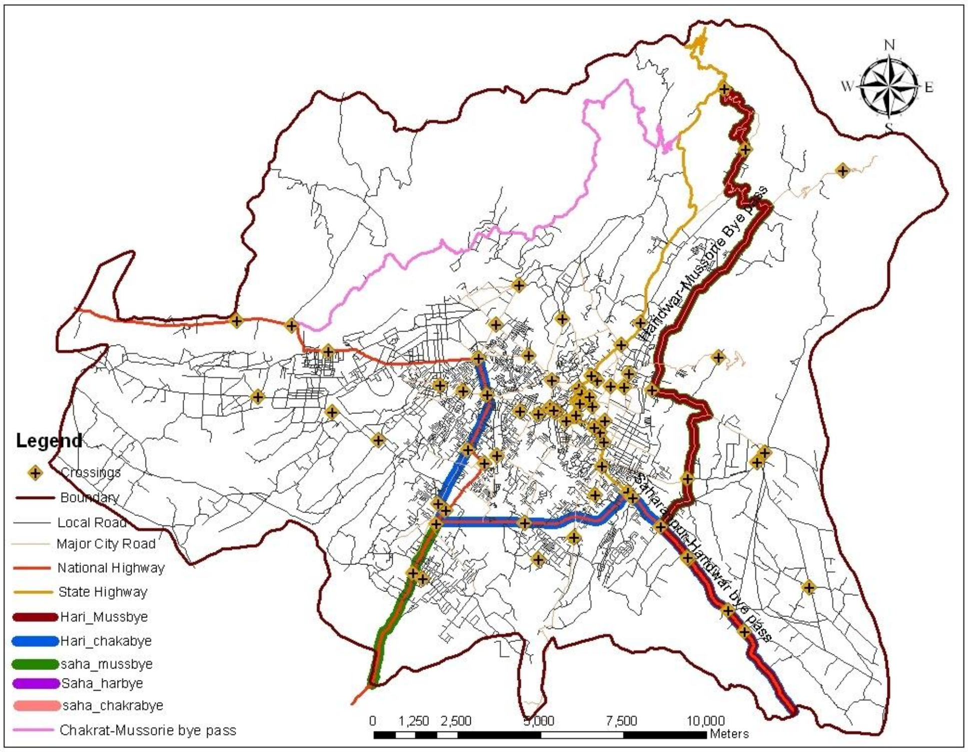


Fig 6.103: Possible Alignment of Byepass

Fig 6.104 shows the formation of a query to get the peak hour traffic. Fig 6.105 shows the results in pictorial form, while Fig 6.106 shows the results in tabular form from web GIS module.

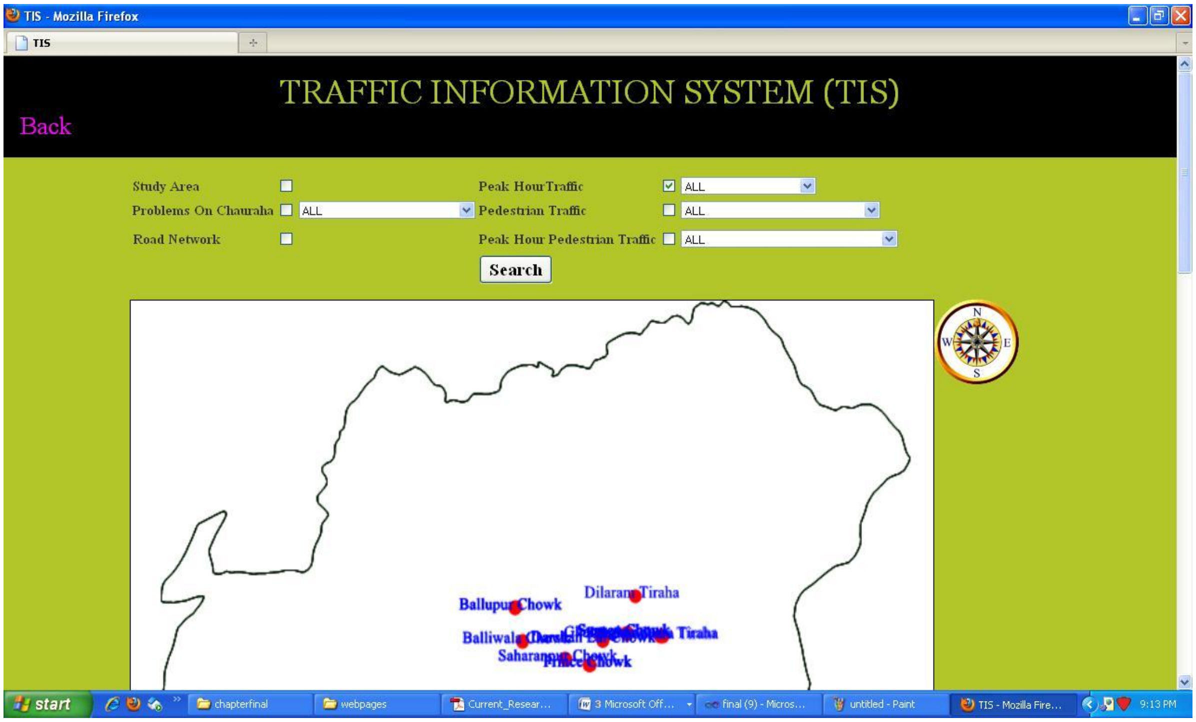


Fig 6.104: Formulation of Query to Get Peak Hour Traffic

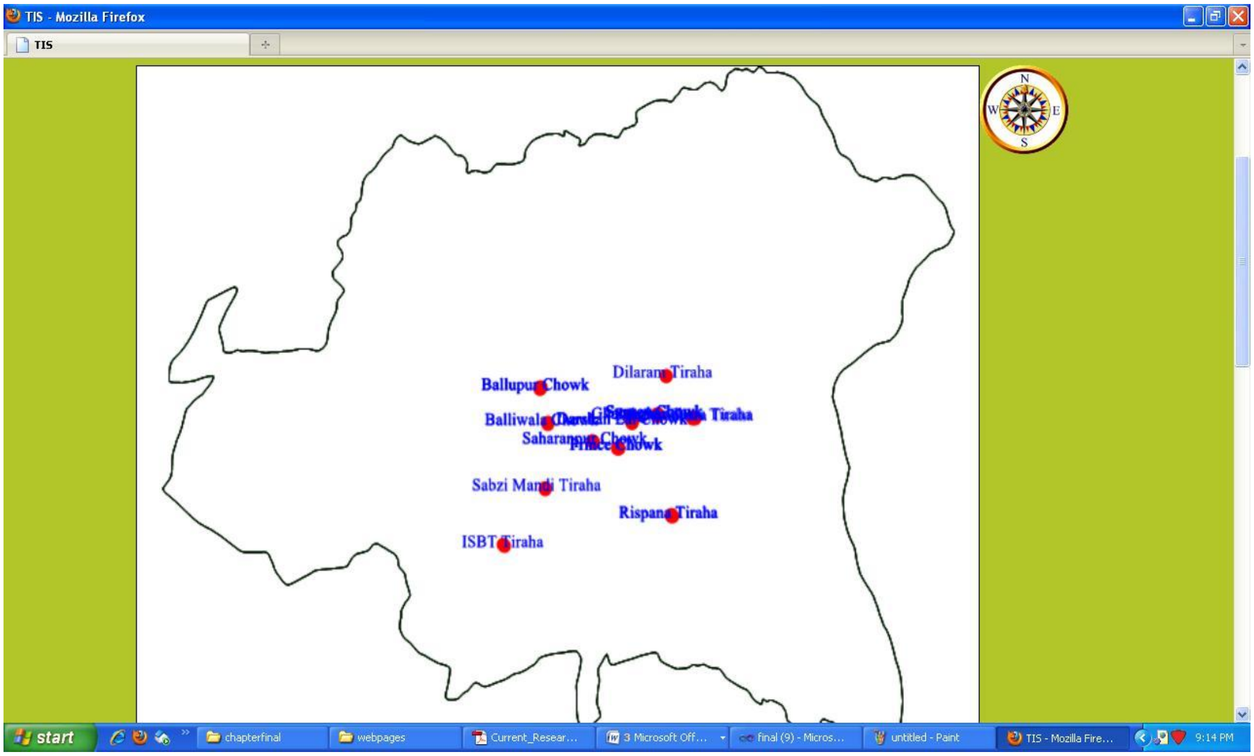
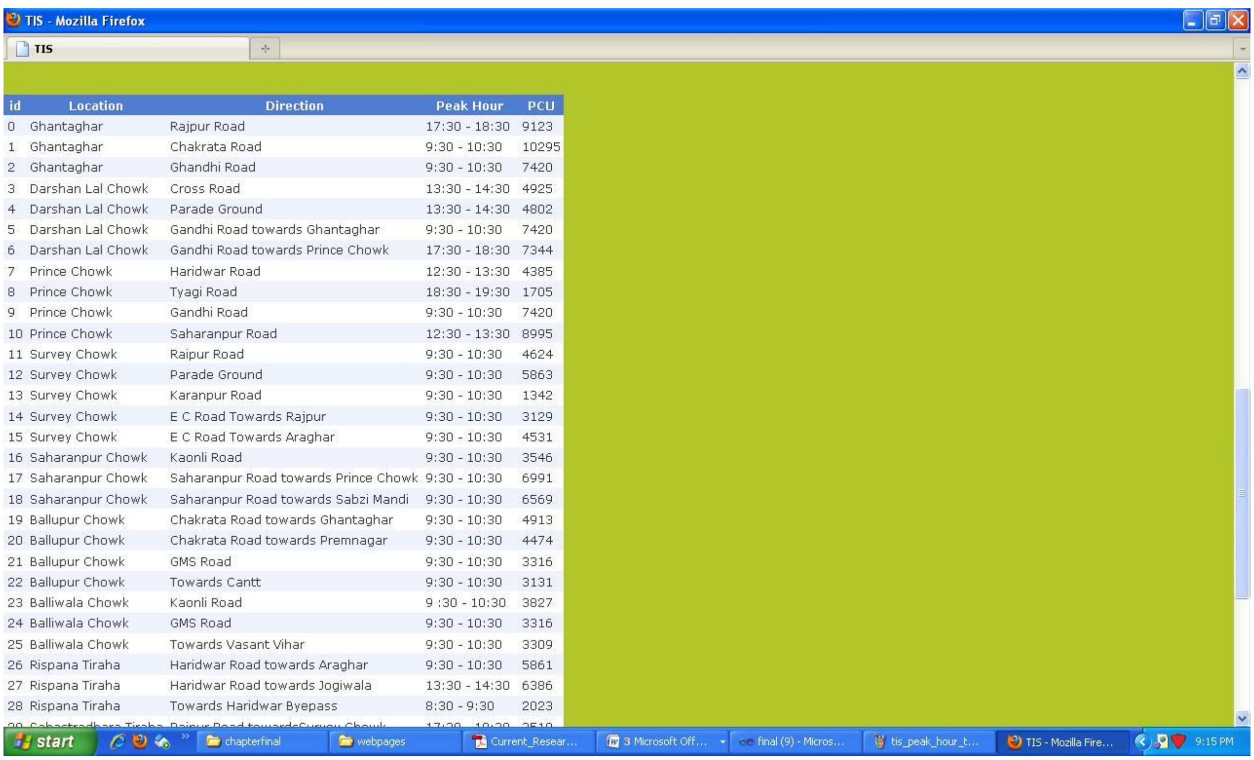


Fig 6.105: Intersections having the Peak Hour Traffic Data



id	Location	Direction	Peak Hour	PCU
0	Ghantaghar	Rajpur Road	17:30 - 18:30	9123
1	Ghantaghar	Chakrata Road	9:30 - 10:30	10295
2	Ghantaghar	Ghandhi Road	9:30 - 10:30	7420
3	Darshan Lal Chowk	Cross Road	13:30 - 14:30	4925
4	Darshan Lal Chowk	Parade Ground	13:30 - 14:30	4802
5	Darshan Lal Chowk	Gandhi Road towards Ghantaghar	9:30 - 10:30	7420
6	Darshan Lal Chowk	Gandhi Road towards Prince Chowk	17:30 - 18:30	7344
7	Prince Chowk	Haridwar Road	12:30 - 13:30	4385
8	Prince Chowk	Tyagi Road	18:30 - 19:30	1705
9	Prince Chowk	Gandhi Road	9:30 - 10:30	7420
10	Prince Chowk	Saharanpur Road	12:30 - 13:30	8995
11	Survey Chowk	Raipur Road	9:30 - 10:30	4624
12	Survey Chowk	Parade Ground	9:30 - 10:30	5863
13	Survey Chowk	Karanpur Road	9:30 - 10:30	1342
14	Survey Chowk	E C Road Towards Rajpur	9:30 - 10:30	3129
15	Survey Chowk	E C Road Towards Araghar	9:30 - 10:30	4531
16	Saharanpur Chowk	Kaonli Road	9:30 - 10:30	3546
17	Saharanpur Chowk	Saharanpur Road towards Prince Chowk	9:30 - 10:30	6991
18	Saharanpur Chowk	Saharanpur Road towards Sabzi Mandi	9:30 - 10:30	6569
19	Ballupur Chowk	Chakrata Road towards Ghantaghar	9:30 - 10:30	4913
20	Ballupur Chowk	Chakrata Road towards Premnagar	9:30 - 10:30	4474
21	Ballupur Chowk	GMS Road	9:30 - 10:30	3316
22	Ballupur Chowk	Towards Cantt	9:30 - 10:30	3131
23	Balliwala Chowk	Kaonli Road	9 :30 - 10:30	3827
24	Balliwala Chowk	GMS Road	9:30 - 10:30	3316
25	Balliwala Chowk	Towards Vasant Vihar	9:30 - 10:30	3309
26	Rispana Tiraha	Haridwar Road towards Araghar	9:30 - 10:30	5861
27	Rispana Tiraha	Haridwar Road towards Jogiwala	13:30 - 14:30	6386
28	Rispana Tiraha	Towards Haridwar Byepass	8:30 - 9:30	2023

Fig 6.106: Peak Hour Traffic Data

Fig 6.107 shows the query formation and the existing problems on intersection (where four roads meet) and T-junction (where three roads meet). By removing them, flow of traffic may be smooth and continuous. Fig 6.108 shows all the road intersections, while Fig 6.109 shows the results in tabular format.

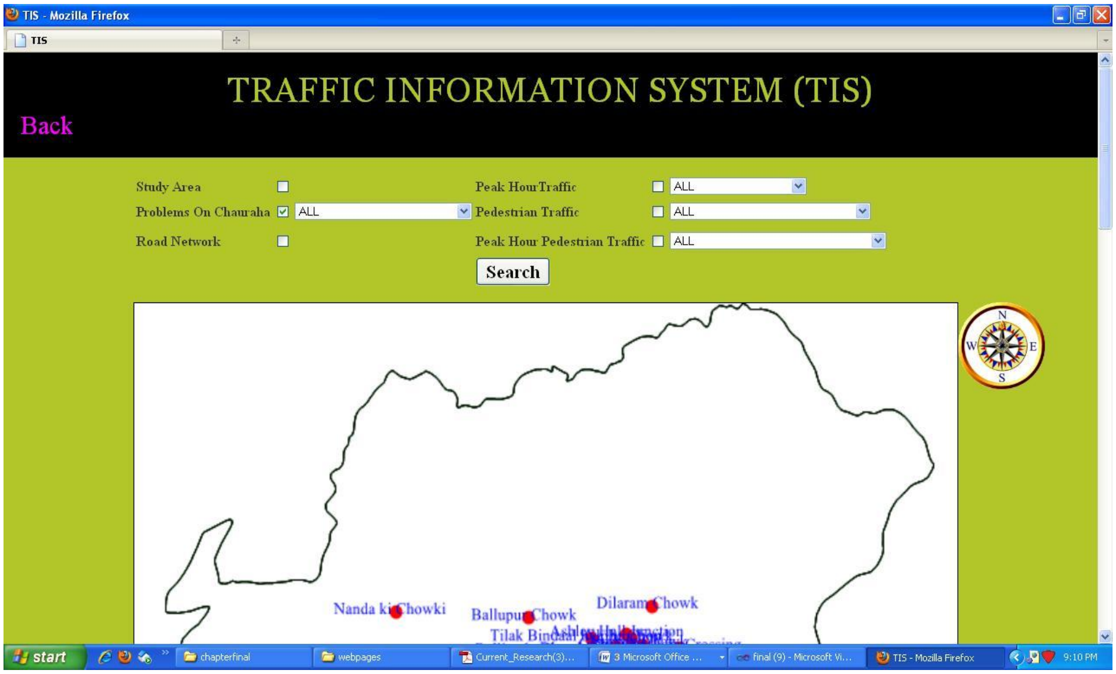


Fig 6.107: Procedure for Query Formation to Know the Problems on Intersections

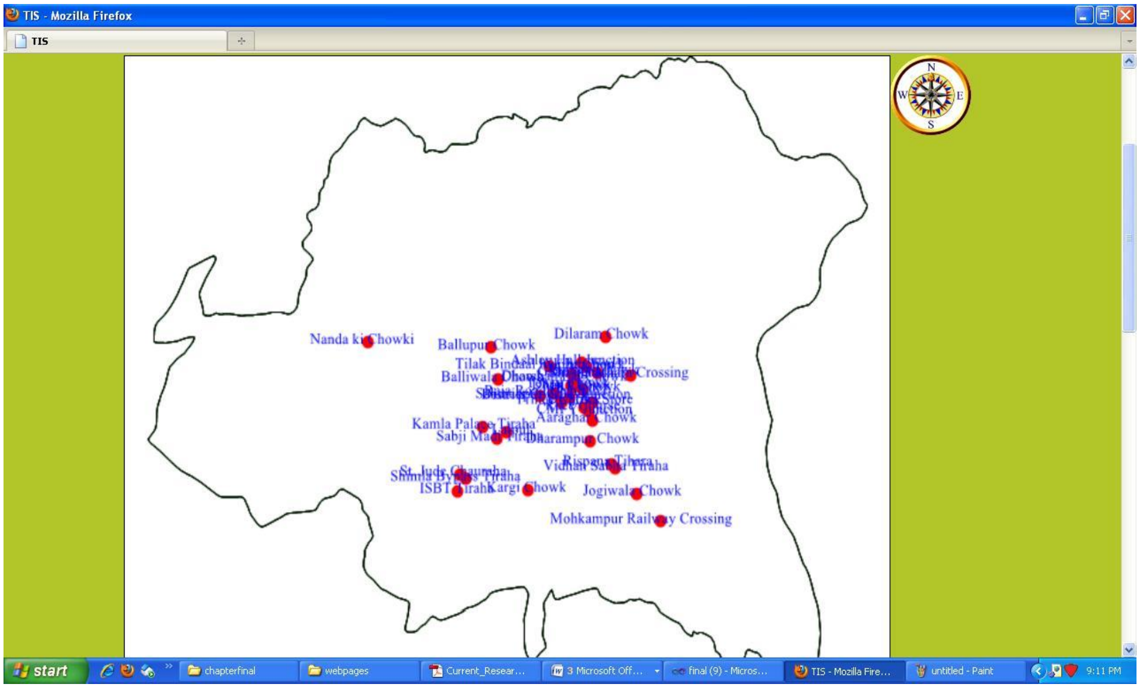
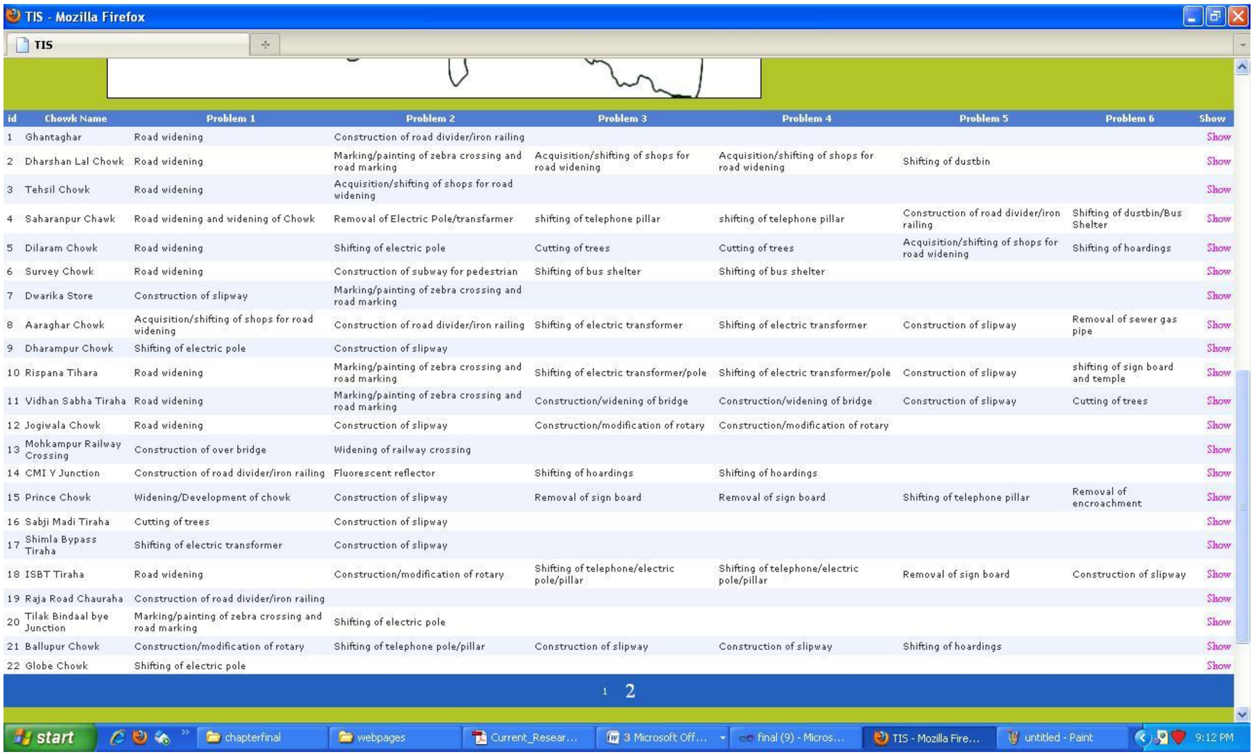


Fig 6.108: Results of Query in Picture Format



id	Chowk Name	Problem 1	Problem 2	Problem 3	Problem 4	Problem 5	Problem 6	Show
1	Ghantaghar	Road widening	Construction of road divider/iron railing					Show
2	Dharshan Lal Chowk	Road widening	Marking/painting of zebra crossing and road marking	Acquisition/shifting of shops for road widening	Acquisition/shifting of shops for road widening	Shifting of dustbin		Show
3	Tehsil Chowk	Road widening	Acquisition/shifting of shops for road widening					Show
4	Saharanpur Chawk	Road widening and widening of Chowk	Removal of Electric Pole/transfarmer	shifting of telephone pillar	shifting of telephone pillar	Construction of road divider/iron railing	Shifting of dustbin/Bus Shelter	Show
5	Dilaram Chowk	Road widening	Shifting of electric pole	Cutting of trees	Cutting of trees	Acquisition/shifting of shops for road widening	Shifting of hoardings	Show
6	Survey Chowk	Road widening	Construction of subway for pedestrian	Shifting of bus shelter	Shifting of bus shelter			Show
7	Dwarika Store	Construction of slipway	Marking/painting of zebra crossing and road marking					Show
8	Aaraghar Chowk	Acquisition/shifting of shops for road widening	Construction of road divider/iron railing	Shifting of electric transformer	Shifting of electric transformer	Construction of slipway	Removal of sewer gas pipe	Show
9	Dharampur Chowk	Shifting of electric pole	Construction of slipway					Show
10	Rispana Tihara	Road widening	Marking/painting of zebra crossing and road marking	Shifting of electric transformer/pole	Shifting of electric transformer/pole	Construction of slipway	shifting of sign board and temple	Show
11	Vidhan Sabha Tiraha	Road widening	Marking/painting of zebra crossing and road marking	Construction/widening of bridge	Construction/widening of bridge	Construction of slipway	Cutting of trees	Show
12	Jogiwala Chowk	Road widening	Construction of slipway	Construction/modification of rotary	Construction/modification of rotary			Show
13	Mohkampur Railway Crossing	Construction of over bridge	Widening of railway crossing					Show
14	CMI Y Junction	Construction of road divider/iron railing	Fluorescent reflector	Shifting of hoardings	Shifting of hoardings			Show
15	Prince Chowk	Widening/Development of chowk	Construction of slipway	Removal of sign board	Removal of sign board	Shifting of telephone pillar	Removal of encroachment	Show
16	Sabji Madi Tiraha	Cutting of trees	Construction of slipway					Show
17	Shimla Bypass Tiraha	Shifting of electric transformer	Construction of slipway					Show
18	ISBT Tiraha	Road widening	Construction/modification of rotary	Shifting of telephone/electric pole/pillar	Shifting of telephone/electric pole/pillar	Removal of sign board	Construction of slipway	Show
19	Raja Road Chauraha	Construction of road divider/iron railing						Show
20	Tilak Bindaal bye Junction	Marking/painting of zebra crossing and road marking	Shifting of electric pole					Show
21	Ballupur Chowk	Construction/modification of rotary	Shifting of telephone pole/pillar	Construction of slipway	Construction of slipway	Shifting of hoardings		Show
22	Globe Chowk	Shifting of electric pole						Show

Fig 6.109: Results of the Query in Tabular Format

6.4 CONCLUSION

A RIS has been developed using geospatial tools. RIS can be used for generation of new information through integration of various thematic layers. Query system in RIS would help planners and decision makers to derive useful information as per need of work. Therefore, it can be used for a large number of applications, such as planning phase-wise development of new facilities and infrastructure, planning of routes for city buses, fix the priority of roads for maintenance and develop a new facility at the right spot etc. Network analysis and buffer analysis enhances the capability of the module manifold.

BMS can be used for the generation of new information through integration of various thematic layers. Query system in BMS would help planners and decision makers to derive useful information as per need of work. Therefore, it can be used for a large number of applications, such as planning phase-wise development of bridges, fix the priority of bridges for maintenance etc.

For demonstrating the utility of AIS, a number of queries have been designed. Examples are presented and the results are tabulated. Buffer analysis was also carried out and critical spots were identified. With the help of this analysis, an administrator can identify and plan the remedial methods to minimize the accidents. Network analysis was also carried out to find the nearest location of hospital with a travel time of within 15 minutes. This information may be crucial in case of road accidents and injury.

From analysis of TIS, intersections prone to traffic jam, identification of locations for over-bridges for pedestrian movement and possible alignment of a bye pass road can easily be identified.

Finally, it is observed that remote sensing and GIS can play a great role for collection and analysis of large amount of information related with the road sector, effectively and efficiently.

URBAN ROAD INFORMATION AND MANAGEMENT SYSTEM (RIMS) USING GEOSPATIAL TOOLS

Ph.D. THESIS

by

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JUNE, 2014