HEALTHCARE INFORMATION SYSTEM USING GIS: A CASE STUDY FROM PUNE METROPOLIS

A DISSERTATION SUBMITTED BY

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Declaration by student

I hereby declare that the dissertation entitled **"Healthcare information system using GIS: A case study from Pune metropolis"** completed and written by me has not previously formed the basis for the award of any Degree or another similar title upon me of this or any other Vidyapeeth or examining body.

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This is to certify that the dissertation entitled **"Healthcare information system using GIS: A case study from Pune metropolis"** which is being submitted herewith for the award of the Master of Philosophy (M.Phill) in ___________________________ of Tilak Maharashtra Vidyapeeth, Pune is the result of original research work completed by Shri / Smt. ____ under my supervision and guidance. To the best of my knowledge and belief, the work incorporated in this dissertation has not formed the basis for the award of any Degree or similar title of this or any other University or examining body upon him/ her.

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TABLE OF CONENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1
INTRODUCTION

1.1. Introduction

One of the most important issues in India and other countries is the accessibility of healthcare. Providing health to everybody in any society is a fundamental human right that should be taken seriously by governments and custodians. The location, quality, and quantity of services available in healthcare center effects on access (Adeyemo, 2005; Ajilowo *et al.,* 2007). Health and quality of life can be improved by the availability of, and accessibility to healthcare facilities with affordable cost (Benachi *et al.,* 1999). Availability in the context of health services refers to the number of healthcare service points which people can choose in an emergency. Accessibility refers to the distance between residential or demand areas and health services or destinations. In other hands, Access describes people's ability to use health services when and where they are needed. Therefore, studying accessibility and utilization requires assessment of the interaction between the locations of demands for health services and the locations of healthcare facilities. Healthcare services are specifically provided at a finite number of fixed locations, nevertheless, they serve populations that are continuously and unevenly distributed throughout a region. Hence, one of the main goals of policymakers in the health sector of any country is to facilitate the access of individuals to healthcare services, so that all segments of society can benefit from these services.

By increasing growth of cities and population, the importance of urban areas in business, service delivery, production and consumption increases. In addition, based on current healthcare utilization patterns, demand for primary care providers is projected to grow more rapidly than physician supply (Bejleria *et al.,* 2016). Although the government provides facilities for citizens, there are some limitations for accessing the services. In 2025, more than 5 billion people are expected to live in urban areas while 80% will be habitat in less developed cities which is challenging for managers and city planners (Messer, 2003). Healthcare and treatment centers are of the most important service centers in cities. Lack of quick access to such services may endanger the health of citizens. Providing quick and easy access to health services for all communities is the main duty of government. Quantity and quality of healthcare centers are the criteria of welfare and life quality (Lokhman *et al.,* 2012). Regards to the increasing role of serving people in the urbanization system, distribution of service centers and access facilities have become extremely important (Jamshidzadeh, 2007). Urban development, caused by developing of paths and communications, highlights the role of displacement.

Health centers are one of the most important urban areas that directly contribute to the health of the individual and the community. Fast, timely and inexpensive access to these centers in every community, especially in urban societies, is very important. Healthcare decisions are strongly influenced by time, cost, the type, and quality of services available in the local area, the distance and ease of traveling to reach those services. Best services provided by each healthcare center will improve the quality of communities' healthcare. It includes the preparation of an information system that helps users to reach each healthcare center for treatment (Lokhman *et al.,* 2012). Inequalities in geographic access to healthcare result from the configuration of facilities, population distribution, and the transportation infrastructure.

Global organizations, including the World Health Organization, consider the right to health as one of the main social goals of a community and having health as a basis for sustainable development is one of the main pillars of social justice. The health condition and healthcare facilities should be accessible for all, and especially affordable and acceptable by the all needy patients. Since equity is a fundamental principle of health service, the geographical or special aspects of health service have been a considerable interest by researchers in these past years. The issue of access to health services in both developing and developed countries is a thinkable matter. There is an urgent need to establish mechanisms that can increase the availability and improve the quality of healthcare in the developing world.

One of the main goals of policymakers in the health sector of each country is to facilitate access to health services so that everybody in society can benefit from these services. Improving the level of service to people in the field of healthcare requires adopting appropriate strategies for use at various levels of planning, management, and implementation. Furthermore, one of the indicators of development of a nation is the health condition for citizens.

Nowadays, the health has been taken into consideration by the government, policymakers and community leaders and, in general, of human society. Since the health of society depends on the centers that provide them, so these centers are directly involved in the health of the individual and the community. World Health Organization (1997), specified the criteria for healthcare planning for third world countries which indicate that each service area should cover a 4km catchment area with a population of 60,000 for primary healthcare in order to have adequate and equity of access to health centers.

In order to have better medical services that require regular contact with service providers, travel time and distance can create barriers to effective service use (Adewoyin *et al.,* 2016). We need a better understanding of the geographical dimension of healthcare needs and utilization to management of health facilities for the determination and satisfaction of healthcare needs of the population. Therefore, development of comprehensive application, which will provide unbiased healthcare information to the users is essential.

1.2. Organization of the Thesis

The first section provides an overview of healthcare services and geographic accessibility. This includes a discussion of the role of Geographic Information

System (GIS) and spatial analytic techniques in analyzing and measuring accessibility as well as an overview of healthcare services, defining what those conditions are, and why they provide an important opportunity to understand healthcare accessibility in the study area. The second section will cover literature review of related studies. The third section, methodology, describes the disparate data sources compiled and utilized to illustrate both the supply and demand sides of healthcare services and the analytical procedures for assessing the data. Finally, our results and conclusions sections highlight and discuss our key findings and offer suggestions for further research.

1.3. Healthcare Services

The healthcare industry (also called the medical industry or health economy) is an aggregation and integration of sectors within the economic system that provides goods and services to treat patients with curative, preventive, rehabilitative, and palliative care. Primary healthcare plays a fundamental role in health system because it is the first defense for the population and a critical part of preventive care. Improved health and quality of life depends to a great extent on the availability of, and accessibility to healthcare facilities at affordable cost (Adewoyin *et al.,* 2016). However, physical access to healthcare is a growing concern for the overall population. Type and quality of services available in the local area and the distance, time, cost, and ease of traveling to reach those services affect healthcare decisions. Rates of mortality influenced by individual patient characteristics and also by levels of accessibility to hospital services and facilities (Hare & Barcus, 2007). Road traffic accidents cause several thousand deaths each year in England and Wales. One approach to reducing this toll is to ensure that services are planned to achieve early response of ambulances to accident victims and their rapid conveyance to a hospital with good accident and emergency facilities. In order to undertake medical care of the highest quality, there has been a policy of concentrating such facilities in large units. Unfortunately, this has the disadvantage that distances and travel times from some accident sites to these centres can be considerable, particularly in rural areas (Jones & Bentham, 1995). The purpose of gaining access to the personal healthcare system is to achieve one or more of an array of possible health outcomes—not only avoidance of untimely death and relief of acute symptoms but also maintenance of long-term functioning and reprieve from anxiety about the meaning of symptoms (shook, 2005). Exploring and analyzing the spatial relationship between locations of health centers and geographic accessibility to those centers have been for long time an important factor for decision-makers, planners, and healthcare systems (Mansour*,* 2016).

Health service is, particularly, one of the most important urban application which concerns numerous population, and covers a vast area of urban space. It faces many problems like lack of sufficient healthcare centers according to the community needs and inappropriate distribution of demanded centers. People maybe travel long distances to find appropriate healthcare services for serious or emergency health problems while their problems can be treatable at a local clinic.

Some emergencies situations are happened by road accidents such as vehicle-vehicle collision, vehicle-pedestrian collision, vehicle-object collision. Other types of emergencies that can be represented on the network include sudden human health problems, like strokes, heart failure or people injured in inter-personal conflicts. The persons who placed in these situations should have access to healthcare immediately. Pregnant women, Children, and general populations may experience greater difficulties navigating the critical healthcare services within designated optimal times with poor geographical accessibility. Assessing the geographical accessibility of these three critical groups to healthcare services within optimal times projects the status of healthcare system in the region and reveals the needs of medical services required by the community (Yerramilli *et al.,* 2014). Consequently, distance to the closest health facility was an important factor influencing mortality. The place of accident is not important; the ambulance must reach that place within a certain time period in order to save the life or to improve the situations of the injured.

Access to healthcare is a multifaceted concept, dependent upon the characteristics of both the population in need of services and the healthcare delivery system. Furthermore, accessibility is a complex concept encompassing locations of services and potential patients, mediated by the needs, perceptions, and socioeconomic characteristics of patients (Hare & Barcus 2007; Joseph &

Phillips, 1984; Martin & Williams, 1992). In fact, optimal access to health services means providing the right services at the right time and in the right place. This goal can be achieved by designing such a system that will help the patients to find the appropriate hospital or clinic according to their need and can avail the proper treatment provided by the healthcare center (Dabhade & Kale, 2014).

The distance between the patient's geographic regions and healthcare facilities and the travel time is taken to reach the healthcare delivery system are the most significant factors affecting the health status and health outcomes. Studying accessibility and utilization requires assessment of the interaction between the locations of demands for health services and the locations of healthcare facilities.

1.4. Application of Geographic Information System in Healthcare Analytics

The large volume of data and their application in urban and regional plans on the one hand, as well as dynamic nature of data in urban systems, on the other hand, necessitate employing electronic tools and new methods. Various geographic accessibility to healthcare may be due to the location/distribution of the population and the characteristics of the transportation infrastructure relative to the spatial arrangement of the healthcare delivery system within a region (Yerramilli *et al.,* 2014). Many of the decisions in the civil and environmental projects and other projects are in some way related to the specific geographic location, as a result, the existence of a geographic information system is essential.

A geographic information system (GIS) is a computer system designed to capture, store, manipulate, analyze, manage, and present all types of spatial or geographical data (Dabhade *et al.,* 2014). ArcGIS is an extensive plan that allows individuals to coordinate, analyze, compile, supervise, and disseminate geographic information (Mahmood & Soomro, 2015).

In recent decades, the rapid development of computer technology in terms of hardware and software has provided many technical signs of progress in graphical and geometric processes of data, as well as possible to organize, manage and employ thematic information. In this regard, the role of GIS as a management and analytical tool of spatial data gets increasingly important. In the mid-1960s, GIS was used to extract required information related to agriculture, forestry, soil, geology from aerial photos, for the first time in the United States. In the 1970s, with the advancement of science and the availability of computer technologies for working on spatial data, GIS was developed to enable analysis of very large spatial data. A geographic information system facilitates collecting and saving up-to-date georeferenced data, as well as combining different datasets. GIS is used by individuals everywhere throughout the universe to put geographic knowledge to work in government, non-government, and scientific discipline. Today's, GIS is used for scientific researchers, resource management, and development plans. The importance of using information in urban management, execution of plans and rules, as well as in dealing with a political, social and natural crisis is evident. Meanwhile, the existence of a logical system is one of the primary requirements since there needs a system to collect, process, analyze, and manage the information, and also to distribute required data to users. Moreover, the GIS application has a user-friendly interface that enables users to easily communicate and interact with other applications.

Nowadays there is an enormous increase in the use of GIS applications in various fields. The GIS has been used in several areas such as retail site analysis, transportation (Ajay *et al.,* 2013), emergency services (Smitha *et al.,* 2012), fire, petrol station mapping (Camille *et al.,* 2010), and healthcare planning for the measurement of physical accessibility (Kibon *et al.,* 2013) etc. Furthermore, a GIS can be used for many roles in emergency management. New applications of GIS in emergency management have flourished in recent years along with an interest in furthering this trend (Kai *et al.,* 2014).

In recent years, GIS and effective use of digital information have improved modeling urban development theories (Wolk-Musial & Zagajewski, 1999). Since the distribution of public services plays an important role in urban planning, the use of geographic information system in health management, as well as the provision of adequate access to healthcare recipients, is very important to use in many applications. GIS application to healthcare facility distribution and accessibility emphasizes the geographical dimensions of access (Adewoyin *et al*., 2016). Since the spatial accessibility is primarily calculated by GIS, it has also been referred to as the GIS-based accessibility (Bejleria *et al.,* 2017). A list of GIS applications in urban services are noted according to the research objective as following (Kibon *et al.,* 2013; Camille *et al.,* 2010):

- Georeferencing: the process of associating a physical map or raster image of a map with spatial locations.
- Optimal routing for emergency services: determining the closest fire station or health center to a specific location in order to find the best solution to reduce casualties and financial losses.
- Network analysis: It is the process of finding out the most optimal path to get to a destination from an origin in a certain network which can be represented as a group of connected edges where there is a certain cost to pay when you go through each of them. The optimal path could be the shortest, fastest, or most desirable route defined by GIS user.

In recent accessibility studies, the traditional distance measure (Euclidean) has been replaced with more plausible measures such as travel distance or time. Such measures range from the conceptually simple counting of the number of facilities within a specified distance from a given location to more sophisticated spatial interaction models (Hare & Barcus, 2007). Technological advances such as GIS can allow emergency vehicles to reach patients more quickly (Wilde, 2009), and efficiency in routing emergency fire and medical vehicles to a traffic incident is critical for saving lives (Cova, 1999). The computational power of network-based GIS methods integrating transportation networks, along with their attribute information such as distances, speed limits and restrictions, provides a framework to assess geographical accessibility by estimating the physical distance or travel time between a right type of healthcare facility and the patient in need of the service (Yerramilli *et al.,* 2014). By this application, an individual can choose particular service and find where it is provided, then travel to further services. Network analysis remains one of the most significant and persistent research and application areas in a geographic information system. Networks can represent an alternative datum for locations in the context of linear referencing and support a set of tools for a graphical display (Zhang *et al.,* 2010).

Both network and raster-based methods are often utilized for estimating travel time in a Geographic Information System (Joseph & Bantock, 1984). The flexibility provided by GIS allows for multiple data representations of the same real-world phenomena. Specifically, travel costs can be represented using a field-based model (raster) or an object-based model (vector). Vector data models represent traversable paths between points along lines (termed edges) in a network, with anything not on the network being non-traversable 'empty space', whereas raster data models represent travel through a pixel (cell) grid, where all space in a defined area is included in the grid (Nesbitt *et al.,* 2014). The vector data model can also be extended to incorporate network or graph features and is referred to as a "network" data model (Delamater *et al.,* 2012). Both models can incorporate travel along roads, and raster models usually include topographic features such as land-cover and void areas that cannot be traversed (e.g. lakes, legally restricted areas). Time or season may modify these impedance values, and space-time models can incorporate changes in topography and land-cover as well as the population over time (Nesbitt *et al.,* 2014). In practice, appropriate measure model depends largely on several issues: data availability, geographic context (topography i.e. water bodies and mountains), road networks and land-cover which is publicly and commercially available.

GIS becomes a common technique that may produce maps, integrate info, visualize and solve issues, and develop valuable solutions (Saeed *et al.,* 2017). There are many reasons for health organizations to use GIS and to benefit from its tools and functions including (Kibon *et al.,* 2013):

- The increasing availability of geo-coded health data that lead to having health information system
- The availability of digital geographic data micro and/or macro scale that has several GIS coverages with enormous attribute data such as addresses and land use, ownership etc.
- The availability of spatial analysis tools, as separate software modules or embedded in GIS

Some challenges in using geographic information system for urban services include: increasing volume of information in urban issues, lack of up-to-date geocoded data in municipalities or other related organizations, inadequate intra- and inter-organizational coordination in acquiring and managing urban information, lack of standard and systematic mechanism for acquiring, storing, updating, processing, application and distribution of information by municipalities, excessive growth of cities and land use changes, unavailability of quick access to accurate information on quantity of facilities, issues and problems of urban management plans, inconsistency between facilities and population distribution, lack of long-term plans related to citizen’s needs, non-integrated spatial data and attributes in most cases (Akbarinasab & Emamipanah, 2015).

Following suggestions should be considered in order to overcome above problems:

a) Establishment of an organized system

b) Collection of accurate and adequate data

c) Ability to analyze information demanded by users

d) Ability to analyze, improve, update and distribute the information

e) Providing preconditions for research, implementation, management, and distribution of information.

A review study reported various spatial analysis measures of health facility accessibility including provider-to-population ratios, travel impedance to nearest provider, average travel impedance to nearest provider, and gravity models. The first kind of measure was identified as the most popular type of analysis since it does not require highly GIS–sophisticated methods. The second measure is well known as a travel cost analysis and it could be applied for rural areas where people's choice to access to health centers is often very limited. The third type of analysis is based on combining both accessibility and availability, and the distance from population or patients to facility points is summed and averaged. The final type is similar to the previous type as it also combines accessibility and availability in the measurement. However, it provides an accurate result of the interaction between population points and any service center within a specific distance (Mansour *et al.,* 2016).

GIS provides the facility of combining spatial data and associated attribute data in a single system. The location and characteristics of everywhere collect in geospatial data. The accurate position of the health centers can be mapped based on their coordinates. The associated information of each location, such as name, facilities, addresses, phone number, can give more additional information in the combination of spatial location. This information can also be useful in network analysis such as measuring the distance and calculating the shortest path from user location (Lokhman *et al.,* 2012).

1.5. Shortest Path

Finding and analyzing a shortest path, fastest path and optimize path are still the need of the day. Finding the shortest path in a large-scale network analysis between any two nodes is a tough but very significant task. According to the shortest path method, the time and cost can be saved. The geographical accessibility varies according to local conditions of transport, as local topography. Geographical accessibility is calculated as physical distance, in kilometers, between the residence and the nearest available medical service, but also to the nearest hospital or ambulance station. The calculation of these distances is done either in line or in the existing line access routes (roads, highways, paths etc.) and is the time used to accede to a medical facility. There is no consensus on what constitutes "away" for a healthcare service, but usually, it is considered that an optimal distance from a primary healthcare service should not be more than 5-7 km and a larger hospital 25-35 km (Jordan *et al.,* 2004; Ursulica *et al.,* 2016). It is considered a great distance to a medical facility may adversely affect directly health status.

There are usually huge amounts of requests which occur at any moment, the key is to find the quick solution for it. The speed, precision, and coordination of the delivery of services by emergency medical are crucial for reducing mortality and disability. Disparities in the geographic accessibility of healthcare services arise due to the manner in which people and facilities are arranged spatially (Delamater *et al.,* 2012). Specifically, healthcare services are provided at a finite number of fixed locations, yet they serve populations that are continuously and unevenly distributed throughout a region. Access is affected by timing and outcomes, and the receipt of good quality service when an individual needs it. The shortest path problem is one of the well-known and practical problems in computer science, networking and other areas (Kai *et al.,* 2014). Regards to quick access to emergency services, the network analysis tools in GIS such as the shortest path and the closest facilities are very useful. Methods of dynamic routing based on real-time information obtained from fire vehicles and ambulances have been greatly considered. It is possible to find optimal routes for emergency services in various situations like road accidents, unwanted health problems, fire, etc. using spatial data such as a map of city, location, and attributes of roads, residential area and service centers, as well as applying proper processes and methods. The rate of unwanted incidents relates directly to population, traffic congestion, road condition, and drivers. Thus, having a digital system for finding the optimal route is one of the requirements for emergency centers and other users (Nicoara & Haidu, 2014). Effective routing for emergency vehicles minimizes access time to service centers and improves the response to community needs (Panahi & Delavar, 2008).

The general problem of the shortest path requires a predefined network. On the other hand, the shortest path problem is a problem of finding the shortest path or route from a starting point to a final destination (Dabhade *et al.,* 2014). GIS is an effective tool for determining emergency vehicle response routing and solving the emergency vehicle shortest path routing problem (Cova, 1999; Panahi and Delavar, 2008). Various criteria such as distance, travel time, route comfort, and path beauty have been considered for analyzing the shortest path in network analysis in spatial information systems.

The shortest path issue has always been one of the most practical issues in transport spatial analyzes as well as locational service systems. Traffic congestion is a major problem in urban areas and can disrupt emergency response (Panahi and Delavar, 2008). With regards to the role of the time parameter in the transportation network, users generally want to get the path with the least time to go.

The shortest path algorithm applied to a routing problem in a transportation network can calculate the path with minimal travel cost or least impedance from an origin to a destination. Depending on the type of cost, the shortest path can be referred to as the shortest, fastest, or most optimal path or route.

There are multiple ways to calculate the shortest path from point A to point B. Dijkstra algorithm (Dijkstra, 1959), A * algorithm (Hart *et al.,* 1968) and Floyd-Warshall algorithm are the three main kinds of shortest path algorithms which have also been implemented in GIS network analysis. The one used by ArcGIS software is Dijkstra algorithm (ESRI, 2014; Nicoara & Haidu, 2014). Also, the modified Dijkstra algorithm is the most suitable method with this network to find the shortest, fastest and optimize route (Mahmood & Soomro, 2015). The algorithm searches for the distance from the starting point to every other vertex until it reaches the destination point and gives the shortest path possible. This makes possible for the rapid calculation of the most appropriate route as well as other functions like closest facility. The model is based on vector data. Vector lines are used to describe spatially distributed streets and points to represent locations along the hospitals or clinics and accidents (Nicoara & Haidu, 2014).

1.6. Importance of Visualization and Spatial Analysis to Healthcare Services

A concerted effort to unleash the potential of healthcare data could significantly improve outcomes for everyone in our society. As mentioned in the last section, health is one of the human rights and it means that everyone has the right to the highest attainable standard of physical and mental health, which includes access to all medical services, sanitation, adequate food, decent housing, healthy working conditions, and a clean environment. Today, researchers have argued that poor access to urban services and utilities leads to social and economic deprivation.

Research results in the United States show that 22.9% of deaths in the community indicate that health services are available and affordable, with an average of 5 years of life expectancy increases with improved health conditions (Gulliford & Morgan, 2003). In fact, optimal access to health services means providing the right services at the right time and in the right place. Considering the importance placed on the role of distance and travel in healthcare accessibility studies, we believe that an examination of the data models and methods is warranted.

The National Rural Health Mission (NRHM) of India as per the 12th Plan document of the Planning Commission aims to provide impelling healthcare to the rural population, especially to the remote and most disadvantaged groups. (Kanuganti *et al.,* 2014)

Nowadays, the consequences of physical and financial losses due to natural and abnormal accidents have a profound and undeniable impact on human life and health. Access to health services, both in developing and developed countries, is a perceptible topic. The three primary components for accessing are (Halden, 2005):

1- People at the source

2- Activities and services in the destination

3- the distance between people and these services

Geospatial methods offer a wide range of analytical possibilities to understand the overall picture of health disparities due to geographical accessibility (Yerramilli *et al.,* 2014)

1.7. The objective of the Thesis

The importance of online health services can also be seen in the development of national health systems and portals. These provide users with health information, access to medically trained people and personal perspectives from patients and citizens. Patients as well as citizens, in general, are becoming more knowledgeable and empowered due to new internet health services (Fox *et al.,* 2005). The detailed information about the availability of medical facilities is not available at one source hence people were facing problem in obtaining correct information before visiting any health facility. By using the shortest path to healthcare center, people can collect information and advice from different sources, and it is also common to get support. The regional variations of mortality rates confirm the significance of spatial methods in measuring the accessibility patterns and further supports the necessity to analyze geographical accessibility from a spatial perspective so as to reduce health disparities (Yerramilli *et al.,* 2014)

Because of Pune's rural nature and uneven distribution of physicians, geographic disparities exist in access to primary care services living women, children, elderly and general populations in underserved healthcare regions. These geographical issues have not been studied before by other authors, for the Pune area. Relatively little research has described the level and detail of actual transportation barriers experienced by patients when they need to obtain health services in Pune.

Accordingly, access to healthcare services, in fact, examines the link between providers of services, such as hospitals and surrounding populations (Hare *et al.,* 2007). Access planning, in fact, provides the conditions and requirements according to which the population have access to the facilities and services that they need.

Following the description is given above, the purpose of the research is to evaluate the spatial distribution of hospitals and healthcare centers in the city of Pune, India. Finding optimal route for quick access to healthcare centers using network analysis is also investigated.

This study opens the perspectives for a more extensive research of population access to health services, considering not only the spatial and temporal conditions but also the other perspectives, such as availability of human resources, the existence, and endowment of healthcare providers and specific aspects of morbidity.

CHAPTER 2
REVIEW OF LITERATURE

2.1. Review of Literature

The spatial or geographic dimensions of access have received considerable attention from planners and researchers for many years. Numerous studies have attempted to measure the distance from patient point to health facility centers, for instance, measuring the accessibility to healthcare locations (Amrapali *et al.,* 2014; Kibon *et al.,* 2013; Kai *et al.,* 2014; Nicoara *et al.,* 2014; Okengwu *et al.,* 2014; Dabhade *et al.,* 2015; Adewoyin *et al.,* 2016; Kanuganti *et al.,* 2016) and travel time to health services (Wilde 2009; Delamater *et al.,* 2012; Smitha *et al.,* 2012; Yerramilli *et al.,* 2014).

Network analysis is one of the vast applications of GIS which is used by emergency services, gas and electricity companies, regional transportation companies, railways and urban services. This type of analysis is used not only to find the shortest and fastest routes but also to model hydrological flows, traffic flows, shipping routes, service areas, directions, and closest facilities. In the following, a number of researchers are presented in this regard.

Hare and Barcus in 2007; tried to assess the geographical accessibility and service utilization related to ambulatory care sensitive CVDs in Kentucky, USA. Data was achieved from the hospital discharge database and the compressed mortality file of Kentucky. Researchers used hospital service locations, ZIP Code zone centroids, and transportation network features connecting all origin and destination locations. They also employed to attribute data, aggregated by ZIP Code zone, include the total population, the number of discharges for heart-related ACS conditions, and associated socioeconomic variables. Data were analyzed based on the several methods of GIS data visualization and a variety of exploratory spatial data analysis techniques. Utilizing the global and local Moran's I, and the bivariate Local Indicators of Spatial Autocorrelation increased their confidence in interpreting spatial patterns in the data. Their findings showed that people living in rural areas travel further to services; populations residing more than 45 min from health facilities are more likely to be socially and economically marginalized. Spatial clustering of high rates of hospital utilization occurs in areas with lower accessibility.

Comber and *et al.,* in 2008; used a network analysis using SANET based on GIS to measure distances between greenspace access points and the centers of 2001 population census output area in Leicester city, England. Polygons of output area are constructed from clusters of adjacent postcodes. In the ethnic group section, there are two levels. Level 1 is a large classification consist of 5 main ethnic groups. Level 2 nests within Level 1, and provides a finer classification (22 groups). The access points for greenspace access were manually digitized using OS 1:50000 scale color raster data and were placed inside the greenspace area. Centroids were used as locations for output areas that are commonly used for GIS analyses. These relate polygon-based objects to linear networks. The results showed that despite having nearly more than twice the recommended amount of accessible green space per capita, its distribution, and pattern showed a considerable variation, especially when spatially analyzed with respect to ethnic and religious groups.

Panahi and Delavar in 2008; developed a spatial decision support system (SDSS) for emergency vehicle routing using integration of GIS and real-time traffic condition. They analyzed the dynamic shortest path algorithm and proposed a practical solution for emergency routing. A geometric corrected digital road network of the study area (a small area of Tehran, Iran) and average traffic volume at streets and freeways were used as base data. Using the Bureau of Public Roads (BPR) model, travel time was estimated for a particular segment of path and summation of all segments of travel time provided total travel time between the origin and destination. The shortest path was calculated based on Dijkstra algorithm with specified rules which intelligently updates the proposed path using real-time traffic information transmitted from the emergency vehicle dispatch center. The results of this study showed the efficiency of the dynamic vehicle routing to reduce travel time in emergency situations. This research confirms the capability of GIS for network analysis, visualization, and management of urban traffic network.

Abbas *et al.* 2009; introduced a district management system for Allahabad Sadar sub-district in India and GIS techniques was employed to obtain spatial information about flood disaster impacts. The disaster management efforts consist of reduction, prevention, relief, mitigation, and rehabilitation. In this study, some maps were needed such as flood-affected areas of Sadar sub-district, the density of the population distributed in flood-prone areas, villages with road connectivity, hospital possibility in flood affected area, route of relief map which all prepared by using ArcGIS 9.1. They collected data from these maps and then the requirement of food, water, camps, and required relief shelter provided for the selected area. The results showed that GIS tool is beneficial to get all the suitable information at the time of occurrence of the disaster. Also, it can help for planning and be prioritizing infrastructure development effort in the area.

Sadeghi-Niaraki *et al.* 2011; proposed a method for network analysis to create a road network in geographic information system by studying some of the major roads in Iran. The main objective of this research was to solve the problems restricting the utility of most route finding analyzes, which are based on one-dimensional impedance models associated with the use of distance, time, and so on. In this research, a general technique was used to weight and integrate various variables in order to create an impedance model for the road network. In this regard, additional realistic variables affecting road networks such as weather, sight-seeing data, traffic, road length, security, and facilities were taken into account. An analytical hierarchical process (AHP) was used to combine these variables and create an impedance model. An AHP has two levels. Main variables build first level elements, and the second level contains sub-variables of each main variable. This technique enables hierarchical formulation and employs the various combination of variables in the model. In other words, this method is dependent on personal experiences to formulate a matter hierarchically; on the other hand, it employs logic to make final decisions. The result of model evaluation using sensitivity analysis confirmed the success of implemented models. All paths of the route planning analysis were matched properly with the paths which would be chosen by drivers in reality.

Owen and *et al.,* in 2010; used road network analysis to quantify access to healthcare services in Alta Verapaz, Guatemala. In this study, we gathered data such as population data from the Guatemalan census, the location of healthcare facilities and distances from the Ministry of Public Health and Social Assistance, and trail locations from the National Geographic Institute. We evaluated the shortest path from each populated area to the nearest healthcare facility and then nearly measured travel time to the health facility based on road surface type. Based on the results of road network analyses about 38.1percent of residents of Alta Verapaz live within one hour of a hospital and 76.8% live within one hour of a basic care facility.

Delamater and *et al.,* in 2012; measured the geographical access to healthcare by using raster and network-based method. According to the results, the raster-based method showed more area and people with limited accessibility. This method was more sensitive to travel speed settings, while the network-based method was more sensitive to the specific population assignment method employed, in Michigan, USA.

Haijuan and *et al.,* in 2012; evaluated the accessibility to urban public sports facilities by use of GIS based on network analysis in Yangzhou, China. For this study position of public sports facility places in the city center, road networks, and block units were determined by GIS software. The accessibility of urban sports facilities in Yangzhou city center within walking distance of 2.5 km for reaching the city block units was evaluated, and different accessibility of block units was also analyzed. According to the results for reaching to the large urban public sports facilities, about 44%, 29% and 5.6% of the block units were within the walking distance of 30 mins, 20 mins, and 10 mins, respectively.

Lokhman *et al.,* 2012; analyzed a GIS-based information system related to healthcare centers of Johor Bahru region in Malaysia. In this regard, spatial data including the map of Johor Bahru, road network (highway, primary and secondary roads), and the layer of government hospitals and their attributes including name and length of roads, as well as the name, address, and facilities of the hospitals were entered in GIS. A database containing all data and their connections was created. Analyzes of the shortest path and the closest facility were performed using network analysis tool in GIS. Using the shortest path analysis is found the shortest route to access a hospital from the patient position. This analysis shows the direction starting from the patient's location. Analysis of the closest facility is usable when there is more than one facility available from patient's location.

Smitha Shekar *et al.,* 2012; designed dynamic routing system based on the integration of GPS and real-time traffic congestion in Bengaluru, India. In this system, the exact location of the ambulance is determined using GPS, and the shortest path to access healthcare centers is calculated. In this study, certain modifications were done on Dijkstra algorithm and instead of using the distance, the time taken for the distance between two nodes was weighted to make a dynamic model. The time was calculated based on the ratio of the distance to speed between the nodes. The speed is the average speed of vehicles traversing the path that is obtained dynamically using VANETs. Optimal routes are programmed based on online information about travel time. The results of this study showed that dynamic routing of emergency vehicles is more efficient than the static solution. The efficiency of this method has a great importance when unwanted accidents and heavy traffic congestion occurs in roads. It is worth noting that in this method, the initially planned routes are stored because only part of the initial routes may change when receiving real-time information. This reduces calculation time which is the main idea of dynamic shortest path algorithm.

Kibon and Ahmed in 2013; evaluated the spatial distribution of primary healthcare facilities by use of GIS in Kano Metropolis, Nigeria. Researchers gathered data through direct observations in the field. Information needed for preparing the maps such as ward, location, address, name, and types of healthcare facilities was collected from the Ministry of Health (Kano State). They collected the coordinates of each healthcare facilities by use of GPS and discovered about 69 primary health facilities. Data was analyzed in Arc View GIS 3.2a. The results showed that most of the healthcare facilities were clustered within Kano

Municipal, Nassarawa, Tarauni and some part of Fagge LGAs. The underserved areas were like RijiyanZaki, BakinBulo, Danbare, other areas include Yan Raki.

Dabhade and Kale in 2014; integrated location of healthcare centers of Aurangabad city in the Maharashtra state of India with their facilities and services in GIS. The shortest path analysis was also considered to find nearest healthcare center from user's location. To this aim, 1:50000 topographic map of the study area was digitized, georeferenced and used as the base map. A network dataset containing a set of characteristics and their relationships was created in GIS. The Dijkstra algorithm was used to find the shortest path to the hospitals. The closest facility analysis using multiple-origin, multiple-destination algorithm based on Dijkstra was used to find lowest cost path to access a healthcare. The service area analysis was also used based on Dijkstra algorithm to show areas within specified network distance or cost cutoff.

Idowu Innocent *et al.,* in 2014; worked on mapping and identification of the special distribution of healthcare facilities in Kaduna North and South Local Governments, Kaduna State, Nigeria. They used GIS to add values to information for public health facilities mapping, decision making, and planning. In this research, the geographical data of healthcare facilities of Millennium Development Goals (MDGs) obtained through GPS from the field. Also, the topological base map of Kaduna North and South Local Governments, obtained from the archive of the GIS Laboratory, Department of Geography, Ahmadu Bello University, Zaria. All data were analyzed using ILWIS 3.2a GIS software. The results showed that the majority of the healthcare facilities were located in North-Western section. Also, a good network of transportation which was covering most of the healthcare facilities was observed in the studied area.

Kai *et al.,* in 2014; analyzed the shortest path using Dijkstra algorithm in an emergency response system to minimize the risk of accidents. In this study, a web application was developed using integration of GIS, web services and Ajax technologies (Asynchronous JavaScript and XML) to find the optimal route paths from response stations to incident locations. The web application of emergency response system includes tools to select the start and end locations directly on the map. The shortest route resulted from shortest path analysis is presented graphically on a map. In this research, length of the road was used to calculate the shortest path and to select the optimal path based on the minimum weight. Other factors needed for identification of more realistic routes such as road width, speed limit, road conditions, and turn restrictions were ignored.

Nicoara and Haidu, 2014; modeled the shortest path in a road network and the closest facilities for ambulances to reach an injured person. The data used in this study included road network of Cluj-Napoca city in Romania, the location of hospitals which recorded with GPS and some incident sites in order to test the network efficiency. Using the ArcGIS software, a database was created containing spatial information and attributes of routes and locations recorded by GPS. Only one-way streets were valued and used for network analysis modeling using Dijkstra algorithm. The analysis showed very good results that's mean the closest facility function had correctly shown the closest facility to the accident site and so the shortest path was matched with the route proposed by Google Maps.

Yerramilli and Fonseca, 2014; identified geographical accessibility to health services by using network-based GIS tools to model geographical access to specific healthcare service scenarios in central Mississippi, USA; which is characterized with urban and rural areas. In this method, the geographic accessibility of three types of critical healthcare facilities: obstetrician/gynecology (women in childbearing age), pediatrics (children) and Trauma/Burn Centers (general population) were investigated. The results showed the hotspots of vulnerable populations, residing outside the optimal service areas, within rural regions moreover, pregnant women bearing most of the health burden due to geographic inaccessibility.

Masoodi and Rahimzadeh in 2015; investigated the accessibility to urban health services using Floating Catchment Area (FCA), Response Time (RT) accessibility technique and minimum distance methods in Bandar Abbas, Iran. The results showed that The RT accessibility technique that uses shortest network path and time distances, provided detailed information about all the possible positions of the patients with respect to available healthcare services based on critical response and times optimum. Additionally, it illustrated that the Euclidean distances were not strongly correlated with network distances.

Abousaeidi *et al.,* 2016; used the GIS modeling approach to determine the fastest route for delivery of fresh vegetable from farms to sale centers and supermarkets. In addition to modeling the transportation network in GIS, a set of network characteristics was also integrated into a database. In this research, a linear regression model with least squares method was used to determine the parameters affecting route selection, taking into account the minimum time for vegetable delivery to Kuala Lumpur, Malaysia. Two categories of spatial and non-spatial data were used to develop the regression model. Spatial data includes base map (road and transportation layers), land use (location of sales centers, residential, commercial and industrial areas, and school zones) and population (number of people who live in a particular area), and non-spatial data includes driving time, distance, vehicle speed for each road, road type (one way or two) and traffic. A spatial database containing digital information about the routes was built up using GIS tools. Then the regression model was developed based on driving time (vehicle speed divided by distance) as dependent and other factors as independent variables. A map of fastest routes for distribution of fresh vegetable was prepared based on all variables. Based on the results, variables of distance, traffic, the presence of schools near transmission routes, roadways, residential areas, and the population had the greatest effect on driving time.

Adewoyin and *et al.,* in 2016; studied the spatial distribution and accessibility of primary health centers in Nigeria using GIS. The study area was in Ife East Local government area of Osun State. Researchers analyzed the spatial distribution of healthcare facilities, the accessibility of facilities, and the responsible factors for the disparity in accessibility level. Data was collected through administered interview and GPS to determine the location of healthcare facilities. GIS environment was used to analyze the Nearest Neighbor and the spatial inequalities of healthcare facilities. Then, data from personal interview analyzed through descriptive statistical analysis to examine the distance travel to hospitals. According to the results, in the studied area there were 22 primary health centers, which 14 of them were functional and the others were non-functional. The functional health centers were clustered and not evenly distributed and mainly located in the urban area of the study area. The results of the personal interview also showed the lack of social infrastructure facilities (i.e. water, electricity, roads, and healthcare) and low population for responsible factors for the non-functionality of the health facility in rural areas.

Luis and Cabral, 2016; investigated the geographic accessibility of population to healthcare centers in Mozambique by use of GIS. Their data included locations of health facilities with population and ancillary and elevation data. Two travel times; driving and walking for accessing to healthcare were estimated. The results showed that in walking scenario there were accessibility problems and about 90.2 % of Mozambique had unserved area. The driving scenario had less problem and about 66.9 % was considered as the unserved area. The results of population coverage showed that the problems of accessibility for driving were less than walking scenario. Therefore, this study highlighted critical areas in Mozambique in which healthcares are lacking when assessed by walking and driving travel time distance.

Unal and Usla in 2016 analyzed the accessibility of urban emergency shelters in Adana City, Turkey by using spatial analysis techniques of GIS-Network Analyst. In this study, some data such as the level of serviceability of urban emergency shelters within maximum capacity, sufficiency, usability and a certain walking time limit were gathered. The distribution of emergency evacuation demands, shelter space accessibility; and evacuation destinations were analyzed. This methodology was used to understand the spatial distribution of urban emergency shelters more accurately and to establish effective future urban disaster prevention planning. It should be mentioned that this study provided a possible way to support an emergency manager in terms of shelter construction and pre-disaster evacuation drills and rescue operations.

Ursulica, 2016; in order to highlight the relationship between the healthcare needs and the accessibility to healthcare services in the period 2000-2013, studied the population accessibility to health services and healthcare needs index by use of GIS in Botosani, Romania. He gathered data from existing statistical online databases of Public Health Department and calculated the healthcare services index by using 10 indicators which refer to the number and type of health facilities in Botosani County. Ursulica calculated the accessibility indicators for healthcare services based on distances and travel/driving times estimated using the computer of Romania's roadmap available on Google in 2015, then with a personal car, he verified on the field works. He used Arc GIS for mapping indicators and emphasized spatial inequalities in the studied area. The results showed that the rural of Botosani area was poorly covered by health services, compared to the urban area, causing a limited access of rural population to health services. Also, based on the results the population's dependence on health services was higher in rural areas and lower in urban areas. The low accessibility of the population to healthcare services overlaps with urgent healthcare needs areas and high deprivation areas, which was reflecting on the population's health outcomes. The outlined inequalities in people's access to health services had serious consequences on the health status of the population of Botosani County.

Donker and *et al.,* 2017; measured distances through dense weighted networks in hospital-associated pathogens in England. Data was collected from the English National Health Service Hospital Episode Statistics to create a network of hospital organizations in England based on patient movements. They used a metric proposed in order to determine the shortest path among hospitals. Largely the number of intermediate hospitals in the network determines the distance between two hospitals far-away in the network.

Saeed et al., in 2017; studied the shortest path based on Dijkstra’s algorithm by using GIS for Baghdad universities, Iraq. In this study toposheets of the city were obtained from Google Earth software. The university information was obtained by visiting the required university and taking the necessary data related to the academic staff, projects, relations, researchers, and university ranking. The data needed was in the form of spatial and attribute data. Spatial data were obtained through the method of digitizing base map of the city. The coordinates of the universities were taken by using Google Earth program. ArcGIS and Dijkstra algorithm calculated distance between two points depended on route length. The shortest path was found by network analysis. This method helped users to minimize traveling time to access specified university.

Chapter 3

RESEARCH METHODOLOGY

3.1. Research Methodology

Urbanization in the third world countries has its advantages and disadvantages. The disadvantages usually have to do with difficulties in controlling urban growth and making available resource to meet the increasing needs and demands for essential public services like education, housing and most especially health (Kibon *et al.,* 2013). Location and Health have been prominent features in determining accessibility rates among communities; and “location” was long considered more a determinant of health than pathogens (Yerramilli *et al.,* 2014). One of the most significant factors that control health status is ‘the distance to healthcare facilities’. The issue of healthcare access has become a research priority in many countries.

There are multiple ways to calculate the shortest path from point A to point B. GIS Software is developed for determining the optimal path and address information. The algorithm searches for the distance from the starting point to every other vertex until it reaches the destination point and gives the shortest path possible. This makes possible for the rapid calculation of the most appropriate route as well as other functions like closest facility. The model is based on vector data. Vector lines are used to describe spatially distributed streets and points to represent locations along the network (hospitals, accidents, junctions). The object of the study is to model shortest paths along the street network as well as the closest facility for ambulances to reach with the injured person (Nicoara *et al.,* 2014). The flowchart of research methodology is presented in figure 1 which was utilized to achieve the objectives of this study. This flowchart portrays the organization of the aforementioned processes and illustrates the order in which the procedures will take place.

All data gathered were analyzed using ArcGIS 10.1 Software. The analyzed data are presented using tables and maps.

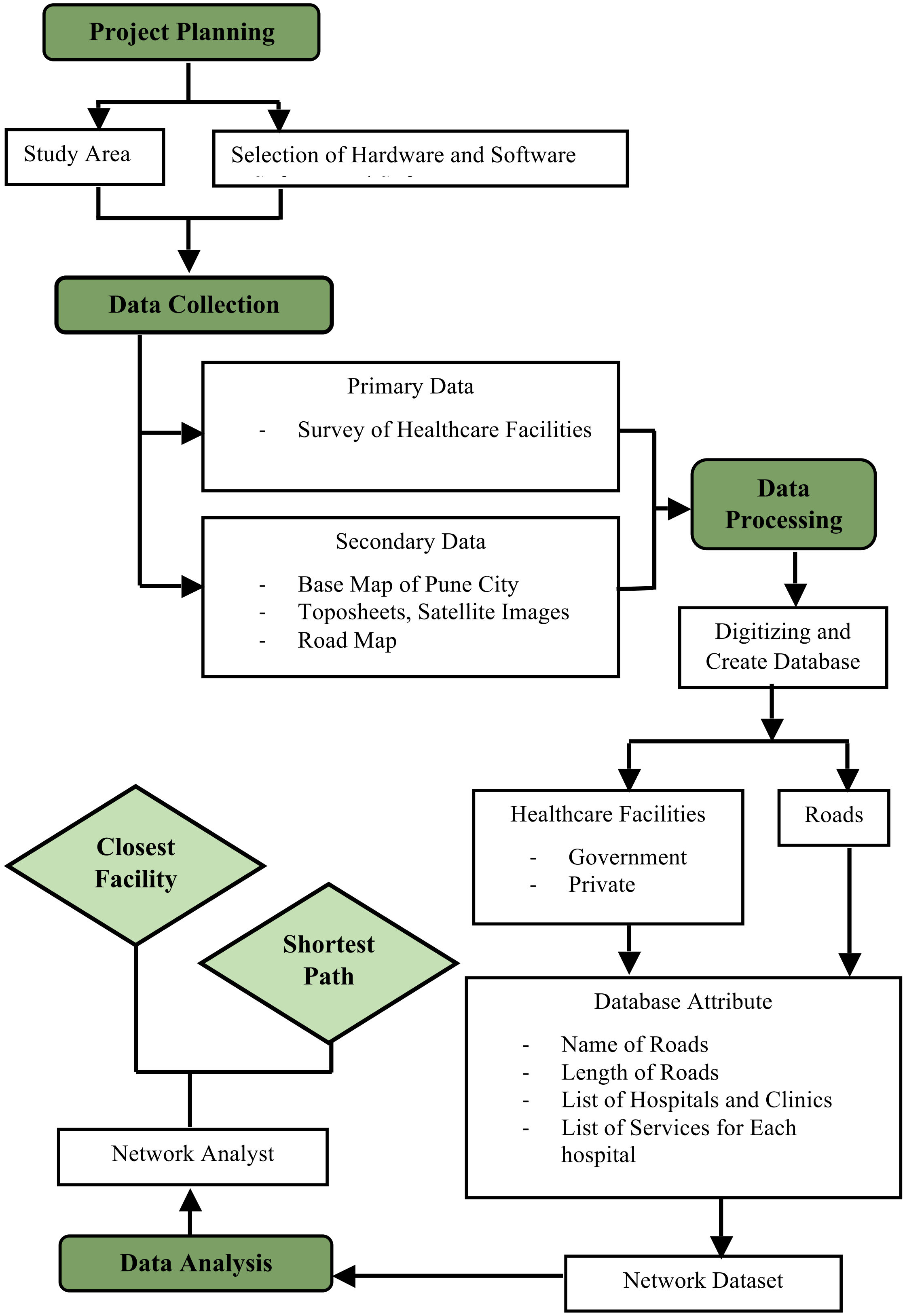

Figure 1. The flowchart of research approach

3.1.1. Study Area

Pune (District) is situated between 17˚ 5′ to 19˚ 2′ North latitudes and 73˚ 2′ to 75˚ 1′ East longitudes in the Maharashtra state of India. Total geographical area of Pune district is 15642 km^2 which lie in the Western Ghats or Sahyadri mountain range and it extends on to the Deccan Plateau on the east. In the most recent census on 2011, the total population of the district was 9,426,959, making it the fourth most populous district in India (out of 640) (The Registrar General &Census Commissioner, 2016, p.28).

Pune city is the district headquarters. It is the cultural and educational capital of the state of Maharashtra that is located in the western belt of Maharashtra State on the South East of Mumbai at a distance of 148 km and at a height of (1837 feet) 560 meters above mean sea level (Nalawade S.B., 2008*)*. It is the ninth most populous city in India and the second largest city of Maharashtra after Mumbai (Pune City Census Department; www.pmc.gov.in).

Pune city and the twin city Pimpri-Chinchwad which is situated to the Northwest of Pune on the Mumbai-Pune National Highway, are the major cities in the district. Pune city is administered by the Pune Municipal Corporation (PMC) while Pimpri-Chinchwad is administered by the Pimpri-Chinchwad Municipal Corporation (PCMC).

According to the 2011 census, Pimpri-Chinchwad has a population of 1.72 million residing in an area of 181 km^2 (Pimpri and Chinchwad City Population

Census 2011, Maharashtra; www.pcmcindia.gov.in.) while Pune has an estimated population of 3.13 million residing in an area of 331.26 km^2 (District Census Handbook-Pune. Census of India. The Registrar General &Census Commissioner. P. 28. Retrieved 1 June 2016).

The map of Pune Metropolis has been procured using Survey of India Toposheets, Scale 1:50000 with Toposheets numbers of 47/F/14/2, 47/F/14/3, 47/F/14/6, 47/F/15/NE, 47/F/15/NW and merged with Google Maps and rectified by the images provided by Pune Municipal Corporation. Figure 2, represents the map of the current study area.

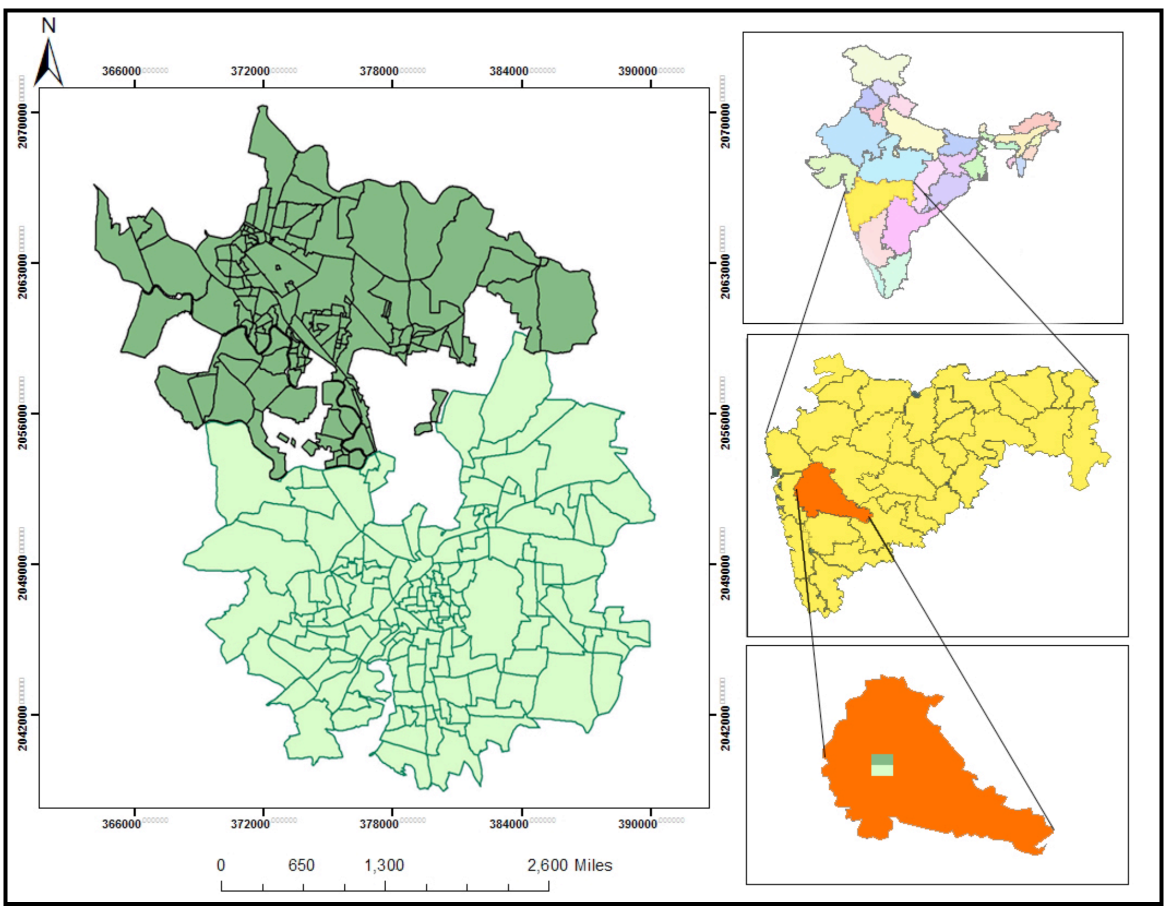

Figure 2. Location map of Pune metropolis region (PMR)

Pune district annually experiences three different seasons: summer, monsoon, & winter. Summer months are usually from March to May. The temperature ranges from 20 °C to 38 °C, though at the peak they may reach 42 °C. The annual average ratio of rainfall in the district is 600 to 700 mm. This is usually during the monsoon months from June – October. Winter season is from November to February. The temperatures range from 10 °C to 30 °C, though at the peak drop they may reach up to 3 °C (Hong Kong Observatory, 2012).

3.1.1.1. Transport System in Pune City

For the last two decades, Pune has registered a steep growth in the number of public-private vehicles. But infrastructures of roads and the utilities have not expanded incommensurate with the increase in the number of vehicles.

Public transport modes in Pune region include Pune Suburban Railway, bus and Rainbow BRTS services operated by PMPML and auto rickshaws. Online transport network companies like Uber and Ola cabs also provide rideshare and taxi services in the city. Construction of Pune Metro, an urban mass rapid transit system, is underway.

Due to the population increase through migration and secondly phenomenal rise in vehicle population; traffic and transportation problems in Pune Metropolitan Region have aggravated very fast. The region has faced experiencing some problems in safe and easy movement of people and goods. The Metropolitan Region is a twin establishment where industrialization at present is concentrated in the Pimpri-Chinchwad Municipal Corporation area, while the Pune City has all the office establishments, state, central, semi-government offices and Commercial Centres with high-density residential habitat (Rukade *et al.,* 2015). Roads in the Pune city were congested during the peak hour of the day. Traffic congestion after 9.00 am and 5.00 pm in Pune can be taken place on major roads such as Shivaji road, Karve Road, Fergusson College Road, J M Road, Dhole Patil Road, Tilak Road, Paud Road, L B Shastri Road, Bajirao Road, Kumtekar Road, Laxmi Road, S.B. Road, Katraj Road, Hadapsar Road Pune Station, and other highways. Therefore, the four main reasons for congestion on roads are an increase in population, the existence of poor public transport, growing economic activity, and increase in student population (Nimbalkar et al., 2008).

The problem of road blocking is due to excessive growth of vehicular traffic on the road. In the Pune city growth of vehicles increases, day by day causes a severe effect on urban transportation. There are many types of vehicles in the Pune city causing traffic congestion and the extra burden of road flowing capacity. The rapidly growing population of motor vehicles and increasing commerce is another very important factor in the Pune city (Butsch *et al.,* 2017).

3.1.1.2. Healthcare Facilities in Pune City

The hospital industry is a section within the economic system that provides goods and services to treat patients with curative, preventive, rehabilitative, and palliative care. The modern healthcare sector is divided into many sub-sections and depends on interdisciplinary teams of trained professionals and paraprofessionals to meet health needs of individuals and populations. Hospital is one of the most complexes of all administrative organizations. The healthcare industry as generally is consisting of hospital activities, dental practices and medical activities and other healthcare services.

Healthcare in the region is provided by private and public facilities. Primary care is given by practitioners of western as well as traditional alternative medicine (i.e. Ayurved, Homeopathy, and Unani). For minor and chronic ailments, people in the region have a preference for practitioners of the traditional medicine (Butsch, *et al.,* 2008).

The central part of Pune is well served by the hospital. The western side of city inward like the confluence area of Baner and Karve road are lacking in hospital services. The services of hospitals need to be more dispersed rather than concentrated in a particular area. However, need an apt update in terms of their numbers.

Generally, Pune metropolis city is served by 233 healthcare facilities, out of which 94 were government healthcare facilities while 139 were private healthcare facilities.

3.1.2. Data Collection

Data on public health facilities were obtained and analyzed within GIS environment. In the data collection, the data required is in the form of spatial and attribute. Spatial data that is required is road network, government and private hospitals and some locations of accidents, in order to test the feasibility of the network for the closest facility. This spatial data is obtained through the process of digitizing base map of the Pune district. The road network map has been prepared by digitizing the major routes from LISS-III (Sensor-IRS p6) satellite images taken from Bhuvan website of National Remote Sensing Centre (NRSC) as well as Google images and rectified by Ground Control Points. As distance in road data, identified as the length of each line segment, is to be used as impedance for each network dataset. For hospitals, spatial data, it must be included the information services provided at each hospital. Attribute data that need to be stored in the database are roads' name and length and name of the hospital and their facilities. The attribute data like name of the hospital, contact number specialty, site address, Facilities, email id, need to be stored in the separate database (Table 1). The data required is in the form of spatial and attribute data. The coordinates of the healthcare were taken by using Global Positioning System (GPS). For hospitals, spatial data, it must be connected to the information services provided at each hospital. The points taken with the GPS were initially in a geographic coordinate system. Based on that coordinates the hospitals are placed on the map as a point feature.

Table

Hospital

Shape	OBJECTID	Id	Longitude	Latitude	Hospital_N	Type	
Point	1	1	73.781122	18.653061	Tongaonkar Hospital,Akurdi	General Hospital	OPD, ECG, X-ra
Point	2	2	73.783394	18.651933	Star Hospital, Akurdi	General Hospital	
Point	4	4	73.824744	18.479153	Patil Hospital, Anand Nagar	General Hospital	
Point	5	5	73.824514	18.478111	Mankar Hospital, Anand Nagar	Children's hospital	
Point	6	6	73.802344	18.564844	Medipoint Hospital, Aundh	Multispeciality	
Point	7	7	73.804836	18.561908	Kotbagi Hospital, Aundh	Multispeciality	Ambulance, CT
Point	8	8	73.811325	18.56065	Disha Diagnostic Centre, Aundh	Diagnostic center	Imaging & Radio
Point	9	9	73.801586	18.502575	Lifeline Hospital, Aundh		
Point	10	10	73.8289	18.542069	Samarth Hospital, Aundh Camp		
Point	11	11	73.7896	18.5593	Dhanvantari Hospital, Baner		
Point	13	13	73.781792	18.516486	Om Hospital, Bavdhan	General Hospital	
Point	14	14	73.874217	18.509461	G. M. Babubhai Hospital, Bhawani Peth	Physiotherapists Specialist Doctor	
Point	15	15	73.874697	18.502164	Oyster And Pearl - Meera Hospital, Bhawani Pet	Mother & Childcare	
Point	16	16	73.869917	18.511658	Todkar Hospital, Bhawani Peth	Multispeciality	X-ray, Sonogra
Point	17	17	73.874217	18.509461	G.M. Babubhai Memorial Hospital, Bhawani Peth	General Hospital	X-ray
Point	18	18	73.850267	18.619983	Pune International Burns & Cosmetic Centre, Bh	Burns Center	Pharmacy, X-Ra
Point	19	19	73.854617	18.624133	Om Hospital, Bhosari	Muti-Speciality Hospital	Laboratory, Her
Point	20	20	73.856694	18.624653	Ankur Hospital, Bhosari	Surgical General Accident	

1 (0 out of 233 Selected)

Hospital

Table 1. Pune healthcare centers attributes

Then we create a database and analyze the type, location and spatial distribution of healthcare centers in the study area.

3.1.3. Creating Map and Geo-Database of Healthcare Facilities

After the data collection, it is important to locate it on the map. We integrate information on the actual position of all government hospitals in Pune with the services and facilities. After all the information about hospitals has been integrated, the result is shown on the map.

A geodatabase within ArcGIS software was used for the storage of data. All the files were within one single dataset which ensured all had the same coordinate system, which was a vital condition for the operation to be correct. The geodatabase is specifically designed for spatial (geographical) information, which provides the ability to set topological rules, such as connectivity, to set a spatial domain of the attributes and to import and export from the geodatabase using a vector format. The advantage of using a file geodatabase is: operating system versatility (the files can be ported to Linux); creates encrypted files; allows a high quantity of data (up to 1 TB); uses more spatial index levels, making a search faster. (Nicoara *et al,* 2014)

The network dataset can then be rebuilt with the up-to-date information. The using a database include: centralized data, all within the same place; high speed for access and manipulation of data; high security, with measures to ensure the data is not damaged or corrupted; only one user can have the role of administrator of the database. The data is managed using a database management system that allows description, manipulation, use, coherence and administration of data. (Nicoara *et al.,* 2014)

3.1.4. Network Analysis

This research utilizes GIS Network Analyst tools to model geographical access to specific healthcare service scenarios in Pune region. The primary analysis capabilities of Network Analyst can be categorized as routing functions that determine the optimal course of travel based on the characteristics of the transportation network is studied.

ArcGIS Network Analyst is a powerful extension of ArcGIS that provides network-based spatial analysis including routing, travel directions, closest facility, and service area analysis. ArcGIS Network Analyst allows you to solve common network problems, such as finding the best route across a city, finding the closest emergency vehicle or facility, identifying a service area around a location, servicing a set of orders with a fleet of vehicles, or choosing the best facilities to open or close. (Dabhade *et al.,* 2014).

3.1.4.1. Creating a Network Dataset

In order to create a network dataset, the following steps is implement (Esri, ArcGIS tutorial, 2010):

Steps:

1. Start ArcCatalog by clicking Start > All Programs > ArcGIS> ArcCatalog 10.1

2. Enable the Network Analyst extension.

a. Click Customize > Extensions. The **Extensions** dialog box opens.

b. Check **Network Analyst**.

c. Click **Close**.

3. On the **Standard** toolbar, click the **Connect to Folder** button. The **Connect to Folder** dialog box opens.

4. Navigate to the folder with the data.

5. Click **OK**.

A shortcut to the folder is added to the **Catalog Window** under **Folder Connections** (Fig. 3).

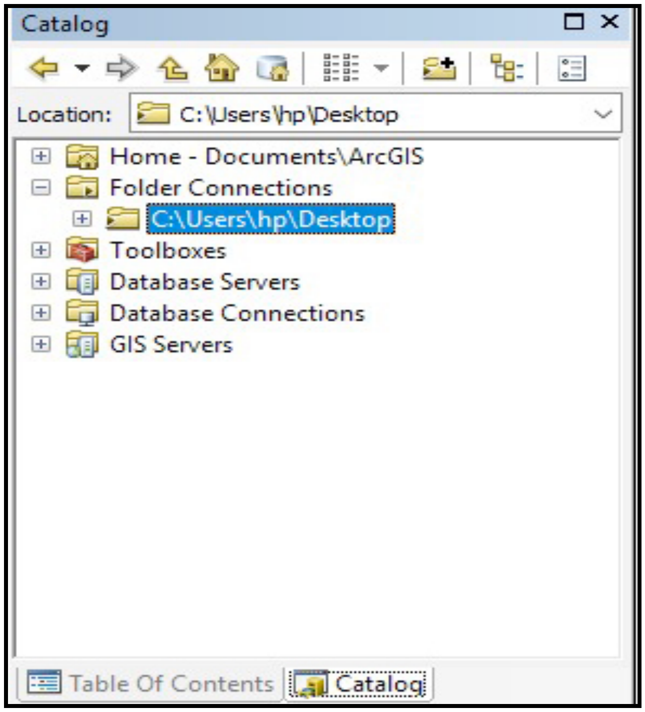

Figure 3. Catalog window

6. In the **Catalog Window**, expand**...\xxx\xxx.gdb**.

7. Click the **Transportation** feature dataset.

The feature classes the feature dataset contains are listed on the **Contents** tab of ArcCatalog.

8. Right-click the **Transportation** feature dataset and click **New** > **Network Dataset** (Fig. 4).

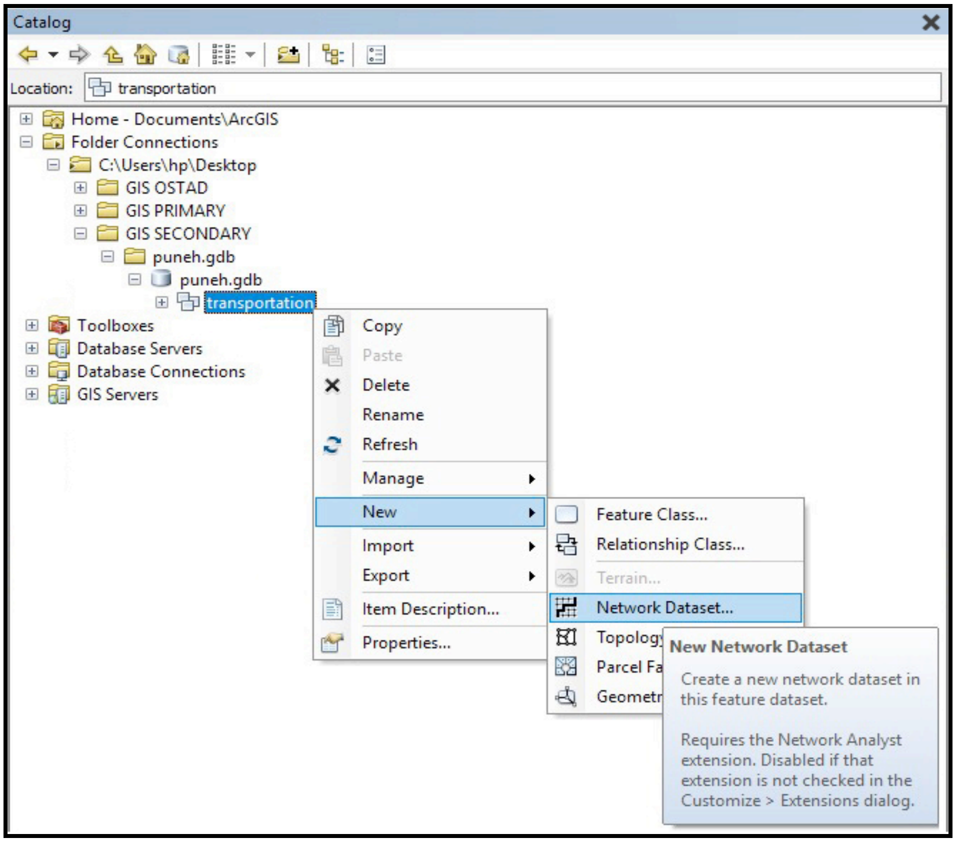

Figure 4. Create new network dataset route

9. Type Streets_ND or for the name of the network dataset (Fig. 5).

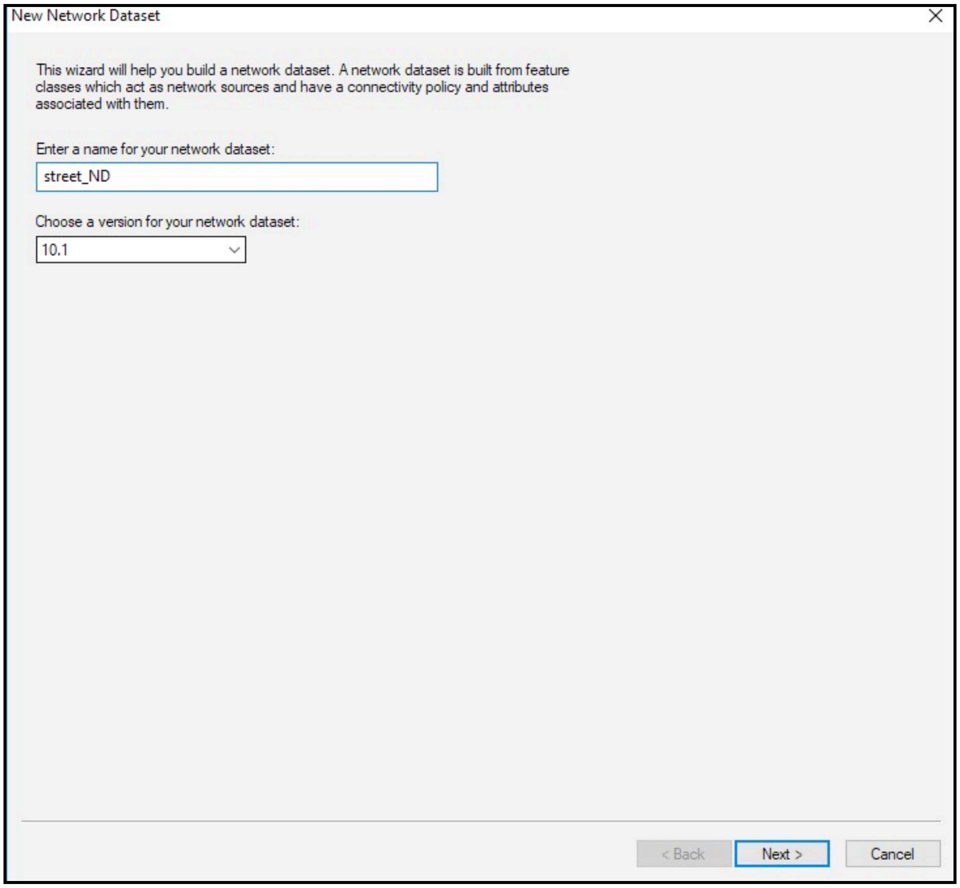

Figure 5. New Network Database window

10. Click **Next**.

11. Check the **Streets** feature class to use it as a source for the network dataset.

12. Click **Next**.

13. Click **Yes** to model turns in the network.

14. Check **<Global Turns>**, which enables you to add default turn penalties (Fig. 6).

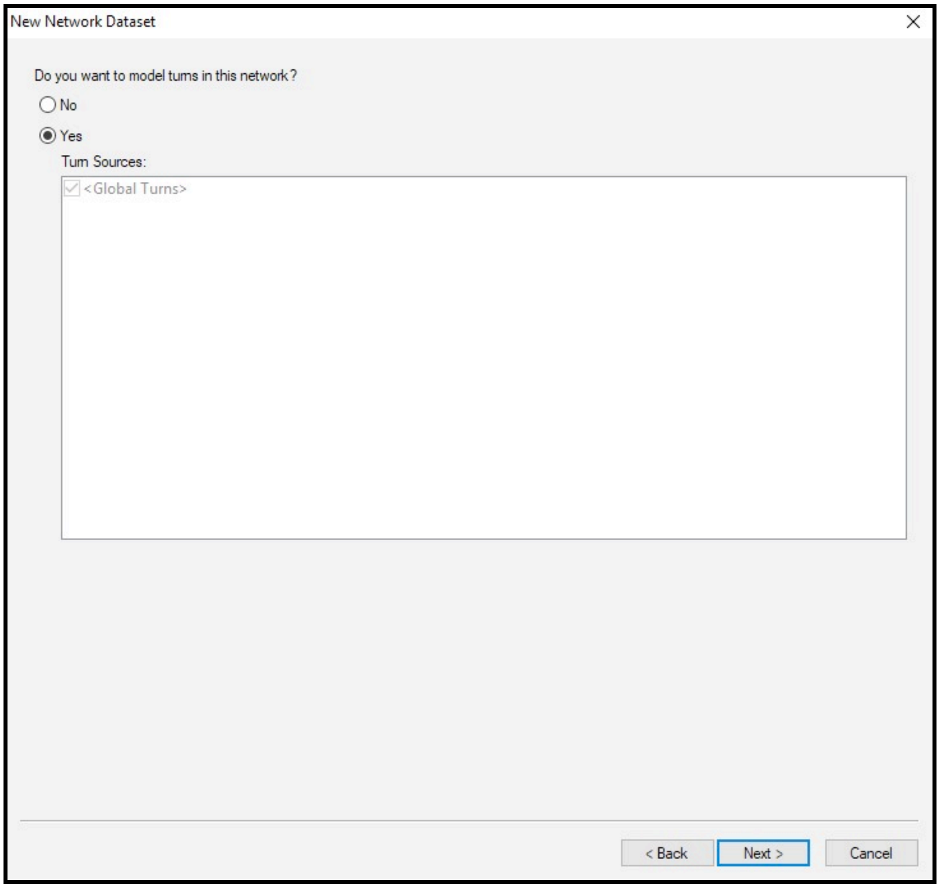

Figure 6. Check global turn window

15. Click **Next**.

16. Click **Connectivity**.

The Connectivity dialog box opens. Here you can set up the connectivity model for the network.

For this Streets feature class, all streets connect to each other at endpoints.

17. Make sure that the connectivity policy of **Streets** is set to **End Point** (Fig. 7).

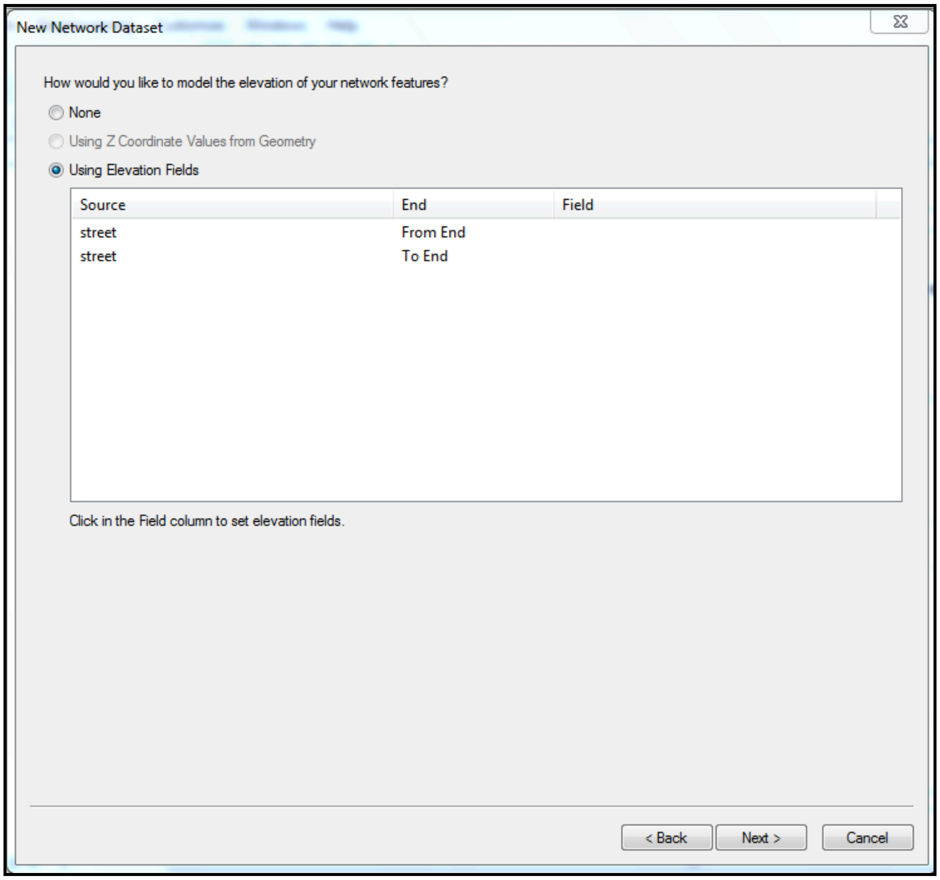

Figure 7. The Streets feature class

18. Click **Next**.

The page for setting network attributes is displayed (Fig. 8).

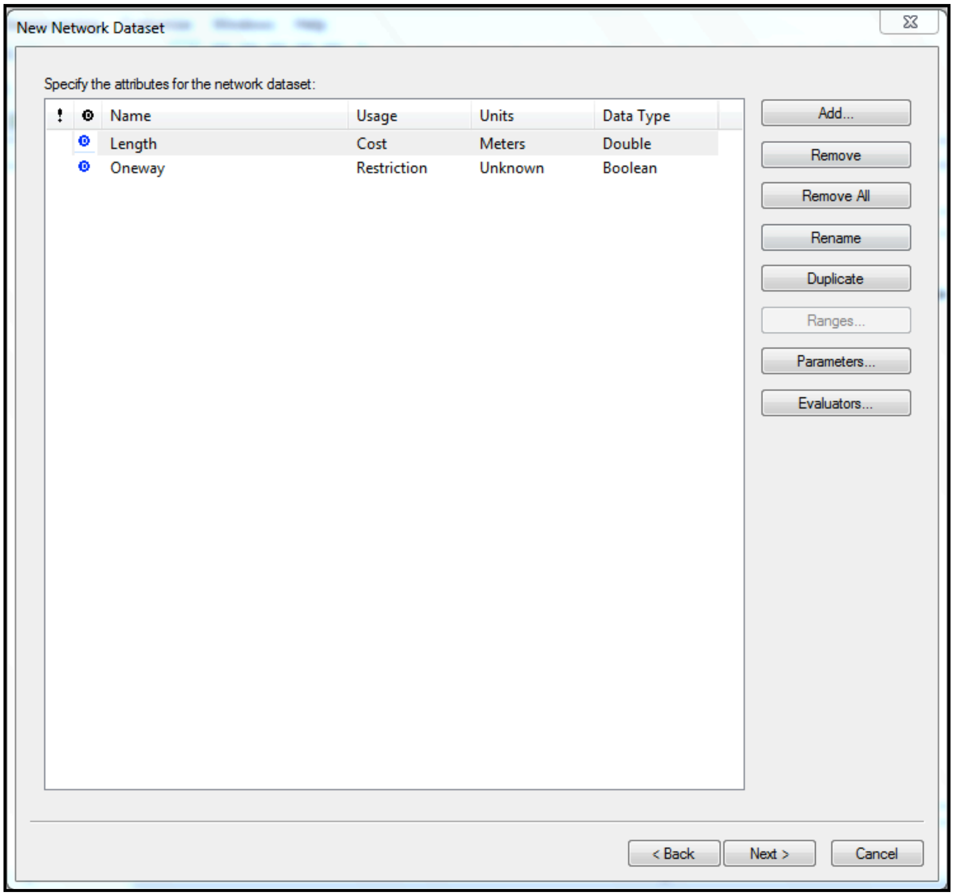

Figure 8. Setting network attributes window

ArcGIS Network Analyst analyzes the source feature class (or classes) and looks for common fields like Meters, and One way.

If it finds these fields, it automatically creates the corresponding network attributes and assigns the respective fields to them. (This can be viewed by clicking **Evaluators**.)

19. Click the **length** row to select it, then click **Evaluators** to examine how the values of network attributes are determined.

The **Evaluators** dialog box opens (Fig. 9).

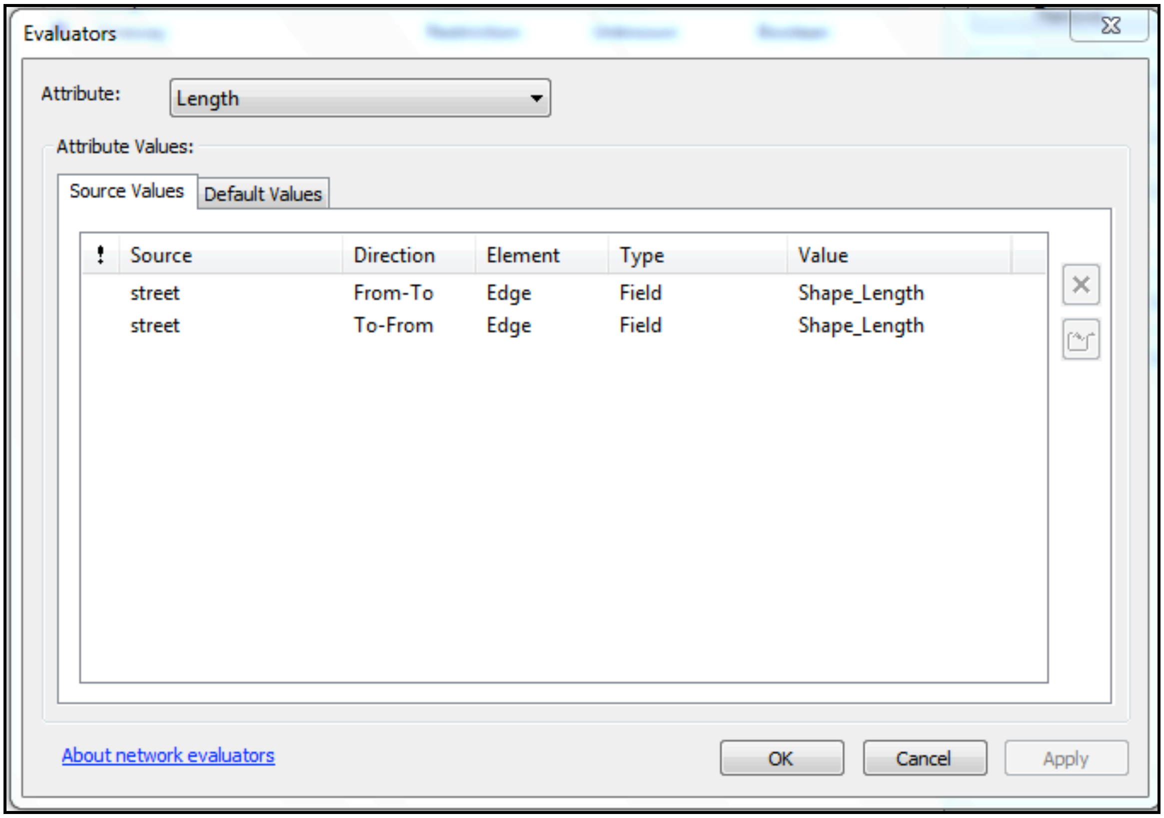

Figure 9. Evaluators dialog box

3.1.4.2. The Closest Facility Analysis

Geographical accessibility centers on the concept of the presence of the right type of healthcare service within the optimum travel time. The concept develops from the spatial arrangement of how people/communities, facilities, and transportation network are connected or configured (Yerramilli *et al.,* 2014).

In this project, the closest facility analysis will be conducted when there is more than one facility chosen from the patient's location. For example, for patients to find the nearest hospital and the shortest route for emergency cases, the closest facility analysis is necessary to be carried out. Closest Facility Analysis finds shortest and most cost-effective route between points of origin and the location of desired destinations.

For the analysis of the Pune network, the locations of the 233 hospitals were loaded into the "Facilities" category to generate routes between an incident and the nearest hospital.

In order to implement closest facility analysis, we performed following steps (Esri, ArcGIS tutorial, 2010):

1. First, the map document included network database which produced in last, the maps of Pune and hospitals opens in ArcMap.

2. The Network Analyst extension should be enabled by:

   a. Click **Customize** > **Extensions.** The **Extensions** dialog box opens.

   b. Check **Network Analyst**.

   c. Click **Close**.

   d. Click **Customize** > **Toolbars** > **Network Analyst.**

The **Network Analyst** toolbar (Fig. 10) is added to ArcMap.

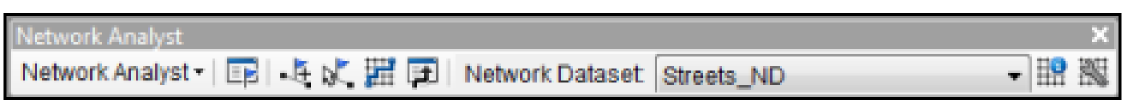

Figure 10. Network Analyst toolbar

3. On the **Network Analyst** toolbar, click the **Show/Hide Network Analyst Window** button.

The dockable **Network Analyst** window opens (Fig. 11).

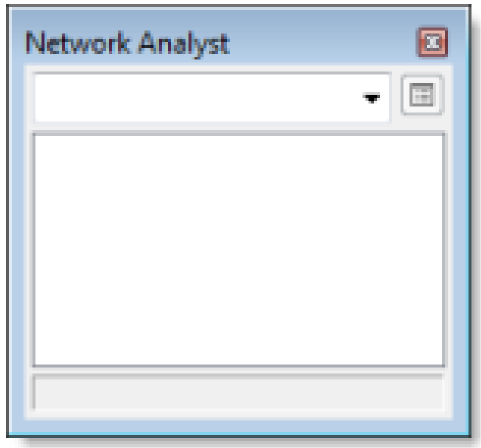

Figure 11. Dockable Network Analyst window

You can dock or undock the **Network Analyst** window.

A. Creating the closest facility analysis layer

Click **Network Analyst** on the **Network Analyst** toolbar and click **New Closest Facility** (Fig.12).

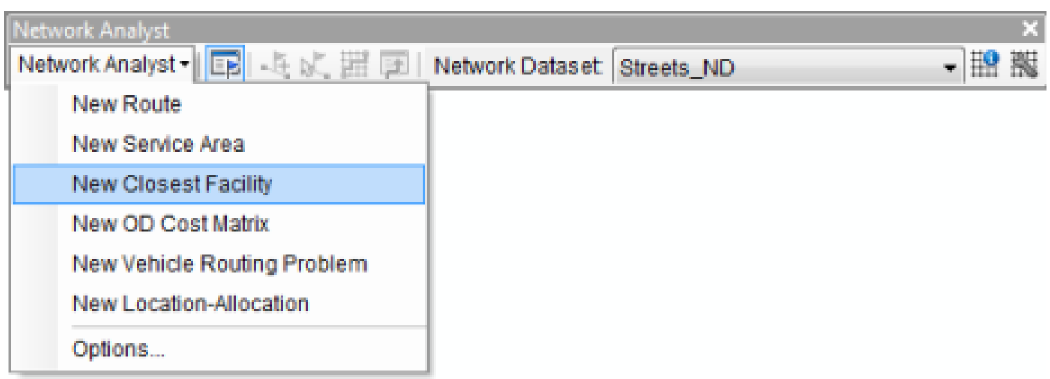

Figure 12. New Closest Facility analyze route

The closest facility analysis layer is added to the **Network Analyst** window. The network analysis classes (Facilities, Incidents, Routes, Point Barriers, Line Barriers, and Polygon Barriers) are empty (Fig. 13).

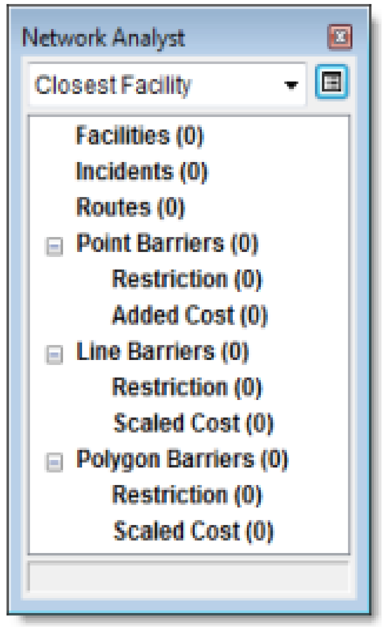

Figure 13. The network analysis classes in the Network Analyst window

The analysis layer is also added to the **Table of Contents** window (Fig. 14).

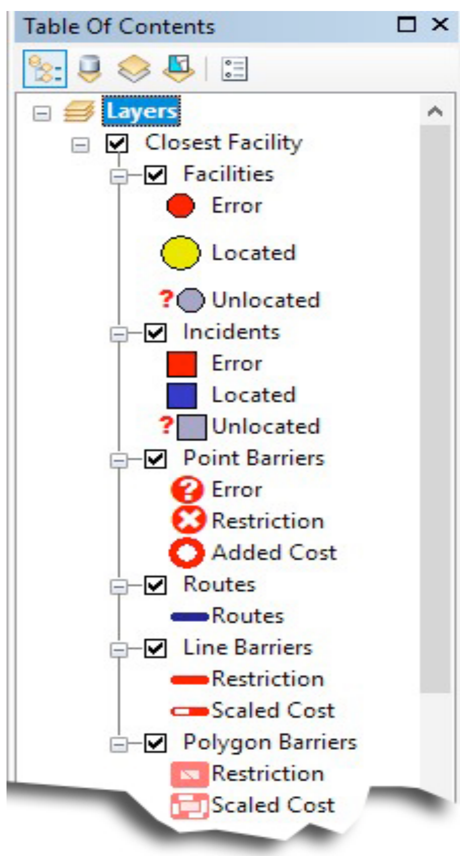

Figure 14. Table of Contents window

B. Adding facilities

Next, you will load facilities from a point feature layer that represents hospitals.

Steps:

1. In the **Network Analyst** window, right-click **Facilities (0)** and click **Load Locations** (Fig. 15).

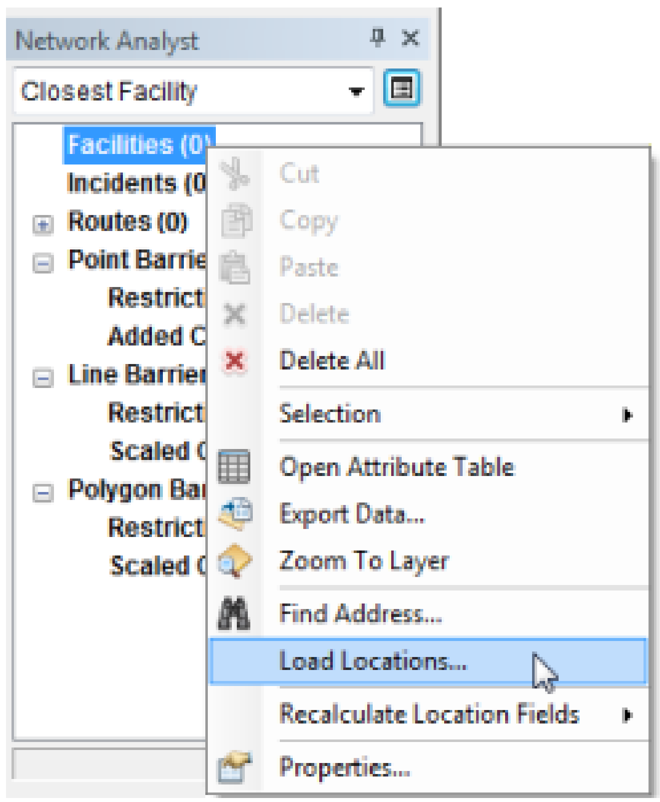

Figure 15. Load Location of Facilities in the Network Analyst

The **Load Locations** dialog box opens (Fig. 16).

2. Choose **hospitals** from the **Load From** drop-down list.

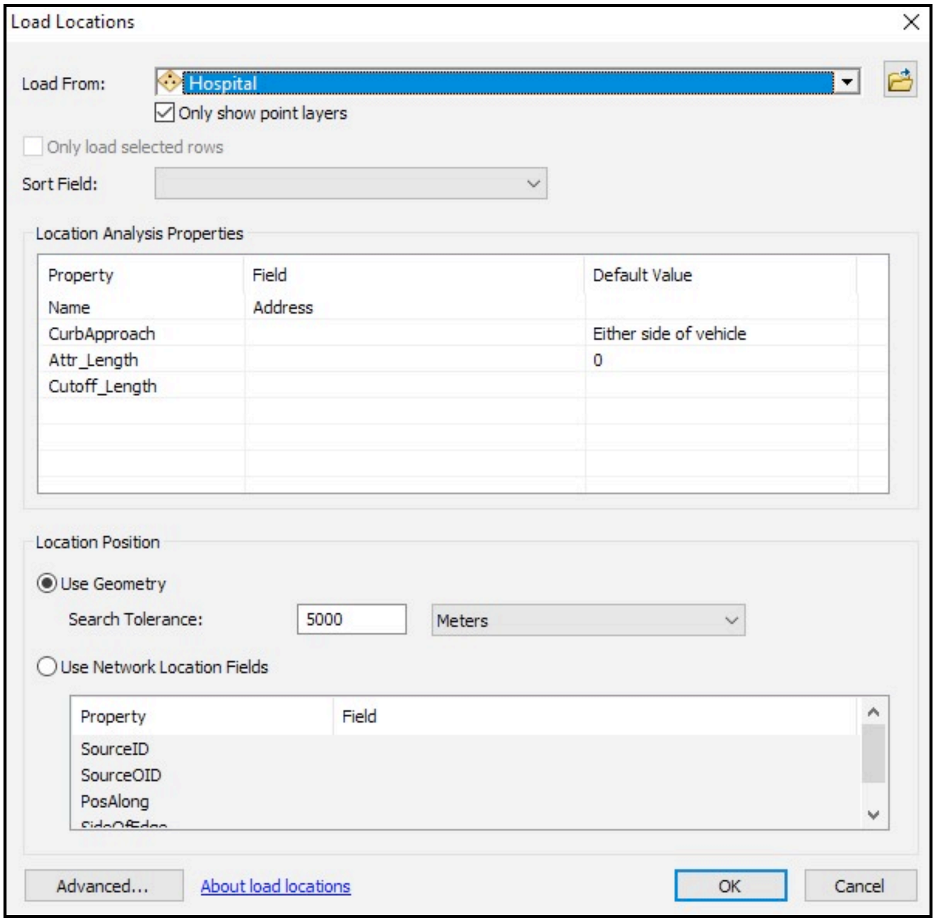

Figure 16. The Load Locations dialog box

3. Click **OK**.

233 hospitals are displayed on the map as facilities and listed in the **Network Analyst** window.

C. <u>Adding an incident</u>

Next, we added an incident by geocoding an address received from an emergency call.

In the **Network Analyst** window, right-click **Incidents (0)** and choose **to Find Address**.

This adds the located address as an incident, which you can see on the map and in the **Network Analyst** window.

D. Setting up parameters for the analysis

Next, we specified the parameters for our closest facility analysis.

Steps:

1. Click the **Analysis Layer Properties** button on the **Network Analyst** window (Fig. 17).

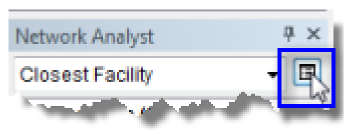

Figure 17. The Analysis Layer Properties button on the Network Analyst window

The **Layer Properties** dialog box opens (Fig. 18).

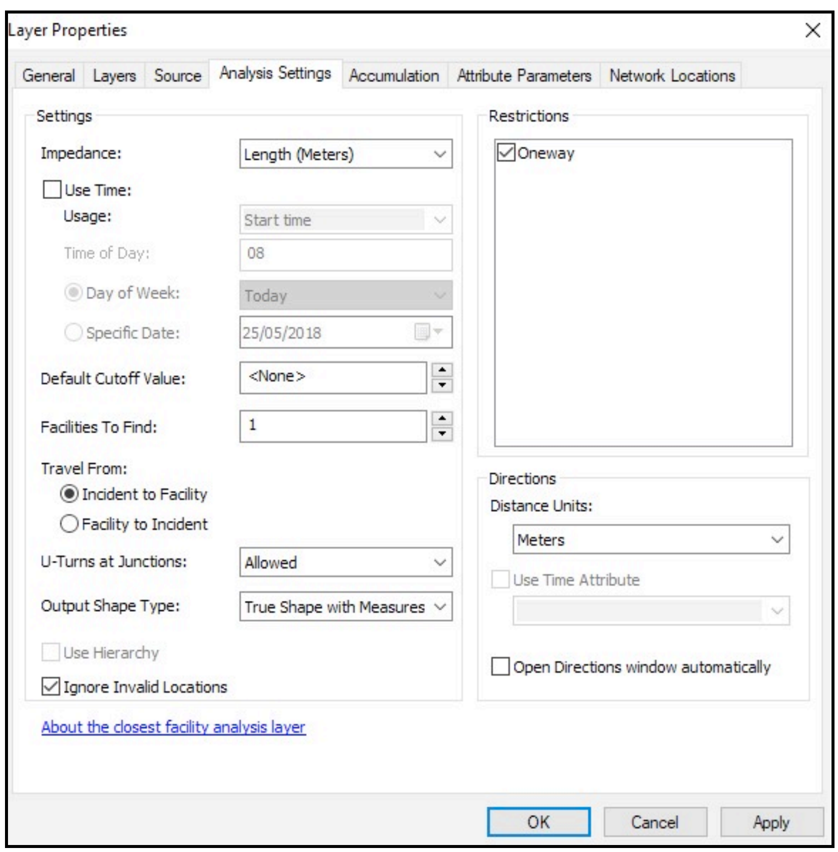

Figure 18. Layer Properties window

2. Click the **Analysis Settings** tab.

3. Choose **Incident to Facility** for the **Travel From** direction.

4. Click the **U-Turns at Junctions** drop-down arrow and choose **Allowed**.

5. Click the **Output Shape Type** drop-down arrow and choose **True Shape with Measures**.

6. Uncheck **Use Hierarchy**.

7. Check **Ignore Invalid Locations**.

8. In the **Restrictions** frame, check **One way**.

9. In the **Directions** frame, make sure that **Distance Units** is set to **Meters**.

10. Click **OK**.

E. Identifying the closest facilities

Steps:

1. Click the **Solve** button on the **Network Analyst** toolbar.

Routes appear in the map display and in the **Route** class in the **Network Analyst** window.

2. Click the **Directions Window** button on the **Network Analyst** toolbar.

The **Directions** dialog box opens. Driving directions to the hospital is listed in the window.

CHAPTER 4

DATA ANALYSIS AND FINDINGS

4.1. Data Presentation, Analysis, and Findings

As mentioned in the last chapter prior to utilizing any of the Network Analyst capabilities, the dataset was prepared for Pune city. The road networks, distances and other dynamics that impact mobility were integrated into a Geographic Information System (GIS) interface to model, evaluate and compare accessibility through closest facility mechanism. Once the network dataset was fully designed, the analytical capabilities of Network Analysis were implemented. Accessibility was measured by using Closest Facility Analysis. The Closest Facility Analysis output reflects the true shape of the route between two destinations. The analysis involved identifying the closest healthcare facility from a location, tracing the best route to the facility and step-by-step directions along the identified route.

Figure 21 shows the extent of the distribution of the Healthcare Facilities including private and governmental healthcare centers within the study area. Most of the Healthcare Facilities were spatially located at the center of the south section of the study area.

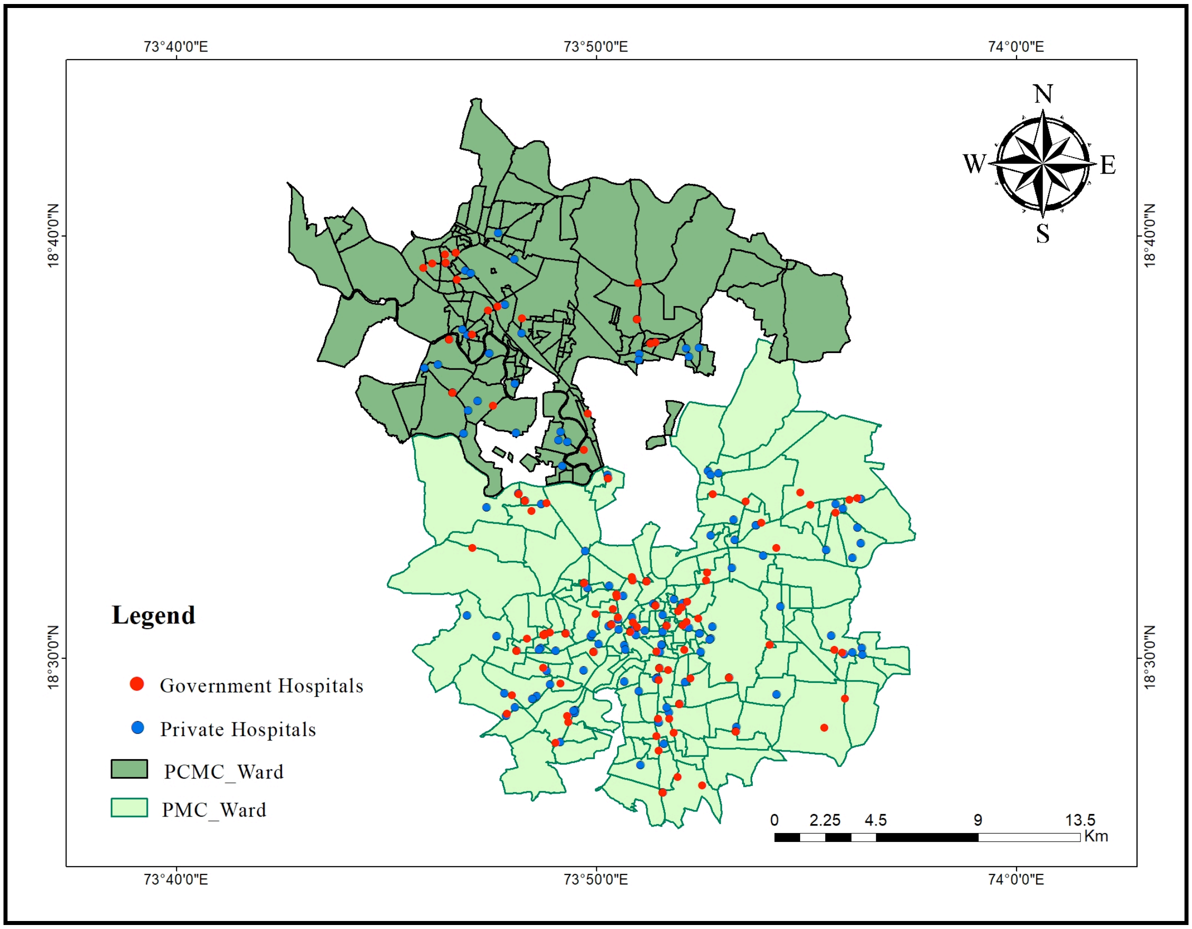

Figure19. The map of the location of healthcare centers in Pune City

The databases, which were created in tabular formats, are presented in table 2 and table 3. The database carries basic information about the attribute data of the Healthcare facilities ranging from their location, coordinates, and status (working condition). Table 2 shows the name of healthcare centers, addresses, website, contact number, facilities, their geographical locations and etc. Table 3 indicates some information about roads such as the name of the road, length and one-way road.

FID	Sha	OBJ	Id	Longitude	Latitude	Hospital_N	Type	Facilities	Specializa	Working_Ho	Close	Address	Contact_No	Website	Email_Id	H_Typ
0	Point	1	1	73.781122	18.653061	Tongaonkar H	General	OPD, ECG, X-ray	Diabetes Mellitu	10AM-10PM	Sunday	Sr.No.815, Near JBGU	Phone:+91 20	www.Tonga	tongaonkarho	Private
1	Point	2	2	73.783394	18.651933	Star Hospital,	General			24 hours		Near Tulja Bhavani Ma	Phone: +91 88		info@accordst	Private
2	Point	4	4	73.824744	18.479153	Patil Hospital,	General					Plot No 5, Swaroop Bui	Phone: +91 20		NA	Private
3	Point	5	5	73.824514	18.478111	Mankar Hospit	Children			3:15-11PM	Wedne	Swaroop Housing Soci	Phone: +91 20		NA	Private
4	Point	6	6	73.802344	18.564844	Medipoint Hos	Multispe			24 hours		241/1, New D.P. Road,	Phone: +91 92	www.medipo	support@medi	Private
5	Point	7	7	73.804836	18.561908	Kotbagi Hospit	Multispe	Ambulance, CT		8am-6pm	Saturda	163, DP Road, Near D	Phone: +91 20	www.kotbagi	info@kotbagih	Private
6	Point	8	8	73.811325	18.56065	Disha Diagnos	Diagnos	Imaging & Radiol		8AM-2PM, 5:3	Sunday	1, Disha Apartment, S	Phone: +91 20	www.dishadi	NA	Private
7	Point	9	9	73.801586	18.502575	Lifeline Hospit				24 hours		Legacy Building, Aund	Phone: +91 20		NA	Private
8	Point	10	10	73.8289	18.542069	Samarth Hospi						Pimple Saudagar, Aun	Phone: +91 20		NA	Private
9	Point	11	11	73.7896	18.5593	Dhanvantari H						Dhanwantari Building,	Phone: +91 90	www.dhanw	NA	Private
10	Point	13	13	73.781792	18.516486	Om Hospital, B	General			10:AM-3:00P		Plot No. 21, Aamchi C	Phone: +91 20		NA	Private
11	Point	14	14	73.874217	18.509461	G. M. Babubh	Physiot			8AM-12:30PM	Sunday	387/A, Bhawani Peth,	Phone: +91 20		NA	Private
12	Point	15	15	73.874697	18.502164	Oyster And P	Mother		Orthopaedics, U	9AM-8PM	Sunday	710/B-4, Shankar Shet	Phone: +91 20	www.onpho	NA	Private
13	Point	16	16	73.869917	18.511658	Todkar Hospit	Multispe	X-ray, Sonograp	General Surger	24 hours		158, Gul Ali, Pune, Bha	Phone: +91 80	www.todkar	jayatodkar@g	Private
14	Point	17	17	73.874217	18.509461	G.M. Babubhai	General	X-ray	General Surger	8Am-12:30PM	Sunday	387/A, Bhawani Peth,	Phone: +91 20		NA	Private
15	Point	18	18	73.850267	18.619983	Pune Internati	Burns C	Pharmacy, X-Ra	Plastic Surgery,	12AM-11:30P		Shiv Ganga Complex,	Phone: +91 90		NA	Private
16	Point	19	19	73.854617	18.624133	Om Hospital, B	Muti-Sp	Laboratory, Hem	Interventional C			198, Bhosari Alandi Rd	Phone: +91 77	www.omhos	omhospital39@	Private
17	Point	20	20	73.856694	18.624653	Ankur Hospital	Surgical		General Medicin	24 hours		S.No. 201/5 A, Jay Ma	Phone: +91 90		NA	Private
18	Point	21	21	73.850053	18.61755	Pritam Hospital	General			9AM-9PM		APTE Colony, Bhosari,	Phone: +91 94		NA	Private
19	Point	22	22	73.862067	18.478161	Sahyadri Hos	Multispe	Pharmacy, Radio	Anaesthesiolog	24 hours		Plot No. 13 S, Swami V	Phone: +91 20	www.sahya	NA	Private
20	Point	23	23	73.858014	18.474347	Suraj Hospital,	Multispe	Outpatient Servi	Orthopedics, Ge	24 hours		3, Bibwewadi Kondhw	Phone: +91 20	www.surajh	NA	Private
21	Point	24	24	73.844303	18.490364	Dr. Purohit Ho	Nursing		Gynecology			Dr Purohit Nursing Hom	Phone: +91 20		NA	Private
22	Point	25	25	73.866211	18.481661	Harsh Hospital	Multispe	Ambulance, X-R	General Physici	10AM-2PM, 5		A 3rd Floor, Todkar Ga	Phone: +91 94	www.inhospi	NA	Private
23	Point	26	26	73.861228	18.480317	Chandralok Ho	General	Outpatient Servi	General Medicin	9AM-9PM	Sunday	Chandrika Society, Bib	Phone: +91 93	www.chandr	NA	Private
24	Point	27	27	73.837608	18.572219	Renu Hospital,	Diagnos			10AM-9PM		57, Old Mumbai - Pune	Phone: +91 98		NA	Private
25	Point	28	28	73.837925	18.570844	Sahyadri Hos	Multispe		Neurosurgery,	24 hours		S.N.10A/3A, Ahead of	Phone: +91 20	www.sahya	NA	Private

(0 out of 233 Selected)

Table 2. Attribute data of Pune healthcare centers

Shape *	OBJECTID	OID	Name	FolderPath	Symb	AltitudeMo	Clamped	Extruded	Snippet	PopupInfo	Shape_Len	Shape_Le_	TYPE	ONEWAY	LANE	Shape_Length
Polyline ZM	1	0		Pune_Road/Features	0	0	-1	0			0.000279	0.000279			0	0.000279
Polyline ZM	2	0		Pune_Road/Features	0	0	-1	0			0.000276	0.000276			0	0.000276
Polyline ZM	3	0		Pune_Road/Features	0	0	-1	0			0.000216	0.000216			0	0.000216
Polyline ZM	4	0		Pune_Road/Features	0	0	-1	0			0.000058	0.000058			0	0.000058
Polyline ZM	5	0		Pune_Road/Features	0	0	-1	0			0.000088	0.000088			0	0.000088
Polyline ZM	6	0		Pune_Road/Features	0	0	-1	0			0.000114	0.000114			0	0.000114
Polyline ZM	7	0		Pune_Road/Features	0	0	-1	0			0.00013	0.00013			0	0.00013
Polyline ZM	8	0		Pune_Road/Features	0	0	-1	0			0.000073	0.000073			0	0.000073
Polyline ZM	9	0		Pune_Road/Features	0	0	-1	0			0.000596	0.000596			0	0.000596
Polyline ZM	10	0		Pune_Road/Features	0	0	-1	0			0.001033	0.001033			0	0.001033
Polyline ZM	11	0		Pune_Road/Features	0	0	-1	0			0.000214	0.000214			0	0.000214
Polyline ZM	12	0		Pune_Road/Features	0	0	-1	0			0.000064	0.000064			0	0.000064
Polyline ZM	13	0		Pune_Road/Features	0	0	-1	0			0.000024	0.000024			0	0.000024
Polyline ZM	14	0		Pune_Road/Features	0	0	-1	0			0.000285	0.000285			0	0.000285
Polyline ZM	15	0		Pune_Road/Features	0	0	-1	0			0.000285	0.000285			0	0.000285
Polyline ZM	16	0		Pune_Road/Features	0	0	-1	0			0.000029	0.000029			0	0.000029
Polyline ZM	17	0		Pune_Road/Features	0	0	-1	0			0.000066	0.000066			0	0.000066
Polyline ZM	18	0		Pune_Road/Features	0	0	-1	0			0.000163	0.000163			0	0.000163
Polyline ZM	19	0		Pune_Road/Features	0	0	-1	0			0.000349	0.000349			0	0.000349
Polyline ZM	20	0		Pune_Road/Features	0	0	-1	0			0.000137	0.000137			0	0.000137
Polyline ZM	21	0		Pune_Road/Features	0	0	-1	0			0.000125	0.000125			0	0.000125
Polyline ZM	22	0		Pune_Road/Features	0	0	-1	0			0.000392	0.000392			0	0.000392
Polyline ZM	23	0		Pune_Road/Features	0	0	-1	0			0.000916	0.000916			0	0.000916
Polyline ZM	24	0		Pune_Road/Features	0	0	-1	0			0.000232	0.000232			0	0.000232
Polyline ZM	25	0		Pune_Road/Features	0	0	-1	0			0.00008	0.00008			0	0.00008

(0 out of 50717 Selected)

Table 3. Attribute data of Pune streets

Table 4 and 5 compare PCMC and PMC areas regarding their healthcare services. As shown in the tables, the density of healthcare centers of PCMC and

PMC are 27% and 56% respectively which means that there are 27 healthcare centers per 100 km^2 in PCMC and 56 in PMC. They also show that there is 28.4 number of hospitals per population in PCMC while this number in PMC is 59 per population.

Population (million)		1.72	
Area (km2)		181	
Number of healthcare centers	Private	30	49
	Government	19	
The density of healthcare centers per 100 km^2	Private	17%	27%
	Government	10%	
Distribution of healthcare centers per population	Private	17.4	28.4
	Government	11	

Table 4. Availability of the healthcare services in PCMC

Population (million)		3.13	
Area (km2)		331.26	
Number of healthcare centers	Private	109	184
	Government	75	
The density of healthcare centers per 100 km^2	Private	33%	56%
	Government	23%	
Distribution of healthcare centers per population	Private	35	59
	Government	24	

Table 5. Availability of the healthcare services in PMC

After collected data, we created network dataset in GIS area. Figure 20 illustrates the road network dataset of Pune. For the network analysis, the locations of the incident were necessary as well as the locations of the accident or injury person. The function used is Closest Facility from Network Analyst, which is an extension of the ArcGIS software.

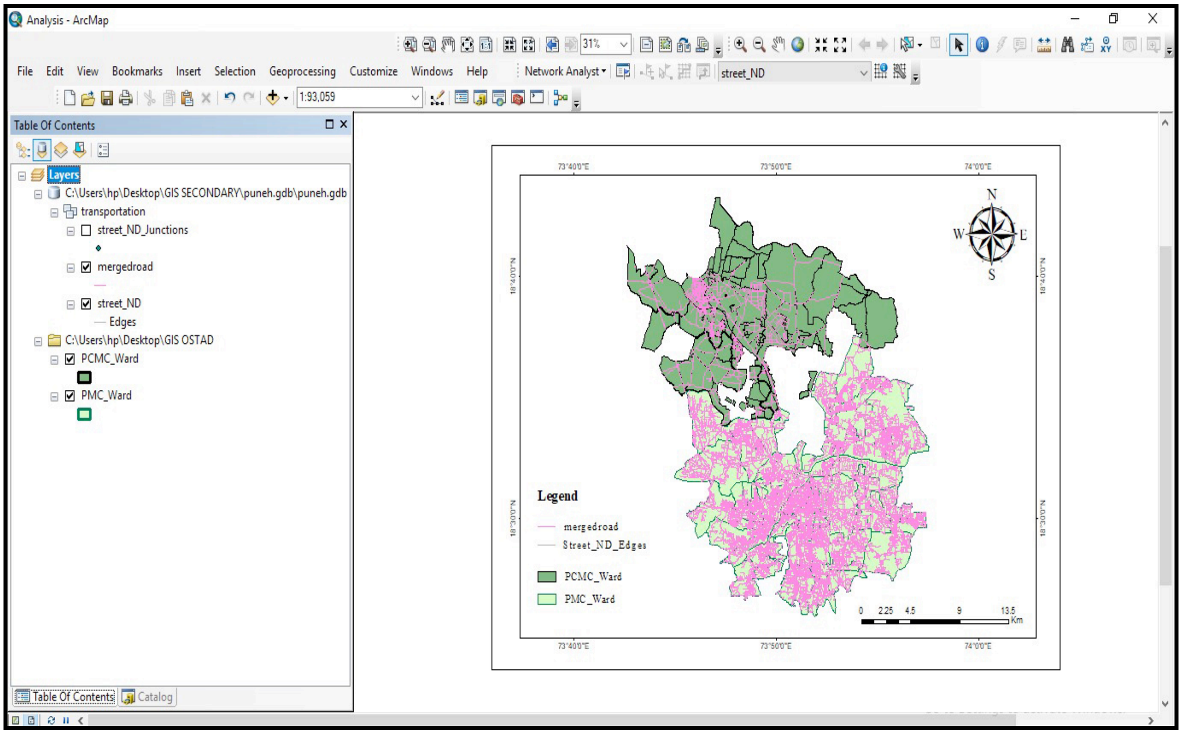

Figure 20. The map of network dataset of Pune

The analysis is done by loading the location of the hospitals taken with the GPS at the Facilities class of objects (Fig. 21) and by loading/placing the location of the accidents at the Incidents class of objects (Fig. 22). By hitting the solve command on the Network Analyst Window, the shortest path to the closest hospital was generated (Fig. 23). In order to find the closest healthcare center and showing the shortest route to the accident or someone in need of healthcare facility, a new closest facility should be made.

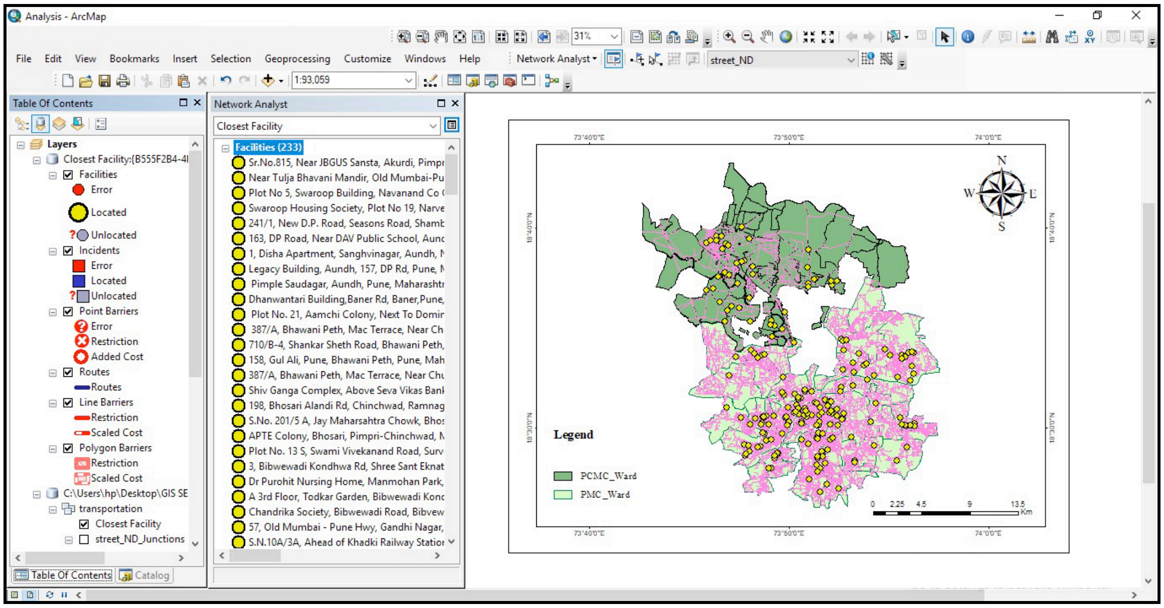

Figure 21. The location of the hospitals taken with the GPS at the Facilities class of objects in the closest facility analysis

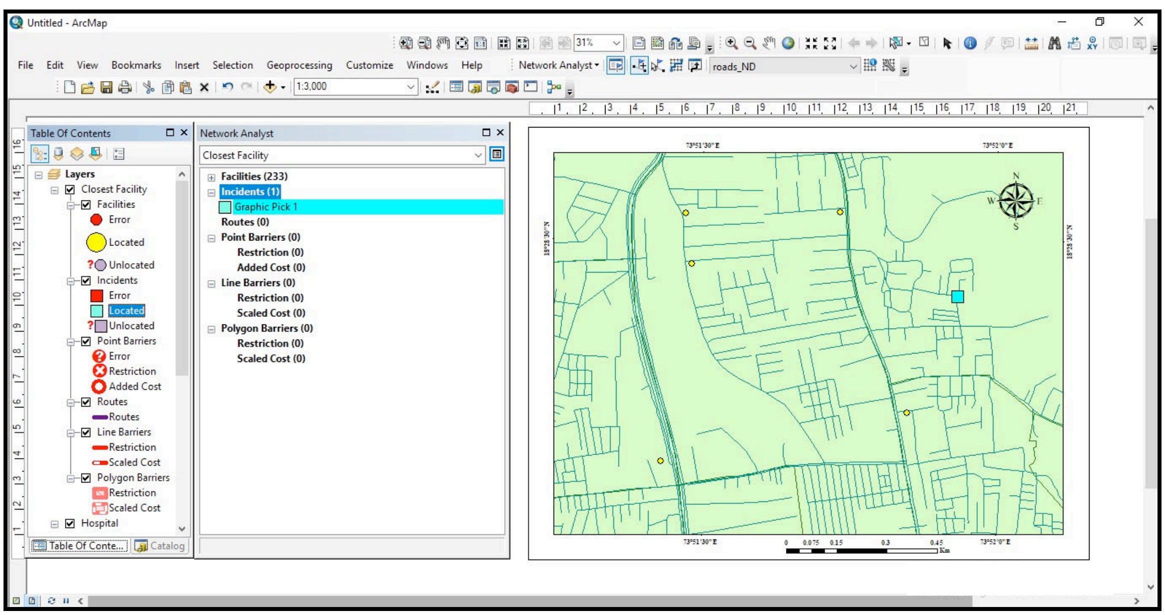

Figure 22. The location of the person who needs healthcare facility at Incidents class of objects in the closest facility analysis

In the case of Pune, the shortest route was done, from the accident site or site of a person who needs help to the healthcare center (Fig. 23). The injured person is then sent to the proper Emergency Receiving Unit, depending on the medical diagnosis. Therefore, a new shortest route was done to fulfill this task.

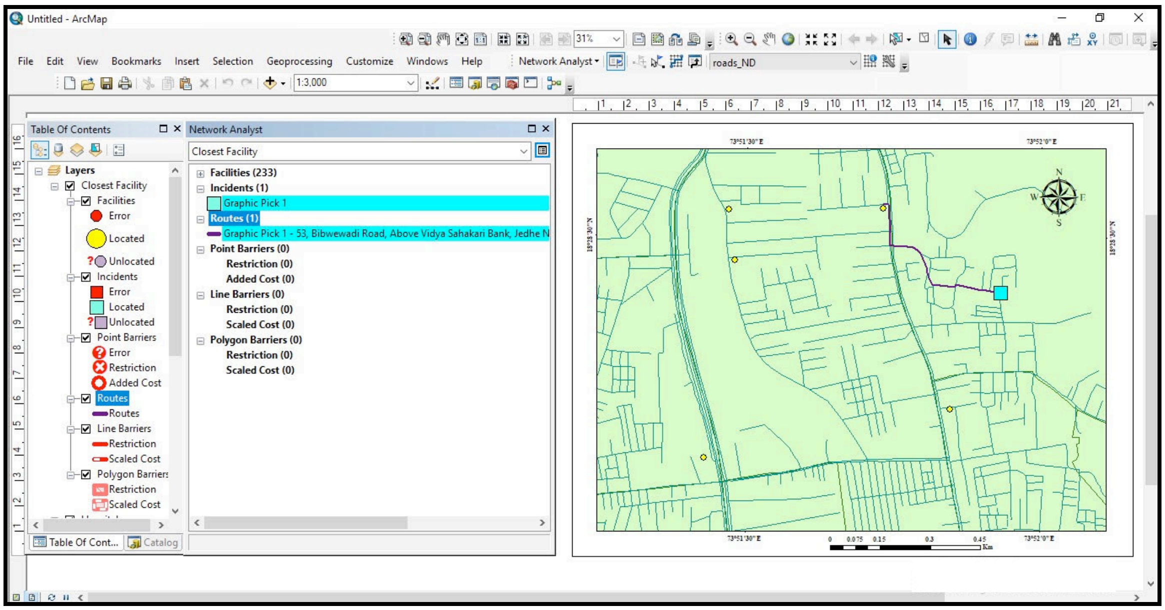

Figure 23. The shortest route from the accident site or site of a person who needs help to the closest healthcare center

After feeding all the required criteria to a model an output has been generated in a form of point locations. A network analysis was carried out to locate the closest healthcare center using a specifically customized toolbar at closest facility analysis in ArcGIS (Fig. 23). A route Network dataset was generated as shown in Figure 23. The green color line in Figure 23 illustrates the nearest route to the healthcare center. Driving directions from the person who needs healthcare facility to the closest hospital are shown in figure 24.

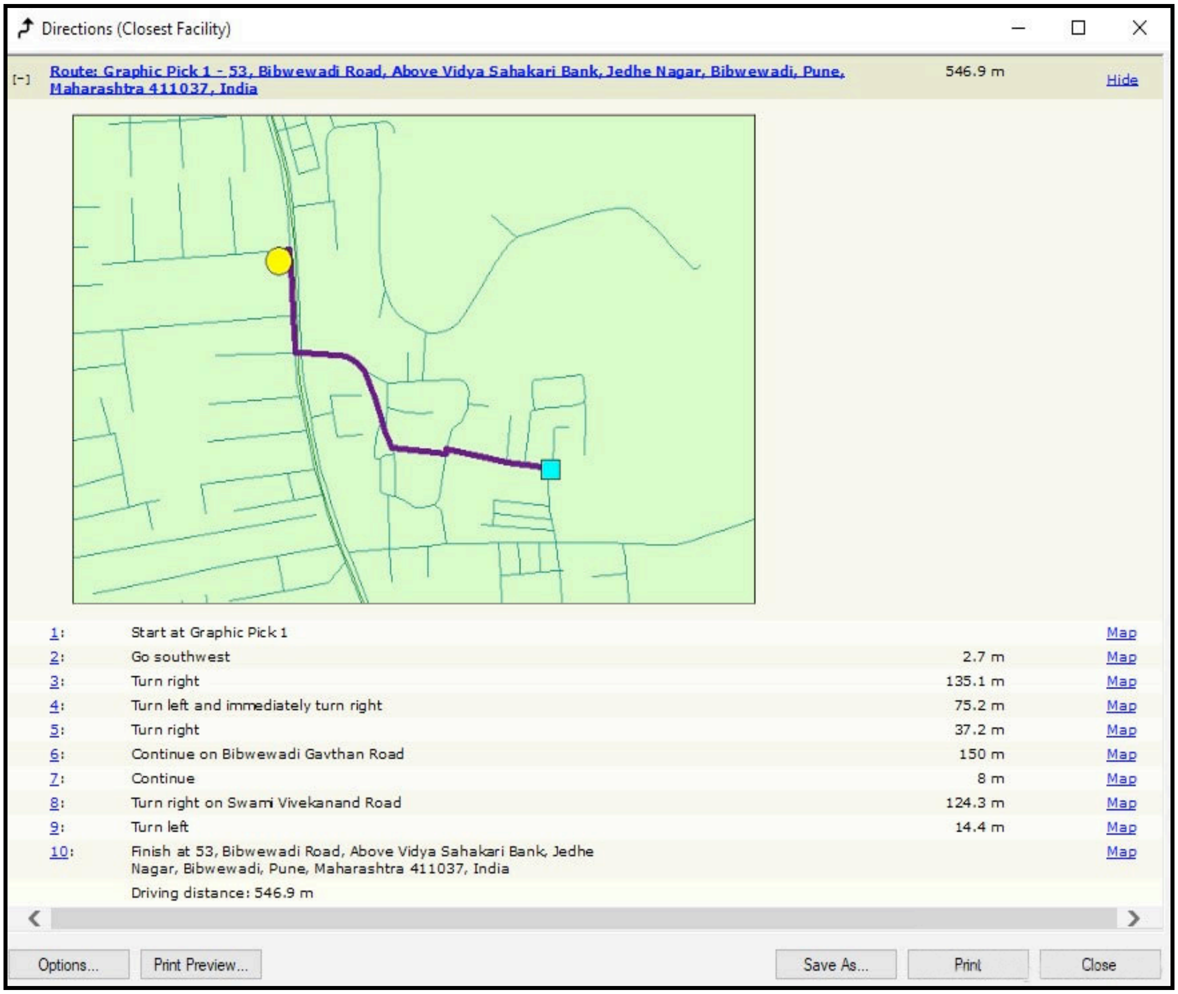

Figure 24. The Directions dialog box which shows the direction from injured or diseased person to the hospital

The results of this study highlight the ability of GIS to be a very effective decision-making tool for accessory healthcare facilities mainly in finding the closest healthcare center for people. Therefore, GIS also help in finding the nearest healthcare center as a facility by using the fiber of road network. GIS can form a decision support system with the help of models that have been generated by using permutations and combinations of different criteria (Awaghade *et al.,* 2014).

Furthermore, in this case, healthcare center has to be concentrating on getting less time consuming and presenting maximum services. GIS is one of the important decision support tools that help healthcare centers to do this task more efficiently.

Due to the ever-increasing number of population, more healthcare facilities need to be provided. There are three important factors that affect the level of accessibility of the facilities. These were the capacity of the facilities, the demand for the facilities and the transportation network that communicated such demand to the relevant capacity (Abbas *et al.,* 2014). A good network of transportation can provide easy access to the healthcare facilities. The study area had a good network of transportation with most of the healthcare facilities spatially located in proximity to roads.

The information of Private and Government healthcare centers in the study area are listed on the following pages respectively.

CHAPTER 5
CONCLUSIONS

5.1 Conclusion

The research work entitled **"Healthcare information system using GIS: A case study from Pune metropolis"** is intended to serve the community using the latest technology of Remote Sensing and GIS:

- In fast-growing megacities, the availability of a digital database of healthcare facilities and readily available route guide to accessing healthcare centers are helpful to take appropriate decisions to provide better healthcare services at the right time in the right place.
- This tool could also be helpful in finding the nearest healthcare center during the crucial situations like disasters, major accidents, fire accidents and other emergencies.
- Determining the closest/ shortest and the best route to healthcare centers is one of the most important applications of network analysis. In this research, this analysis was carried out in Pune, so that all residents of the city of Pune could use these optimal routes.
- Therefore, it is the need of the hour to gather information about the general as well as specialty hospitals and clinics in rapidly urbanizing cities like Pune to tackle the emergency situations efficiently.

Primarily due to the limitations in data and availability of transportation modeling software, the results of this study were relatively limited in scope and hence the focus was to cover the major and prominent hospitals and clinics in the city.

Based on the findings of this study, one can offer an optimal solution to the ambulance /emergency vehicles in finding the most suitable path through the city. It may make the job of the drivers much easier, and be sure that they react at the place of accident in less time than previous. This system could be improved by tracking the position of ambulances and injured a person in real time, using GPS. Further, its efficiency can be enhanced by taking into consideration the traffic flow, peak traffic hours, signals and one way traffic rules, type of roads, road width etc.. The information system so generated will be the significant tool for town/city planners and developers to make the decisions of improving road network and connectivity to the healthcare centers.

Geographical Information System (GIS) provides a reliable base for mapping the facilities like the location of high schools, banks, bus stops and city hospitals with the scope of regular information updating. A timely communication and information received about planned road modifications will mean that the system always be up-to-date and the time to reach the accident spot will be minimal. The same system can be used for other similar situations such as the police department in order to regulate the crime as well as for fire brigade in case of fire emergencies.

GIS tool could be used to perform spatial analysis of various aspects of health services like hospital, blood bank, pharmacy and diagnostic laboratory of Pune city with the help of user interface. In this thesis, the work is illustrated to demonstrate the potential contribution of geographical analysis in planning and management of healthcare centers all over the city. The study also revealed the role of geospatial technique in the development of healthcare services in different aspects of health issues. The shortest route from the accident site or location of the injured person who needs help to urgently visit the closest healthcare center has been demonstrated in this study. Furthermore, it is concluded that the GIS is one of the important decision support tools that help in identification of shortest path to healthcare centers in emergency situations.

5.2. Looking to the Future

The availability of healthcare centers plays an important role in rescue and life-saving during a disaster. If any city has adequate hospital facility, then epidemics can be tackled very quickly and efficiently using Geographical Information System with updated route map as an attribute data. Similarly, monitoring and forecasting the spatial distribution of communicable diseases which are spreading through water and air (viral diseases) are important subjects for analysis in future. Therefore, a need to demonstrate the GIS contributions for epidemic analysis, as these can help maintain the better health of citizens.

- Due to constraints in the collection of data and time this research has been restricted only to Pune city. However, we would like to place on record that there is a lot of scope for developing this work by gathering more detailed and specific information such as routes condition, traffic congestion, traffic rules, type of roads etc. With regards to the amount of work which needs to be done and further research that has to be conducted, there would be more emphasis on patient satisfaction and more efficient healthcare.

5.2.1. Recommendation for Future Research:

- Identification of spatial problems in healthcare facilities in Pune city.
- Locating new health centers for Pune city to enhance access to healthcare.
- Evaluating the GIS as a useful instrument in urban planning, especially in locating healthcare centers.
- This application and the same type of this can be developed and evaluated for other megacities as well.

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