Geospatial technology for fire service area analysis and route optimization in the case of Shimla, Himachal Pradesh (India)

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(Received: January 19, 2012; in final form November 1, 2012)

Abstract: The study attempts to analyze fire service area that can be reached from fire facility based on drive-time for the Shimla Planning Area through the use of Geographical Information System (GIS) based on the secondary sources and other free sources of information. In addition, the paper also estimates the drive-time distances from the fire stations to heritage buildings, other important buildings of public importance such as schools, and other institutional buildings based on origin and destination cost method of network analysis. But first of all, it discusses as to how GIS can become a strong tool in handling large spatial/non-spatial databases, assist in analyzing spatial pattern, and indicating optimal route for fire services for effective decision-making.

Keywords: GIS; emergency; planning; mitigation; preparedness; response; recovery; service area; fire; route-optimization; response-time.

1. Introduction

Fire and rescue service provides firefighters to deal with fire and rescue operations, and may also deal with some secondary emergency service duties. Firefighters and rescuers are extensively trained primarily to put out hazardous fires that threaten civilian populations and property, to rescue people from car incidents, collapsed and burning buildings and other such situations. Greater proportion of poor quality housing, abundance of wooden furniture, inadequate planning, poor monitoring and control, inadequate road width, all these contribute to growing number of fire accidents.

Municipalities in India are bound by law to have a fire brigade and participate in a regional fire service. Each city has its own fire brigade. All the industrial corporations also have their own firefighting service. Each airport has its own fire-fighting units. The main functions of fire fighting service in India are provision of fire protection and of services during emergencies, such as building collapses, forest fire, drowning cases, gas leakage, oil spillage, road and rail accidents, bird and animal rescues, fallen trees, evacuation during landslide, appropriate action during natural calamities, and providing consultancy in implementing fire protection and fire safety in industries and high rise buildings and other buildings having special fire risks etc.

The state of Himachal Pradesh has 22 fire stations. The Fire stations in the state functioned under the control of Municipal Committees (MC) till the year 1972, but subsequently, the state Government took over the control of fire stations. During the succeeding years some more fire stations were opened.

Shimla Planning Area (SPA) has three fire stations situated at Mall, Chhota Shimla and Tilak Nagar at Boileauganj. Due to narrow and congested road network and ever-expanding cityscape, firefighting is a not an easy task in Shimla. The city has been witnessing growing number of fire incidents over the years. Even surrounding forest cover is severely affected by regular occurrences of fire (Figure 1).

Figure 1: Forest fire on Shimla Hills a regular occurrence

In addition to fire control, the fire department is also involved in evacuation during landslide, road accidents etc. The infrastructure available at the three fire stations are as given in table 1.

SPA has a geographical spread of approximately 100 km^2. As per the recommendations of the Standing Fire Advisory Committee (SFAC), one fire station may be allowed for every 10 km^2 area of a town. By this parameter, SPA should have approximately 10 fire stations. Demographically, Shimla city had population of about 1.88 lakhs during 2010 and floating population of 82,000 making a total of 2.7 lakhs (Statistical Outline of HP, 2009-10). Therefore, Shimla city may need 5 pumping stations as per the SFAC yardstick. The SFAC recommends one fire engine for every fifty thousand

population and it may change as per the actual survey and requirement based on the risk factors such as industrial nature and other factors. The SFAC was constituted by the Government of India (Ministry of Home Affairs) on the recommendation of Chiefs of Fire Services in 1955 to examine the technical problems relating to fire services and to advise the Government of India on matter concerning the organization and speedy development of fire services all over the country. Since then SFAC had a number of meetings.

However, keeping in view of the physiographic constraint and more than 50 percent of its area being under forest cover, operating 10 number of fire stations may not be economically viable. Nevertheless, planning for fire station needs to take into account the response time coverage of fire services. This paper seeks to estimate fire service response time of each fire station of Shimla.

2.Study area

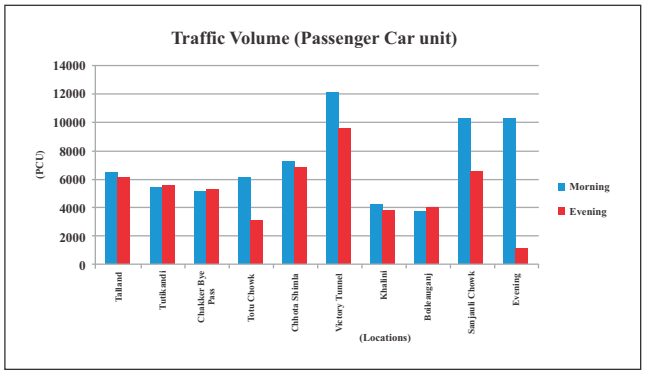
Being a hill city, it is not easy to operate emergency services efficiently keeping in view of the congested narrow roads. The traffic volume on the Shimla roads are very high and getting congested day by day on account of burgeoning private vehicles, rampant encroachments and lack of any other alternative mode of transportation. The traffic speed at many points of the city gets seriously compromised. Traffic jams have become a regular feature on most of the networks such as cart road, circular road or other MC roads on each passing day in Shimla (Figure 2).

Figure 2: Traffic jams in Shimla are a regular feature

Cart Road is the main arterial road of Shimla and the only road open for city traffic movement without much restriction. The Cart road also known as Circular road or Motor Round Road is part of NH - 22 starting from Railway Tunnel No. 103 to Dhalli Tunnel and traversing round the Shimla Hill. The name Cart Road itself suggests that the road was initially designed for carts during British time. Over the time, development has led the same road to be used by Motor vehicles. Even today, the width of Cart road at few locations is restricted to only 5m owing to non-availability of land space. Though the average road width is about 8m and 18 km delimiting Core Area. Cart Road is the only option for traffic movement and is functioning beyond its capacity. Other important roads of Shimla share more or less the similar features.

All the roads connecting to Cart Road are municipal roads that are maintained by Shimla Municipal Corporation. The total length of roads for vehicle movement under the Shimla Municipal Corporation (SMC) as per data available with the SMC is 74.6 km.

The major tourist attraction of Shimla is the Mall. The Mall is the central market place in the core area and houses a number of heritage sites and buildings. The road from Boileauganj to Scandal Point and from Scandal Point to Secretariat and from Scandal Point to Sanjauli Chowk forms the Mall road. The road along the Mall is basically for pedestrian movement and entry is restricted for vehicles except for vehicles with permits and emergency vehicles. Department of Town and Country Planning, Government of Himachal Pradesh conducted Traffic Volume Survey at nine locations during the hours 8.30 AM to 10. 30 AM and 4.30 PM to 6.30 PM on 19th October, 2004. Actual traffic volume is 3018 PCU/per hour.



(Source: Draft Development Plan of Shimla Planning Area, pp – 149)

3.Route optimization through GIS

It is important to realize that the main objective of developing guidelines is to minimize response time of fire services and reduce the fire losses. GIS provides a primary capability to organize, display, and analyze information for sound decision making. In addition, it can be used to analyze, dissect, and plan for fire protection problems quicker and with greater detail than previously possible. It is high time to introduce

GIS, which can become strong tool in handling large databases and analyzing spatial pattern and indicating optimal route pattern, which can play a pivotal role in effective decision-making. This could be a very useful tool while planning fire safety. GIS can also help define station locations; realign response area; and identify and better understand hazardous materials locations, industrial facilities, commercial occupancies, water supply locations, etc. The goal of fire protection planning is to improve fire department's level of service. Establishing standards and expectations for fire protection is essential. Figure 3 depicts the quickest route (based on time-based cost attribute) from the fire service to fire accident area (hypothetical situation) with drive-time of 433 seconds (about 7 minutes) and a distance of approximately 2.2 km. The GIS software provides the vector route network along with attribute data indicating travel time and travel distance.

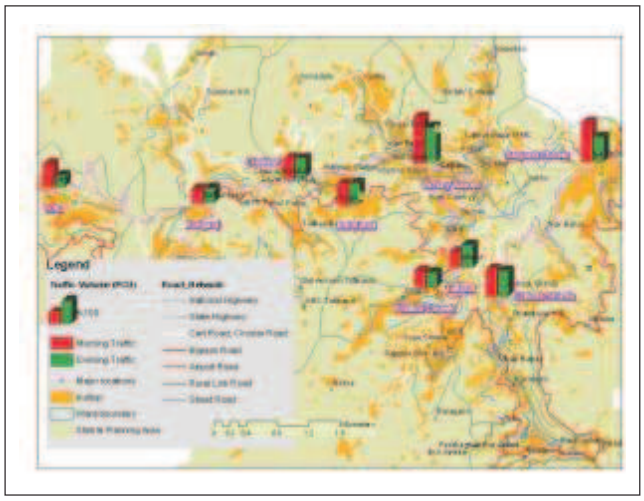


Figure 3: Traffic volume is more than designed capacity

GIS Modeling – GIS can also display a model (plume, explosion, flood, earthquake, epidemic, etc.) and postulate/predict different scenarios. The model can also be used with other GIS data to analyze infrastructure damage, road closure requirements, casualties, and other issues important for planning and response to potential or unfolding events.

4.Route Optimization through GIS

There are five steps in the fire department's total reflex time sequence. GIS can be employed on each of the five steps, after receipt of an alarm, as defined below:

1. Dispatch time: Amount of time that it takes to receive and process an emergency call (Figures 4 and 5 shows the GIS analysis reduces the dispatch time by optimizing route and exploring the closest facility).

2. Response time: The time that begins when fire services are en route to the emergency incident and ends when fire services arrive on the scene (Figure 7 deals with service area analysis of each fire station).

3. Access time: Amount of time required for the crew to move from where the apparatus stops to where the emergency exists (Figure – 6, indicates building, database and drawing plan).

4. Set-up time: The amount of time required for fire department services to set-up, connect hose lines, position ladders, and so on, and prepare to extinguish the fire.

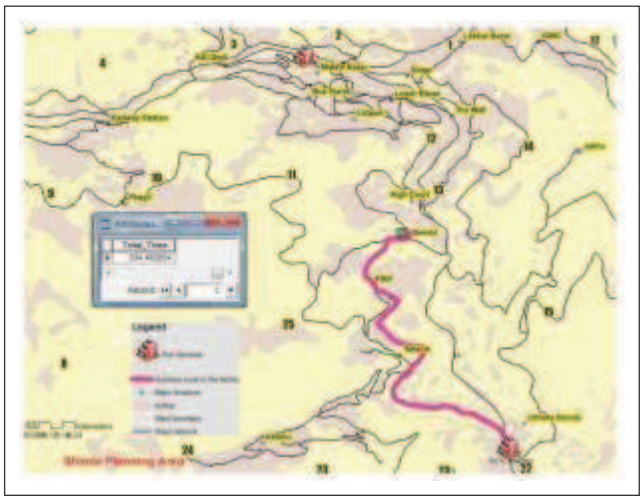


Figure 4: Quickest route (based on time-based cost attribute) to place of fire incident from fire station

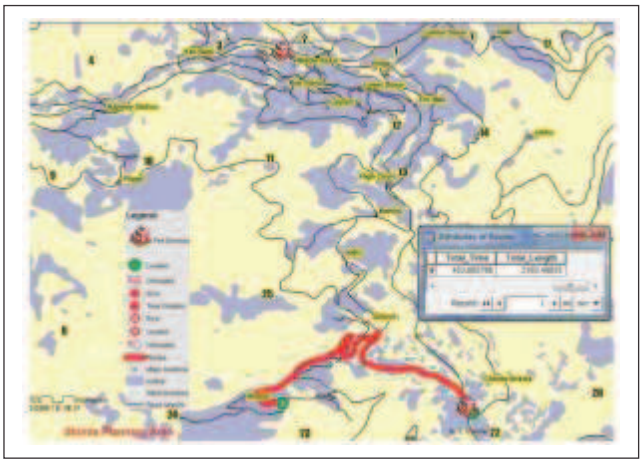


Figure 5: Closest facility analysis: Here is one hypothetical scenario, wherein a fire has been reported near Bemloi, GIS provides information on the closest fire service near Chhota Shimla along with the quickest (based on time-based cost attribute) & shortest route (based on distance-based cost attribute).

Service area analysis: The figure 7 delineates response time based on drive-time of 5, 10, 15 and 20 minutes excluding dispatch, turnout, access and setup times. The road networks have been collected from sources such as Shimla

Development Plan, Google Earth & MS Bing Map, which were digitized, geo-referenced and re-projected onto the UTM projection system. Driving speed of each road network invariably differs due to traffic volume, road width, road surface quality and area. Drive-time of each network was found out through the secondary sources data and remaining from the author's own personal experience. Nevertheless, the map is indicative only, there is good scope of better accuracy and high precision needed for accurate analysis. Based on the above attribute and geometric data, geo-database has been prepared based on which the following map has been generated.

Figure 6: Risk analysis in combination of database, photograph and drawing plan of the fire building

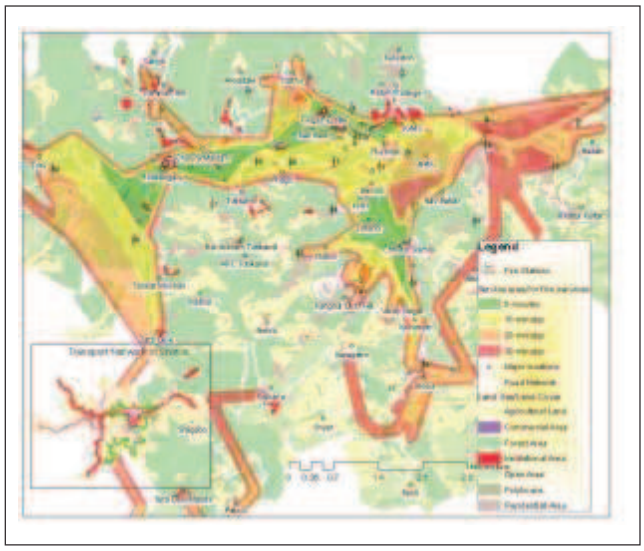


Figure 7: Service area of fire station in Shimla

From the above maps, it is obvious that there are some very efficiently serviced areas falling within 5 minutes response time. But sub-urban areas are not efficiently served. The Mall and Lakkar Bazar, Chhota Shimla, Talland and Boleauganj seem to be better served, which are falling within 3-5 minutes drive-time. However, Sanjauli, Panthaghati, Kasumpti and Dhalli areas are comparatively poorly served. Turn impedance has been modeled as per the 2D distance owing to lack of high resolution DEM/DTM for 3D turn impedance modeling.

5.Origin destination cost of fire service vis-à-vis heritage/other important buildings/ locations

Shimla, the Summer Capital of British India, is popularly known as 'Jewel of the Orient'. Amidst the Central Himalayas, it is a charming hill resort for tourists from all over the globe. Ever established by the British on hill top, with unique urban design, it is known as 'Queen of Hill Stations'. Shimla possesses distinct British heritage. During recent decades, after acquiring the status of state capital of Himachal Pradesh, it emerged as a major cultural, educational and institutional centre. Still considered as the star of India's hill resorts, Shimla is dominated by 19th Century colonial buildings. The British established many architectural masterpieces such as Vice Regal Lodge, Gorton Castle, Railway Board Building, Gaiety Theatre, Town Hall, Auckland House, Ellerglie, Barnes Court, Bungalows, Churches and Challet Day School, which are our precious heritage. The city possesses distinct British heritage including institutional buildings, bungalows, churches, socio-cultural spaces, hotels, cemeteries, coffee houses, clubs, theatres, schools, hospitals, street pattern and street furniture, immensely add to grace of the city with their distinct expressions. Thus, protecting these heritages, in addition to lives and property, is an additional task for Fire Department of Shimla.

All these heritage buildings are being protected and maintained through the concerned State/Central level agencies. The origin (Fire services) and destinations (Heritage and other important buildings/locations of the town) cost matrix is presented below to find out drive-time (response time) for identified heritages/buildings from the fire service facility (Figure 8).

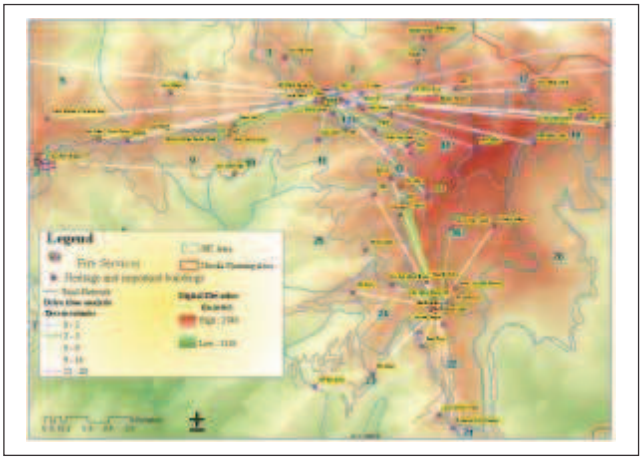


Figure 8: Drive-time between origin (fire services) and destination (important buildings/locations)

Spatial Data	Non-spatial Data
1. Land Use/Land Cover Map (from high resolution airborne/satellite sensors with better than 1 meter resolution).	1. Right of Ways of each road (Primary survey).
2. Transportation network with maximum accuracy (with input/information from differential GPS).	2. Traffic volume, driving speed, traffic restriction, congestion points and bottlenecks and traffic composition on each road during peak and lean season/time.
3. Fire Stations (GPS locations).	3. Fire Station-wise records (secondary sources).
4. Police Stations (GPS locations).	4. Photograph of fire station & building plans (primary source).
5. Water Filling Points (GPS locations)	5. Names of Police Stations (secondary source).
6. Building footprints (from high resolution airborne/satellite sensors with better than 1 meter resolution).	6. Ward number, population, density (Secondary sources such as Census, Municipal Corporation, Urban Development) as per Census 2011.
7. Street data with address points or address range from high resolution airborne/satellite sensors better than 1 meter).	7. Name of owner/occupants/tenants etc from primary survey.
8. Water lines and hydrants placement	8. Building types (wooden, RCC) primary survey
9. Utilities information for electric systems and gas main locations (GPS locations).	9. Risk zones as per National Building Codes (NBC) guidelines derived using GIS and published by other secondary sources.
10. Development services information on buildings and zoning information.	10. Demographics – secondary source data.
11. Hazardous material and target hazard locations.	11. Other ancillary data.
12. Topographic features (DSM/DEM either from CARTO DEM/LIDAR).	
GIS Analysis	
1. Georeferencing, digitization, attribute table development.	
2. Preparation of geo database for network analysis.	

From above analysis, it is emerging that out of 76 important places plotted for the analysis, 39 are falling within a drive-time of less than 5 minutes from fire services, 23 within 5-10 minutes drive-time, 9 within 10-15 minutes drive-time and remaining five are outside 15 minutes drive-time. The response time for responding to a fire call, information of which is received in the fire station is approximately 30 seconds to one minute. However, the basic assumption of this study is that these drive-time distances are applicable in the normal traffic conditions and does not take into consideration the traffic jams, other barriers such as landslide, tree falling, turn impedance due to elevation change, road accidents, poor road quality, and inadequate road width etc.

The above analysis presents only the indicative scenario. It needs to be updated with accurate and high resolution spatial data for decision making purposes, for which the following data would have ideally been required:

6.Conclusion and recommendations

Emergency services need to be planned in such a way that it caters to most areas/locations within quickest possible time. As the city tends to expand south, east and westwards, the emergency services need to be decentralized in these directions, which seem to be poorly served. This goes without saying that it is necessary and fundamental for policy-makers to make technologies like GIS and Remote Sensing imperative for the emergency services in particular and urban planning in general.

The fire service mission is to protect life and property from fire and other natural or manmade emergencies through planning and preparedness, incident response, public education, and code enforcement. To accomplish this mission, GIS is rapidly becoming an essential tool to analyze, define, clarify, and visualize community fire problems in the development and execution of fire protection policy. GIS can model a community or landscape; analyze and display features important to the fire service mission; and provide access to important documents, photographs, drawings, data tables, and so forth, associated with features on the GIS map display. Therefore, implementation of GIS in fire Department of Himachal Government along with others is pre-requisite.

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Table 1: Fire fighting vehicles and fire equipments under three fire stations in Shimla MC (2012)

Sr. no.	Fire Fighting Vehicle	Fire Fighting Equipments	Water Capacity in liters	Foam Capacity in liters	FS Mall Road	FS Chotta Shimla	FS Boileauganj
1	Advance Water Tender		4500		1	1	1
2	Co_2 Foam Tender		3000		1		
3	Water Houser		9000		1	1	1
4	Small Water Tender		3000		1	1	
5		G Fire Engine	N	N			1
6	Quick Response Vehicle		300	50		1	1
7		Fire Hydrants			200	200	180
8		Compressed Air Form System			1	1	1