Application of Geospatial Technology in Disaster Management with A Focus on Urban Incident Response And Monitoring: Case Study of Shillong Urban Area

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ABSTRACT

Geospatial Technology has become an important and indispensable tool for planning, monitoring, assessment and analysis of disaster events; therefore, it is highly recommended by many policy makers, engineers, disaster managers and the reason for this is because of its comprehensive visualization, analytics, modeling functionalities of the geographical entities. Fire incidents in urban areas have become a problem with the increasing building built-ups an ever-increasing population, with the increasing population density cases of fire incidents has also risen up. The functionalities of the Fire & Emergency services in the recent trend have now become multi-tasking and demanding in the urban areas, therefore there is a need in the intervention of Geospatial Technology for assessing, gap analysis, incident reporting, inventorying, refining and improving the services in the urban scenario. This research examines on how Geospatial Technologies can be utilize for disaster incident pre- planning, incident data collection, analysis of the fire incident trends, inventorying of disaster incidents, assessing of the existing coverage areas of the Fire &Emergency services using proximity analysis and network analysis, establishing the relation of other non-spatial attributes with the fire incidents particularly in urban Shillong areas and ranking of the fire zones based on population density factor. For this research study QGIS and ArcGIS was used for data processing and analysis, Google Earth pro was used to collect the locations of F&EMS stations, Hospitals, and localities. Urban Shillong area and town boundary was obtained from open-source data. Road network data was collected through open-source data sources; it was rectified and improved in the QGIS environment with the help of HCMGIS plugins for basemaps overlaying. Population data for the major town in urban Shillong area was collected from census website. Fire incidents were collected from the F&EMS department, and also augmented with news report data. Epicollect mobile application was used to demonstrate the use of mobile application in incident reporting and also locating, the data was later used for simulation in assessing the response time and also locating of the nearest health facility center. For landslide incident data meant for inventorying into the GIS database system open GSI data was downloaded and used for overlay analysis. The field trial of Epicollect mobile application have resulted in effective incident data collection and inventorying which can be used by F&EMS department in further analysis and also maintaining a digital data with a geospatial element incorporated into the incident data.

Keywords: Spatial Analysis, F&EMS, Google Earth, QGIS, Epicollect, Population Density, ArcGIS, Opensource

INTRODUCTION

Geospatial technology in the recent age and in this digital era has become an indispensable tool for many fields of scientific applications, it has become a supportive tool for decision making and planning purposes. GIS can be regarded as a technology which allows data capturing, manipulation, processing, analyzing and displaying of geographically referenced data in the form of Maps or digital web maps which can be hosted in the internet. GIS is an effective decision support system tool and have resulted in many effective executions of projects etc. The application of Geospatial Technology particularly in the field of crises management with respect to various hazards is gaining a great importance. GIS through a participatory approach can be effectively used in the process of identifying suitable sites and location for setting up of emergency shelter sites in rural and urban areas to cater

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to the needs of the public masses substantially, it is also used as a tool in reporting of any disaster incidents which has helped the disaster managers in facilitating the timely response to the disaster site. The spatial analysis functionalities have been a boon to many emergency planners because it allows for the identification of the areas that are vulnerable which will help in the timely response to the affected area and also in identifying of evacuation shelters through spatial analysis. GIS in terms of post-disaster activity have also been very fruitful since it allows for accurate damage assessment, reporting of the recovery activity and also supporting the monitoring activity at the disaster site, such activity will help in the transparent and effective disaster management. In the context of disaster risk reduction activities GIS has a wide scope of applications in the various cycles or phases of disaster management particularly in the pre-disaster, during disaster and post disaster, it is to be mentioned that it is effectively used for all of the stages and in particular with mitigation, preparedness, and response stage therefore allowing to identify the population at risk and also deriving at the various vulnerable areas which later help in taking preventive measures to minimize or reduce the elements at risk. In the recent age information that are generated by the public masses through social media, mobile apps also play an important role and in particular Crowd sourcing GIS has gain importance in disaster response.

BACKGROUND

Fire and Emergency services department in the recent trends their role and functionalities have become very demanding and also multi-tasking, they not only cater to disaster events related to fire but they also response to multi hazard events like landslides, cyclones, accidents etc be it natural or man-made, therefore there is an impending pressure on the F&EMS department. In the context of urban scenario, the F&EMS department will have to response to muti-hazards events which makes it very challenging for them. Therefore, in case of any fire incident in the urban areas and particularly in Shillong Urban area, the likelihood of the fire spreading to other areas or adjacent buildings is very high. The Fire service department is always on the defense of all emergency situations from petroleum fires, hazardous material, high-rise building fire, domestic fire, floods and terrorist attacks (Pondi Brian Ochieng, 2015). There are many factors which may contribute to such urban fire incidents but the major driving factor is the ever-increasing population. The increase in population and development of industries gives Fire service departments a serious challenge in responding to emergencies on time when called upon by the public in emergency situations. (Pondi Brian Ochieng, 2015). With the advancement of technology in the recent age, such factors can be analyses from a geographical location perspective which can be a decision-making factor for the F&EMS department and the technology which provide such functionalities is Geospatial Technology. GIS technology plays a major role in helping to evaluate risks and hazards, time response to an emergency, mapping fire incident hot spots and interactive maps to provide necessary information for quick decision making in an emergency situation. In order to attain better fire service coverage, there has to be timely service delivery and effective emergency management (Pondi Brian Ochieng, 2015). The analysis of emergency response times has been used for years in developing statistical data for the fire services. (Chad M. Hanson, 2012). Analysis of response data in GIS can show both the efficiencies and deficiencies of current fire station coverage for a specified travel time and provide a model for future fire station coverage using the specified or other travel time standards (ESRI White Paper, 2007). Disaster incidents are inevitable and inescapable, however situational awareness about the existing conditions is important and, in this context, GIS provide the capabilities to create such information and also displaying such information in a comprehensive way which will help in effective planning. The paradigm shift of Geospatial technologies to mobile GIS has been a great boon to the users. In the context of urban fire incidents mobile GIS can be a tool for reporting as well as monitoring wherein incidents can be directly reported to the incident command center where further analysis of such events can be processed.

Statement of Problem

Time is a critical element for effective emergency response. The time difference between fire outbreak and the beginning of firefighting is directly proportional to property loss due to fire. (Pondi Brian Ochieng, 2015). It is hypothetically assumed that such records of fire incidents are not maintained in digital formats or perhaps not in a proper database, such records are normally maintained in simple file paper formats without any elements of geographical locations which perhaps may not help in understanding the trends of the fire incidents in Shillong urban areas and also will not be effective enough for pre-disaster planning and also in refining and improvement of response activity. In most of the cases many of the planning process is made on the basis of mere knowledge and human assumptions. In the context of Shillong urban area, there is only one major Fire & EMS station and two Fire & EMS sub-stations. As the urban population in the Shillong urban areas is increasing there is always

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likelihood for man-made disaster or perhaps natural disaster induced by anthropogenic activities and for this reason there is an impending pressure on the Fire & EMS department and the Disaster Management department and the role has become more challenging and multi-tasking. For any kind of emergency be it man-made of natural disasters the first focal point to reach is the Fire & EMS department, and later the SDRF or NDRF, however in such context there is a need on the part of the Fire & EMS to understand the response time, the area of coverage within the assigned time enroute to the incident, zones of risks be it fire, landslides etc. this will help in effective planning and also in refining the response time. Hypothetically it is assumed that at the time of any incident there is a missing element of location information of incident reporting to the Incident Command Centre (ICS) or perhaps the reporting may be in verbal through various mode of communication but however lacks the essential elements of location in the geographical space. Therefore, to address the mentioned issues there is a need to use the intervention of science and technology and in particular applying Geospatial technology. In connection to the problems as described, the proposed study will address and try to achieve the following major objectives in the stipulated time:

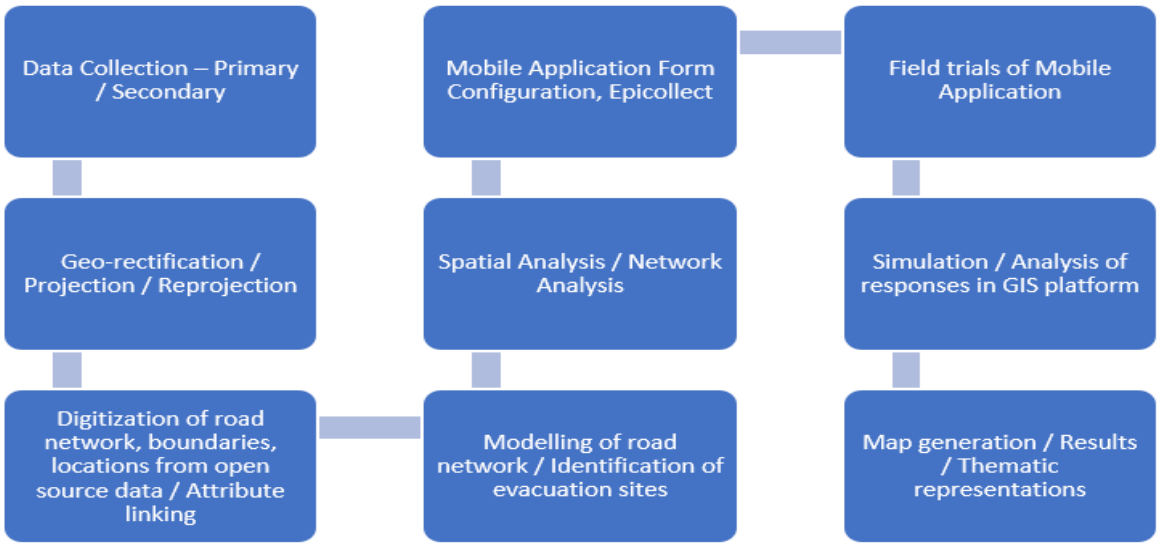
1. Spatial assessment of the existing Fire & EMS coverage area and prospecting for
2. location of new Fire & EMS stations.
3. Modelling of the road network in Urban Shillong for incident response
4. Inventorying of disaster incidents, Emergency Shelter site in a GIS based database and thematic presentation in GIS
5. Identification of the probable emergency shelter sites
6. Demonstrating and simulating the use of mobile application for incident monitoring and reporting.

For adding value to the research study research questions are proposed to base the entire research study.

a. Are the existing F&EMS stations enough to response to emergency situations.
b. Whether GIS is utilized as a tool for pre-incident mapping?
c. Whether such plans are presented in a map form?
d. Whether the important emergency services utilities are mapped?
e. Whether the F&EMS department understands the coverage area within the response time?
f. Is population directly related to many of the incidents in the city?

RESEARCH METHODOLOGY

This study is based on an exploratory approach and to exhibit the potential of GIS in solving emergency issues, planning process etc. As it is it also takes into the consideration of the methods and the procedures applied by many research scholars, scientist, planners, the literature materials and experimental case studies have been incorporated in to this dissertation to achieve the statement of the problem and the objectives of the study. The methodology has been designed to suit with the selected study area. The process includes from data collection to processing of data and generation of thematic maps for understanding.



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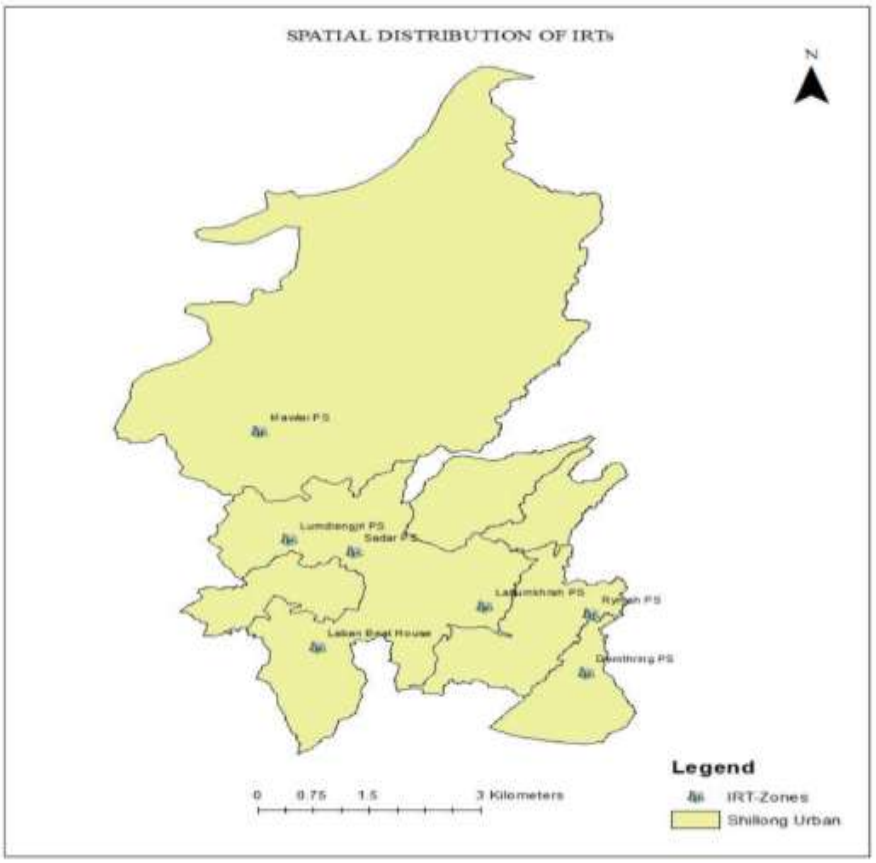
Data and Sources of Data

Open data sources were majorly used to collect all the materials for the study, primary data such as locations of the important utilities such as F&EMS stations, Hospitals, Health Centers, School locations etc. were collected using Google Maps and Google Earth pro. The road network layers were also collected from open GIS data sources which was further rectified and improved by using QGIS software and the recent QGIS basemaps plugins. Census data as per Census 2011 was collected from Census India sites, the population data was incorporated into the GIS layers. The secondary data consist of the boundary maps of the study area and its associated features which were collected from available literature materials and open data sources which were then imported into the GIS environment for further processing, Bhukosh a GSI open data portal was used to collect landslides areas in point layers format.

RESULTS AND DISCUSSION

The results from the proposed methodologies and the data analytics. It is seen that in this exploratory study, Geo-spatial technology is a right tool for such disaster and incident response planning. The reason of GIS being the right tool is that it provides an easy framework for data capturing, processing, manipulation and analysis. The Geo-database concept that GIS offers has made the inventorying of the important features and spatial information that has relevance in this study. Within the given stipulated time the spatial database with the important features was created, and the non-spatial attributes linked to the features in the database. The database can be further improved by addition of incidents data, feature layers which can be helpful in further analytical studies etc. Geodatabase is a collection of geographic datasets of various types held in a common file system folder. (Esri) A geodatabase is an alternate way to store GIS information in one large file, which can contain multiple point, polygon, and/or polyline layers. ESRI is pushing the geodatabase idea, because it is a less “messy” way of organizing data than having multiple shapefiles. in multiple folders. While shape files are still very popular and commonly available. (John Baldridge, 2012). The important features that were incorporated into the Geodatabase are in the following:



a. Road networks

b. Hospital locations

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c. Schools locations

d. Landslide points

e. Emergency Evacuation shelters

f. Police stations

g. F&EMS Stations

h. Expected Boundary

i. Town locations (Census/Municipal)

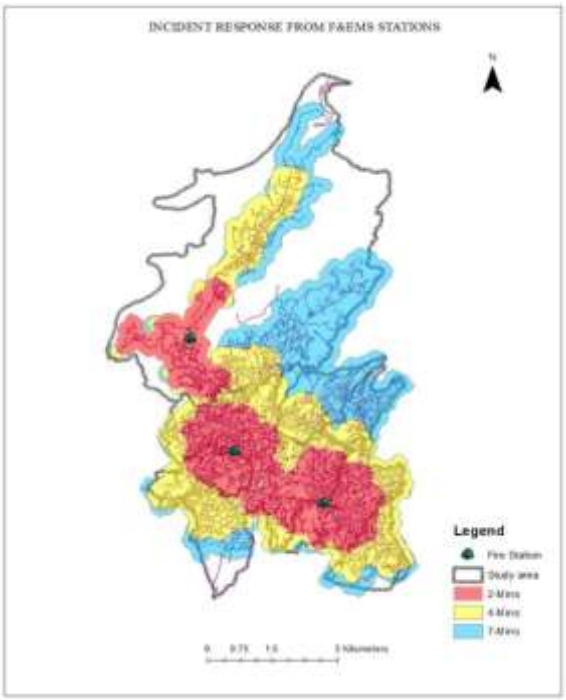
j. Fire incident locations

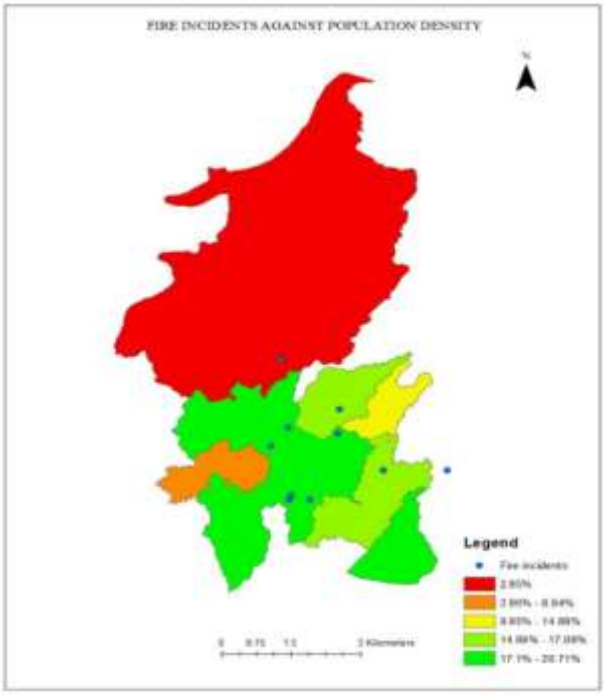
k. Petrol / Gas Stations.

l. IRT Zones (Police stations)

Results of Descriptive Statics of Study Variables

Facility ID	Name	From	To	Area in SqKm
1	Nongthymmai F&EMS: 4 - 7	4	7	2.43
1	Nongthymmai F&EMS : 2 - 4	2	4	4.59
1	Nongthymmai F&EMS : 0 - 2	0	2	5.33
2	Iewduh sub F&EMS : 4 - 7	4	7	2.56
2	Iewduh sub F&EMS : 2 - 4	2	4	5.66
2	Iewduh sub F&EMS : 0 - 2	0	2	4.01
3	Mawlai Fire Sub-Stn : 4 - 7	4	7	8.15
3	Mawlai Fire Sub-Stn : 2 – 4	2	4	4.13
3	Mawlai Fire Sub-Stn : 0 - 2	4	2	3.72





Proximity analysis and Network analysis module was used to analyze the service coverage area of the existing F&EMS stations. Before conducting certain parameters are needed to be incorporated. As discussed in the Methodology chapter, the analysis is unique from the conventional method since in this analysis, the slope

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parameters are considered, the respective slope parameters were derived from the DEM, and were accordingly adjusted to the speed limit of the road network using the method as described by Mike Price, (Arcuser, 2008). Service area analysis in the GIS environment is found to be effective in understanding the coverage area of the response team from the F&EMS stations based on the response norms. The norms that are followed are based on the SFAC, (Standing Fire Advisory Council). In the initial process buffer analysis was performed taking into the consideration the radius coverage of 200m, 500 m and 1000 m. However, the buffers do not take into the consideration of the response time, it only gives the radial coverage which perhaps may help in understanding that with a specified radius. Therefore, to accurately understand with respect to the response time, service area analysis was taken into the consideration, the functionality is available in the Network Analysis module of ArcGIS Software application. Conforming to the SFAC norm the time impedance of 2, 4 and 7 minutes were incorporated into the network analysis module. It is observed that from the existing F&EMS stations within the given time impedance the entire area is appropriately covered, provided that there are no hindrances for the response team.

Town/MB Name	Poluation 2011 Census	Area	Density	Households
Nongthymmai	38004	3.45	11007.23	8691
Madanrting	29194	2.24	13031.41	5494
Pynthorumkhrah	27219	2.35	11596.92	5755
Cantomnent MB	11930	1.97	6068.56	2473
Mawlai	55012	27.45	2004.44	10661
Shillong Municipal	143229	10.19	14051.97	31025
Nongmynsong	15017	1.49	10101.03	3242
Total	**319605**	**49.13**	**67861.65**	**67796**

The Fire incident's locations were incorporated into the Geodatabase, the location of the fire incidents was obtained from the news report and through knowledge base information the location of the incidents were captured from Google Earth pro application, the coordinates where then imported into the GIS environment with the specified projections, attributes such as the year of the incident, locality of the incident was attributed into the feature layer. Population data of the urban towns of Shillong City were obtained from the 2011 census data which was available on the archive site, the data was linked into the expected boundary of the corresponding urban towns of Shillong City, the density was calculated and the population density was derived from the data in the GIS environment. In the literature survey it was mentioned that the population perhaps may be one of the factors for many of disaster incidents, therefore to test this factor and to come at a substantial result, a basic overlay analysis was performed, the fire incidents layer was overlaid on the population layer, the basic overlay analysis resulted that the majority of the fire incident had occurred in areas where the density is high. This result helped in understanding for the fire risk hazard zonation, therefore based on the occurrence of the fire incidents, the presence of flammable materials in areas such as petrol stations etc, the zones were accordingly marked. For identifying of the emergency shelter site following parameters were used, open space, proximity to hospitals, health centers, school buildings etc. According to the DDMP for East Khasi Hills and particularly the emergency shelter areas were already identified however thethematic presentation is needed and to also facilitate effective planning. Therefore, referring through the literatures a similar procedure was followed, the visual interpretation, the slope information that was derived from DEM was used as a source to identify the areas which can best fit for emergency shelter site along with the other parameters. The proximity to the health centers would be one of the major criteria, perhaps the response time from the health centers to the proposed emergency site. Therefore, to understand the effectiveness of the health centers in providing the needed responses at the time or the onset of any emergency, a similar coverage analysis was performed with a time impedance of 2 & 5 minutes, this will give an understanding of the areas that health centers are near to the emergency shelter areas, this will also facilitate in the identification of the sites for emergency shelter etc. Therefore, the polygons that was generated from the service area analysis was overlaid on a Google Satellite imagery along with the existing school locations, in the GIS environment, for the ease of identification a spatial query was performed by selecting only those polygons with coverage of 2 & 5 minutes respectively. This analysis facilitates in the identification of the emergency shelter sites accordingly. The process was performed on GIS environment using QGIS software. The required feature layer was created namely Open space and schools, and accordingly was digitized and the attributes added to the feature layers. The overall general user knowledge was used in the process of the designated schools using Google satellite base maps; this exhibits the basic skills of image interpretation and

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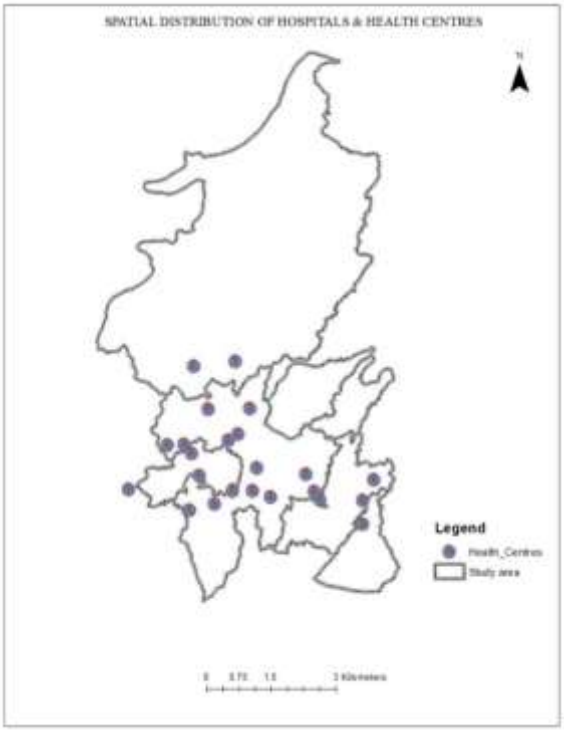
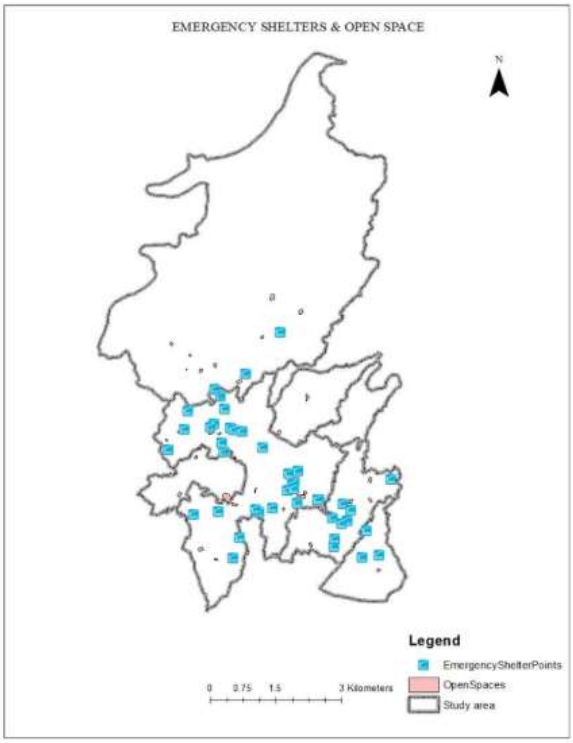
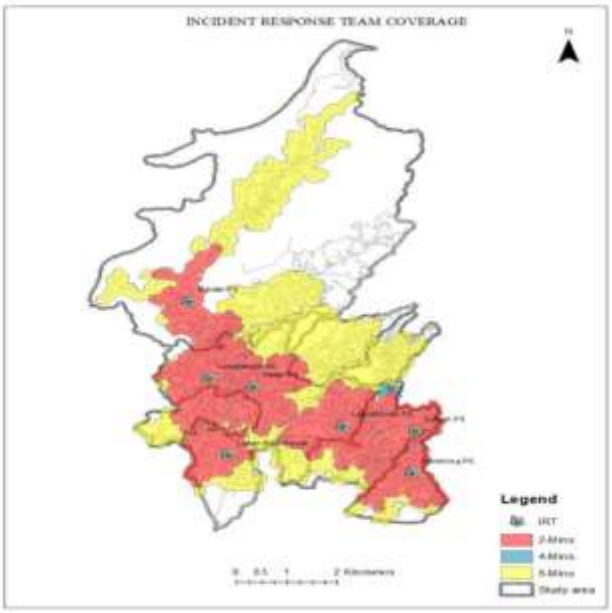
data collection. The closer or nearer the emergency shelter sites is to the health centers the better will be the response in giving emergency aids to the affected, GIS provides the functionality to performed clustering or grouping of the shelter sites under a health center. An analysis of the closest facility was performed and the closest facility was derived, a join and relate analysis was performed to link the route derived from the closest facility with the emergency shelter points to derive at the expected time to reach the shelter site. On the similar lines the analysis was also conducted for the open space to health centers. The results from this analysis will help in understanding the various routes and also the ETA to the proposed shelter sites and the open spaces.







For the purpose of experiment and also exploring the feasibility of using mobile application to report incidents and also for incident monitoring purpose, Epicollect mobile application was used, the justification of using Epicollect app is that firstly it is an open-source mobile application and that it allows configuration of the forms accordingly to user's requirements. A Project was created in Epicollect desktop application, forms and queries were designed in the desktop-based application accordingly Two groups were created accordingly (i) for Incident Reporting and (ii) For post Disaster Reporting/ Field data collection. Epicollect form builder allows for the grouping of the forms and question according to the subject requirements.

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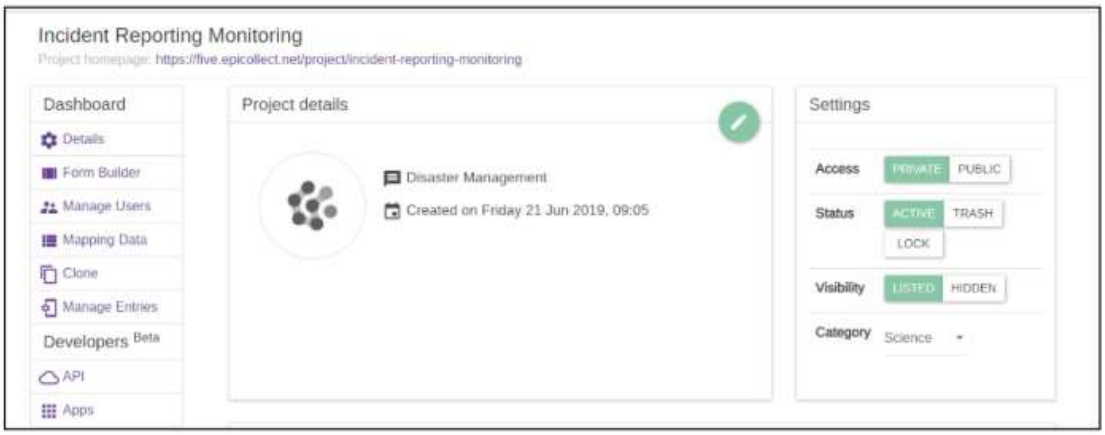
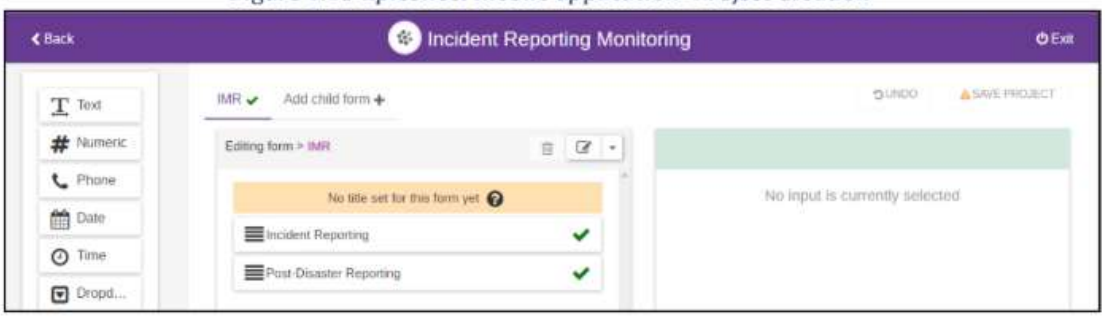
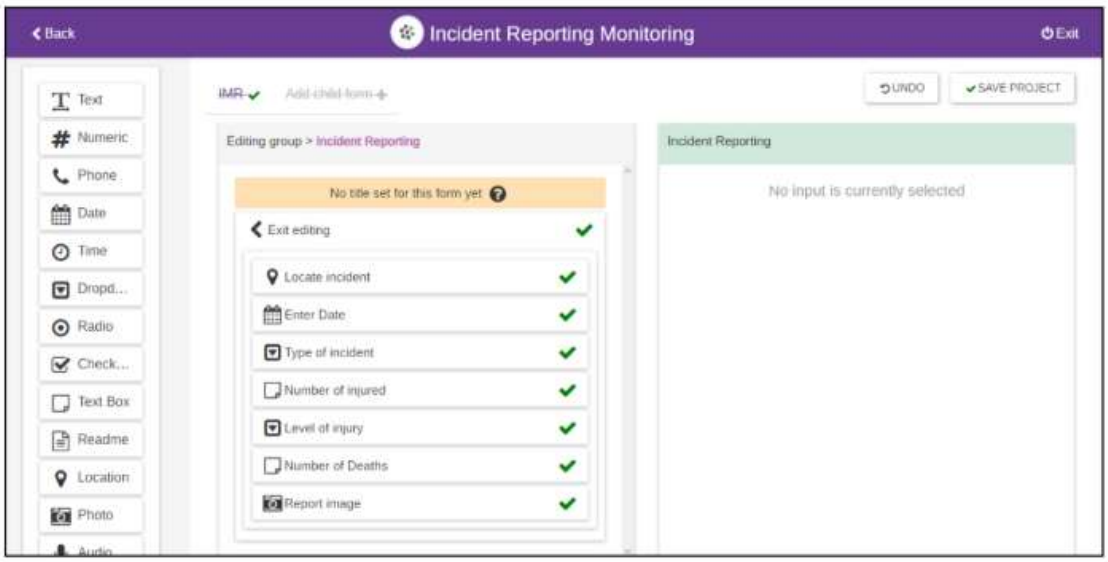


Figure 1.13 Epicollect mobile application- Project Creation





Field trials were conducted for randomly selected sites in the urban areas of Shillong; to achieve the desired results, Epicollect Mobile application was downloaded from the play store, and was installed in mobile phones. The system requirement of Epicollect is simple and it works on most of the new versions of mobile phones OS. The GPS location of the incidents was recorded on the application and uploaded as well. The entries were viewed on the dashboard and accordingly the data were imported into the GIS environment and simulated for the response accordingly.

This research study introduces the use of Geospatial Technology in the Disaster Management domain. It is seen that Geospatial Technology will revolutionize the planning aspects of every phase in disaster management particularly in preparedness, mitigation, and response cycle. Geospatial Technology enables risk managers, disaster planners to have a comprehensive idea of geographical area, city location etc., it empowers the planners to make quick and effective decisions to counter act any disaster incidents. The coverage analysis or the service area analysis in particular for the study area exhibits an important planning strategy, to help in improving the response and also in having a comprehensive view of the area that can be covered within the given response norms, this will also be helpful for the F&EMS department to accordingly manage the route and also the staffs.

The research study also observes that there are certain areas that are have small lanes which perhaps may be a accessibility problem for most of the fire tender vehicles, in this connection it is recommended that mobile fire tenders be used so that such incidents in such areas can be addressed accordingly. It is also suggested that the F&EMS department to use Geospatial technology in many of the planning. It is prerogative that the controlling authorities concerned should use GIS as a decision and planning tool for incident planning. The use of mobile application is also highly recommended since it is handy and easy to use. For effective reporting and timely response, it is recommended that crowd-sourcing method should be implemented. It is also expected that Shillong City will be growing and expanding as the population increases, therefore it is recommended to have a pre-defined plans of emergency planning using GIS for

expanding areas. For the IRT team and the respective teams it is recommended that they should be using mobile application for reporting as well as for monitoring purposes. Form the Service area analysis it is seen that certain areas of Mawlai are not completely covered within the response time, therefore it is recommended that perhaps another IRT zone may be placed accordingly to facilitate efficient response to the uncovered and expanding areas.

Shillong urban areas will be growing in the coming years, and it also expected that population will multiply accordingly; similar studies can be conducted with an advancement on certain areas such as incident response taking into the consideration the traffic conditions such as blockages, stoppage, U-turns, No entries etc. Spatial analysis on the accessibility of the response team, fire tenders to the areas was roads are small or low width. Mobile application as it is seen will be best fit for such programmes, therefore there is a huge avenue and rooms of development in this aspect, perhaps study on the use of mobile application can also be taken up with respect to instant field reporting and monitoring and linking the information into a public domain. It is envisaged that the controlling authorities should have a master control dashboard of incidents, therefore there are also room for the development of a state disaster spatial data infrastructure which will have information of the IRT teams' locations, disasters timeline, simulation, analysis and also action plans. A similar study on a detailed vulnerability analysis, population can also be taken up for the respective designated IRT zones can be taken up which can be integrated into a disaster spatial database infrastructure. Future studies on the detailed HRVA on the respective IRT zones can be taken up that perhaps may bring in an understanding the areas and the gaps to be addressed to prevent or reduce the impact of any impending disaster be it man-made or natural disasters. Studies on developing map materials for the incident managers and responders may also be taken up and such materials can help during field action work during disasters. As it is seen particularly for Shillong Urban area it is expanding with the years to come, therefore there is a need to study the expansion pattern on the lines of disaster risk reduction, which can give an understanding the possible vulnerabilities which can help in risk reduction strategies planning. With the expanding area there is also a need to study the placement of F&EMS stations and also the placement of IRT teams accordingly. Further studies on using UAV for incident response would also be fruitful in disaster risk reduction; perhaps the studies can be taken on detailed aspects of incident response planning.

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