Urban Fire Risk Assessment Using GIS: Case Study on Sharjah, UAE

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Abstract

In many cases researchers are faced with non-availability of data from some departments due to security or other reasons. Few proxies are available in that cases and one of them is the newspapers. Geographic locations of events reported in the newspapers are not accurate but can give the nearest landmarks and names of districts. Such type of data is sufficient for many applications where the intention is to show the general distribution and pattern rather than the actual locations. In this study, the researchers used Geographic Information Systems (GIS) technology for mapping 220 sampled fire incidents in Sharjah city, UAE. The incidents were extracted from the newspapers for 10 years (2002 to 2012). Network analyst tool is used to measure the emergency time response of the fire vehicles in the city and weighted overlay analysis is utilized to propose new suitable locations for fire stations.

Keywords: Newspapers data, Fire, GIS, Sharjah, UAE

Introduction

The last several years have witnessed a momentous change in the geographic dynamic of urban fire due to the rapid development and expansion of cities and industrial areas. More than 10,000 people have been evacuated from Chile's port city of Valparaiso to escape a moving fire that has killed at least 12 residents and destroyed hundreds of homes on Saturday12/4/2014 [1] . Governments are spending millions of dollars to protect citizens and the society from fire. Fire causes serious damages to people and properties and can cause permanent loss, so government and decision makers should concern and study all the factors to select the best locations for fire stations with the maximum coverage and minimum cost. One of the factors is the historical records of fire occurrences and telephone calls. Unfortunately, such type of data may not be available due to non-availability of historical fire incidences records or the concerned departments are reluctant to share their data as in this study. Therefore, newspapers can be a proxy. Newspapers hold huge geographic information such as country, city, town, village, and sometimes coordinate system such as latitude and longitude [2]. If the newspapers are available in digital form then search engines for unstructured data can help in automation of data extraction without reading the whole context and made it easy to visualize events in an earth projection with time stamp [3].Sometimes, historical archives of newspapers are not available in digital form, therefore, manual search may be needed. In UAE, there are main six local newspapers that can provide information about the fire incidences in space and time and the user can use GIS to geocode them for further analysis.

GIS is a powerful tool for planning, it offers understanding of the situations, and allows the user to create, edit, display and analyze locations from real world into the digital world. There are many studies conducted around the world that use GIS-based suitability modeling for the site selection and allocation of facilities in modern planning process [4]. However, till date, only a handful studies have investigated about the urban fire in UAE. Given the profound importance of the urban fire in social, political, and economic life, understanding the spread of it, is becoming a paramount importance.

GIS, mathematical, and network analysis were used to study fire in Kadiköy district in Turkey [5]. Their strategy was to choose optimum location by maximizing coverage and minimizing total cost. They used soil, hydrography, hospitals, shopping mall, roads, schools and cultural facilities as selection factors. Their criteria include calculating distances, reclassifying them, adding weighted overlays to define attractive locations and service areas. Tools from the network analyst were used for station coverage visualization.

GIS was used to assess fire fighter exposure and fire emergency management actions relative to values at risk. Critical infrastructure and building locations were identified from fire spread probability model in real-time [6].

A geospatial probabilistic model was developed that predicts fire growth and designed was supported for decision making on wildfires, the model used GIS, ignition point, time period, and both historic and forecast weather data [7]. The City of Scottsdale Fire Department produced maps to illustrate fire density calls, fire station locations, response areas, and areas within four minutes from fire stations, city facilities, and major landmarks to familiarize station personnel with the location of assets within the city [8]. A mathematical model for fire stations in Dubai was developed by [9]. They assessed and evaluated the distributions of fire stations and created criteria for setting new fire stations. The criteria included cost, travel time, distance, service areas, political, and water availability. In this research, some of their criteria (depending on data availability) are used and GIS is utilized to study the distribution of historical urban fire and choosing suitable new fire stations locations. A fire station is a long term investment in the safety of the community. In establishing fire emergency response database, emergency preparedness planning is an important issue that can impact people lives. If planned properly and implemented quickly, it can save hundreds or thousands of human lives and mitigate some of the economic losses in affected areas [10].

Objectives

While there are documented evidences of fire incidents increase in Sharjah, there is limited geographic analysis of the pattern. Therefore, there is a need to understand how fire distributed in space and time. Specifically, this study raises the following research questions:

- Are there any distinct patterns of fire occurrences in Sharjah?
- How might GIS analytical tools enhance the understanding of fire incidents in the city and citing new fire station locations?

To map the fire pattern, data were gathered from newspapers. Existing fire stations were evaluated by measuring coverage areas and driving time. Criteria and spatial overlay analysis were carried out for selecting new suitable areas for fire stations in the city putting into account fire incidents happened, response time, fire station coverage area, and network analysis.

Study Area

Sharjah emirate is the third biggest emirate in UAE in terms of area after Abu Dhabi and Dubai. It has a total area of 2,590 square kilometers. The emirate is famous for its cultural dedication. In 1998 Sharjah named as the 'Cultural Capital of the Arab world' by UNESCO. The emirate host many historical places including forts, museums, ancient houses, old markets (souk) which show the care to the cultural development under the guidance of His Highness Sheikh Sultan Bin Mohammed Al Qassimi.

Economically, the emirate in the past traded with pearl and fishing. After UAE union, plenty amount of natural gas was found in here which increased the revenue and consequently improved quality of life. Recently, the modern industries in the emirate have diversified themselves to encourage national products and increase economic level.

Sharjah is famous for its green spaces which contribute to environmental sustainability and making the city looks more pleasant, attractive, and beautiful. In education sector, Sharjah University City was built in 1997,which includes many academic institutes such as: University of Sharjah, Higher Colleges of Technology, American University of Sharjah, Police Academy, Skyline University, and University Hospital.

Recently, the emirate is giving more attention to tourism. This study focused on the urbanized Sharjah city, which is the capital of the emirate (Central Latitude 25.354^{o} N, Longitude 55.3925^{o} E) (Figure 1). The city has a population of 793,573 as in 2005 [11].

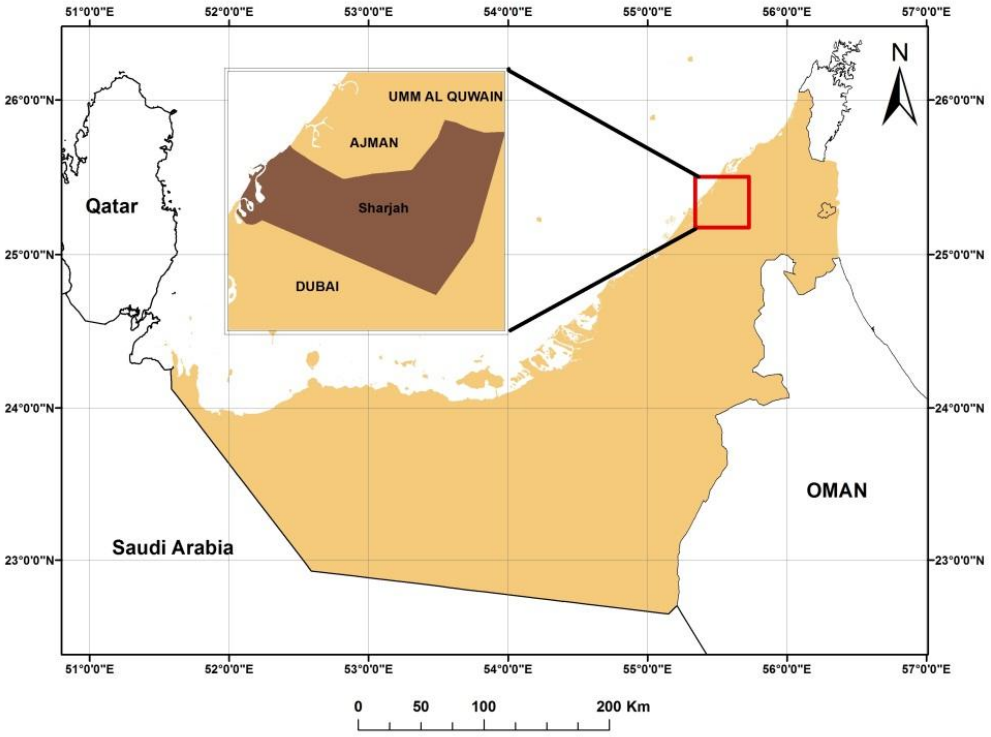

Figure 1. Study Area

Methodology

Different data layers were digitized and prepared in GIS environment. High resolution satellite image, IKONOS 2010 was acquired and transport layer was digitized on that. Fire stations, hospitals, police stations were acquired from Google Earth, Wikimapia and Sharjah explorer by digitization. The main source of the fire incidences information was local newspapers for the period of 2002-2012. The other non-spatial data like households and district information was taken from Sharjah Water and Electricity Authority as well as Sharjah Directorate of Town Planning and Survey.

Reports in the media showed that there is an increase in the number of fire incidences in Sharjah and as a result, this research is designed with the intention to utilize GIS for community services. Unfortunately, and due to some security reasons the researchers were not able to get data about fire incidents from the concerned departments. The researchers pinpointed newspapers as a proxy source that may help in getting general idea about the fire pattern in the city. Reported fire incidents were gathered from six local newspapers (Gulf News, Al Khaleej, Al Emarat Elyoum, Al Bayan, AlIttihad, and Al Khaleej Times) for the period 2002-2012. In addition to that, blogs, journals, books, and Internet sources were used. Reports from these sources provide important information such as: nearest land mark, coordinates, date of the incidents, time, type, injuries, fatalities and total loss. Each report about fire incident is geo-coded in ArcGIS as point to the nearest district or landmark. Using GIS analytical tools various maps were produced indicating the spatial pattern of fire incidents in the city.

The Network analysis is a system of interconnected elements which are lines (edges) and points (junctions). It allows solving network problems, such as finding the best route in the city, finding the closest emergency vehicle or facility, identifying a service area around a location, or choosing the best facilities to open or close [12]. To find suitable locations for new fire stations, criteria is set first and weighted overlaying and Network analysis tools were used. Defining criteria is the most essential part to frame out the results by limiting factors and constrains to achieve potentials. The criteria used in this study were based on previous experience around the world (Table 1). Although some factors such as water availability, hazardous materials locations, floor plans, and hydrant locations and capacity are important in selecting new location for fire station [13], the authors faced difficulty in obtaining such data.

The Analytical Hierarchy Process (AHP) approach integrated with GIS was used. This is because there are many layers and different hierarchal attributes such as highway and arterial roads. A highway will gain more weight than a local road because of its importance. Weighted overlay allows setting of criteria and giving them weights based on priorities. The Weighted Overlay tool applies one of the most used approaches for overlay analysis to solve multi-criteria problems such as site selection and suitability models. This tool helped to reclassify values in the input raster into scale of suitability preference. For example, from 1 to 10, multiplies the cell values of each input raster by the raster's weight of importance, and then finally it adds the resulting cell values together to final raster output [14]. In order to perform analysis some data need to be prepared, created, changed, reformatted and reclassified. All spatial data were projected to the spatial reference of Sharjah city (WGS84, zone 40 North) (Table 2).

Table 1. Criteria used for locating fire station

No.	Factor	Criteria	Source
1	Roads	• To be within one Km from highway • To be within 500 meter from arterial road	[18]
2	Hospital with Emergency Rooms	• To be near from	[5]
3	Police Stations and Quick Intervention	• Within 3 kilometers	Suggested by local fire-fighting experts
4	Existing Fire Stations	• To be away from existing fire station from 1-9 Km	[15]
5	Households Density (Population)	• High population is favored	[16]
6	Incidents (gathered from newspapers)	• Near areas with high fire occurrences	Suggested by the authors

Table 2. Data used

Data Layer/s	Source
Districts, Satellite Image (IKONOS 2010)	Sharjah Directorate of Town Planning and Survey
Fire Incidents	Newspapers and Geocoding
Fire Stations, Hospitals, Police Stations	Digitized by the authors from Google Earth, Wikimapia, and Sharjah Explorer
Households 2011	Sharjah Water and Electricity Authority
Road Centerline	Digitized by the authors

The spatial data were linked to attribute data. ArcGIS was used to digitize roads from satellite images. Attribute table was filled with important fields like length, speed, and time. Network dataset was created and edges and junctions were refined to support the network analysis. All data were converted to raster format for modeling process. The raster cell values were then reclassified in a scale range from 1 to 7 and all factors (parameters) were assigned percentage weights (Table 1). The weight is set in consultation with local experts in fire-fighting and made user friendly for possible changes.

Results

The researcher gathered 220 incidents from the newspapers. The process of extracting these events included data mining from six newspapers for a period of ten years and this is equivalent to (6 newspapers X 10 years X 12 months X 30 days = 21600). The process is time-consuming, but reflects the importance of the newspapers as a source of data. The use of search engines is not possible because some newspapers are not in digital form. ArcGIS was used to create a point feature that has important attribute information about each individual fire incident in Sharjah city (Figure 2). About 60% of fire incidents were found occurred in warehouses and

structures such as buildings, apartments, and villas. 25% of the incidents were at industrial and commercial areas such as shops, factories, workshops, malls, and restaurants. 10% were vehicle fires due to car accidents, collisions, crime acts, and burned cars. 5% of fires happened in scarp yards and landfills. The majority of the fire incidents happened during the month of May in the period investigated and this may be linked to high temperature during summer at which the usage of air conditions and the melting of electric wires are high. This can be supported by the fact that the incidents decreased in winter. Sharjah city faced extreme fires in the recent years in comparison to other cities in UAE (Table 3). This happened for many reasons: weak safety regulations in the past, industrial clustered zones, economic growth in the city, ignorance of safety procedures, and violated facilities which makes the incidents extreme, devastating, and cost a lot of money. In the last few years the city stepped up its efforts for fire prevention by developing new emergency management strategies, hiring additional qualified staff of inspectors, adopting fire fighters, and creating training programs for local Emirati firefighters and quick intervention units.

Table3. Fire incidents in Sharjah Emirate

Year	Number of fire incidents in UAE	Number of fire incidents in Sharjah	% Fireincidents in Sharjah
2002	2,158	426	20
2003	2212	-	-
2004	2075	401	19
2005	2298	466	20
2006	2588	590	23
2007	2557	488	19
2008	2602	218	8
2009	2285	460	20
2010	4980	-	-
2011	4347	1520	35
2012	2827	760	27

The UAE Ministry of Interior made strict safety standards to make sure that all the facilities in the UAE are abiding by safety regulations such as: installing fire detection systems, defining the evacuation plans/routes and exits, providing fire equipment in the facilities, removal or safe storage of dangerous materials, and controlling building designs and materials. The Ministry created laws, policies and fines starting from 500 Dirhams up to millions of Dirhams. On the other hand, the Ministry and the media played a great role in raising public awareness about fire prevention and evacuation plans among schools, universities, governmental departments, shopping malls, industrial facilities, etc.

Sharjah city is currently served by five fire stations and these stations are not meeting the urban expansion of the city (Figure 2). Therefore, there is a need to find suitable new locations for fire stations. Network analysis and weighted overlay method were used to aid in citing the new locations. A network service area is imaginary polygon that displays all accessible areas with known impedance. For example ten-minute service area for a point on a network includes all the streets that can be reached within ten minutes from that point. Service area helped to evaluate accessibility also show how accessibility varies with impedance. This study loaded the fire stations as facilities and then determined the impedance either as distance or time (Figure 3).

The time used in this study is based on international standard of response time and is adopted from the National Fire Protection Association (NFPA) [17], where in urban areas it is from 5 to 8 minutes while in rural areas can be up to 10 minutes [18]. Analysis of the existing fire stations response time showed that large portion of the city is beyond the eight minutes response time (Table 4). These areas included residential areas, Sharjah University City, Sharjah Airport and under construction suburbs. By applying the criteria (Table 1), response time, and weighted overlay method which resulted in a final Like-scale map that showed potential sites generated (Figure 4). Based on this, six new fire stations were proposed to serve the city. The response time and service area covered by the proposed stations will improve the civil defense performance related to fire rescue in Sharjah city.

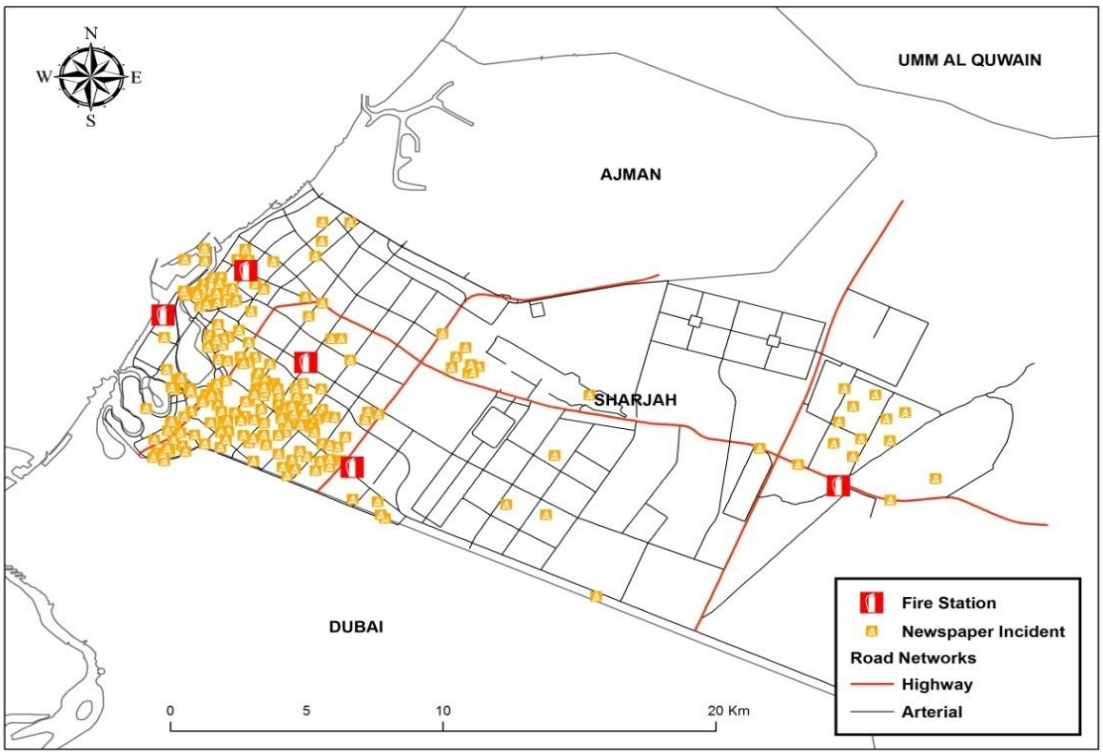

Figure 2. Geo-Coding of fire incidents gathered from the Newspapers

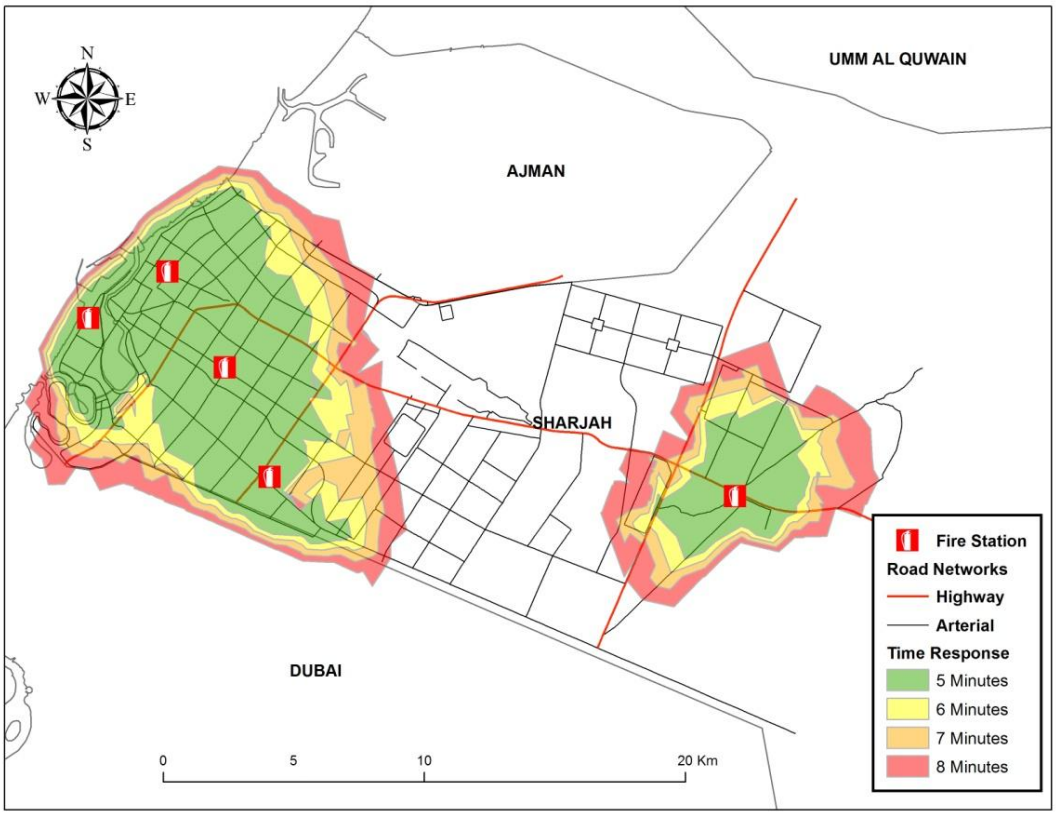

Figure 3. Response time of existing fire stations

Table 4. Comparison between Existing and Proposed Fire Stations in Sharjah City

Existing	Response time (minutes)	4	6	8
	Coverage percent (%)	21	36	53
Proposed	Response time (minutes)	4	6	8
	Coverage percent (%)	50	75	89

Figure 4. Suitability map for fire stations

Conclusion and Recommendations

GIS technology was used in mapping incidents from newspapers and locating new fire stations in Sharjah city, UAE. The newspapers as a proxy source of data are found very useful in case of non-availability of real data. The spatial pattern of the ten years (2002-2012) fire incidents reported in newspapers showed that the majority (60%) of the incidents in the city clustered around the warehouses and structures. Temporal analysis showed that the highest number of fire incidents occurred in 2011 and 2012 and generally seasonal variations is higher in summer. This is may be due to the heavy use of cooling systems and wearing of electric connections during summer. Other reasons may include illegal and improper electric connections and narrow spaces between stores especially in the industrial areas. Analysis showed that Sharjah city is not well-covered by fire stations. This lack is mainly due to urban development and expansion of the city in the last few years. Multi-criteria analysis resulted in proposing six new fire stations that will cover 75% of the city within 6-minutes response time. This will improve the current fire stations that covered only 36% of the city for the same response time. GIS helps in visualizing fire incidents in the whole city and as a result it assists in figuring out where there is lack of coverage and response time. It is recommend that fire departments provide access to their data and fire calls so a value can be added to the historical data and pattern and causes can be revealed. This will help in planning and decision

making. It is suggested that newspapers events be recorded with GPS locations in order to help in accurate geo-coding of events.

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