Status of Spatial Analysis for Urban Emergency Management

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Abstract This paper provides multidisciplinary coverage for the use of geospatial information systems for urban emergency management with emphasis on selected common types of emergencies. The paper presents selected urban emergencies that are globally known and pose a high risk for considerable parts of the world. The review addresses the application issues of how spatial analysis can be utilized in addressing emergency management issues by defining its usability and limitations in dealing with the questions of vulnerability and risk assessment as well as the state of the art of approaches that can be used for risk mapping and visualization. The objective is to provide conceptual coverage to timely solutions for emergency preparedness and response. The paper emphasized that among issues that may face accurate utilization of spatial analysis, is the accuracy of data and time of processing, as well as shared coordination among stakeholders. This research concludes that a challenge to effective risk reduction is providing disaster managers with access to data and approaches that may help them in analyzing, assessing, and mapping risk models.

Keywords GIS · Emergency management · Urban centers · Spatial analysis · Environmental modeling

1 Introduction

The applications of GIS in Disaster Management are increasingly becoming an integral element of disaster and emergency management activities globally. The time factor is very critical in emergency management operations, and it demands decision-makers to make swift decisions under time pressure. The spatial nature of critical information makes spatial data to be very crucial in decision-making

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operations, for disaster management. It is imperative for decision-makers to access the right data at the right time presented inaccurate models to allow them to respond, plan, or mitigate disasters. The time versatile of emergency do not permit decision-makers to gather the necessary information. Thus, most of the time, pre-planned emergency management scenarios are used (Becerra-Fernandez et al. 2008). GIS Technology can fill the gap of visualization and analysis of what-if scenarios. This allows emergency managers to have access to adequate information stored in spatial databases and presented in a computer-generated maps or interactive models (Miura et al. 2007). GIS can be very helpful to make a well-thought plan for emergency response operations, and it can address the general public. It is a training, very useful tool in emergency management table top exercises, and an integral part of Emergency Operations Centers (EOC) (ESRI 1999). GIS provides a mechanism for visualization and modeling of critical information at a single or multiple locations during an emergency (ESRI 1999). This provides a user-driven framework, which encompasses the phases of disaster management, to support the process of enhanced decision-making and increases the degree of involvement of each team of personnel associated activities and analytical procedures (Smirnov et al. 2006).

When discussing emergency management, mostly we are addressing the issues of preparedness. This is a fundamental component of disaster and emergency management and can play a vital role if emergency response actions become essential. The usefulness of GIS as a decision-making tool in helping emergency management decision-makers falls in the following:

1. Assessing risks
2. Evaluating threats
3. Tracking what-if scenarios
4. Maintaining situational awareness
5. Documenting disparity
6. Ensuring the focused allocation of resources
7. Alerting and notifying communities
8. Minimizing the disruption caused by necessary interventions during the response phase. Figure 1 shows the elements of GIS in Urban Emergency Management.

The factors above are particularly of importance from spatial analysis perspective (Saadatseresht et al. 2009) In an emergency situation, spatial analysis can be run for evacuation, to relocate public from a hazardous region to a safer region, and it usually times critical activity (Anjum et al. 2011). It is necessary to utilize the functionality of spatial analysis tools to formulate evacuation strategies to have a good response in an emergency state. A central challenge for using spatial analysis in developing an evacuation plan is in determining the disruption of services and in the distribution of evacuees into the safe areas. Precisely, supporting the decision of where and from which road each evacuee should go is a key functionality of spatial analysis (Cova and Church 1997). To effectively achieve the aim of spatial analysis

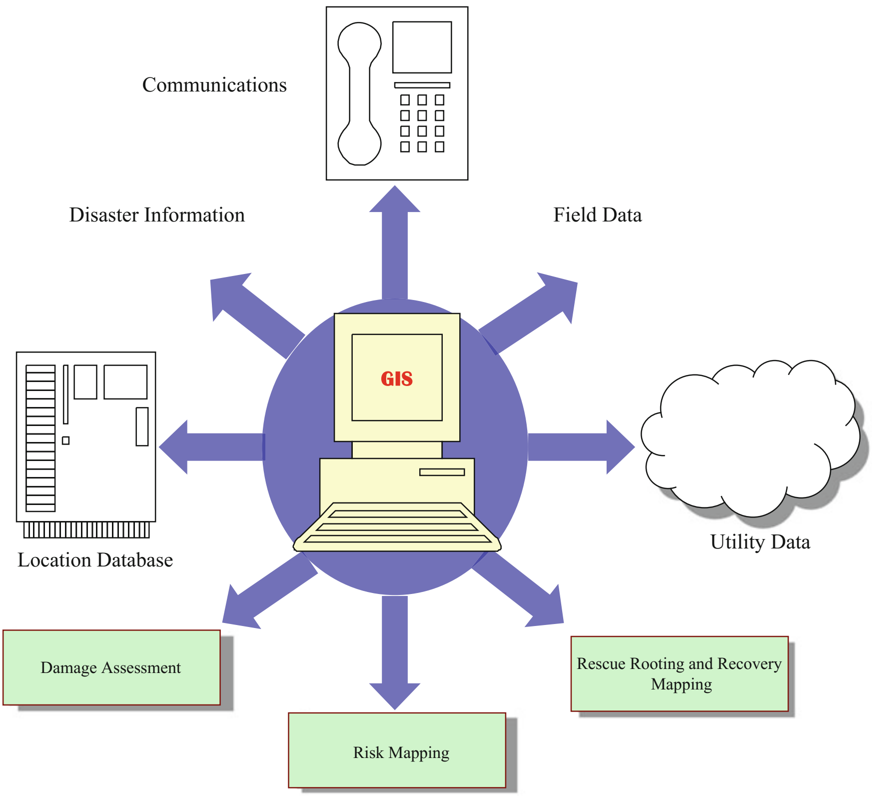

Fig. 1 Various GIS emergency management elements

in emergency management operations, several objectives are brought into consideration and satisfied simultaneously through this paper, nevertheless, these impartial roles may repeatedly encounter with each other. These goals are: (A) How a decision-maker can utilize the functionality of spatial analysis to make critical decisions during emergencies? (B) What are essential functions that spatial analysis can help with during emergency management cycle in the ten selected emergency types? (C) How emergency managers could better implement spatial analysis operations as part of their day-to-day operations?

Effective disaster management calls for involving multimodal decision support capabilities, that involves groups at all levels of forecasting and response, in addition to collective mitigation efforts that address the origin of vulnerability (Morrow 1999). The vulnerability of community is directly attributed to the socioeconomic factors that affect the community, i.e., it directly impacted, whether increased or decreased as a result of the socioeconomic well-being of a community, as it relates to their day-to-day activities (ESRI 1999). Emergency planners, policy-makers, risk analysts, and first responders usually try to classify and locate high-risk sectors using the tool known as Community Vulnerability Maps, incorporating this data into GIS systems where practicable, and for this, spatial analysis is crucial (Kumar 2013).

2 Overview of Urban Emergency Situations

This section provides a critical review on the usability of spatial analysis in selected urban emergency situations. It provides an in-depth coverage of the work cited in this regard with emphasis on enhanced decision-making process. The scope of the coverage will focus on the most notable advancements in the use of spatial analysis techniques for emergency management in urban environments.

2.1 Earthquakes and Humanitarian Coordination for Internally Displaced Persons (IDP)

The literature review on GIS and humanitarian coordination began by first examining the different ways in which GIS can be applied humanitarian coordination. Despite the fact that GIS has been predominately seen, inside of the emergency management community, as a cartographic apparatus, a way to deal with critical thinking, or an electronic navigational guide, this does not satisfactorily portray the state-of-the-art use of GIS in humanitarian assistance (Currion 2006). There are many potential applications of GIS for humanitarian aid. For example, the application of optimization, which is the use of advanced GIS algorithms to solve a design problem, can be used to find suitable locations for evacuation. For instance, a buffer analysis, which is a GIS transformation tool, can be used to estimate vulnerability based on proximity to different hazards.

In 2005, a Complex Humanitarian Emergencies Study (Verjee 2005) drew from case studies and patterns in technological advancement to layout the potential GIS applications for humanitarian emergencies, which were:

1. Mapping and Cartography (Land use Mapping, Infrastructure Mapping, demographic Mapping, Logistics, and Sustainability).
2. Outreach, Media, and Communications (Public information, Reporting, Program Assessment, News coverage).
3. Modeling and Simulation for Disaster Scenarios (rehearsal, Data and information flow patterns, planning for contingencies).
4. Environmental Management and Planning (Yield cultivation, resources assessment, and planning).
5. Risk and Hazard Management (seismic analysis, site location planning, and water-level measurement and mitigation).

6. Vulnerability Analysis and Assessment (Early warning systems for drought, desertification and famine, Epidemics modeling, and Tsunami Planning).
7. Risk Reduction ("hot spots" identification and mitigation programming).
8. Response Policies and Organizational Management (management, planning, and training) (Verjee 2005).

Table 1 is showing the application of GIS in this situation. Although there are numerous applications of spatial analysis as a GIS technique, they all share the ultimate objective, which is to make the most of the situational awareness of all specialists participating so that main concerns can be recognized and then jointly attained.

Table 1 Applications of spatial analysis in humanitarian coordination modified Abdalla (2016)

GIS application	Description of application	Tools	Application examples
Queries and measurements			
Queries	Does not change the database or produce new data but reveals information	Scatter plots, residuals, and structured/standard query language	To determine water sources near potential IDP settlements
Measurements	Numerical interrogations of GIS, which make an analysis of spatial data	Makeup distance, area, length, shape, aspect of spatial data	To estimate the total area needed to set up IDP settlements To determine the length between food distribution points
Transformations			
Transformations	Creates new data from existing data	Buffer analysis	Used to comply with Sphere humanitarian standards. For example, can be used to ensure that toilets are within 50 m of shelters
Spatial interpolation	A transformation analysis method used for intelligently guessing the value of the discreet object	Thiessen polygons, inverse-distance weighting, and kriging	To predict infection rates in IDP settlements To estimate flow rates of well to large aquifer
Optimization			
Point optimization	Determines optimal locations amongst nodes of a network		To select location for critical infrastructure such as food storage areas
Route optimization	Determines optimal routes amongst nodes of a network		To access accessibility of road networks to potential IDP settlements

(continued)

Table 1 (continued)

GIS application	Description of application	Tools	Application examples
Path optimization	Solves are routing problems by minimizing friction value and does not require a network		To determine paths for utility infrastructure for IDP settlements
Analysis			
Geostatistical analysis	Used to measure geographic distributions, identify pattern and clusters, and analyze geographic relationships		To determine historical rainfall averages over a particular area, which could be applied to potential IDP locations
Centroid analysis	Used to identify trends over various phenomena in a set period		To determine trends in infectious diseases and household income levels within IDP settlements
Pattern analysis	Used to identify distribution points. Can determine whether the point is random, clustered, or dispersed		To identify links between water wells and infectious diseases
Relationship analysis	Used to determine the relationship between various geographic phenomena		To assist in increasing the efficiency of daily operation of IDP settlements
Geovisualization	Simple three dimensions (3D) and high-resolution mapping are used globally to access a variety of information	Google Earth, ESRI's ArcExplorer, and Microsoft Virtual Earth	Allows a layperson to understand the unfolding of humanitarian emergency

A recent analysis by Eveleigh et al. (2007) acknowledges, in the context humanitarian emergencies "GIS technology is struggling with how to address complex problems that require the modeling of dynamic phenomena, feature behavior, and process information". Eveleigh et al. (2007) conclude that there is a strong potential for GIS-based analysis models to provide the breakthrough needed to address the complex nature of humanitarian emergencies. Figure 2 is showing some of the impact of earthquake in populated areas.

The (Bally et al. 2005) 'Indicated that Remote Sensing and Humanitarian Aid provide a life-saving combination'. The use of remote sensing and GIS allowed 200,000 IDPS to be relocated to longer term settlements that had renewable water reserves as well as development potential regarding sanitation, agriculture, and even hydroelectricity (Bally et al. 2005). Another influential GIS application used to support humanitarian emergencies was The Global Connection Project, which involved Carnegie Mellon University, NASA, Google, and National Geographic, contributing to the relief planning for the October 8, 2005, South Asian earthquake.

Fig. 2 IDP settlement during Nepal earthquake of 2015, photo credit OCHA

In this project, GIS was used to acquire and deliver high-resolution imagery from Digital Globe's Quickbird.

2.2 Urban Fire

To accurately portray a wildfire situation, spatial analysis can be used to identify high-risk fire zones and establish buffer areas (ESRI 1999). In addition to the identification of high-risk areas, spatial analysis can be combined with statistical analysis as a verification method for estimation of the concentration of population in different zones as well as for determining damage assessment models for the region (Goodchild 2006). Pew and Larsen (2001) provided guidance by identifying potential layers that can be used for urban fire detection. Our first step is to use latitude and longitude coordinates to plot the various fires (based upon a choice of lightning or human-ignited fires) within a given period. Fire data may appear to be located within bodies of water, but this is simply a cause of rounding error and buffer zones provide some leeway for such error. The process of linking attributes data and present four analytical methods for wildfire. Although they focus specifically on human-caused fire disasters, in suggesting the four recommended options for complete urban fire analysis:

1. the area affected
2. temporal variation
3. spatial variation
4. probability.

The urban fire hazard is difficult to prevent. However, through the identification of the high-risk zones, the frequency of fire can be minimized. This research indicates that GIS when combined with satellite imagery can identify high-risk areas within a given proximity and grade the level of sensitivity to fire about surrounding areas. Jaiswal et al. (2002) discuss the use of ArcGIS for this concept, asserting that the combination of topographic infrastructure information and remote sensing for vegetation mapping can create an accurate estimation of high-risk fire areas used for mitigation and response purposes. In Jaiswal et al. (2002) layers of vegetation types, slope, proximity to settlements, and distance from roads were created about high-risk fire areas (Jaiswal et al. 2002). After plotting this data, buffer zones of 1000, 2000, 3000, and 4000 m surrounding the high-risk areas were plotted to project the different levels of danger (Jaiswal et al. 2002).

Although Jaiswal et al. (2002) looked specifically at the case of India, this concept of GIS combined with satellite imagery for identification of high-risk areas proved the effectiveness of GIS as a tool for disaster management. If GIS can be used to map high-risk zones with a buffer area, which provides baseline understanding that GIS could also be used to demonstrate damage assessment models using ArcGIS.

Pradhan et al. (2007) used GIS analysis to determine fire susceptibility, using a "vector-type spatial database" with GIS and combined with topographic data, fuel data, base survey points, and maps. This allowed for calculating factors, which were then converted to a raster grid, identifying 112 cells within the fire occurrences (Pradhan et al. 2007). A frequency-based ratio approach was adopted to define the "relationships between hotspot locations and the factors in the study area" (Pradhan et al. 2007). The difficulties, however, were in processing "a significant amount of data" (Pradhan et al. 2007). The conclusion drawn from Pradhan et al. (2007) regarding the use of such projections for mitigation purposes was of particular interest. In predicting fire susceptibility when using frequency analysis, the authors recommend using the results with caution. The authors recommend that their analysis be used primarily during fire situations, which suggests mapping fire-affected areas rather than leading toward the mitigation portion of fire disaster management.

2.3 Terrorists Attacks

Kwan and Lee (2005) displayed that terrorist attacks at the World Trade Center (WTC) in New York City and the Pentagon on September 11, 2001, have not just influenced multilevel structures in urban ranges additionally affected by their quick surroundings at the road level in ways that impressively decreased the velocity of crisis reaction. The capability of utilizing ongoing 3D GIS for the advancement and execution of GIS-based clever crisis reaction frameworks (GIERS) was analyzed. The point was at encouraging snappy crisis reaction to terrorist assaults on multi-level structures (e.g., multistorey office structures). A framework engineering and a system information display that coordinates the ground transportation framework with the interior courses inside multilevel structures into a safe 3D GIS was inspected. Issues of utilizing versatile representation stages were additionally talked about particularly the requirement for the remote and portable arrangement. Key choice bolster functionalities of GIERS were additionally investigated with specific reference to the use of system-based most limited way calculations. A test usage of a coordinated 3D system information model utilizing a GIS database for a close study range was displayed by Kwan and Lee (2005). The study shows that response delay within multilevel structures can be much longer than delays incurred on the ground transportation system, have the potential for considerably reducing these delays.

Johnson (2003) indicated that in times of emergency, the emergency management decision-makers have the essential obligation regarding rapidly and effectively dealing with any situation that may happen. An altered GIS application was produced empowering a fleeting-based investigation of a disaster event coordinated with the centralization of populaces identified precisely to the room level. The GIS Emergency Management System (GEMS) application is an intelligent framework to be used in the Emergency Operation Center to boost the bearing of the reaction. If a disaster has to happen, the mediation and recuperation endeavors could be at first centered on the most basic regions with the biggest concentration of individuals.

2.4 Infrastructure Failure

Cova and Church (1997) presented a technique for deliberately distinguishing neighborhoods that may confront transportation challenges during the evacuation. A characterization of this nature offers an interesting way to deal with evaluating group helplessness in locales subject to quick moving risks of indeterminate spatial effect (e.g., dangerous spills on roadways). A heuristic calculation is depicted which is fit for delivering productive, high-quality solution for this model in a GIS setting, as it was connected to a study area.

A new computerized risk management system for use by personnel who are not risk experts may reduce the probability and seriousness of accidents (Camps 1993).

The system, which was created is appropriate for use in oil, gas, or chemical processing sites. It incorporates mathematical models, calculation tools for accident simulation, and a database that includes accident scenarios. It can also be used in an emergency situation to determine preferred ways to find external assistance.

2.5 Flood Scenarios

Correia et al. (1998) showed that GIS has been perceived as an effective intends to coordinate and examine information from different sources with regard to far-reaching floodplain administration. As a component of this worldwide way to deal with floodplain administration, it is vital to have the capacity to foresee the results of various situations in regard to overflowed territories and related danger. Hydrologic and water-powered displaying assume a fundamental part, and there is much to pick up in consolidating these demonstrating abilities in GIS. Johnson (2003) presents results in view of the utilization of Intergraph GIS combined with IDRISI GIS. Utilizing these two frameworks generously expanded the adaptability of utilizing GIS as an instrument for surge concentrates on. As the hydrodynamic reproduction is straightforwardly consolidated with a GIS, the outcomes can be effortlessly handled as neighborhood immersion profundities for spatial danger dissects.

The role of GIS in flood emergency management was examined by Cova (1999), through the viewpoint of complete crisis administration (CEM) and its four stages: moderation, readiness, reaction, and recuperation. In the wake of a calamity, GIS is getting to be necessary for supporting harm appraisal, modifying, and state-funded training. The part of GIS in surge crisis administration was inspected by Cova (1999), according to the analysis of far-reaching crisis administration (CEM) and its four stages: alleviation, readiness, reaction, and recuperation. In the wake of a catastrophe, GIS is getting to be necessary for supporting harm appraisal, reconstructing, and government-funded instruction. Abbas et al. (2009) proposed a GIS-construct study on the improvement of surge displaying and representation for Allahabad Sadar Sub-District (India) be exhibited. This incorporates the outline, the procedure/approach that intended to investigate the degree for spatial examination application for catastrophe administration. The surge-inclined zones have been distinguished, and their positions are checked, where the GIS usefulness has been abused to get the spatial data for the successful catastrophe administration for surge-influenced ranges. The created approach has helped in distinguishing issues that may enhance the present practices of debacle administration process. The methodology gives an appropriate and fast basic leadership instrument for quick reaction to crises if utilized viable, which thusly would help in minimizing death toll and property. Al-Sabhan et al. (2003) proposed a GIS-construct study in light of the improvement of surge demonstrating and representation for Allahabad Sadar Sub-District (India) be introduced. This incorporated the configuration, analyzed the present status of ongoing hydrological models utilized for surge now throwing and danger alleviation, and showed how electronic frameworks can conquer a portion of the impediments of existing frameworks. While hydrological imaginative and vigorous models are accessible, they are ineffectively suited to the constant application and are regularly not very much incorporated with spatial datasets, for example, GIS. The researched framework may need adaptability, adaptability, and openness by a scope of end clients; in any case, it gives frontline answer for compelling basic leadership. The framework takes into consideration intelligent and aggregate preparing of continuous precipitation information from a remote observing system. A spatially appropriated GIS-based model is incorporated by this approaching information, approximating ongoing to create information on catchment hydrology and overflow.

Buchele et al. (2006) presented a modern approach for integrated flood risk assessment. Figure 3 provides a view on flood modeling and simulation technologies. In light of the setting of a more relative examination of various surge hazard evaluation models, for peril and hazard mapping, amid amazing circumstances. The adequacy of synchronous and organized departure procedures utilizing was examined by Chen and Zhan (2008) using agent-based simulation. The study utilized an operator-based strategy to model movement streams at the level of individual vehicles and to research the aggregate practices of emptying vehicles. Reenactment results show that no clearing technique can be considered as the best system crosswise over various street system structures, and the execution of the procedures relies on upon both street system structure and populace thickness. It

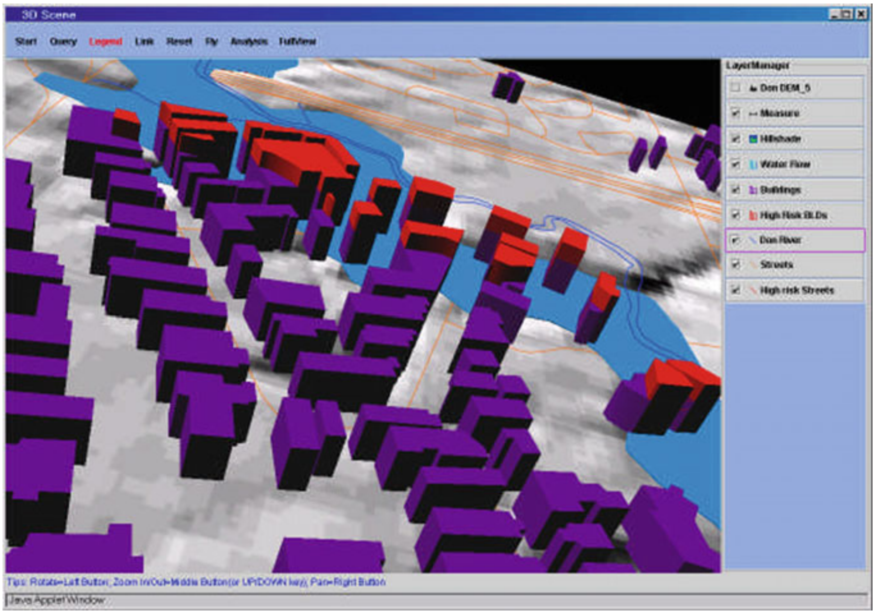

Fig. 3 Simulation of flood impact on urban center, after (Abdalla and Niall 2009)

has additionally highlighted that the populace thickness in the influenced range is high to be transported on the whole by the street system. De Silva (2000) introduced a model spatial choice emotionally supportive network (SDSS) which was expected for plausibility making courses of action for calamity departure which joins reaction operations with spatial data taking care of and representation limits of a GIS. It interfaces together the geospatial part with the spatial examination segment given by the GIS, with a modernization model proposed to mirror the stream of a clearing procedure in the inconspicuous component. The point has been to plot an SDSS, so that gives an instinctive clearing recreation framework with a component outline that mulls over experimentation with courses of action by giving speedy departure from the reenactment. The thought is that calamity administrators will have the ability to use the SDSS to attempt diverse things with crisis departure courses of action; to get prepared for different potential outcomes.

Moreri et al. (2008) proposed a way to deal with making an electronic Geographic Information Systems (WebGIS) application, which would bolster individuals living in surge fields, who may at one point be defenseless because of their nearness to the stream and the sufficiency of the flooding. The principle result is an electronic GIS framework that gives suitable data to the applicable power and overall population, quickly and for simplicity of presentation to take into account point-by-point understanding. Experienced powers, for this situation, may incorporate surge administrators, surge cautioning specialists, proficient accomplices, and crisis administrations. The simple way to utilize an interface that was produced permit non-GIS specialists, also to be in a position to intelligently see and investigate, and also inquiry the database, to choose distinctive information variables and to see maps at a few levels of the subtle element. Zerger and Wealands (2004) demonstrated that spatially fast hydrodynamic surge models can expect an imperative part in typical peril hazard lessening. A key part of these models that make them appropriate for danger demonstrating is the ability to give time game plan inundation information about the onset, length, and setting off to a crisis circumstance. Such information can be the premise for area use arranging, for mapping, for clearing steering, and for finding reasonable emergency administration to give a few illustrations risk reactions. The examination reasons that powerful calamity hazard decrease is in giving catastrophe supervisors access to model results in a sorted out and versatile structure that licenses results of different danger circumstances to be overviewed and mapped. To address these restrictions, a structure has been made that interfaces business financial databases administration structure with a GIS-based choice emotionally supportive network.

2.6 Pandemic Outbreaks

One of the key applications of GIS in pandemic modeling and simulation is to facilitate access to health services by residents who live in and around the security area of a mass gathering event. This will be done by designing an application GIS to assist healthcare authorities in the planning and implementation of the emergency medical response with a focus on optimizing service to vulnerable populations, including (Sharma et al. 2008):

1. Ensuring uninterrupted routine healthcare services during periods of limited access to a security area;
2. Ensuring evacuation procedures for medical emergencies that are nonevent related;
3. Ensuring timely evacuation and health care in the event of a mass casualty incident.

This can be achieved by designing a mapping tool to identify vulnerable populations within the impacted area in case of a pending natural or technological disaster such as a heat wave or power outage (Becerra-Fernandez et al. 2008). GIS will identify access and evacuation routes for impending or in-progress emergency or disaster events. Destinations may include shelters, schools, or other predefined sites outside of the security zone (Chandana et al. 2007). The key support of GIS in a pandemic outbreak can be through providing an appreciation of the use of GIS in addressing public health issues, specifically, to define its uses and limitations in dealing with the questions of defining vulnerable populations. GIS supports possible interventions such as (Daley et al. 2015):

1. Choosing sites for community influenza clinics and vaccination stations
2. Monitoring and evaluating impact of immunization clinics and stations
3. Canceling public events, meetings, and gatherings
4. Closing schools, public places, and office buildings
5. Restricting use of public transportation systems
6. Identifying potential group quarantine and isolation facilities
7. Enforcing community or personal quarantines.

2.7 Extreme Heat Attacks

Disasters and health impacts, in particular on vulnerable populations; and access to health care; GIS are usable in extreme heat attacks in the following (Cioccio and Michael 2007).

GIS applicability

The scope and limitations of the GIS literature search relate to its applicability in health situations, and was targeted but not restricted to mass gatherings, vulnerable populations, and disasters. The intent was to survey the many applications of GIS in health through review of abstracts and conduct a more thorough review of methodology and practical applications to the three domains listed above in articles selected.

2.8 Mass Gathering and Civil Unrest

Many types of mass gatherings and the populations attend them vary accordingly. For example, civil demonstrations, outdoor rock concerts, and a football match. These events normally do not attract one kind of attendee, and risks may be associated with weather-related illness, toxic effects of drugs, or trauma due to attendees trying to get close to the stage (McDonald 2008). Political events such as political party conventions or summits have different risks, which include trauma or toxic effects of dispersion agents during political protests, and terrorism-related incidents (Bradler et al. 2008). GIS-related literature revealed that GIS can be effective in Becerra-Fernandez et al. (2008):

1. Specifying the distribution of people around the event area.
2. Analyzing the scope and approach for mapping evacuation in case of emergency.
3. Determining the positions and direction of a move for law enforcement in the field.
4. Analyzing the pattern of movement of masses.
5. Supporting effective decision-making regarding evacuation and response to an emergency.

2.9 Sandstorms

Dust storms are also known as sandstorms represent one of the natural hazards with a broad range of environmental impacts; the occurrence of a dust storm impact human health in different ways. Dust storms are a significant cause of traffic accidents and cause air transportation delays. The eruption of a storm introduces fine particles, salts, and chemicals (including herbicides) into the atmosphere, with a suite of health impacts, including not only respiratory complaints but also other serious illnesses. Dust storms can transport allergens including bacteria and fungi, thus impact human health (Goudie 2008).

The recent developments in global warming and climate change have led to increased activity of dust storms in different parts of the world. Many scholars including Goudie (2008), Xu et al. (2006) have worked on the investigation of sand–dust storm events and land surface characteristic using GIS and Remote Sensing. The main procedure depends on the analysis of weather stations data and visualization of the spread of particulate matter in certain space in connection to Dry Mid Temperature and Sub-Dry Temperature, specifically in the desert or semidesert zones (Goudie 2009). Statistical analyses demonstrate that the occurrence of sand–dust storms associate extremely with wind speed, which in turn is strongly related to land surface features; on the other hand, a significant correlation between storm events and other atmospheric quantities such as precipitation and temperature were not observed. This is in addition to the factor of vegetation cover, which has been strongly correlated to dust storms.

Spatial Analysis can be very effective in modeling and visualizing the extent and the impact of dust storms. In particular, we can use GIS to provide the following capabilities in dealing with dust storms emergency management.

3 Challenges and Future Directions

Numerous occasions, including the Indian Ocean wave of 2005, the Hurricanes of the 2005 season, and the 7/7 and 9/11 terrorist assaults, have made every one of us intensely mindful of the weakness of the modern society (Goodchild 2006). Knowing the historical record of the events and where such events have occurred, in addition to the geographic limits of their impacts are evidently necessary, principally when combined with information on human populations, infrastructure, and other spatially distributed phenomena that may be relevant to response and recovery (Abdalla et al. 2014). In any case, GIS and spatial technologies that collect, analyze, and allow for visualization of such data (GIS, remote detecting, GPS, and Photogrammetry.) are unmistakably vital in all parts of the disaster management cycle, from protection, response, and recovery through recognition to the reaction and possible recuperation. Geographic Information and Technology (GI&T) gives the premise to assessing and mapping hazard, for arranging evacuation routes and shelters. It also allowed on deciding ranges where human populations are well on the way to have been affected by a disaster, and for assigning resources during the recovery process, among numerous other indispensable and vital tasks that the GIS brings (Abdalla 2015).

One of the observed challenges in the application of GIS for urban emergency management is the location dependency of the event, or what is known as the geographic interdependence of the event. The proximity of the event can lead to complexity in determining the space and location coverage of the case because the occurrence of multiple incidents in the same location can result in cascading or escalating effects among the differently impacted entities.

Regarding the utility of Spatial Analysis in coordination policies, the status of the spatial analysis faces significant deficiencies that can be summarized by the lack of some standard procedures in some regions as well as the unstructured protocols that are in use when dealing with complex scenarios of emergencies in different parts of the world. Part of this can also be attributed to the lack of training in using GIS systems, which can sometimes cause first responders to act inefficiently when dealing with disasters. Spatial Analysis can support effective training for emergency management personnel to deal with complex situations. More importantly, the justified need for geospatial data in some regions of the world requires effective access to global SDI using advanced access protocols and to support the development of procedures and methods for decision-making. This can be attributed to the lack of interoperability in data exchange and standardization.

The decision-making processes face some challenges regarding the lack of common operating picture for the decision-making process. Decision-makers require to access spatial models effectively in the form of real-time data feeds from planning groups, from field observers and remotely collected data. This supports the effective access to operations fields monitoring devices and also the effective decision-making process.

4 Conclusions

The spatial analysis provides effective means in dealing with hazard and risk mapping and assessment. It is also effective in providing visual models that help decision-makers to utilize these technologies effectively. However, spatial analysis cannot be effective without accessing accurate data, formulating efficient policies, and securing effective performance of human resources involved in Emergency Management.

The scope of this research is challenging, with an attempt to cover several environmental hazards that might cause disasters in urban regions. It is imperative to deal effectively with emergency management in any of its four phases, i.e., preparedness, mitigation, response, and recovery is crucial. The detailed discussion of the state-of-the-art spatial analysis in urban emergency management has raised some issues related to the maturity of the use of spatial technologies in emergency management, particular issues are:

1. The co-locality of impact by multiple events might require more advanced spatial analysis solutions for providing information about the event location and the extent of the impact.
2. Issues with data and systems interoperability are crucial in providing a timely solution through spatial analysis.
3. Health-related emergencies are more complex to analyze spatially due to issues related to private access to patient's information, as well as the difficulty of covering multiple scales of events.
4. Although the current GIS systems provide advanced capabilities of spatial analysis, yet new approaches for analysis, visualization, and integration are required to provide additional means of support to urban emergency management community.

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