Intelligent and Automated Emergency Evacuation of populated areas in an event of volcanic activity

Hisham Albataineh[1], Mais Nijim[2], Nikhil Mantrawadi
[1]Department of Electrical Engineering and Computer Science. Texas A&M University – Kingsville
[1]Department of Physics and Geoscience, Texas A&M University - Kingsville
Kingsville, TX, USA
[2]Department of Electrical Engineering and Computer Science. Texas A&M University – Kingsville

Abstract— This paper attempts to conceptualize an Intelligent Emergency evacuation system. The research aims to facilitate timely and orderly evacuation of densely populated towns and cities falling under the immediate impact zone of post volcanic eruption. Unprecedented growth in population has exerted immense pressure on infrastructure, utilities along with severe changes in global weather. Unplanned growth also leads to breakdown in emergency services in providing assistance to each individual in an actual scenario of a massive disaster.
Wildfires in the state of California, in 2018 highlighted this grim reality. The road infrastructure through the state was not cable to handle a sudden influx of vehicles evacuating from their cities.

Keywords: Emergency, evacuation, GIS, volcanic eruption.

I. INTRODUCTION

United States has about 169 active volcanoes. These volcanoes are part of high seismic and volcanic activity addressed as the Circum-Pacific belt. Globally they are a part of the high seismic activity zone called as "Ring of Fire" [1]. A majority of these active volcanoes lie on the western coast line of United States from Alaska in north to the city of San Diego in southern state of California.

High populated areas in the vicinity of an active volcanic zone can lead to chaos in carrying out an evacuation. Emergency evacuation on a large scale has its own bottlenecks. Numerous agencies both federal and state are involved in coordinating and carrying out disaster relief and evacuation.

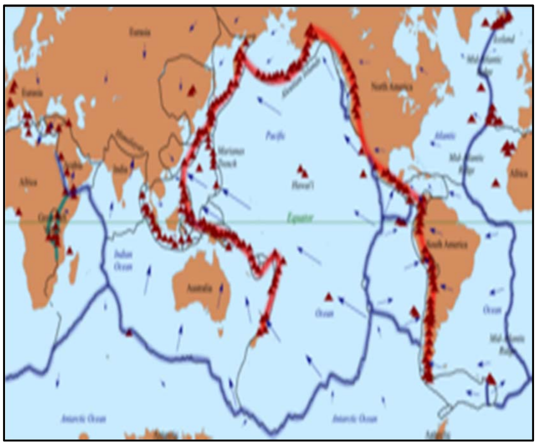

Fig.1. Tectonic plates and Ring of fire [2]

Often each agency has its operating policy which might not overlap with another leading to gaps in operations. Public safety officials acknowledge and share the fear people have post disaster, however they insist people should be aware of their surroundings and if agencies ask people to evacuate and leave, it must be strictly followed.

The evacuation often leaves communities to themselves gathering the essentials before moving out, with almost no time for planning a way out. The information is static and not consistent to the disaster unfolding. People often resort to take the closest known freeway leading out of town which results in nightmare traffic jams. This research aims to facilitate end user with safest possible evacuation route based upon his GPS location.

The system we propose would integrate real time information from different agencies that monitor parameters such as wild fire, volcanic progression and seismic activity which would be analyzed and mapped using a Geographic Information System [3] to provide a shortest and safe evacuation route.

978-1-7281-5092-5/19/$31.00 ©2019 IEEE

II. Background

The state of Washington has 18 listed volcanoes, [4] of which three have erupted in the last century. The volcanoes are located on the Cascadian Subduction zone which indicates another explosion is inevitable. Mount St. Helens in the cascade mountain range in southwestern Washington rises to 3,000 meters above sea level. It erupted violently as recent as May 18, 1980. Abrupt release of pressure over magma chamber creates a cloud of superheated gas and debris is blown out at supersonic speeds. The release of debris wiped off everything in an eight-mile radius instantly. The shockwave rolled over another 19miles levelling everything in its path. A second explosion spread ash and gasses more than 12 miles (19kilometers) into the air. It was estimated that nearly 540 million tons of ash glided up to 2,200 sq. miles landing over seven states [5].

Heat from the eruption melts and erodes glacial ice and snow this when combines with dirt and debris creates volcanic mudflows. According to USGS, these mudflows reached a speed of 90Mph (145 Kilometers per hour) demolishing everything in its path. The 1980 Mount. St. Helens was the most destructive in US history. Nearly 185 miles of road and more than15 miles of rail network were destroyed. Fifty-seven people and thousands of animals too lost their lives [5].

Mt. Rainier ascends to 14,140 feet above sea level. An eruption similar to Mount St. Helens can create mudflows that can threaten the entire Puyallup River valley. This region has over 80,000 residents which are at complete risk. The mountain is located just 59 miles south-southeast of Seattle a major city and seaport [6].

As the Cascadian Subduction Zone lies parallel to the North American tectonic plate a possibility of other disasters along with volcanic eruption cannot be ruled out. An under ocean earthquake can trigger a Tsunami along the western coastline. A combination of these disasters of large magnitude can cripple the evacuation process. The system proposed aims at facilitating an intelligent evacuation route based on the active location of the end user.

III. Methodology

Management of emergency evacuation is a complex process. Several factors are interrelated and codependent. Disaster mitigation can be stated as energies of efforts to reduce the risk of disaster, both by physical development, increasing awareness and enhancing the capabilities to manage disaster threats according to Bhatt et al. [7]. The Intelligent and automated evacuation system is being designed to use the Google Maps platform and its API to facilitate end user locating, calculating route and directions and for geocoding and Geolocation.

A referential database will comprise location details such as City Name, Coordinates, Elevation details, Road Information etc.,. A knowledge base can be developed from this static information.

It is extremely important to identify the disaster prone area (DPA) to plan evacuations.

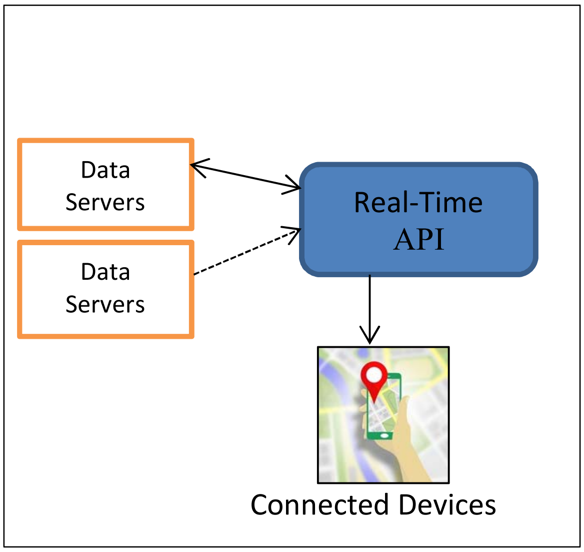

Fig. 2. Block schematic of application

978-1-7281-5092-5/19/$31.00 ©2019 IEEE

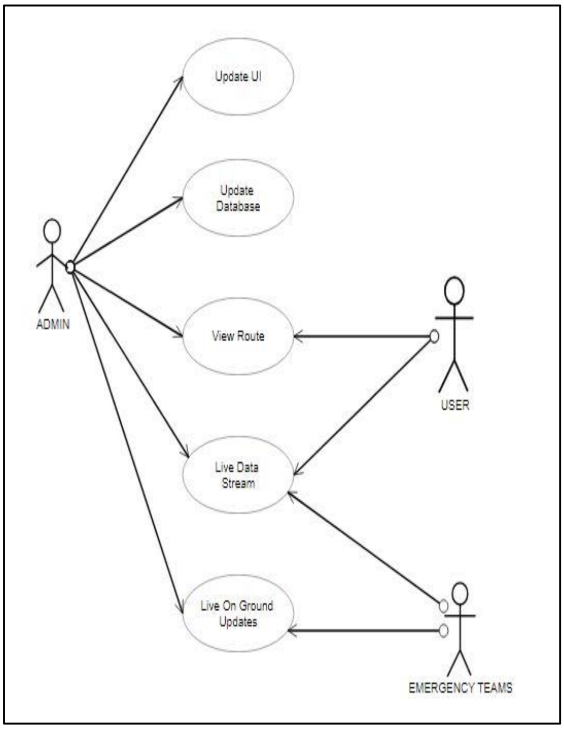

Fig. 3. USE Case Diagram

The design phase of the application is depicted by the Use Case diagram as in Fig. 2. The system will have three primary actors: administrator, end user and emergency teams.
The system administrator will be responsible for maintaining the system and will have access to all the components. The end User will be able to access the system without authentication. User will access the ViewRoute component. This will facilitate the end user with a detailed route out of the evacuation zone. The third actor in the system is the Emergency Team. The emergency teams will facilitate live on ground status reports and coordinates. The can also view the live data stream as it is being updated real time.

A. Concept

This paper aims at proposing, building a knowledge base decision support system (DSS) [8] to successfully mitigate and manage a complex multi disaster scenario.
The principal aim is to propose intelligent alternate evacuation routes in close vicinity of the affected area when multiple hazard occur as subsequent events and often there is no time to mitigate for the second of the third impending crisis. The system is being designed as a cooperative DSS focusing on capabilities, which would make it simple to be used by a layman in an interactive mode. It would enhance flexibility to incorporate changes in rapidly changing environment and in the decision making approach of system mangers. The three primary components in this system are the knowledgebase as represented in Fig.5 through 7, the Model the decision making parameter and criteria and the interaction with end user [9].

B. Case study

The violent explosion of Mount St. Helens on May 18, 1980 and subsequent active seismic activities in recent times laid emphasis for the basis of this paper.
The region under study is a 100 Sq. miles around Mt. St Helens. The seismic active zone has the pacific west coast on its west less than 60miles and sits on an active tectonic plate. The Columbia River which is the largest river in Pacific Northwest, originates in British Columbia emptying into Pacific Ocean. [10] This river channel can bring in Tsunami waters about 60miles up to the city of Kelso inundating major cities and cutting off vital freeway I5-S.

Fig. 4. Major connecting roads and cities [11]

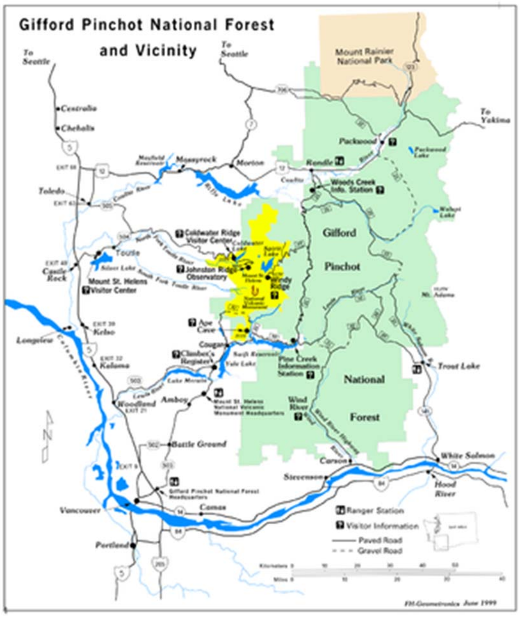

Fig. 5. Study area Mt. St Helens vicinity [12]

In this study, two hypothetical scenarios are assessed. In the first scenario a high intensity earthquake triggers a volcanic activity. An evacuation route can be shared with residents based on predictive analysis and knowledge based decision. In the study area as depicted in Fig. 5 there are two possible evacuation routes. Route one leads to North towards major city Toledo and Centralia. The second route leads south towards major city Castle rock, Kelso and Vancouver.

The study area lies close to the Pacific fault lines. An aftershock earthquake in the western region to the Mt. St. Helens region can trigger a Tsunami which can make its way to the major city of Kelso, Vancouver on the I5-S freeway cutting off Important evacuation routes. An intelligent route decision system based on inputs from multiple sensors can be integrated to tackle such a scenario.

C. Knowledgebase

Following information as depicted in Fig.6. To Fig.8. below can be used for building a compound decision support system.

D. Sample datasets

A	B	C	D
Code	CityNM	Elavation(feet)	Coordinates(DMS)
C1	Warrenton	8	46° 9' 54" N, -123° 55' 27" W
C2	Astoria	23	46° 11' 16.37" N, -123° 49' 52.50" W
C3	Wesport	15	46° 53' 27" N, 124° 6' 36" W
C4	Clatskanie	59	46° 6' 11" N, 123° 12' 13" W
C5	Kelso	75	46° 8' 31" N, 122° 54' 22" W
C6	Lexington	33	38° 2' 26.101" N 84° 30' 13.379" W
C7	Castle Rock	59	46° 16' 26" N, 122° 54' 18" W
C8	Toutle	499	46° 19' 29" N, 122° 44' 11" W
C9	KidValley	784	46° 22' 22" N, 122° 37' 9" W
C10	Toledo	121	46° 26' 21" N, 122° 50' 53" W
C11	Centralia	187	46° 43' 14" N, 122° 57' 41" W
C12	Olympia	95	47° 2' 16.3392" N,122° 54' 2.5056" W
C13	Vancover	171	45° 38' 0" N, 122° 36' 0" W
C14	Portland	50	45° 31' 12" N, 122° 40' 55" W

Fig.6. Sample City-elevation database

In Figure 6, records city details such as Elevation of the city and its GPS coordinates. The information from this table will be used to cross reference and correlate to other collected datasets.

A	B	D	G	H	I	K
Code	CityNM	Coordinates(DMS)	Dist_Volc(miles)	Dist_Ocean	Associated Freeway	Population
C1	Warrenton	46° 9' 54" N, -123° 55' 27" W	113	0	US-30E	5602
C2	Astoria	46° 11' 16.37" N, -123° 49' 52.50" W	108	5.5	US-30E	9477
C3	Wesport	46° 53' 27" N, 124° 6' 36" W	82	31.6	US-30E	2080
C4	Clatskanie	46° 6' 11" N, 123° 12' 13" W	73	40.6	US-30E	1815
C15	Mist	45° 59' 47" N, 123° 15' 19" W	85	52	OR-47S	
C5	Kelso	46° 8' 31" N, 122° 54' 22" W	55.7	57.9	I5-S	12130

Fig.7. Sample City-Distance from Tsunami, Volcano.

Sample table shown in Figure 7 that assists in determining the relative position of City from Ocean and from Volcano.

978-1-7281-5092-5/19/$31.00 ©2019 IEEE

Code	CityNM	Elavation(feet)	Dist_Ocean	Associated Freeway	Tsunami Landfall(Min)
C1	Warrenton	8	0	US-30E	30
C2	Astoria	23	5.5	US-30E	40
C3	Wesport	15	31.6	US-30E	58
C4	Clatskanie	59	40.6	US-30E	70
C15	Mist	535	52	OR-47S	NA
C5	Kelso	75	57.9	I5-S	142
C6	Lexington	33	62	I5-S	NA
C7	Castle Rock	59	69.7	I5-S	NA
C8	Toutle	499	NA	WA-504E	NA
C9	KidValley	784	NA	WA-504E	NA
C10	Toledo	121	NA	WA-504E	NA

Fig.8. Sample data for Tsunami threat

Sample table shown in Fig. 8. Maintains City details with its Tsunami impact information [11]

IV. RESULTS

Data gathering or knowledgebase for the decision context and user criteria has been generated. Evaluation is underway to determine most suitable decision system is being done. Both knowledge-driven and model driven decision support system can be very useful in implementation.

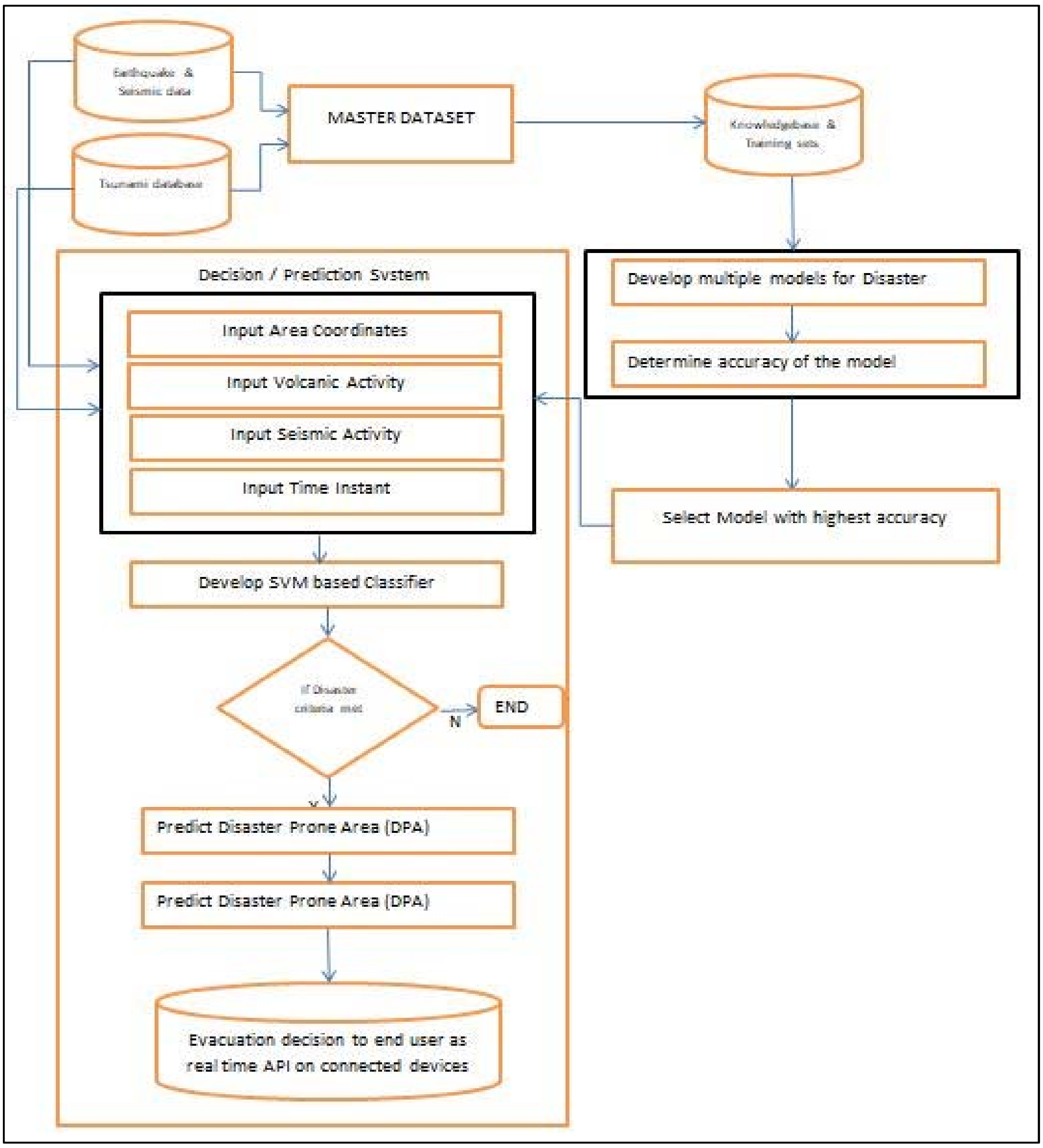

Fig.9. Flowchart for designing a decision support system for multiple disaster scenarios

V. CONCLUSION AND FUTURE WORK

The work on Intelligent and automated response platform is intermediate and is being enhanced by including additional sensor information such as wind speed, direction, road parameters such as bridges and their detail specifications, information of arterial roads, close proximity emergency services etc. With the addition of other dimension the system will generate more significant results.

The eminent threat of volcanic eruption coupled with a realistic Tsunami probability along the pacific coast line warrants an automated emergency evacuation platform. The data presented in this paper is still limited to building up of the knowledge base to facilitate smart decision making. Future research is expected to map other secondary information which will enhance the accuracy of results.

VI. REFERENCES

[1] Tyson Brown, 2019. Ring of fire, Resource library National Geographic https://www.nationalgeographic.org/encyclopedia/ring-fire/, [online accessed Wednesday, May 01, 2019].

[2] Astroskiandhike, 2018, Tectonic plates and ring of fire https://commons.wikimedia.org/wiki/File:Tectonic_plates_and_ring_of_fire.png#file,[Open license Image online accessed and used Monday, April 29, 2019].

[3] ESRI,"What is GIS?," 2018. https://www.esri.com/en-us/what-is-gis/overview [Online accessed Tuesday April 30, 2019].

[4] U.S. Volcanoes and current activity status. https://volcanoes.usgs.gov/index.html, [online accessed Friday, May 03, 2019].

[5] Mary Bagley, 2018.Mount St. Helens Eruption: Facts & Information, Live Science https://www.livescience.com/27553-mount-st-helens-eruption.html, [online accessed May 01, 2019].

[6] Robin Andrews, This may be the most dangerous U.S. Volcano https://www.nationalgeographic.com/science/2018/07/news-most-dangerous-volcano-mount-rainier-supervolcanoes-yellowstone/, [online accessed Monday 29, 2019].

[7] G.D.Bhatt, K. Sinha et al., "Flood Hazzard and Risk Assessment in Chamoli District, Uttarakhand Using Satellite Remote sensing and GIS Techniques," Int. J. Innov. Res. Sci. Eng. Technol., vol.3, no. 8, pp. 15348-15356, 2014.

[8] Holsapple, C.W., and A. B. Whinston. (1996). Decision Support Systems: A Knowledge-Based Approach. St. Paul: West Publishing. ISBN 0-324-03578-0

[9] Sprague, R H. and E.D. Carlson(1982). Building effective decision support systems. Englewood Cliffs, N.J., Prentice-Hall. ISBN 0-13-086125-0

[10] United States Geological Survey fact sheet,"Largest Rivers in the United States"

[11] Washington State Department of Natural Resources,https://www.dnr.wa.gov/news/new-videos-show-tsunami-impacts-washington

[12] GPNF & Vicinity Image used from Wikipedia originally owned by Forest Service of the United States Department of Agriculture https://en.m.wikipedia.org/wiki/File:Gpnf_vicinity.png

[13] Washington State Department of Natural Resources, https://www.dnr.wa.gov/news/new-videos-show-tsunami-impacts-washington