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ICT Implementation- GIS Application for Disaster Evacuation

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Abstract

An application has been developed to handle the situations of disaster efficiently by use of Information and Communication Technology (ICT). This application shall aim at providing an effective solution during disaster and help in minimizing its impacts. Application not only incorporates the maps of safe zones and evacuation zones but also at same time shall be able to send push notifications in alerting users about disaster in advance which directly shall help in restricting the impact of a disaster. The application shall make use of Java language in android application development, XML for layout designing and PHP for making web pages. There shall be an application component called an activity that shall provide a user interface with which users can interact in order to do something, such as dial the phone, take a photograph, send an email, or view a map.
Keywords: Disaster, ICT, Evacuation

I. Introduction

The unique climatic conditions cascaded with socio-cultural-economic and political diversities of India have made it exceptionally vulnerable to both natural and manmade disasters. India has a long history of coping with and recovery from disasters. The recurrences of natural disasters like cyclones have increased essentially over the last decade particularly in the coastal line of Odisha in India which is affirmed with the impact of climate change. The state of Odisha on the east coast of India is called the disaster gateway as it is one of the most vulnerable states in the country with a very high probability of cyclonic hits.

The present research analyzes that the country has had a series of studies on the mathematical modeling of the cyclonic surges or social analysis of the human apathy. However, there are not many cases where a combination of information, technology and humanistic approach is being tested.

The research intends to bridge the gap between the Information Communication Technology (ICT) and the need. The permutations of social networks and spatial analysis is seldom tried with an outcome poised to aid the community in being more aware and informed thereby leading to sustainable Disaster Risk Reduction(DRR) and resilience. Over the past decade, numerous analysts and decision makers have invested resources into developing geospatial (GIS) databases to support their risk management decision making. Most of these models generate results that are spatially explicit (mapped). Little work has been done to link the models with the GIS databases such as road networks, building locations and key utility databases in a decision support framework. Such initiatives can be brought into an integrated GIS decision support system.

Complete prevention of natural disaster is beyond human capabilities but the involvement of the state-of-the-art Information and Communication Technology (ICT) systems are panacea for implementing reliable disaster prevention and mitigational measures. ICT provides capabilities that can help people grasp the dynamic realities of a disaster more clearly and help them formulate better decisions more quickly.

The paper aims to address the role of ICT infrastructure as a framework for facilitating disaster management in the study area of Kendrapara,one of the most cyclone hit area of Odisha. The ubiquity of handheld computing technology has been found to be especially useful in disaster management and relief operations.

II. Methodology

A. Evacuation Planning and Transportation Modeling

The methodology carried out is to map evacuation routes on the transport (road) networks of the identified villages of Kendrapara for massive evacuation using optimization of the carrying capacity of the roads and the maximization of the capacity handling at the end/destination points. After identification of the village i to be evacuated from the stage of vulnerability analysis, a methodology is developed to identify the topological network of the routes/roads of village i based on the demographic features of that village. This result in the computation of an optimization model that can be used to identify and evacuate to the safer zones (say the cyclone shelters). This model integrated with a GIS System can be used to make reference (ready real time scenario based) maps (road wise) for the evacuation risk minimization.

The research shall keep the scope limited to road networks only which have witnessed cyclonic destruction, the emergency response of evacuation being short term and it is assumed that the evacuation zones shall have been so carefully planned that each of them will have a sufficient demand after cyclone and that traffic originating from different evacuation zones can be destined to any safe zones. Subsequent to findings of the previous steps, a more realistic post cyclone travel model is formulated to analyze a realistic scenario. The traveler's behavior and routes change significantly, and it necessitates the travel demand modeling, to establish spatial distribution of the travel between the travel areas. Evacuation From the village i (impact zone) to village j (safe zone) depend on a number of factors:

Number of people in need or in demand of the evacuation i.e., demand_pop_evac (pop_{vi})

Transport Carrying (vehicle load) for population pop_{vi} for village i to village j., i.e., $Trans_{(vij)}$

Rate at which the demand is fulfilled(R_D)

Rate at which the capacity is actually provided(for shelters),i.e., R_{cap}

Finally, R_{cap} - R_D = People at Loss (i.e., Human Loss)

e.g., during a cyclone, an area needs to be evacuated, even though the bulk capacity of all vehicles may be large enough to carry out all the people in danger out of that area, the maximum flow rate of the transport or road network (number of lanes available) may become a limiting factor. e.g., there may be no information about the shortest paths in the topological graph of the road network, e.g., or a shortest path (P_i) may not be practically feasible to be used because of some obstructions etc. For this reason, emergency planning zones (EPZ) also are sketched well in advance which help in evacuation planning . The procedure is two a step process:

1) Step 1: To build a topological graph for the road network

Build up a topological (road based) network from the GIS map of the district available. Sketch a graph (directed) out of this network.

Build up nodes and edges of that graph in such a way that the nodes are assigned as villages and edges represent total traveling distance on these roads. Now we find a shortest path /optimal path on that graph from node i to node j and also create a subset of shorter paths on every node or intersecting points.

2) Step 2: To calculate the Evacuation Risk Factor- The carrying capacity of the existing vehicles to carry the total population in demand is estimated.

B. Formulation of the problem as an Optimal Routing Problem (ORTP)

These set of problems deal with routing from a specific set of source nodes to a set of destination nodes through a transportation network. Denoting the symbols used in the equation for minimizing Z, where Z=linear combination of Dis_{min} and $T_{cl\ min}$.

i.e., Z= fn (linear) {Dis_{min} , $T_{cl\ min}$}

Where $Dis_{min} = \sum pop_{vi} \sum (x_{ijk} * d_{ijk})$

for k = index for kth shortest paths;

if k= 1 (1^{st} shortest path selected)

$Dis_{min} = \sum pop_{vi} \sum (x_{ij1} * d_{ij1})$

The evacuee will travel Dis_{min} only if he/she is assigned the first shortest route, therefore this Dis_{min} is the lower bound value for the evacuation paths set.

Similarly, $T_{cl\ (min)} = \sum t_1^{(1)} \sum pop_{vi} \sum (x_{ij1} * \alpha_{ij1})$

Where α_{ij1} =1 if the road link l is on the route present; 0 otherwise. and $t_1^{(1)}$ = minimum expected travel time on the route selected.

C. Network reachabilty and reliability analysis of the transportation network.

The paper discusses the reliability of network reachability of transportation infrastructure systems. The paper explains not only where the evacuations originate from and where do they go, but also addresses what routes are to be followed. For transportation systems, the connectivity denotes the reachability of a random node-pair via at least one path. Connectivity is dependent upon the post-cyclone connectedness of a transportation network and hence it is a suitable metric for the case of immediate post-disaster humanitarian aid. The paper carries out the reachability analysis determining whether a path remains operational (or connected) between the given sources and destinations. If the path connects the selected node-pair following an impact, serviceability (or performance) analysis seeks additional information on the remaining capacities that can be found mathematically.

The reachability analysis has been computed by Recursive Decomposition Algorithm (RDA) which is an analytical algorithm and which decomposes the topological network of Kendrapara area into sub graphs using DeMorgans' rule and the disjoint theorem till no path exists between the source destination pair in all sub graphs; In an emergency, it is critical to identify the passable ingress and egress routes for emergency response within a short time frame, e.g., to send search and rescue teams into the impacted area immediately after a disruptive cyclone. Immediately after a disruptive cyclone, emergency managers and rescue workers often face the problem of promptly identifying the emergency routes to send rescue teams and relief resources into the impacted area.

The analysis takes into consideration the key issues like road damage assessment and travel time estimations. After a disruptive event such as a major cyclone, the travel behavior (i.e., route choices) and travel demand could change significantly due to travelers' reaction to road damage, road closures, and congestions. Though it is still infeasible to obtain realistic behavior of traveler route choice and "real-time" travel demand, post-cyclone travel demand can be approximated with some general principles to capture the essential characteristics of post-cyclone travel patterns and effects of emergency facilities such as hospitals and emergency shelters. This approach approximates the "abnormal" travel demand by adopting several general principles.

The proposed methodology does not attempt to provide "real-time" post-cyclone traffic simulation. Instead, it aims at providing general principles and procedures for emergency training and planning purposes. The cyclone scenarios for demand modeling are created which specifically consider the occurrence time of day (e.g., morning and late-night period). In this paper, two hypothetical scenarios are developed to model the impact of a no-notice event on transportation systems—one occurring during morning rush hours (the day scenario), and another at late night (the night scenario). The hypothetical scenario cyclones will leave several roads (e.g., major river crossings) and essential facilities (e.g., schools) severely damaged. The research has been carried out with the following underlying assumptions:

- This study assumes that people will evacuate directly from their current locations immediately after cyclones. Social vulnerability to disasters such as race, gender, and social inequality has a crucial role in shaping the evacuation patterns, but is beyond the scope of this study.
- Contingent upon the vicinity of attractants (e.g., hospitals, dispensaries or emergency shelter) and repellents (e.g., harmed facilities); the TAZ (Traffic Analysis Zones) can be categorized into four zone types. The underlying suppositions are that: (i) if a zone does not have damaged facilities, its trip production won't be influenced by the cyclone, while the trip production will increase in the influenced zones due to facilities damage and (ii) if a zone does not offer emergency shelters or hospitals, its trip attraction will stay unaltered; while the trip attraction will build in light of the vicinity of emergency shelters, medical dispensaries and hospitals.
- Emergency shelters and hospitals are assumed attractive sites to injured or displaced people. The attracted trips to shelters and hospitals are proportional to their capacities (e.g., the number of beds in a hospital).

D. ICT implementation - GIS for disaster evacuation modeling and rescue operation in Kendrapara district.

The plan of action for ICT implementation has been implemented on a QGIS (Quantum Geographic Information System) for efficient analysis and map building. Following are the steps undertaken for application building and further analysis:

- Map the mentioned areas on a QGIS as a vector layer. This can easily be done by entering the co-ordinates of the area or mapping them using an OSM (Open Street Map) layer plug in using the existing maps.
- After we get the shortest route by analyzing the possible routes and using the algorithms mentioned in this documentation, we can map these routes by drawing appropriate lines.
- Also, we can easily call the inbuilt function of distance matrix to get the minimum distances geographically between each point as shall be shown in the maps.
- As we can see in these maps, the zones at potential risk are shown in red color and the evacuation zones are shown with a green color. Moreover in the same map layer in the QGIS, we can have a single database having all the relevant data like the nearest evacuation zone, its distance in kilometers, total population, number of males and females etc. Unlike before we don't need to refer different excel sheets and search for the relevant information corresponding to a relevant zone instead, we can just select the region in the QGIS layer and get all the required information at one glance.
- The use of QGIS can make data interpretation easier and can make analysis and creation of evacuation plans easier.

III. RESULTS

A. Evacuation map for Village 'Baro' in District Kendrapara

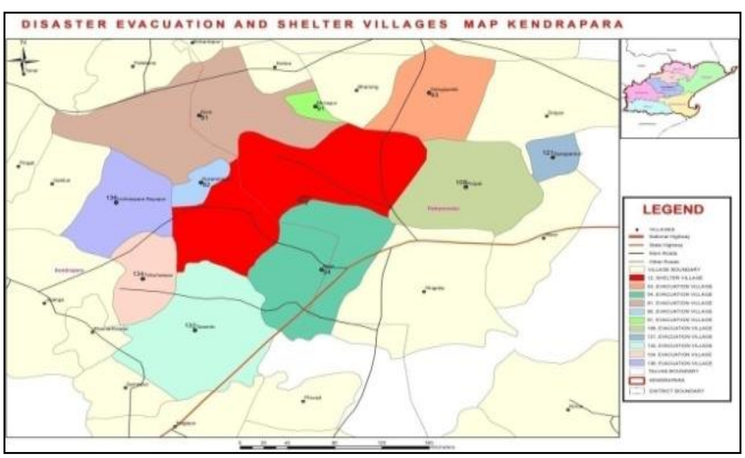

Fig. 1: Evacuation map: Village Baro (Shelter Zone)

Figure 1 illustrates the evacuation map depicting the shelter Baro (Village numbered 12 as depicted in map) and shows that the adjoining villages can be evacuated and rescued down to Baro. The color codes indicate the disastrous villages and the red color code indicates the shelter. This map has been created for reference in ICT applications such as web portals or smart phone devices; specific village views can help vulnerable and disaster hit people evacuate the place as soon as possible without any delay. If such kinds of maps are available on the ICT enabled devices like mobiles and smart phones, vulnerable people can be rescued and evacuated with much ease. A greater possibility lies in the hands of the rescue team to evade the disastrous places and to reach the most possible and safer shelter zones.

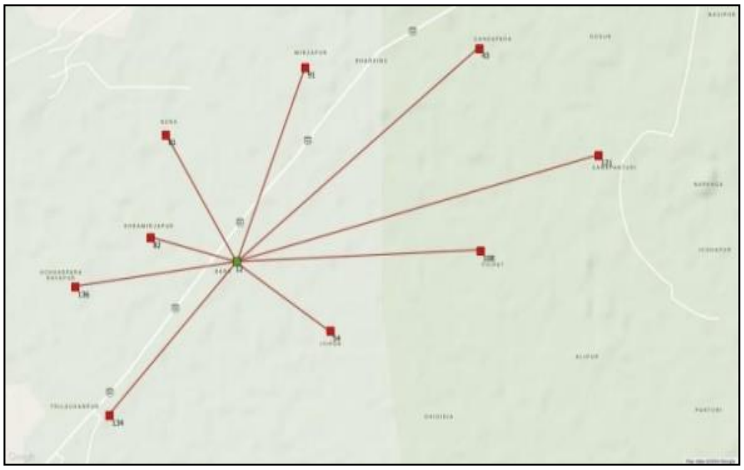

Fig. 2: Evacuation Map (Public View: Village Baro)

A simpler version of the map has been developed for the public in general as shown in figure 2. The analysis has been done with respect to the TAZ and developed in ArcGIS and QGIS platforms.

B. Evacuation Map with database view of vulnerability indices.

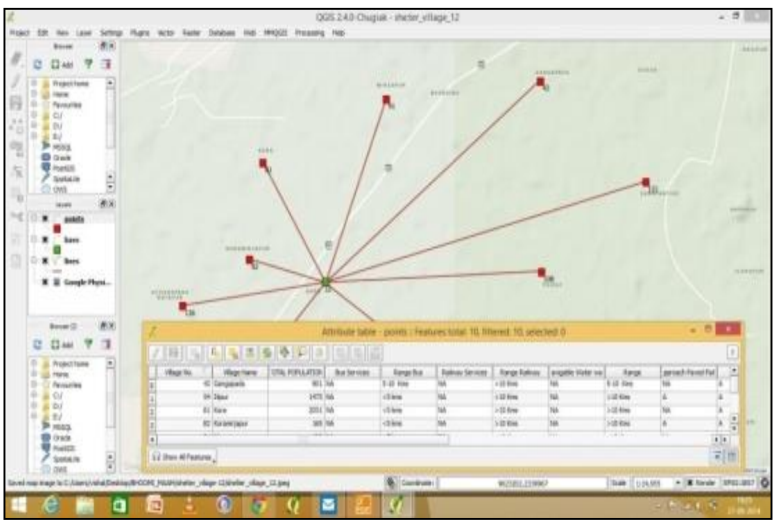

Fig. 3: Database view of vulnerability indices in concern for evacuation with respect to village Baro.

Figure 3 shows the vulnerability indices, their values and all other social and demographic data related to the village Baro for quick reference to the administrators to take quick response and action regarding evacuation.

Table - 1
Distance Matrix between Shelter Village (id: 12 indicated as InputID; Title: Baro) and Disaster hit Village (indicated as TargetID); Distance between shelter id and disaster id is given by Distance (measured in meters).

InputID	*TargetID*	*Distance(m)*
12	*82*	*924.3*
12	*54*	*1173.1*
12	*81*	*1399.4*
12	*136*	*1701.0*
12	*91*	*1958.0*
12	*134*	*1962.7*
12	*108*	*2542.9*
12	*43*	*3225.1*
12	*121*	*3899.5*

Table 1 as obtained and calculated from Google open street views and QGIS are found to be matchable with the distances computed from shortest path Recursive Decomposition Algorithmic analysis.

IV. CONCLUSIONS

The application developed facilitates the work of administrators and rescue teams to track their evacuation progress ceaselessly so that they can take immediate steps whenever needed. In brief, the developed methodologies shall allow state and local authorities; and emergency managers to perform:

- Risk Modelling and Vulnerability Analysis: Model risks, evaluate post-cyclone damage, and assess the performance and functionality of critical vulnerability indices; hence understanding disaster resiliencies for sustainable growth.
- Transportation Modeling and Reliability Analysis: Assess the contingency plans in a transportation network for emergency training and response, secure the critical ingress and egress routes for emergency response as well as avoid excessive queues and delays.
- GIS Map Implementation: Implement Geographical Information System based maps for a ready reference to the evacuees and the administrators for quick decision making and self evacuation; hence causing optimization of the rescue operations.
- ICT Based Smartphone Application Development: Implement a smartphone application in the disastrous area for successful evacuation; results being presented in a handheld device like a smartphone for a ready reference to the evacuees.

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