Environment Risk Reporting And Information System - A Gis Based Framework For Managing Industrial Risks In India

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ABSTRACT

Every year, industrial accidents like the Bhopal disaster take their toll on business and communities - in terms of lives, injury to workers and financial resources. India has been witnessing fast paced industrialization since the liberalization of the economy in the early 1990's. Resultantly, medium sized industrial towns and development zones have been witnessing a steady induced growth of population because of a "honey pot" effect. This has in turn led to increase in vulnerability of people to technological risks posed by potentially hazardous industries. It is well accepted now that the accessibility of up-to-date information on industrial hazards, exposed neighborhoods, population vulnerability, resources available for response, etc. in an easily accessible information. Management system can enable decision makers and responders to better prepare for and respond to an industrial disaster. Moreover, since technological risk management is principally a spatial problem, an integrated GIS based system that can be accessed by administrators, relevant stakeholders and social actors can play an important role in industrial disaster risk management. With this in mind, the Environmental Risk Reporting and Information System (ERRIS) Project was launched by the Indian Chamber of Commerce as a Corporate Social Responsibility initiative for industrial corporates in the industrial towns of Haldia and Durgapur in eastern India in consonance with the precautionary approach for environment protection mandated by the Rio Declaration and the UN Global Compact. At the first level, the project aims to promote a structured mechanism for voluntary reporting of risk related information by potentially hazardous industries in these two towns. At the second level, the project is in the process of establishing a computerized and collective GIS based system for management of technological risks arising out of the industries. The information system would contain spatial and non-spatial data comprising of digitized maps of the industrial areas, location- specific data on hazardous industries, vulnerable population, and first responders such as police, fire, medical agencies. The data is stored in a relational database designed to meet the requirements for risk management and would be made available through a customized user interface to responders and stakeholders of concern.

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KEYWORDS

Technological Hazards, Risk, Geographical Information System, Vulnerability, Risk & Hazard Map, Loss Estimation, Web-GIS, Geo-database.

ABBREVIATIONS

MAH - Major Accident Hazard, GIS - Geographical Information System, HDA - Haldia Development Authority, ADDA - Asansol Durgapur Development Authority, GPS - Global Positioning System, MSDS - Material Safety Data Sheet, MSIHC - Manufacture Storage and Import of Hazardous Chemicals, EPPRCA - Emergency Planning Preparedness and Response to Chemical Accidents, TRI - Toxics Release Inventory, IT - Information Technology, CSR - Corporate Social Responsibility, MARS - Major Accident Reporting System, SPIRS - Seveso Plant Information Retrieval System, RDBMS - Relational Database Management System.

1. INTRODUCTION

South Asia, comprising of India, Pakistan, Bangladesh and Nepal, has been the second fastest growing region in the world in the past decade with a GDP growth averaging around 5% per year. However, despite considerable progress, the region continues to face fundamental constraints on sustainable development including unchecked population growth; rapid and unplanned urbanization; weaknesses of local governments; exclusion of most of the people from decision making; lack of access to information and failure of institutions to sufficiently integrate environmental and social developmental considerations into economic policy objectives.

The region also stands out as most vulnerable to natural disasters such as floods, cyclones, earthquakes and landslides which occur regularly. Statistics show that in the period 1990 to 1998, the region accounted for over 60% of disaster related deaths worldwide [1]. In many cases, the effects of such disasters are borne by the weaker segments of the society who are already disadvantaged in many other ways. As an example, the Tsunami in December 2004 that caused more than 500 deaths in Chennai alone, affected mostly the poor people living in hutments on the shoreline.

On the other hand, risks arising out of human activities are also on the increase as a result of the fast paced industrialization that India has been witnessing since the liberalization of the economy in the early 1990's. Resultantly, medium-sized industrial towns and development zones, where most of such industrial growth is taking place, have been witnessing a steady induced growth of population because of a "honey pot" effect, attracting population from the surrounding rural areas to these potential sources of employment. This has in turn led to increasing population densities in the vicinity of potentially hazardous industrial facilities and to an increase in the vulnerability of the local population. Therefore, there is an urgent need to adopt *integrated risk management strategies* that will effectively address the issues of risk reduction, emergency preparedness and response planning in order to mitigate the adverse consequences of any technological accident that might occur [2, 3].

2. REGULATORY FRAMEWORK

As compared to natural hazards, where very little can be done to avoid the occurrence of the phenomena, a certain degree of human control can be exerted on preventing the occurrence of technological accidents. Among the important tools for this are regulatory and institutional frameworks that exist in most countries that try to address disaster preparedness and response for a technological risk scenario.

After the Bhopal Disaster in 1984 policy and decision makers in India realized the true nature and severity of the environmental problems inherently linked with the process of economic development. As a result, the need was felt to further broaden the regulatory framework to encompass areas like environmental hazards caused by chemicals and wastes, as also other areas which were earlier not considered to be a priority. Since then, there has been a gradual evolution of a fairly comprehensive legislative framework and the Central government through the Ministry of Environment and Forest has promulgated a wide array of legislation that covers almost all aspects of environmental protection and related issues.

Legislation specific to prevention and management of accidents arising out of hazardous installations was formulated in the form of the Manufacture, Storage, Import of Hazardous Chemicals Rules (MSIHC) in 1989 (recently amended in 2000) and the Emergency Planning, Preparedness and Response to Chemical Accidents (EPPRCA) Rules in 1996. According to MSIHC Rules, industries storing and handling hazardous chemicals are required to submit a safety report and an Onsite Emergency Plan to the regulatory agencies containing vital industry specific information that would enable the regulators to attain swift control of an industrial accident. The EPPRCA Rules which complement the MSIHC Rules envisage a four-tier crisis management system in the country involving the Central Crisis Group, the State Crisis Group, the District Crisis Group and the Local Crisis Group - to manage emergencies arising out of industrial operations. Effectively, the EPPRCA thus provides statutory backup for setting up of Crisis Groups at various levels to ensure the management of risk arising out of Major Accident Hazard (MAH) installations.

However, with an inadequate institutional framework, government agencies and regulatory bodies have been severely constrained in implementing most of the regulations under a "Command and Control" regime. Consequentially, many industries default on providing right and timely information on risks present within a MAH installation while on the other hand, the government is yet to set up and make operational functional Crisis Groups who can coordinate effective response in a contingency situation. The local emergency control centres are also handicapped with lack of proper information resources. As a result, the triggering of an industrial incident / accident may result in a situation that may be as severe in proportion as the Bhopal disaster of 1984.

3. GIS AND MANAGEMENT OF TECHNOLOGICAL RISKS

With the rapid advances made in the field of information technology (IT) and the development of the understanding that having access to time-critical information is the key to achieving control of an emergency arising out of an industrial accident, efforts were initiated to implement IT tools and technology with the science of risk management in the last few decades. In the United States several software databases and electronic information systems have been put in place, such as the "Vulnerable Zone Indicator System" and the "Toxic Release Inventory (TRI) of Chemicals[5]" which provide communities with vital information to manage risks arising out of hazardous industries operating in the neighborhood. In Europe also, recent initiatives under the EU Joint Research Commission (JRC) has led to the setting up of the Major Accident Reporting System (MARS), Seveso Plant Information Retrieval System (SPIRS) and the Area Risk Analysis (ARIPAR) software fulfilling the information exchange obligations towards the EU Member States under the Seveso II Directive [4, 5].

The evolution of Geographical Information Systems (GIS) as a tool for doing risk based planning and emergency management has provided further impetus to technological risk management initiatives. This is because, the science of risk management is an information intensive process needing large volumes of technical information from different sources which have to be collected, shared, managed, combined and displayed, preferably, in a spatial context to enable decision making and analysis. GIS technologies provide an adequate framework for converting geo-

5. The Vulnerable Zone Indicator System and the Toxic Release Inventory databases in the US are the outcome of the Emergency Planning and Community Right-to-Know Act (EPCRA) that was enacted in 1986 with the intent of informing communities and citizens of chemical hazards in their neighbourhood.

referenced raw data into useful information, for the integration of spatial data from several sources, for building linkages with related databases as most importantly for the modeling of hazard and risk scenarios and making these available to decision makers. Furthermore, with advancement in IT, such operational systems can now be implemented and deployed on distributed clientserver architectures that support real time remote access over the Internet, through mobile clients, thereby allowing the system to be used by a host of responders and decision makers.

4. ERRIS AND CORPORATE SOCIAL RESPONSIBILITY

The ERRIS project has been conceived as a Corporate Social Responsibility (CSR) initiative with the foundation being based on the voluntary disclosure of risk related information by hazardous industries. Hazardous industries in India, as a regulatory obligation, are required to submit information on hazardous substances they store and process in their premises to regulatory bodies. Besides complying with the law, some industries with hazard potential have developed codes of practices and management systems that address accident prevention and community involvement. For example, many Indian corporates subscribe to the Responsible Care® [6], a set of voluntary management codes that address safety practices, product stewardship, and community involvement in environment and risk related issues. Voluntary disclosure of environmental and risk related information to stakeholders and interested sections of the community also form the mainstay of the Global Reporting Initiative (GRI) [7] and the UN Global Compact[2] initiatives.

After sensitization to the overall project objective of setting up a collective industrial risk information database and the potential benefits that may be accrued from the system to effectively manage a technological risk scenario, the hazardous industries in Haldia and Durgapur now understand the necessity of sharing such information through a voluntary framework thereby helping to involve the local authorities and communities as partners in managing chemical risks and planning for chemical emergency response.

5. CASE STUDY AREA

The industrial town of Haldia lies in the eastern region of India at the southern tip of the state of West Bengal, approximately within the geographical coordinates 22° 04" 53.00 22 ° 03" 43.89 N latitude and 88 ° 07" 53.15 88 ° 09" 03.61 E longitude. The Haldia Municipality covers an area of 104 sq kms and the Haldia Planning Area which is managed by the Haldia Development Authority (HDA) occupies a larger area of 326 sq kms including the Haldia Municipal area. The town is located on a peninsula bounded by the rivers Rupnarayan to the North, Hooghly to the East and Haldi to the South and

6. The Global Compact is a direct initiative of the UN Secretary-General and through the power of collective action, seeks to promote responsible corporate citizenship so that business can be part of the solution to the challenges of globalization. Refer website http://www.unglobalcompact.org.

falls within the coastal plains of East Medinipur District. It is connected by road to other cities, including the metropolis of Kolkata by the National Highway 41 and State Highway 4. There is also a railway line that links Haldia with the main railway link between Kolkata and Kharagpur. In addition, it is connected by waterways to towns on the other bank of the rivers.

The total population of the Haldia Municipality is 169996 persons as per the 2001 Census. The area recorded a decadal growth rate of 32.7 % in its population over the last ten years as a result of increased urbanization and potential employment opportunities At present, the Haldia industrial region is fast growing into the single biggest manufacturing centre of eastern India with a major concentration of industries like oil refineries, petrochemicals, and chemicals that is supported by a large port complex and other infrastructural facilities. With its key location advantage and existing industrial base the port city is becoming a good choice for prospective investors.

However, like most other industrial towns in India, urbanization of Haldia has happened without proper land-use planning and resultantly the town has evolved in a haphazard manner. From the industrial risk standpoint, no zoning approaches have been applied that separate hazardous or polluting industries from residential areas [8, 9]. This has resulted in a mixed land-use with no clear demarcation of zones for industries, residential areas and agricultural lands. In the early 1970s, before the first industries like the Indian Oil Refinery, Hindustan Fertilizer Corporation and the Haldia Port were set up, the region was scattered with villages, agricultural lands and low lying wetlands. At present, more than 20 medium and large-scale industries have come up in the town thereby comprising the predominant land-use, with pockets of vulnerable population sandwiched in between. Many of these industries are hazardous in nature and include petrochemicals, chemicals, tank farms, gas storages, etc.

It is only of late that some efforts are being undertaken by the local development authority to evolve a systematic land-use plan for optimal use of available land for future industrial and infrastructural development of the area while also keeping in mind the overall needs of the community. It is also expected that with the operationalisation of ERRIS, consideration for setting up future hazardous units will be integrated with land-use planning controls at the local level.

6. MAIN CHARACTERISTICS OF ERRIS

Industry Information

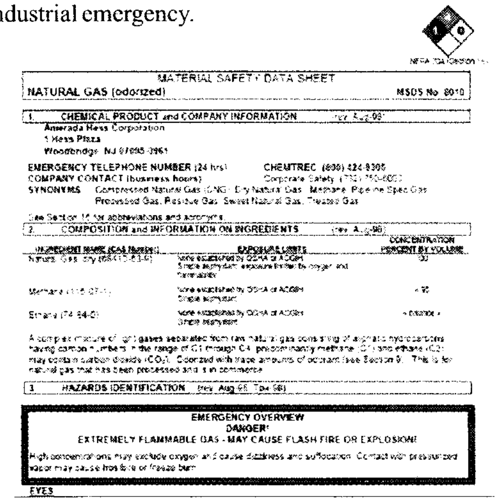
Technological risk arises out of the hazardous substances stored and processed in industrial facilities, storage depots and also when such substances are transported from one location to another. The availability of information about hazardous facilities and the hazardous substances they store in the form of raw materials, intermediates or products is the key to the development and functioning of any information system for technological risk management. As a part of the voluntary reporting scheme, approximately 20 Major Accident Hazard (MAH) industries in Haldia have already disclosed information in a structured reporting format containing the following information:

- Facility / Industry identification;
- Emergency contact information;
- Hazardous substances inventory;
- Properties of the storage containers, primary and secondary control, containment systems;
- On-site emergency response resources.

The above information has been stored in a structured industry database called the Risk Reporting System (RRS). The data thus gathered can be used by the ERRIS software application to process and analyze risk related information and may be selectively presented to the stakeholders in a spatial context through the Risk Information System (RIS). Through the RRS the industries will have the flexibility of adding information on new storages as and when they come up in the future or modify existing information, if the need arises. Authenticated and filtered access to the above information will be provided to each industry through a secured login to the system, so that data can be added and updated by the respective industry only.

Chemical Database (MSDS)

In addition, a fully searchable database on Materials Safety Data Sheet, commonly known as the MSDS, has been developed for each of the hazardous chemicals that have been reported by the industries (Figure 1). The MSDS has been integrated with the ERRIS system with an aim to provide the decision makers and the first responders with real-time information on the type of chemicals involved in a risk scenario, properties, and mitigation action to be taken to prevent injuries and damage to vulnerable receptors thereby assisting them in emergency preparedness planning, response and mitigation, in the event of a industrial emergency.



MATERIAL SAFETY DATA SHEET

NATURAL GAS (odorized) MSDS No. 8010

1. CHEMICAL PRODUCT and COMPANY INFORMATION

Amerada Hess Corporation
1 Hess Plaza
Woodbridge NJ 07095-0961

EMERGENCY TELEPHONE NUMBER (24 hrs) CHEMTREC (800) 424-9300
COMPANY CONTACT (business hours) Corporate Safety

SYNONYMS Compressed Natural Gas (CNG), Dry Natural Gas, Methane, Pipeline Spec Gas, Processed Gas, Residue Gas, Sweet Natural Gas, Treated Gas

See Section 16 for abbreviations and acronyms.

2. COMPOSITION and INFORMATION ON INGREDIENTS

INGREDIENT NAME (CAS Number)	EXPOSURE LIMITS	CONCENTRATION PERCENT BY VOLUME
Natural Gas, dry	None established by OSHA or ACGIH	100
Methane	None established by OSHA or ACGIH	
Ethane	None established by OSHA or ACGIH	

3. HAZARDS IDENTIFICATION

EMERGENCY OVERVIEW
DANGER!
EXTREMELY FLAMMABLE GAS - MAY CAUSE FLASH FIRE OR EXPLOSION!

EYES

Figure 1 : Sample MSDS

Use of high resolution satellite images for making GIS maps

The effective management of technological risk is an information intensive process and has a strong spatial dimension. The overall goal with regard to obtaining spatial data for Haldia and using it for risk management was towards delivering accurate, appropriate information on spatial features that may pose a technological risk or can be considered to be a vulnerable element at risk or may be an important resource for the purposes of emergency response and mitigation (critical facilities). With the objective of building digitized GIS maps of the Haldia region, Panchromatic and Colour composite IKONOS imagery of 1m and 4m spatial resolution respectively have been used to identify land-use of the study area using the ArcGIS 9x software package. The images were geo-referenced based on ground-truthing done using handheld GPS. The land-use cover classification of the area carried out includes agricultural lands; residential areas, villages and slum clusters, industrial and commercial areas; forests and greenbelts; ponds, wetlands and rivers; and transportation corridors and has been stored in the land-use geo-database layer as polygon parcels. Figure 2 below illustrates the various land-uses that have been mapped.

Figure 2 : Land use mapping for Haldia

The MAH installations have been stored as a separate layer to facilitate better viewing and efficient querying from the RDBMS. The exact location of storage sites for hazardous substance was matched with site maps made available by the industries and were digitized as a point feature geo-database layer. In a similar manner, the exact location of critical facilities like educational institutions, hospitals, commercial complexes and response agencies like police, fire stations and administrative buildings have been identified and digitized on the map as separate point feature geo-database layers. In total four individual layers were prepared: land use, hazardous storages, critical facilities and elements at risk.

In addition, detailed attribute information on elements at risk have been stored in the RDBMS and linked to the spatial features to enable querying during various stages of disaster risk management, such as emergency planning, preparedness, response and mitigation. Such information includes the demarcation of high population risk areas related to the impact by a toxic release, fire or explosion at a nearby hazardous facility, areas which are environmentally sensitive or have fragile ecosystems and critical facilities like educational institutes, hospitals and market places. Varying patterns of population occupancy during different times of the day in each of these receptors has been taken into account to provide accurate temporal information to decision makers and responders when they plan for evacuation or location of shelters.

7. ERRIS SOFTWARE AND WEB-GIS COMPONENTS

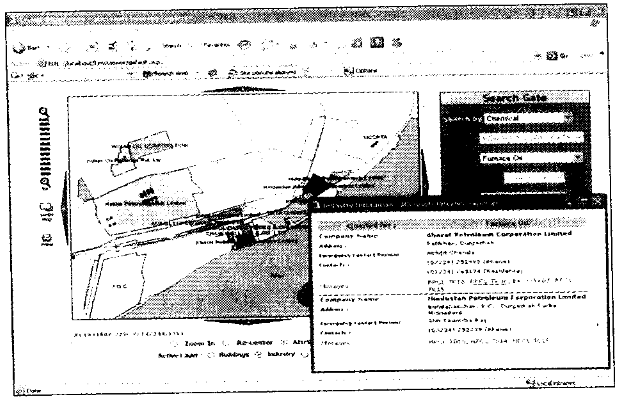
The most crucial component of ERRIS is a customised Risk Information System (RIS) application that provides spatial information on various facets of risk management. This application software is capable of performing real time data access, retrieval, analysis and presentation through a customized web browser based interface and is linked with spatial maps and back-end databases so that various queries can be handled when required.

The following are the key components of the application:

- A spatial geo-database storing geometry and attribute data in a Relational Database Management System (RDBMS).
- A set of web server, spatial data server and application servers that can pre-process and extract data from the RDBMS, handle queries in real time and forward them to a customized user interface.
- A customized browser-based user interface that enables access to the maps and risk related data for users connected to the internet or the local intranet.

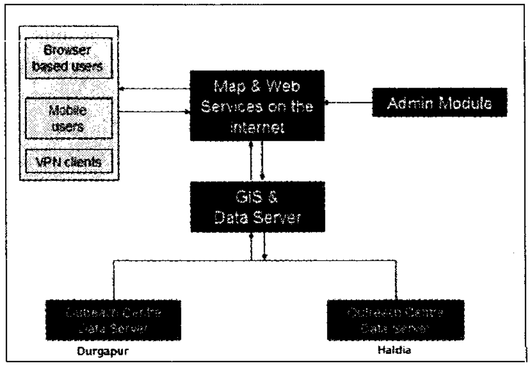
Using the components described above, the RIS would enable the stakeholders with a relatively simple, low-cost, yet powerful way of sharing and accessing critical industry and risk related information for emergency response planning or in real-time at the time of an emergency (Figure-3).

Figure - 3 : ERRIS Software Application Interface showing map browser and the information windows that pop-up on querying



As mentioned earlier, the ERRIS software application is based on a thin-client Web-GIS architecture that ensures easy maintainability of the application while at the same time providing scalability to accommodate future changes. Since communication of the various software components is based on the standard HTTP protocol, a high degree of hardware independence has also been achieved. At present local outreach centres at the industrial towns of Haldia and Durgapur are being set up and linked to the Risk Management Resource Centre (RMRC) at the ICC. The RMRC would host the central data and map servers that would coordinate the various information resources and provide regular updates to the outreach centre local servers, across the internet.

Figure 4: ERRIS Deployment Architecture



8. DEVELOPMENT OF A DECISION SUPPORT SYSTEM

It is important that users of ERRIS are able to make a judicious decision under constraints of time and resources during an emergency scenario. Consequently, the ERRIS system is presently being upgraded to assist in basic decision-making. This is being done by integrating a modeling sub-system to the software application, which will help to predict the consequences of accidental chemical releases and resulting fire or explosions and display the same on the GIS map as a 'hazard footprint'. The models being used are based on standard equations formulated by the US Environmental Protection Agency (10) and will be able to predict an endpoint distance in terms of concentration of toxic chemicals, exposure to heat radiation or explosion overpressure due to a particular accident scenario at a hazardous facility. The endpoints would then be rendered dynamically on the GIS map as a hazard footprint and would assist the decision maker and the administration to issue an early warning to residents of the affected area or direct responders to initiate preventive evacuation or rescue operations. It would also help extract information on the probable number of people at risk or elements at risk which may potentially be affected by the simulated accident. The prediction of potential off-site consequences would be based upon a minimum set of data requirements so that it is easy to use during an emergency scenario and the aim is to conservatively delineate areas that may get affected by the accident. To enable this, the model would directly input chemical specific and storage related data from the RDBMS and also provide options to the user to make a rational choice between different probable scenarios. Also, when the exact nature of the accident is confirmed by the responders, a fairly accurate estimate of the potential loss suffered as a result of a risk scenario can be assessed and evaluated by the system.

9. CONCLUSIONS

The ERRIS project, when operational, is envisaged to have a significant beneficial impact on all the stakeholder groups involved. It would help in building capacity at the local level to manage local environmental risk related issues, which is in accordance with the goals of UNEP's Local Agenda 21. The project would also boost the efforts of the Indian and State Government machinery to enable local authorities to plan and operate an environmental infrastructure as has been mandated by the Indian Constitution through the 73rd and 74th amendment of 1994. Additionally, the ERRIS would play a central role by helping the various government bodies at the state and local level, industries and communities to work in unison with increased levels of cooperation and coordination with the goal of enhancing the exchange of information and knowledge amongst each other. In the process, following a bottom up approach, it would seek to shape local level strategy and policies that would assist in the implementation of national and regional policies and regulation in the area of risk management.

At the same time it would significantly improve the capability of the local decision makers, other social actors (including response personnel, police, fire brigade and hospitals) and the community to respond to a risk situation. With the availability of GIS maps of the regions where risk management planning is being carried out, these data can be easily accessed by the industries, and administrative bodies thereby providing the responders and other stakeholders appropriate and sometimes time-critical information on industrial risks. Additionally, given the existing status of institutional frame-work and the supporting infrastructure, ERRIS would go a long way establishing an effective and efficient system for risk management that can be emulated and implemented in all industrial towns of the country.

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