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Training Module

Geoinformatics Applications in Chemical Risk Management

Anandita Sengupta, Debanjan Bandyopadhyay and Nilanjan Paul
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SENES Consultants India Pvt. Ltd.

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Training Module

Geoinformatics Applications in Chemical Risk Management

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Message from GIZ–IGEP



Dr. Dieter Mutz
Director
Indo–German
Environment Partnership
(IGEP)
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GIZ–Germany India Office
New Delhi, August 2013

National Institute of Disaster Management for implementing the "Environmental Knowledge and Disaster Risk Management" (ekDRM) project, aimed at strengthening capacity building initiatives in knowledge management and risk reduction for disasters caused by natural hazards, such as floods, cyclones, drought, or manmade disasters caused by industry. The design and development of training tools, such as an internet based training and knowledge management system and blended learning training methodology and the development of training materials are important activities under this project.

It gives me great pleasure to introduce these training module to help trainees in developing knowledge and skill in specific thematic areas, to reduce the risk of disasters by careful spatial planning.

I take this opportunity to express appreciation of the commitment of NIDM, Ministry of Home Affairs, Govt. of India, New Delhi, SENES Consultant (India), the Faculty of Geo-information Science and Earth Observation, University Twente, the Netherlands, and ifanos c&p, Germany who extended their support and cooperation to this effort. I wish that such modules are used extensively by all stake holders across the country.

Foreword



Dr. Satendra,
IFS Executive Director,
NIDM
New Delhi, August 2013

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 like SEZ have been witnessing a steady induced growth of population. Along with the development of economy, this has also in turn led to increase in vulnerability of people to chemical risks posed by potentially hazardous industries. Recent natural disasters like Sichuan earthquake (2008) and Fukushima earthquake (2011) have also triggered chemical and nuclear disasters. These experiences call for the need to adopt an integrated approach to disaster management and establishing a linkage with spatial planning.

Geoinformatics is a powerful tool for Disaster Risk Reduction. Special emphasis has been given in National Policy on Disaster Management 2009 on use of Geoinformatics for hazard zonation, mapping and vulnerability analysis in a multi–hazard framework for all disaster prone areas, including Hazard and Consequence Mapping on GIS platforms for all chemical accident prone districts. National Disaster Management Guidelines on Chemical Disaster Management, 2007 also recommends the use of GIS based tools like GIS Based Emergency Preparedness and Response System (GEPR) developed by MoEF with technical expertise of NIC and Environment Risk Reporting and Information Systems (ERRIS) initiated by Indian Chamber of Commerce (ICC), Kolkata under a project funded by the European Union with the technical collaboration of ITC Netherlands.

Accessibility of up–to–date information on industrial hazards, exposure, vulnerability and resources available for response etc. in an easily accessible information management system can enable decision makers and responders to prepare for and respond to chemical disasters. Similar to natural disasters, chemical risk management is also a spatial problem and an integrated geo–informatics system can play an important role in chemical disaster risk management. Simple, low–cost and open source GIS systems can be used by disaster

managers and local authorities to properly plan the areas under their jurisdiction, and to incorporate the local knowledge and ensure community participation, combined with modelling results from experts.

Despite the tremendous potential these tools are yet to be used by the disaster managers and authorities primarily due to the lack of awareness and skills. Hazard Mapping, Vulnerability analysis and risk assessment exercises are carried out by various national and state level agencies and institutions like NRSC, State Remote Sensing Applications Centres, BMTPC and so on. However, most of these agencies are carrying out natural disaster focused analysis and are yet to include chemical risks as a part of the HRVC exercise. GEPR tool implemented by MoEF is yet to be integrated with the HRVC and Emergency Planning process.

NIDM and GIZ Germany, under the aegis of Indo–German Environment Partnership Programme (IGEP) with Ministry of Environment and Forests, implemented a joint project entitled "Environmental Knowledge for Disaster Risk Management (ekDRM)" wherein development of case studies and training modules are the key activities. The module "Geoinformatics Applications on Chemical Disaster Management", developed by the faculty members of NIDM and SENES Consultant India in cooperation with the Faculty of Geo-information Science and Earth Observation, University Twente, the Netherlands, is a praiseworthy effort. This module covers learning units on hazard mapping, risk assessment, emergency response and risk sensitive spatial planning with case studies and hands on exercises.

I am sure, the module is first of its kind developed in India and shall be of significant contribution in the capacity building and training within the country and outside. NIDM would welcomes suggestions from the users of this module for improvements in future.

Contents

1	**Learning Unit: Introduction**		1
	1.1	Objectives and Scope	1
	1.2	Chemical Industry and Risk – The India Perspective	2
	1.3	Use of GIS for Chemical Risk Management	6
	1.4	GIS Tools to be used in this Training	7
	1.4.1	Quantum GIS	7
	1.4.2	Risk Management Information System	7
	1.5	Introduction to RiskCity	8
2	**Learning Unit: Geoinformatics Basics**		13
	2.1	What is GIS"?"	13
	2.1.1	The Components of GIS	14
	2.2	GIS Data Types	15
	2.3	Fundamentals of Remote Sensing	18
	2.3.1	Geo–referencing a Raster Image	21
	2.4	Spatial Analysis	22
	2.4.1	Spatial Interpolation of Population	23
	2.5	Deficiencies of Traditional GIS and Way Forward	25
3	**Learning Unit: Regulatory and Institutional Framework for Chemical Risk Management**		27
	3.1	Introduction	27
	3.2	Regulatory Framework in India	28
	3.2.1	Regulatory Scope and Definitions	31
	3.3	Institutional Framework	34
	3.4	Information System and Regulatory Support	35
4	**Learning Unit: Chemical Risk Management Practice**		39
	4.1	Risk Management for Chemical Hazards	39
	4.2	Type / Nature of Chemical Hazards	41

	4.2.1	Toxic Release	41
	4.2.2	Explosion	45
	4.2.3	Fire	48
4.3		Risk Assessment	50
	4.3.1	Risk Identification	50
	4.3.2	Identification and Development of Accident Scenarios	54
	4.3.3	Risk Analysis	55
	4.3.4	Risk Evaluation and Risk Mapping	58
5	**Learning Unit: Emergency Management**		63
5.1		Introduction	63
5.2		Emergency Management Process	64
5.3		Emergency Management and Information Requirements	66
5.4		Emergency Management and GIS	67
5.5		Emergency Management Tools	69
	5.5.1	ALOHA	70
	5.5.2	Web–GIS based Emergency Management Tool– EMDSS	72
5.6		Emergency Evacuation	73
5.7		India Emergency Management Perspective	75
6	**Learning Unit: Risk and Land–use planning**		**7**9
6.1		Introduction	79
6.2		Land–use Planning – Fundamentals	82
	6.2.1	What is Land–use Planning?	82
	6.2.2	Land–use Planning System– Scale and Nature of Planning	83
	6.2.3	Land–use Planning Perspective	85
6.3		GIS and Land–use Planning	86
6.4		Risk Informed Land–use Planning	90
6.5		Indian perspective on risk and land use planning	95
6.6		Risk Based Land–use Planning Techniques, Tools	96
	6.6.1	Semi–quantitative Method for Calculating Cumulative Risk	97
	6.6.2	Web–GIS based Planning Support System for Risk Management	99

List of Tables

Table 4–1: Explosion damage and endpoints 47
Table 4–2: Fire damage and endpoints 50
Table 4–3: Frequency ranking 59
Table 4–4: Consequence ranking 60
Table 4–5: Risk ranking 60
Table 6–1: Planning paradigm and application of information systems 85
Table 6–2: Population density ranking 98
Table 6–3: Risk Ranking Criteria 99

List of Figures

Figure 1–1: XII Five Year Plan – Growth projections for chemical industry segments 3
Figure 1–2: Map showing concentration of MAH Units in Districts of India 5
Figure 1–3: Change in land–use in RiskCity 9
Figure 2–1: Six Components of GIS 14
Figure 2–2A: An ortho–image. 16
Figure 2–2B: A digital raster graphic. 16
Figure 2–3A: A vector point layer. 17
Figure 2–3B: A vector polyline layer. 17
Figure 2–4: Satellite based remote sensing. 19
Figure 2–5: Conversion of Remote Sensed Data 20
Figure 2–6: A High and Low resolution image of the same area of interest in RiskCity 21
Figure 2–7: Population Interpolation on a 100 X 100 m Grid using Census Tract Data 24
Figure 3–1: Regulatory framework for managing industrial risk 28
Figure 3–2: Institutional framework 34
Figure 3–3: The risicokart interface which can be viewed at http://www.risicokaart.nl/en/ 36
Figure 4–1: Framework for chemical risk management as per ISO 30001 40
Figure 4–2: Gaussian Dispersion 43
Figure 4–3: Fuel Triangle 48
Figure 4–4: Template of a MSDS 52
Figure 4–5: A Event tree for LPG storage tank releases 54

Figure 4–6: Flowchart of QRA based risk assessment 56
Figure 4–7: Risk matrix 60
Figure 5–1: Emergency management cycle 65
Figure 5–2: Emergency Management Paradigm 68
Figure 5–3: Modeling of consequences 70
Figure 5–4: Toxic Threat Zone Modelled by ALOHA 71
Figure 5–5: ALOHA Threat Zone overlaid on GIS map using MARPLOT 71
Figure 5–6: Web–GIS enabled Emergency Management Decision Support Interface of the RMIS 72
Figure 5–7: Evacuation difficulty model 74
Figure 6–1: Sustainable land management paradigm 81
Figure 6–2: Cartographic modelling 88
Figure 6–3: Schematic procedure for spatial multi–criteria evaluation based on AHP 89
Figure 6–4: Interface of the SMCE based planning support system within RMIS 99

List of Boxes

Box 1–1: What happened in in Bhopal 4
Box 2–1: GIS, paper maps and the issue of scale 17
Box 2–2: Image data characteristics and spatial resolution (source) 20
Box 2–3: Tobler's law of geography and spatial measurement 23
Box 3–1: Key regulations 29
Box 3–2: Category of hazardous chemicals 31
Box 3–3: Definition of MAH industry 32
Box 3–4: Setting priorities for management of hazardous chemicals 32
Box 3–5: Community Right–to–Know about Risk 35
Box 4–1: Key facts about toxic chemicals 40
Box 4–2: Effects of hazardous incidents – Damage functions and probit 44
Box 4–3: Toxic endpoints – "Emergency Response Planning Guidelines" 45
Box 4–4: Flammability limits (UEL and LEL) 46
Box 4–5: Hazard identification standards – NFPA guidelines 52
Box 4–6: Risk metrics – individual and societal 58
Box 4–7: Risk map 61

Box 5–1: GIS based Emergency Planning and Response System 76
Box 6–1: Managing land from a holistic perspective 80
Box 6–2: National Urban Information System 87
Box 6–3: Article 12 of Seveso II Directive 91
Box 6–4: National examples on risk guided land–use planning approaches 93
Box 6–5: Risk based land–use planning – ARIPAR tool 96

List of Exercises

HANDS–ON GIS EXERCISES 106

Exercise for Learning Unit 2 107
Exercise 2A: Exploring Spatial Data using QGIS 107
Exercise 2B: Fundamentals of Remote Sensing 121
Exercise 2C: Spatial Analysis 126

Exercise for Learning Unit 3 131
Exercise 3A: Regulatory Criteria for Hazardous Industries 131
Exercise 3B: Finding Safe Distance from Storage Tanks 133
Exercise 3C: Finding Risk Information from risicokaart.nl 137

Exercise for Learning Unit 4 139
Exercise 4A: Hazard identification from Labels 139
Exercise 4B: Identification of Chemical Hazards and its preventions Using MSDS 142
Exercise 4C: Risk Identification using GIS Application 143
Exercise 4D: Calculation of Hazard End–point for Pool Fire using Equations 145
Exercise 4E: Consequence Analysis– Generating the Hazard Scenario for Vapour Cloud Explosion 146
Exercise 4F: Preparing Risk Map using Chlorine Scenario 148

Exercise for Learning Unit 5 153
Exercise 5A: Estimating hazard footprint for Vapour Cloud Explosion using ALOHA 153
Exercise 5B: Using a simulation model like ALOHA to determine the number of affected population from a toxic release. 157

Exercise 5C: Using RMIS to determine the number of affected population from a toxic release. 161

Exercise 5D: Calculating evacuation vulnerabilities as a measure of emergency response preparedness 164

Exercise for Learning Unit 6 167

Exercise 6A: Establishing Zoning Plans (Risk based approach) 167

Exercise 6B: Establishing zoning plans continued (consequence based approach) 172

Exercise 6C: Identifying land for industrial development 172

Abbreviations

GIS	–	Geographic Information Systems
RS	–	Remote Sensing
EMDSS	–	Emergency Management Decision Support System
GDP	–	Gross Domestic Product
CAGR	–	Compound Annual Growth Rate
MAH	–	Major Accident Hazard Units
LPG	–	Liquefied Petroleum Gas
UEL/UFL	–	Upper Explosive/Flammable Limit
LEL/LFL	–	Lower Explosive/Flammable Limit
NFPA	–	National Fire Protection Agency
MSDS	–	Material Safety Data Sheet
ALOHA	–	Areal Location of Hazardous Atmospheres
RMIS	–	Risk Management Information System
MIC	–	Methy IsoCyanate (gas)
PCPIR	–	Petroleum, Chemicals and Petrochemicals Investment Region
SEZ	–	Special Economic Zone
NDMA	–	National Disaster Management Authority
QGIS	–	Quantum GIS
GIS	–	Geographical Information Science
GPS	–	Global Positioning System

RCDA	–	RiskCity Development Authority
GP	–	Gram Panchayats
ICT	–	Information and Communication Technology
DBMS	–	Database Management System
OISD	–	Oil Industries Safety Directorate
MSIHC	–	Manufacture, Storage and Import of Hazardous Chemical (Rules)
EPCRA	–	Emergency Planning and Right–To–Know Act
TLV	–	Threshold Limit Value (TLV)
IDLH	–	Immediately Dangerous to Life and Health
SMCE	–	Spatial Multi–Criteria Evaluation
PSS	–	Planning Support System
DSS	–	Decision Support System

1

LEARNING UNIT 1 INTRODUCTION

1.1 Objectives and Scope

The overall objective of this training module on "Geoinformatics Applications for Chemical Risk Management" is to provide theoretical and practical inputs that will encourage the application of Geographical Information Science (GIS) and Remote Sensing (RS) for management of risks originating from hazardous chemical industries and storage facilities. The specific objectives can be delineated as follows:

- Provide the necessary theoretical inputs to understand and appreciate the decision making requirements in chemical risk management and related theory and concepts that guide such decision making;
- Provide the necessary theoretical inputs to understand and appreciate how GIS & RS, with their abilities to consolidate and manage spatial data and undertake spatial analysis, can play a key role in supporting decisions pertaining to chemical risk management.
- Reinforce theoretical and analytical constructs through practical hands–on training.

The training will gradually progress from undamental understanding of GIS and chemical risk assessment to providing inputs of solving complex risk assessment and management problems that may be encountered by planners, decision makers and other interested stakeholders. These problems have been categorized into three principal focuses:

1. Obtaining risk information
2. Emergency preparedness and response
3. Risk reduction through land–use planning

For successful learning, it is imperative that a realistic case study situation be selected so that the participants can put in perspective the problem and understand the various dimensions of risk management being laid out in the program. Accordingly, an area in the country which houses a cluster of Major Accident Hazard (MAH) industries and is witnessing fast paced development has been selected as case study area (Section 1.6). Maps and other information from the area will provide participants with the scope for experiencing a realistic learning context and hands–on exercises.

For the purposes of simplicity, we will not consider other risks that may arise from hazardous chemicals: radioactive or oil spills and related accidents. Also we are not going to consider natural hazard induced chemical risks and cascade scenarios for hazards from mobile sources.

1.2 Chemical industry and risk – the India perspective

Since the 1990's, India remains one of the fastest growing economies in the world, with the compound annual growth rate (CAGR) for gross domestic product (GDP), over the decade ending 2012–13 being 7.9 %. Further, India's Economic Survey for 2012–13 predicts a healthy growth rate between 6.1–6.7% for the current fiscal. Such sustained growth has resulted in the doubling of India's per capita GDP within the last seven years and presents an immense opportunity for improving economic and living conditions of a large percentage of population. A considerable part of this growth is because of the good performance of key industrial sectors including the chemical industry sector. The chemical industry constitutes a key segment in India with a market share of 14% of the overall industrial production in the country. With estimated revenue of Rs. 500,000 crores, India today is the 3rd largest chemical manufacturer in Asia (after China and Japan) and 12th largest in the world.

In the last decade, the country has witnessed the setting up of some of the largest petroleum refinery complexes in the world and the government plans to launch several large chemical industry clusters in Petroleum, Chemicals and Petrochemicals Investment Regions (PCPIRs) and Special Economic Zones (SEZs). The outlook to the 12th Five Year Plan (2012 – 2017) envisages that the country will become a favourable destination for the chemical industry with a projected annual growth rate varying between 11–15%. The anticipated growth rates for specific industry segments are shown in Figure 1–1.

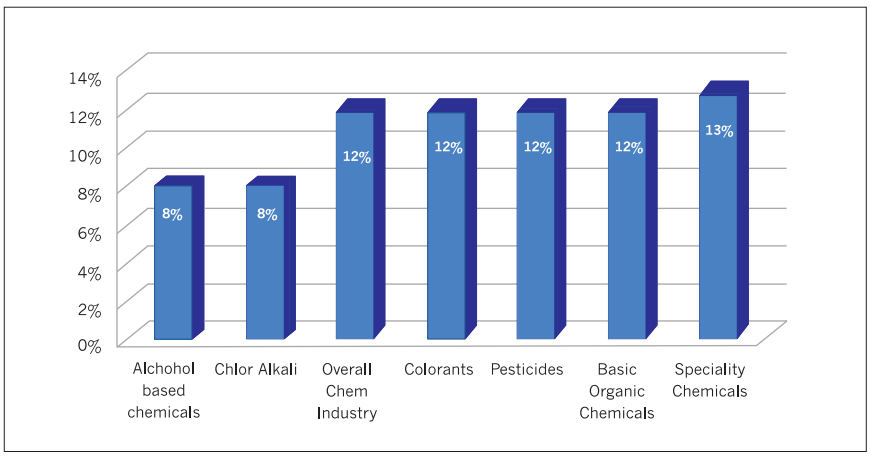


Figure 1–1: XII Five Year Plan – Growth projections for chemical industry segments

However, there is also a flip side of this positive story. India has pursued a development model that is hinged on rapid industrialisation, but in many cases such industrialisation has occurred in a disorganised manner. This has often led to the growth of polarised industrial urban centre's that do not have adequate infrastructure, appropriate housing facilities, other urban amenities and support systems. In the absence of such planning, many industrial clusters have not taken into account environmental and risk considerations during their development phase. This, in–turn, led to large number of low–income and marginal people setting adjacent to highly hazardous industries, thus becoming vulnerable to any industrial accidents of which the Bhopal disaster, one of the worst man–made disasters in history, is rather telling example (Box 1–1). Subsequent accidents at chemical industry sites across the country have caused considerable damages and fatalities to workers as well as communities in the immediate vicinity of chemical plants. The major accidents include the vapour cloud explosion at HPCL Refinery in Vishakapatnum (1997), explosion at Gas Cracker Complex in Nagothane (2008), fire at IOCL Fuel Depot in Jaipur (2009).

Box 1–1: What happened in in Bhopal



like India witnessing fast paced development still remains crucially important. About 30 years back, on the night of December 1983, highly toxic methyl–isocynate (MIC) gas leaked from the Union Carbide pesticide manufacturing plant located at the heart of the Indian town of Bhopal. The official immediate death toll was more than 2000 and injured or disabled up to 200,000 others. Later, the government of Madhya Pradesh confirmed a total of 3,787 deaths related to the gas release. A government affidavit in 2006 stated the leak caused 558,125 injuries including 38,478 temporary partial injuries and approximately 3,900 severely and permanently disabling injuries. Though such estimates vary and the full impact of the accident may never be calculated, by any standard, it was a watershed event and qualifies as the worst manmade disaster that the world has witnessed to this day.

The immense loss suffered as a result of the incident, triggered a worldwide rethink on how industrial and chemical risks are to be managed with a number of countries taking proactive steps in terms of formulating regulations, planning criteria and establishing more stringent management control over hazardous industries. Though, considerable progress has happened worldwide, and more specifically in India, to reduce such risk through improvement in technology, better analysis resulting in protective measures and community awareness, the gravity of aspects related to management of chemical risk, in a densely populated country like India that is witnessing fast paced development, still remains crucially important.

Source: Jasanoff, S. "Bhopal Disaster and Right to Know", 1988 and Wikipedia

According to latest survey information available with NIDM, a total of 1871 MAH (Figure 1–2) industries were identified in the country. There are about 47 industrial clusters all over the country which house more than 10 MAH units and the numbers continue to grow. Many of these industrial towns are witnessing a steady growth of population, leading to a disproportionate increase in risk to its citizens. While considerable progress has been made in managing risks originating from such facilities, at the same time, several weaknesses are also currently identified as part of a review undertaken by a high level Committee set up by NDMA. These weaknesses cover the present regulatory and institutional context, the risk assessment process, risk treatment, communication and consultation with stakeholders and the system for monitoring and review of risk. Other key weaknesses are the unavailability of valid and updated information on industrial hazards and

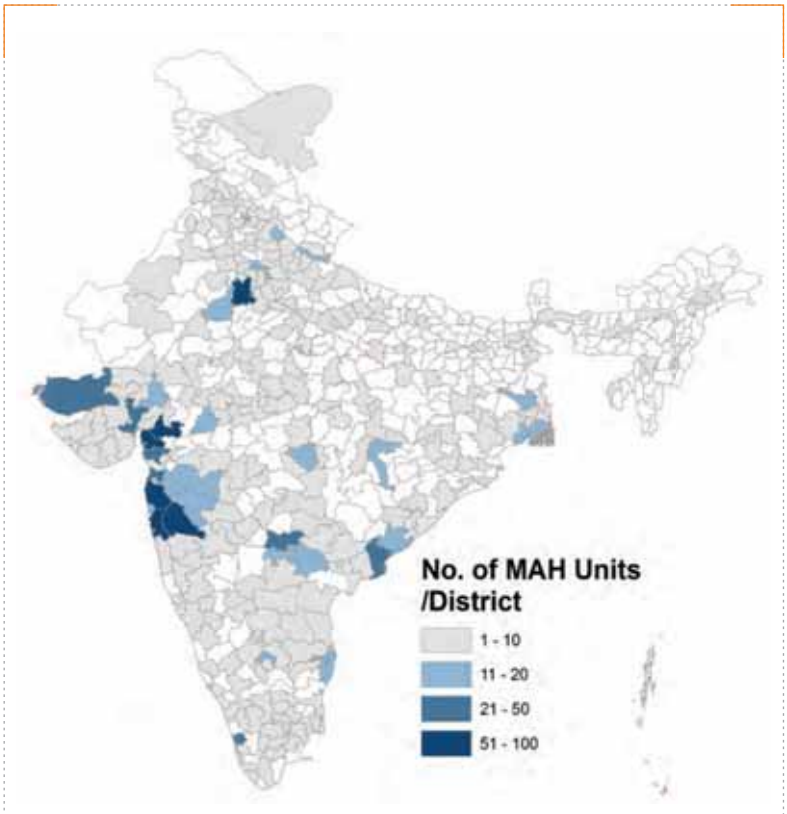


Figure 1–2: Map showing concentration of MAH Units in Districts of India

Source: Own compilation

potential risks and the inability to adequately factor these issues into the planning process. Increasingly, there is an emerging debate between various stakeholders including policy and regulatory bodies, the corporates and the community on the effective management of industrial risk.

1.3 Use of GIS for chemical risk management

Several aspects involved in management of chemical risk arising out of hazardous installations have a strong spatial component. The spatial problem can range from the simple (like locating and finding information about the potential source of a major hazard in the neighbourhood) to the more complex (mobilising emergency resources efficiently after assessing the probable footprint of a toxic plume that has been released as a result of a leakage in a chemical storage). Finding a solution to such problems:

- often require data on hazard and vulnerability to be brought together in an integrated database;
- need spatial analysis functions that can predict the footprint of a potential accident scenario;
- map exposure to elements at risk over an area of concern; and
- deliver the information to decision makers, authorities and planners through an effective interface wherein they can understand the results and take appropriate and timely decisions for risk reduction and mitigation.

Most of these functionalities can be provided by a well–designed GIS tool that is crucial for solving problems relating to risk assessment and management.

However, the situation in India indicates that the use of GIS in risk assessment for both natural and chemical hazards have not permeated to planners and decision makers. Some of the key reasons cited for lack of wider acceptance of GIS as an effective tool for risk management have been attributed to reasons like:

- inability of contemporary GIS software to capture and consolidate information from different sources;
- inadequate integration or linkage between GIS and risk management practices;
- lack of interoperability between presently existing datasets and tools, quality and accuracy issues in existing data;

- insufficient coordination and information sharing between different government departments and other actors who are involved in risk assessment and management;
- high cost of procuring and maintaining proprietary GIS software.

As a result, many of the GIS based analyses that are presently applied for risk assessment have more of an academic than a practical value.

There is an urgent need for developing standardised GIS based processes, methods and tools which can be made available to the risk management actors in the country.

This training manual would make an effort to lay down such processes, methods and tools which can be tried and tested on an Indian case study to prove their applicability, taking into account the opportunities and constraints that presently exist.

1.4 GIS Tools to be used in this training

1.4.1 Quantum GIS

Quantum GIS (QGIS) is a user friendly Open Source GIS, licensed under the GNU General Public License and provides basic as well as advanced GIS functionality through several individual components. The key component of QGIS is the QGIS Desktop application that enables the user to undertake several map–based tasks. These include data/layer analysis, editing and production of maps. Using QGIS Desktop the user can: visualize map data, associate symbols to the data, make selections, perform spatial analyses, create and present spatial data. The application can be operated through normal menu–based tool bars, icons and menus. QGIS allows the use of the most commonly used spatial data files – the shape (.shp) files. For the purpose of this training, we will use Quantum GIS Desktop (1.8.0).

1.4.2 Risk Management Information System

The second application to be used is an online tool called **Risk Information Management System (RMIS).** The RMIS is an integrated platform that allows for collation of risk and vulnerability related information from several sources and makes it available to risk actors through a customised web–GIS interface. It provides a simple, intuitive and user friendly interface through which the users can query and seek spatial as well as attribute information on risk sources, vulnerability and other aspects that

could play a significant role in managing chemical risk effectively. In addition, the RMIS also provides advanced decision and planning support capabilities which can be used by decision makers for specific uses like emergency management or land–use planning for an industrial area.

Note: It is important to note that both the GIS data provided to you for undertaking hands–on exercises (in the form of *.shp files) and those available in the RMIS database essentially originate from the same source data and closely resemble the situation on the ground for the case study area called RiskCity, which is a real–made–virtual area of interest selected for this training module.

1.5 Introduction to RiskCity

Risk City is located somewhere in the eastern part of India. Physically, the land mass of RiskCity falls within lower riverine plains of one of the major rivers flowing through the eastern part of the country, the Hooghly. Situated in the deltaic reaches of the river, it is located on a peninsula like area which is bounded by three rivers. The altitude varies between 2–4 meters above mean sea level. As a result there is very intense pressure on land resources. The population of the area has increased significantly over time since the industrialization and urbanization process commenced a few decades back.

By road, the main access to the RiskCity is either through a four lane national highway or a state highway that runs parallel to each other for most part. The city is also connected by rail one of the major railway corridors in the region passing about 50 km to the north–west. The nearest airport is about 200 km away in the nearest metropolitan city. Though, there are no records of natural disasters hitting the area in the recent past, the region is prone to cyclonic storms and tidal surges. Some localized flooding is also witnessed in low lying areas of RiskCity during the heavy rainfall months.

Since the commissioning of a port in RiskCity in the early 1970's, industrial development in the area has occurred at a rapid pace (Figure 1–3). Subsequently, with the onset of industrialization, the predominantly rural land–use of the area started to change considerably. The industries attracted population from the neighbouring regions and districts leading to the gradual urbanization of the RiskCity. At present the city has developed into a large industrial cluster that houses more than 20 major accident hazard (MAH) units.

From the planning point of view, the region happens to be one of the most densely populated regions in India, and even in the world, sustaining an average population density of 904 persons per km² resulting in a citizen to have an average of only about 0.11 hectare of space around him. RiskCity and its adjoining region, comprising of about 786 km² in total, has been declared as a planning area under the State Town and Control Planning Act[1] . As a result the planning and development of the area, including land–use planning, land management, setting of infrastructure, etc. is managed by the RiskCity Development Authority (RCDA).

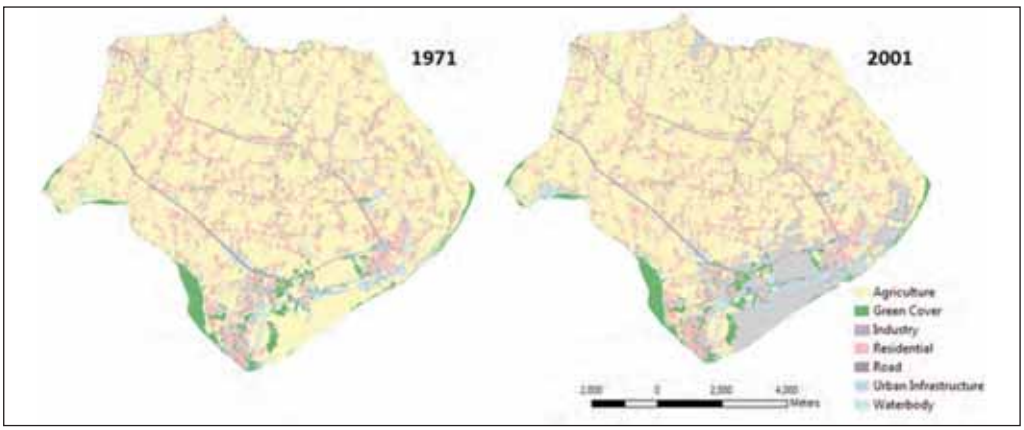


Figure 1–3: Change in land–use in RiskCity

Source: Own compilation

The area has also evolved as an educational hub with a large number of academic and professional training institutes which have come up to support the need for skilled manpower in the industries. In addition, a number of healthcare facilities and hospitals have also recently come up in the city.

The area is governed by the District administration and the block development offices which represent the Tier 3 of the administrative hierarchy. The local government in rural areas of RiskCity comprises of Gram Panchayats (GPs) and the urban area comes under a Municipality.

With a surge in the number of hazardous industries coming up and the gradual in–migration of people, the risk levels in RiskCity are continuously on the rise. However, till date, potential risks arising out of hazardous industries have never been previously factored into the planning process or the

[1] In the case of RiskCity, the West Bengal Town & Country (Planning & Development) Act, 1979

development of the region. Consequently, no effort has been made to maintain any exclusion or separation distance of residential areas or habitations from hazardous industries. In addition, unplanned development like slums and shanties still keep coming up right adjacent to boundary walls of large chemical industries. As a result, populated areas often co–exist with hazardous industries side–by–side resulting in very high vulnerability to the residents of the city.

In future, industrial development in RiskCity is supposed to happen at a more rapid pace, than at any other time in the past. The region has been selected as one of the locations for setting up a petroleum, chemicals and petrochemical investment region as per a central government program that aims to make India a large base for chemical manufacturing in the world. This industrialization is planned to encompass the total area of the RiskCity and its hinterlands.

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2

LEARNING UNIT 2 GEOINFORMATICS BASICS

2.1 What is GIS"?"

Geographic Information Systems (GIS) have emerged in the last decade as an essential tool for spatial planning and management. Their capacity to store, retrieve, analyse, model and map large areas with huge volumes of spatially related data has led to an extraordinary proliferation of applications. Geographic Information Systems are now used for disaster and emergency management, land–use planning, utilities management, environmental modelling, landscape assessment and planning, transportation and infrastructure planning, market analysis, visual impact analysis, facilities management, tax assessment, real estate analysis and many other applications.

GIS has obtained a distinct position in the Information and Communication Technology (ICT) for solutions that have a relation with location related computing. Some of the principal reasons are:

- The capability to act as a special purpose database in which both spatial and other related data can be stored based on a common coordinate system. The database can be manipulated for performing numerous tasks like route optimisation, land–use suitability analysis, resource mapping.
- The capability to provide a platform for integration of several technologies and data from different sources including remote sensing, GPS, internet, sensors, and other related technologies. These technologies can in turn be integrated with a number of analytical and decision making tools and techniques.

- The capability to act as a decision support system that involves the use of spatially referenced data in a problem solving environment based on which various alternatives can be evaluated and preferred decisions taken.

We will learn more about these aspects with specific reference to chemical risk management in the later chapters.

2.1.1 Components of GIS

A GIS comprises of a number of components that make it possible to enter, manipulate, analyse and present location related information to users. The main components (Figure 2–1) can be categorized as:



Figure 2–1: Six components of GIS

Source: Longley P.A., Goodchild M.F., Maguire C.D.J., Rhind D.W.; Geographic information systems and science

Hardware: Hardware is the computer or device in which the GIS software runs – it may vary from desktop computers to centralized computer servers and recently to hand held devices like tablets and smartphones.

Software: GIS software generally forms the most conscious component associated with GIS and comprises of computer programs which provide the functions and tools needed to input and store geographic and associated information. It also provides tools for feeding data into the system, querying and analysing information and interfaces for presenting maps and enabling user interaction.

Database: All GIS software packages rely on an underlying Database Management System (DBMS) for storage and management of the geographic and attribute data. The GIS communicates with the DBMS to perform operations and fetch specified by the user.

Procedures: Any organization intending to use GIS effectively, needs to establish procedures for managing the system – this will include creating lines of reporting and levels of access, mechanisms

for inputting and handling data. In addition, in order for GIS to be able to undertake specific and repeated analysis, GIS designers often have to create tools using easily executable scripts and macros.

People: The real power of a GIS comes from the people who use them and the ones who design, program and maintain it, provide data and interpret results. Today, GIS is being used by people in many different fields as a tool that enables them to perform jobs that have any relation to maps and dealing with locational information more effectively. Increasing, GIS technology is also being democratized with people increasingly subscribing to and getting a range of benefits from publicly accessible web–based tools like Google Earth, Wiki Mapia, etc.

In addition to these components, there is another element which is becoming inseparable from modern day GIS – the Network. Increasingly, GIS technologies are becoming network centric wherein the databases are centrally located and are being made available to users through web–client interfaces (ex. the Web Browser) using internet as a vehicle for content delivery. Such an arrangement is proving to be cost effective in providing GIS services to a wider range of stakeholders, and at the same time allowing non–experts users to explore GIS related services through intuitive and user friendly interfaces.

One of the greatest advantages of using GIS is its capacity to combine multiple layers of information into a composite map, thereby providing scope to use them in conjunction by making queries between related data sets to get relevant answers.

2.2 GIS data types

There are two principle methods that have been used to represent geographic aspects in a manner that it can be coded into computers and can be made available to users as geo–coded information – they are called raster and vector methods. Consequently, there are two types of data used by GIS: raster and vector data. In essence though, the datasets are mostly used in conjunction and complement each other in many forms of GIS analysis.

Raster is a method for the storage, processing and display of spatial data where space is divided into a rectangular array of rows and columns, which form a regular grid structure. Each cell within this matrix contains location co–ordinates as well as an attribute value – the individual cells are often called pixels (short for picture elements). Raster layers generally acts as a useful background layer in GIS and as a source for digitization and revising of vector data. In addition, raster data has a strong association for being able to represent continuous fields like digital elevation models showing

variation of altitude over space or showing distribution of temperature in space based on discrete readings recorded by weather stations. One of the commonest forms of raster data comes from remote sensing (Figure 2–2A) in the same way as digital photographs are taken of a subject. In addition, historical and existing paper maps are also scanned as digital raster graphic (Figure 2–2B) for use as GIS datasets.



Figure 2–2A: An ortho–rectified remotely sensed imagery that combines the image characteristics of a photograph with the geometric qualities and has been positionally corrected distortions and other errors. Here the high resolution imagery of RiskCity is shown.



Figure 2–2B: A digital graphic raster image of a scanned paper map which is geo–referenced to a real–world coordinate system. The figure represents the same area of RiskCity as per the city map made available by the Municipality.

Source: Own compilation

Generally, remotly sensed raster datasets with small cells contain more information than those with larger cells. Your application should dictate the resolution of the data that you use. High resolution data provides a great deal of information, but have a large amount of data, making them cumbersome to work with. There is also a greater cost associated with purchasing high resolution data, as the costs for collecting these data are generally much higher than for acquiring low resolution data.

Vector is a data structure that is used to store spatial data in a discrete form comprising of points, lines or arcs. The lines and arcs are defined by beginning and ending points, that meet at nodes, and if closed, form polygons. The locations of these nodes and the topological structure are usually stored explicitly. An area in vector form is captured by series of points or vertices connected by straight lines – the resulting vector representation is called the **'polygon'**. In a similar fashion, lines (including

curved features) are captured using a series of straight segments joined by nodes, with the representation being called the **'polyline'** (Figure 2–3B). In addition, each node can also be used to represent a specific geographical location and is called the **'point'** feature (Figure 2–3A). The vector format provides a much more efficient form of representing geographical data in terms of accuracy and also in terms of volume or size of data, which is an important aspect to be considered when using computer systems.



Figure 2–3A: A vector point layer representing storage location of hazardous chemicals and the polygon layer representing the industry boundary of one of the industries in RiskCity.



Figure 2–3B: A vector polyline representing the road network and the underlying land–use represented by a polygon layer in RiskCity.

Source: Own compilation

Box 2–1: GIS, paper maps and the issue of scale

In order to better understand the role of GIS in map making,there is an important comparison we need to make here – the difference between digital maps prepared using GIS and paper maps. The paper map still remains a powerful and effective means of communicating geographic information through an analogue representation of a real world model i.e. a part of the world that is scaled to fit the size of the paper. As a result, a paper map always shows a scale which can be measured physically (ex. in cm or inches) or a representation fraction indicating the ratio of the distance the Earth's surface and compared to the map (ex. 1:50,000 which is the scale of a toposheet in India) – both the scale representations are related and one can be calculated from the other!

In many cases, GIS produces a printed map on paper, along with a scale which is then used for making spatial decisions.

However, digital maps on the computer are more versatile. They allow closer interaction with the spatial data and allow the user the flexibility to choose only specific information to be displayed, for example by switching on and off map layers. GIS tools also provide for functionalities to create new layers, create overlays and make complex spatial analyses with the map layers and related information. These processes of overlays, analyses of interferences of different layers, producing other overlays or combining different layers is the power of GIS that support decision making. We will see examples of such uses in the later chapters of this module.

It must be remembered though that the concept of scale in a digital map is somewhat misleading – when a scale is at all quoted for a digital geo–database it is usually supposed to mean the scale of the map that formed the source of the data. So if a geo–database is said to be at a scale of 1:10,000 one can assume that it was created from a paper map at that scale and including representations of the features that are found on maps at that scale or an imagery that is not of sufficiently higher resolution to assist in developing a more detailed map (say to be able to see building footprints which become visible at a scale of around 1:500).



At this stage you should get acquainted with a GIS tool and learn how to visualize and interact with spatial data. For more details, please refer to EXERCISE 2A in annexure.

2.3 Fundamentals of Remote Sensing

Remote Sensing (RS) can be described as the process of making measurements or observations without direct contact with the object being measured or observed. In the context of GIS, remote sensing involves taking images of the Earth's surface using sensors which are placed on–board platforms comprising of satellites or aircrafts. The sensors record the reflected electromagnetic energy which is then processed and analysed for getting the necessary information for an area of interest on earth. Remote sensing data in the form of imagery of the earth's surface obtained by such a sensor can play an important role in disaster planning and response.

The general remote sensing process involves an interaction between incident radiation from the sun and the targets of interest which are physical features on the Earth's surface. In this form of remote sensing, called passive remote sensing, the sun provides a convenient source of energy which is either reflected (for the visible wavelengths of light) or absorbed and then re–emitted (as for infra–red wavelengths). This reflected energy is then captured by passive sensors placed in satellites or aircrafts – the mechanism is pictorially represented in Figure 2–4.

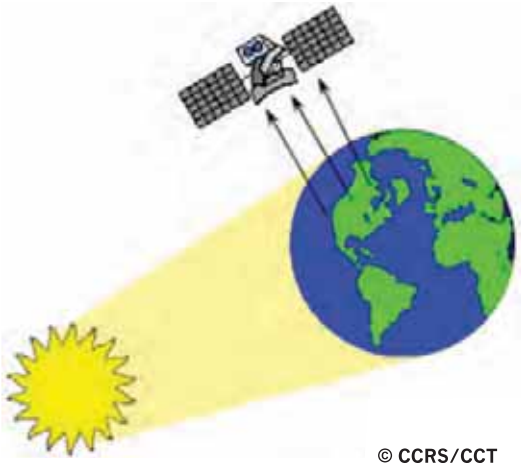


Figure 2–4: Satellite based remote sensing.

Source: CCRS/CCT website

It should be noted though that passive sensors can only be used to detect energy when the naturally occurring energy is available. For most reflected energy, this can only take place during the time when the sun is illuminating the Earth i.e. there is no reflected energy available from the sun at night. However, remote sensing can also be 'active' wherein the sensors emit their own energy and which is then reflected by the earth and captured – radars and laser scanning are common examples.

Remotely sensed data is normally procured in the form of digital images. In order to extract useful information from these images, several image processing techniques are employed to enhance the image, help in visual interpretation, and to correct or restore the image if the image has been subjected to geometric distortion, blurring or degradation by other factors. In many cases, image segmentation and classification algorithms are used to delineate different areas of the image into thematic classes. The resulting product is a thematic map of the area. This thematic map can then be combined with other databases of the area for further analysis and utilization. The overall process is shown in Figure 2–5.

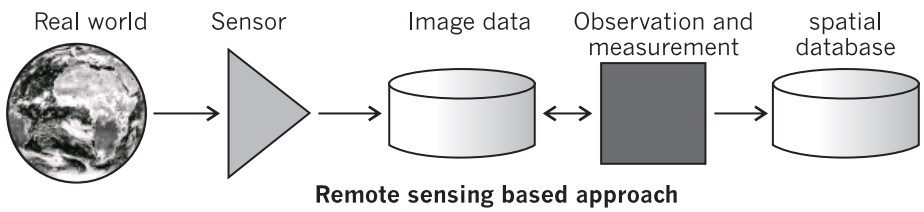
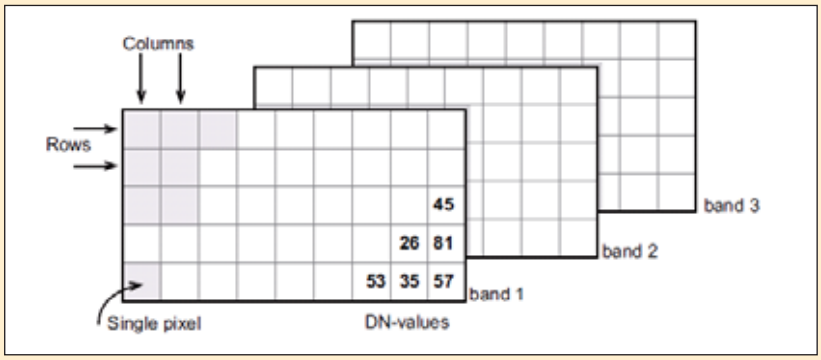


Figure 2–5: Conversion of Remote Sensed data of earth's features to spatial information in database

Source: ITC (2004) Principles of Remote Sensing

Box 2–2: Image data characteristics and spatial resolution (source)

As discussed in section 2.2, remote sensing image data comes in raster form and is stored in regular grid format (rows and columns). A single image element is called a pixel and for each pixel the measurements are stored as digital numbers or DN values. Typically, for each measured wavelength range a separate dataset is stored, which is called a band or channel.



The quality of the image is primarily determined by the characteristics of the sensor–platform system and one of the key elements of quality is indicated by the 'spatial resolution' of the data. Spatial resolution refers to the ability to distinguish small adjacent objects of data which

means that better the resolution of the data, more easily the structure of objects (on the ground) can be viewed in the image.

In current remote sensing practice, the data acquisition (sensor) systems are grouped into the following categories:

- Low resolution systems, with a spatial resolution of 1 km to 5 km
- Medium resolution systems with a spatial resolution of 10 m to 100 m
- High–resolution systems with a spatial resolution better than 10 m

Source: ITC (2004) Principles of Remote Sensing



A LISS false composite colour image with a spatial resolution of 22 m showing the industrial area of RiskCity. Note that the details are not very clear.



An IKONOS false colour composite image with a spatial resolution of 2 m showing the same area with higher degree of detail.

Figure 2–6: A high and low resolution image of the same area of interest in RiskCity

Source: Own compilation

2.3.1 Geo–referencing a raster image

One of the key issues in any GIS application is the correct geometry of the maps. Raster data is commonly obtained by scanning existing paper maps or obtaining aerial photographs and satellite images of the study area. As the earth is round and the maps are worked upon on a flat environment (either paper of computer screen), without appropriate processing, certain distortions may creep in

to the data. In addition, scanned map datasets do not normally contain spatial reference information (either embedded in the file or as a separate file). Even with aerial photography and satellite imagery, sometimes the location information delivered with them is inadequate, and the data does not align properly with other existing geographical data that one may have. Thus, in order to use raster datasets in conjunction with existing geographical data, it is required to align it or geo–reference it to a map coordinate system.

- First, a map coordinate system is defined using a map projection (a method by which the curved surface of the earth is portrayed on a flat surface).
- Second, the raster dataset is geo–referenced by assigning it to the coordinate system and defining its location using the map coordinates. Geo–referencing raster data allows it to be viewed, queried, and analysed along with other geographic data.

EXERCISE 2B

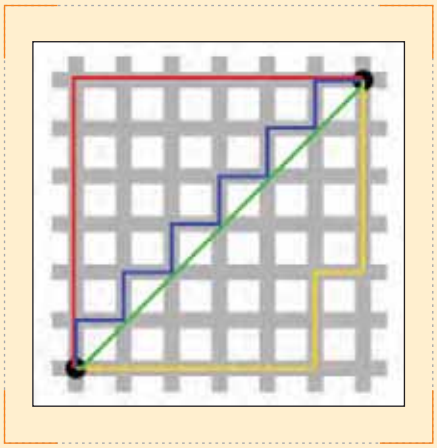


For a better appreciation of remote sensing data, geo–referencing and interacting with satellite images using a GIS tool please refer to EXERCISE 2B in annexure.

2.4 Spatial analysis

In addition to capabilities for storing and manipulating spatial data, another key functionality of GIS is to enable spatial analysis which can applied to find solutions for spatial and locational problems like finding the shortest route to a location, taking decisions on the siting of a new facility based on suitability analysis, understanding relationships between spatial disposition of features in space and likewise. Probably, the simplest of spatial analysis that is most frequently applied when using GIS tools is finding of distance and area. However, spatial analysis can also focus on more complex analysis that fall in the domain of spatial statistics, spatial distribution and interpolation of data and spatial decision and expert support systems. Such analysis assists in representing spatial and temporal phenomena like landscape evolution, environmental dynamics, consumer behaviour, urban growth, vulnerability estimation, etc. in the real world perspective and is backed up by theory, methods and technologies that are commonly highlighted as GIScience.

Box 2–3: Tobler's law of geography and spatial measurement



In geographic space, observations correspond to locations in a spatial measurement framework that captures their proximity in the real world. The fundamental tenet as per Tobler's First Law of Geography: if the interrelation between entities increases with proximity in the real world, then representation in geographic space and assessment using spatial analysis techniques are appropriate. Applied to the Manhattan City Block problem in urban settings, where the movement of a taxi is often constrained by paths parallel to the axis, the red, blue, and yellow lines have the same length (12) in both Euclidean and City Block metric. In Euclidean geometry, the green line has length $6\times\sqrt{2} \approx 8.4$, and 8 is the unique shortest path. In City Block geometry, the green line's length is still 12, making it no shorter than any other path shown.

Source: Wikipedia

2.4.1 Spatial interpolation of population

We will make an attempt to appreciate spatial analysis through a practical problem, which is very relevant in context of disaster management – to use a interpolation technique to accurately estimate population distribution in space (than what is available as census tract population) and a as result make a better prediction on vulnerability to risks.

It is commonly known that by convention census population counts are normally available for administrative zones such as villages or wards (in urban areas) and can be spatially represented in the form of chloropleth maps showing population size or density. While the area of such administrative zones can vary in between a few square kilometres, accurate vulnerability assessments require downscaling of data to finer spatial resolution or more refined units. This means, it should be possible to overlay the area exposed by a hazard on the population data in order to arrive at a more detailed estimate of people to be affected. In this context, being able to estimate population more accurately

can provide immense benefits for emergency preparedness and response, risk reduction planning and management. Several methods for such interpolation of population are available using spatial analysis techniques.

A technique for refining population distribution by combining complementary data on land–use interpreted from high resolution satellite imagery and population data available as per census tract has been formulated in this Section (Figure 2–7). Through the method, population information is spatially disaggregated from census tracts or administrative zones to actually inhabited residential areas of RiskCity. The resulting interpolated population is then presented as population density in the form of a unit grid area.

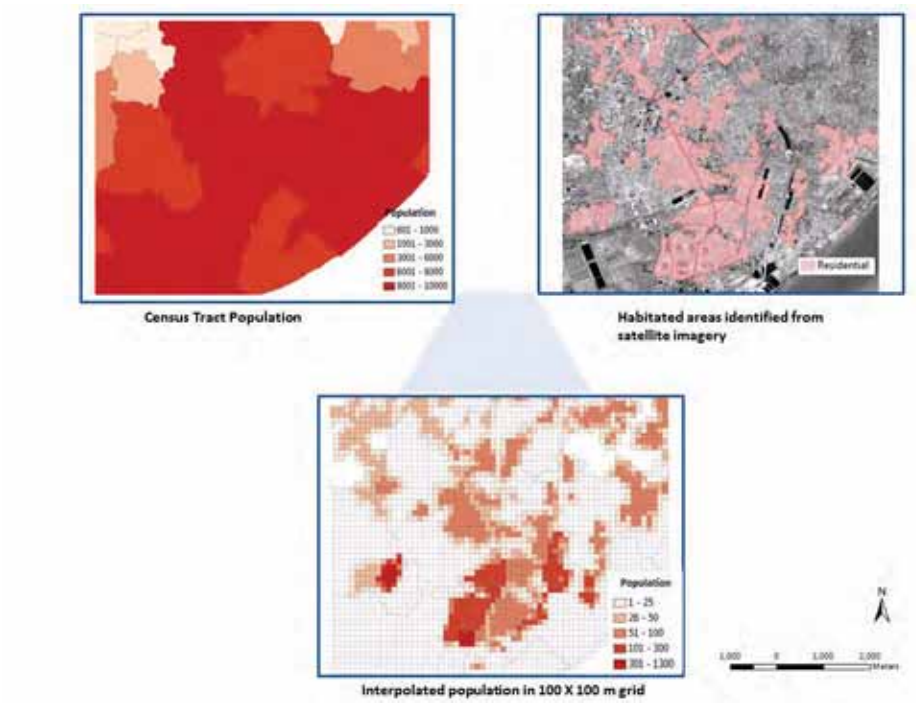


Figure 2–7: Population interpolation on a 100 X 100 m grid using census tract data

Source: Own compilation

EXERCISE 2B



You may refer to EXERCISE 2C in annexure for step–by–step instructions on how to undertake spatial analysis using a GIS tool.

2.5 Deficiencies of traditional GIS and way forward

It is important to realize that the set of functionalities available in commercial GIS software for modelling, planning, and decision making is still quite limited. Many functions need to be added through specially designed add–in's: for example, statistical, optimization, simulation, and decision algorithms; and there is no single tool that will meet all the analytical needs of a high level user. In addition, the complexity involved in operating most GIS software makes it necessary that the users have obtained some specialized training in geo–informatics. In the absence of such focused training, it has often been observed that the use of geo–informatics is often limited amongst planners and decision makers, who may have specialised domain knowledge, but have little or no experience in handling such tools.

At the same time, with the rapid progress of computing and networking technology and the proliferation of the internet, the last decade has witnessed considerable progress towards the use of distributed GIS. Increasingly, the internet is providing the new solution space through which GIS is being propagated and made available to users. Evolving web–services architecture is increasingly providing customised spatial analysis functions to users accessing a particular solution through a web–client interface using an online computer. Geo–browsers like Google Earth, Bing provide innovative ways of organizing and presenting geo–data through the Internet. Building on this success of web–GIS, there has been increasing interest in using the power and flexibility offered by systems to deliver spatial decision and planning support to users, while hiding the complexity of spatial analysis tools, decision models and algorithms. As a result, through these tools, the use of GIS is being increasingly democratized and it is becoming more accessible to planners and decision makers.

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3

LEARNING UNIT 3 REGULATORY AND INSTITUTIONAL FRAMEWORK FOR CHEMICAL RISK MANAGEMENT

3.1 Introduction

Most countries have regulations that potentially hazardous industries and operations need to comply with in order to demonstrate sound environmental and safety performance and minimize the chances of a major accident. Some regulations focus on setting up an adequate institutional framework at the administration level to enable proper decision making on issues related to emergency preparedness, response and mitigation while others try to ensure better risk management by potentially hazardous industries. Specific clauses in risk related legislation also lay stress on making risk information available to the stakeholders and the public so that they are better prepared to face emergencies.

Internationally, the Emergency Planning and Community Right–to–Know Act (US) and the Seveso II Directive (EU) are typical examples in developed countries. A comprehensive regulatory regime also forms the cornerstone for better management of chemical risks, especially in developing countries like India. The environmental regulations in India are still in process of development and the legal system for polluting and hazardous industries is gradually moving towards the principle of 'polluter pays'. Recently, the Government has also enacted a law to look at different aspects of disaster management planning at the Central, State and District levels. A separate module " Training Module on Chemical (Industrial) Disaster Management" published by the National Institute of Disaster Management (NIDM) discusses in further detail the regulatory and institutional framework for chemical risk management in India

(www.nidm.gov.in/PDF/modules/chemical.pdf).

3.2 Regulatory framework in India

After being a party to the Stockholm Convention[2], the government of India formulated several environmental regulations starting with the Water Act of 1974. Additional impetus to broaden the portfolio of regulations to cover issues like industrial hazards and risks was prompted primarily by the Bhopal disaster of 1984. The immense damage caused by the accident made it obligatory for the government to create an overarching framework regulation called the Environment (Protection) Act of 1986 and drawing powers from it, a number of subsidiary regulations in the form of Rules that focused specifically on control and minimization of risk from hazardous installations. The key regulation in this context was the Manufacture, Storage and Import of Hazardous Chemical Rules of 1989, the Public Liability Insurance Act of 1991 and the Emergency Preparedness Rules of 1996. In addition, provisions of existing regulations like the Factories Act and Rules, the Petroleum Act and Rules, the Explosive Act and subsidiary Rules that were concerned with regulating safety performance of industrial operations and plants involving hazardous operations or handling of the hazardous chemicals and explosives were strengthened. The overall regulatory framework for chemical risk management can be represented as in Figure 3–1.

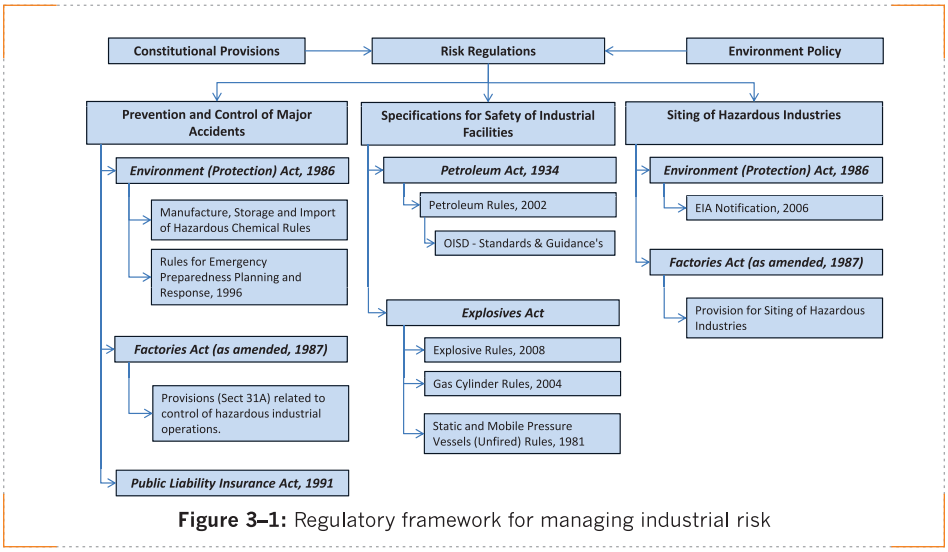


Figure 3–1: Regulatory framework for managing industrial risk

Source: Own compilation

[2] In 1972, the UN General Assembly decided to convene the Stockholm Conference to discuss the state of the global environment. Attended by the representatives of 113 countries, 19 inter–governmental agencies, and more than 400 inter–governmental and non–governmental organizations, it is widely recognized as the beginning of modern political and public awareness of global environmental problems.

A summary of the key regulations and their requirements are briefly summarised in Box 3–1.

Box 3–1: Key regulations

The Manufacture, Storage and Import of Hazardous Chemical Rules were notified in 1989 under the powers conferred by the Environment Protection Act, 1989 on 27th November, 1989 and were subsequently amended in October, 1994 and in 2000 to widen the scope and provide for a few additional requirements. The principle objectives of the rules are the prevention of major accidents arising from industrial activities, the limitation of the effects of such accidents both on man and on the environment and the harmonization of various control measures and agencies to prevent and limit major accidents. As per provisions of the Rules, industries storing or handling more than a certain threshold of hazardous chemicals (as mentioned in the Schedules of the Rules) are categorised as Major Accident Hazard (MAH) industries. These industries have to fulfil a number of obligations in order to ensure that they are in control of hazards and risks that may originate from the facility and ensuring the public is informed about suitable safety measures to be adopted in case of an accident. Following are the key requirements:

- Take necessary precautions to prevent major accidents and limit their consequences to humans and the environment;
- Bring, major accidents involving the release of major emissions, fire or explosion linked with a hazardous chemical that has the potential cause substantial loss of life and property or adverse impact on the environment, to the notice of concerned authorities;
- Prepare safety reports on that industrial activity and submit it to competent authorities;
- Prepare an On–Site Emergency Plan;
- Inform the public about the accidents that might occur and the do's and don'ts in case of particular accidents;
- Provide assistance in the preparation of an Off–Site Emergency Plan in accordance with guidelines provided;

The Rules on Chemical Accidents (Emergency Planning, Preparedness and Response Rules) notified on 2nd August, 1996 by the Ministry of Environment and Forests under the powers conferred by the Environment (Protection) Act, 1986, complement the Manufacture, Storage and Import of Hazardous Chemicals Rules on accident prevention and preparedness and

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.

The **Factories Act** of 1948 was amended in the backdrop of the Bhopal gas tragedy and the Supreme Court's judgment in the Shriram gas leak case to incorporate regulatory requirements to ensure safety of hazardous industries producing or using hazardous chemical substances. The Factories (Amendment) Act, 1987 which came into force with effect from 1st January, 1987 introduced special provisions on hazardous industrial activities. It imposed a number of limitations on the factory management with a view to ensure the health and safety of workers as well as the public at large, living in the adjacent areas. The amending Act has also conferred vast powers on the Factory Inspectors with the objective of implementing the safety provisions of the Act.

The other regulations like Petroleum Rules complemented by the OISD Standards and Guidelines provide industry specific criteria with regard to operational procedures, maintenance of safety distances between storages and safeguards for processes and equipment's.

However, in spite of having a comprehensive set of regulations, one of the key weaknesses of the Indian regulatory system has been its inability to keep pace with the rapid economic development and respond to the diversity of the environmental pressures and problems resulting from the process of intense industrialization and urbanization in the last two decades. Operating mostly in the reactive mode, the regulatory system is often unable to pre–empt future or upcoming problems and the issue of management of environmental risk appears to be one of them. For example, though there have been two amendments to the MSIHC Rules of 1989, which remained the principal regulation focusing on major accident prevention and control of hazardous industrial activities, both have effected only cursory changes to the original legislation. As a result, **at present there is no linkage of hazard prevention with land–use planning, an aspect which assumes significance considering the effect of the Bhopal disaster and subsequent accidents in the country that has led to considerable loss of life and property.**

3.2.1 Regulatory scope and definitions

Hazardous chemicals are substances, compounds or mixtures that can lead to potential health hazards by causing adverse effects on exposure to the chemical or can cause physicochemical hazards because of their physical or chemical properties like flammable, corrosive or explosive substances. However, given the fact that there are thousands of chemicals and with more chemicals being discovered every day, it is felt important that hazardous chemicals are identified based on certain criteria and thresholds for applicability of regulations. The MSIHC Rules provide a definition of hazardous chemicals based on listing of chemicals and certain other physicochemical criteria which are specified in Schedule 1, 2 and 3 of the regulation. In order to obtain an understanding of what the regulation implies, the broad categories of hazardous chemicals are provided in the Box 3–2.

Box 3–2: Categories of hazardous chemicals

Toxic Chemicals

Chemicals like ammonia, chlorine and hydrogen sulphide, in high concentration, may cause immediate harm when it gets into the human body through different routes, especially when inhaled. It may affect the functioning of various vital organs leading to death or disability.



Flammable Chemicals

Chemicals like petroleum products, LP Gas that we use for cooking etc. can catch fire very easily if it gets a source of ignition. Fires caused by large amounts of flammable chemicals can sometimes pose additional hazards and can sometimes even lead to an explosion.



Explosives Chemicals

Some chemicals like ammonium nitrate can explode if not carefully handled and stored thus resulting in damaging effects similar to bomb blasts that may happen during wartime.



Corrosive Chemicals

Acids and bases are common corrosive chemicals. Such chemicals are capable of damaging skin, eyes and the respiratory system on contact.



Certain chemical industries or fixed installations storing large amount of hazardous chemicals (like tank farms) are considered to be highly hazardous facilities and are called Maximum Accident Hazard (MAH) industries. Identifying hazardous industries which has high accident potential is important for chemical risk management. Whether a facility is MAH is decided based on the nature of hazard associated with the chemical and a threshold limit of storage provisioned within the facility. In case it is categorized as MAH, certain additional regulatory controls and safety considerations have to be instituted at such facilities and the same are mentioned in the MSIHC Rules.

Box 3–3: Definition of MAH installation

"Major accident hazards (MAH) installations" means – isolated storage and industrial activity at a site handling (including transport through carrier or pipeline) of hazardous chemicals equal to or, in excess of the threshold quantities specified in, Column 3 of Schedule 2 and 3 respectively.

Whether an industry/facility comes under MAH category is guided by the regulations, in this case the MSIHC Rules. Further, the levels of regulatory control is decided upon based on the quantity of chemical stored as specified in Schedule 2 and 3 respectively. The details on the level of requirements are summarized in Box 3–4.

Box 3–4: Setting priorities for management of hazardous chemicals

Low Level Requirements

684 hazardous chemicals listed in Schedule 1 or falls under any of the categories under Part I are subject to general or low level requirements. An occupier of an industry in control of an activity or process involving any of these chemicals is required to:

- Take necessary precautions to prevent major accidents and limit their consequences to humans and the environment;
- Provide information, training and necessary safety equipment's to persons working at such sites;
- Bring major accidents to the notice of concerned authorities and furnish a report on the accident;
- Prepare and maintain safety data sheets of hazardous chemicals
- Report import of hazardous chemicals.

Medium Level Requirements

179 chemicals and six classes of chemicals as specified in Schedule 3 of the Rules are subject to medium level controls. These apply to potentially hazardous activities using hazardous chemicals in beyond certain threshold quantities. The requirements state that:

- A person in control of a hazardous activity obtain approvals from the concerned authority after furnishing necessary information;
- Prepare an On–Site Emergency Plan;
- Inform the public about the accidents that might occur and the do's and don'ts in case of particular accidents;
- Provide assistance in the preparation of an Off–Site Emergency Plan.

High Level Requirements

30 chemicals and three classes of chemicals as specified in Schedule 2 are subject to specific or high level requirements. They are potentially more hazardous and threshold limits are specified for each. The handling and storage of these chemicals by a person would require him to (in addition to the lower and medium level requirements):

- Prepare safety reports on that industrial activity and send a copy to the concerned authority;
- Provide information to members of the public who may be affected by a major accident;

EXERCISE 3A



To understand how the MSIHC Rules and its Schedules are applied in identification of hazardous industries, please refer to EXERCISE 3A in annexure.

EXERCISE 3B



Application of Petroleum Rules, 2000 in determining in–plant safety distances is demonstrated in EXERCISE 3B in annexure.

3.3 Institutional framework

The nodal agency at the federal level for instituting and implementing an environmental regulatory framework in the country is the Ministry of Environment and Forests. At the central level, such regulations are often prepared in consultation with other line and sectoral ministries and sometimes in consultation with stakeholders, before being ratified by the Parliament as legislation. Other federal agencies like the Central Pollution Control Board and research institutes feed into the process, in order to ensure that legislation is feasible and will be effective in controlling environmental degradation or bringing about improvements in environmental quality. At the State level, such responsibilities and roles are played by multiple agencies, but led primarily by the State Pollution Control Board. The responsibility for control and management of risk from hazardous industries is not covered by such a cohesive approach; rather, the responsibilities are dispersed amongst multiple organizations, which come under the ambit of several federal line ministries. Many of these institutions do not have sufficient strength or capability to play the role of regulators thereby weakening the role of the government to manage chemical risks. A review of the institutional framework for management of various aspects of risk is shown in the Figure 3–2.

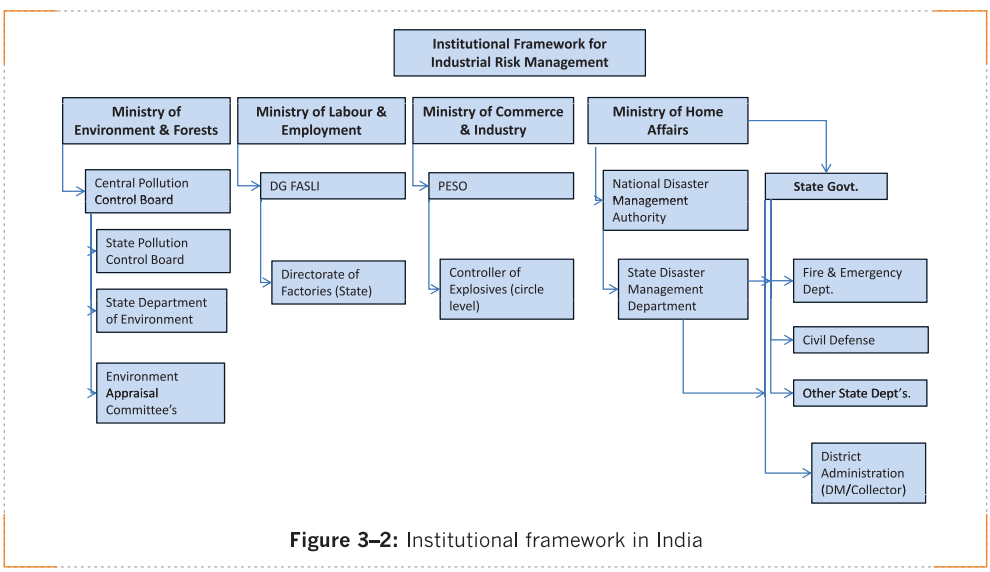


Figure 3–2: Institutional framework in India

Source: Own compilation

3.4 Information system and regulatory support

Increasingly, regulatory systems worldwide are moving towards adopting a more transparent and risk informed approach, a philosophy where risk insights are considered together with other factors to establish requirements that better focus licensee and regulatory attention on design and operational issues are prioritized based on their importance to health and safety. Such shifts are increasingly becoming notable in the developed world. For example, in the USA the principal statute "The Emergency Planning and Right–To–Know Act (EPCRA)" has been designed to improve community access to information about chemical hazards and to facilitate the development of chemical emergency response plans by state and local governments. In Europe, amendments in the Seveso Directive require hazardous industries to 'actively' provide information on hazardous operations and substances to local communities in order to inform them about risks and prepare them for an impending accident.

Box 3–5: Community Right–to–Know about Risk

The Indian regulatory system recognises the need to inform the public on risks originating from hazardous industries in their neighbourhood and provisions for information disclosure by hazardous industries now figure in a number of regulations. They are briefly discussed as follows:

- The Factories Act require hazardous industries to provide information regarding dangers, including health hazards and the measures to overcome such hazards arising from the exposure to or handling of the materials or substances in the manufacture, transportation, storage and other processes to the regulator, local authorities as well as the public residing in the vicinity of such an installation.
- The Manufacture, Storage and Import of Hazardous Chemical Rules emphasizes the need for information sharing by stipulating that occupier take appropriate steps to inform the public and the District Emergency Authority on the nature of major hazards present in the facility as well as the safety do's and don'ts which should be adopted in case of a major accident. the
- The Emergency Prevention and Preparedness Rules assign responsibility to crisis groups to make available information to the public on request and inform those who are likely to be affected by a chemical accident.
- The Right to Information Act, 2005, reinforces the right to citizens to seek information regarding hazardous substances and it effects.

In order to advance this philosophy, regulatory agencies in many countries are keen to take support from online information systems to communicate about risks to stakeholders. Some agencies have shifted to using web–GIS technologies to provide location specific information on hazardous industries, hazardous chemicals they store, probable area that can get affected by an accident thereby developing a better understanding of the risk to which population exposed. Availability of updated information from such regulatory databases can play a significant role in assisting the government and regulatory agencies to plan for appropriate risk reduction measures in an industrial area. The regulators can also check online whether permitting requirements for hazardous industries are valid and up–to–date, whether safety distances are being adequately maintained or consider the siting of new hazardous industries taking into account risk posed by the existing industries. In addition, such systems can play an important role in risk communication by educating the public about the risk present in the neighbourhood and on possible preventive and appropriate mitigation actions, should an accident take place. An example of such an information system which is readily accessible on the internet is the "Risicokaart" system of the Netherlands. It provides for a map based interface for identifying hazardous industries in any locality and find out about the degree of risk posed to the surroundings.

EXERCISE 3C

To understand how a web–GIS helps in risk identification and communication, please refer to EXERCISE 3C in annexure.

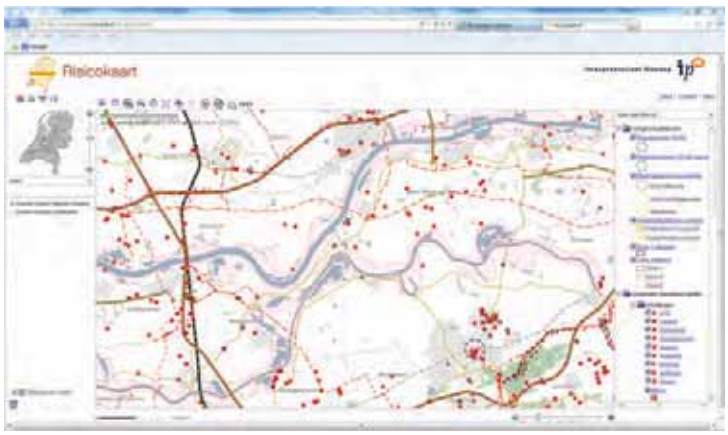


Figure 3–3: The risicokart interface which can be viewed at http://www.risicokaart.nl/en/

Source: risicokaart website

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4

LEARNING UNIT 4 CHEMICAL RISK MANAGEMENT PRACTICE

4.1 Risk management for chemical hazards

Risk management in context of chemical hazards involves a decision making process that deals with making choices on risk reduction and control measures based on assessed risk and agreed upon risk acceptability levels. The risk management process can play a significant role in promoting better regulation, improve understanding of chemical risk and provide a basis for decision making taking inputs and guidance from scientific principles and factoring opinions of stakeholders. It should be noted here that the principles governing the management of natural risks like floods and earthquakes are similar to those that are applicable for chemical emergencies. However, dealing with and influencing the results of potential chemical emergencies is comparatively easier as both the chemical hazard (setting up of hazardous industry) and often the vulnerabilities (the people and infrastructure that are vulnerable) are created by humans. Resultantly, the treatment of chemical risk provides distinct opportunities for decision makers to set up management and control frameworks to deal with such scenarios.

There are several conceptual flows that attempt to explain the risk management process and in order to maintain generality of interpretation, adaption of the concept delineated in ISO Standard 31000:2009 for Risk Management–principles and guidelines on implementation is used to develop a better understanding of the process flow for managing risks related to chemical hazards. The same is presented through Figure 4–1.

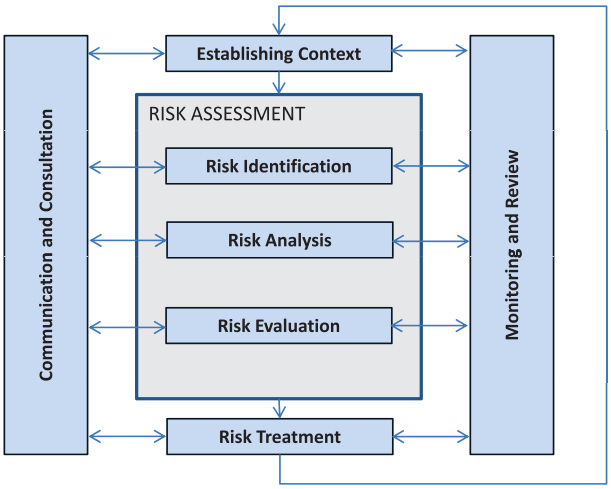


Figure 4–1: Framework for chemical risk management

Source: ISO 30001

In risk management framework that is applicable at a country level, the context is generally provided by regulations that are promulgated for controlling and mitigating risks from hazardous industries. In addition, the culture of a society and the community perception on risk also plays an important role in how the risk assessment process in managed.

The risk assessment process, which lies at the heart of risk management, comprises of systematic steps to identify, analyse and evaluate the existing chemical risk and generally end in representation of risk. One of the not so common ways is to spatially represent risk through a 'risk map' wherein the prevailing risk can be compared to acceptable risk criteria inked to potential hazard sources and vulnerabilities present in an area. Based on this input, the risk treatment step can then involve the consideration of one or more options for modifying risks and implementing them in order to bring residual risk to levels that are acceptable to society. For chemical risks, key risk treatment methods include:

- improvement of plant safety,
- drawing up of emergency preparedness and response plans and
- incorporating risk as a factor for land–use planning in industrial areas.

It must be kept in mind that the selection of a risk treatment option almost always involves the balancing of costs and efforts of implementation against perceived benefits with regard to regulatory requirements and social responsibility with regard to protection of citizens and the environment. In addition, two other aspects are also important:

- communication of risk to build on a proper perception of risk amongst stakeholders is important so that their views and concerns can be identified and incorporated in the decision making process;
- the monitoring and review mechanisms which evaluate whether the risk treatment measures are being able to effectively reduce risk to desired levels and provide feedback to the entire process.

4.2 Type / nature of chemical hazards

4.2.1 Toxic release

A hazard involving a toxic release results from a discharge or emission of toxic chemical from a container or storage, mostly in gaseous form to the atmosphere. The released substance can then disperse in the atmosphere and can lead to a build–up of concentration, with the potential to cause adverse effects to humans and the bio–physical environment. The greatest potential for far–field effects is generally associated with the release of a toxic gas. However, situation involving toxic releases can also occur due to release of vapours from toxic liquids, reaction of materials resulting in toxic vapours or because of toxic products resulting from combustions or thermal decomposition of toxic chemicals. Other forms of toxic release many involve liquid spill of chemicals into water bodies or soil leading to contamination of soil, surface or groundwater; however, their potential to cause damage is lesser. Therefore, it is not part of the scope of this module.

For a toxic chemical to cause harm to the human system, it has to then enter the body through one of the possible routes – by inhalation, ingestion or through dermal contact. Box 4–1 discuses dosage of chemicals entering human body and resultant type of toxicity it can cause.

Box 4–1: Key facts about toxic chemicals

Dose – The effects of any toxic chemical depends on the amount of the chemical that actually enters the human body.



Acute toxicity – the measure of how toxic a chemical is in a single dose over a short period of time.

Some chemicals will only make you sick if you get an 'acute" or high dose all at once. Example – ammonia

Chronic toxicity – the measure of the toxicity of exposure to a chemical over a long period of time.

Some chemicals are mainly known for their chronic or long–term effects.

Source: Chemical Hazard Communication Training Kit; The Washington Department of Labor and Industries (L&I), WISHA Services

In order to understand and estimate probable damage that may be caused by a toxic release into the atmosphere, a number of complex dispersion models have been developed and they are briefly discussed in subsequent sections.

Dispersion phenomena

In context of predicting consequences from gaseous pollutant or toxic releases into the atmosphere, the term 'dispersion' is used to include the phenomenon of advection (moving) and diffusion (spreading) of gas in a downwind direction and spread in a crosswind and vertical direction. Such dispersion phenomena through which a gas gets transported and results in a certain concentration of a contaminant at a downward location can be influenced by a number of factors like:

- Releasing conditions – whether source is point or area, release conditions like high pressure, low temperature of the vessel, rate of release, diameter and height of stack/flue from where release occurs;

- The conditions prevailing in the atmosphere–wind speed and direction, atmospheric stability;
- The nature and density of the gas relative to air– whether lighter or heavier than air;

For example, gas clouds which are lighter than air tend to rise, limiting the harm they can inflict. Dense clouds stay at low levels for a considerable distance downwind and pose a much greater hazard. Many hazardous substances are either denser than air (e.g. LPG or chlorine) or behave as if they are much denser due to their low temperature on release (e.g. LNG or ammonia).

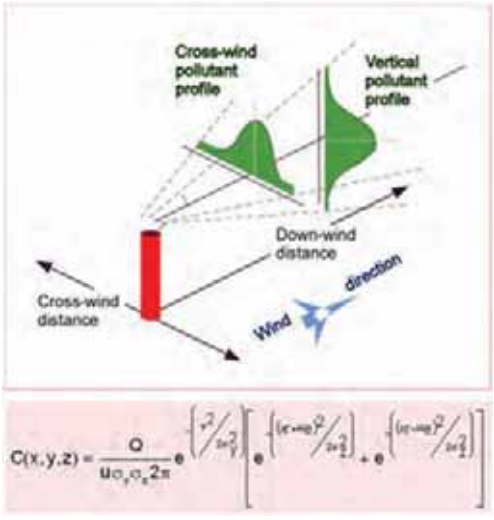


Figure 4–2: Gaussian dispersion

Source: Adapted from Wikipedia

To be able to estimate concentration and time profiles of toxic or flammable gases from the point of release into the atmosphere, several types of dispersion models are used to estimate concentration /time profiles of flammable or toxic gases at various distances downwind from the point of release. The Gaussian dispersion model is one of the most commonly used models to predict concentration of toxic gases at a downwind location from a point of toxic release. The Gaussian model that takes into account a graph of gas concentration within any crosswind slice of a moving pollutant cloud looks like a bell–shaped curve, high in the centre and lower on the sides as a result of turbulent mixing of toxic gas molecules released into the air. As the toxic cloud drifts farther downwind, it spreads out and the "bell shape" becomes wider and flatter and the concentration of the gas goes down as a result of increased spreading and mixing. It should be noted though that heavier than air gases behave in a different manner compared to neutrally buoyant gases. The concentration of a gas at a downwind location x, y can be predicted based on a typical Gaussian equation as shown in the Figure 4–2.

Box 4–2: Effects of hazardous incidents – Damage functions and probit

To be able to quantify risk, a metric that converts physical consequences of a hazardous incident into information of the effect on people, property or the environment is required. The most common way of doing this is to agree on a particular consequence level that may represent a particular adverse outcome in terms of damage it can cause i.e. a certain toxic gas concentration in air, intensity of radiation or degree of overpressure that can kill a person or other lesser endpoint values which can cause significant injuries from a certain time exposure to the hazard. However, given that such a measure will also depend on the susceptibility of people and may vary with circumstances, a more logical approach is to define a probability damage function like 'probit' that can predict the probability of an adverse outcome (usually fatality) given knowledge of exposure conditions.

Toxic effects and end points

The analysis of the effects of exposure to toxic substances is very complex. The primary reason for this is because a certain toxic dose can affect people in many different ways and the seriousness of the effect will depend considerably on the sensitivity of the individual and on the duration of the exposure. Effects of exposure to toxic gases or chemicals can range from fatality or injuries to respiratory or nervous systems if inhaled or ingested, cause irritation of eyes, throat or skin to a nuisance effect. To convert such effects into a measure, the estimated dose to which an organism may be exposed is translated into an effect based on dose–effect functions for a certain duration of exposure and is expressed as levels of concerns such as threshold limit value (TLV) or concentration which is immediately dangerous to life and health (IDLH).

It is also widely accepted that one of the key tasks while planning for emergencies involving a toxic release accident is to stay prepared for identifying, notifying, evacuating, sheltering, or otherwise protecting the vulnerable population who may be exposed to such gases and vapours. Such goals are sometimes set as a part of Emergency Preparedness and Response Guidelines (EPRG) through delineation of concentrations in air–based on which, isopleth boundaries can be defined to represent a hazard footprint for the affected area.

Box 4–3: Toxic endpoints – "Emergency Response Planning Guidelines"

EPRG – 3: The maximum airborne concentration below which it is believed, nearly all individuals could be exposed for up to one hour without experiencing or developing life threatening health effects.

EPRG – 2: The maximum airborne concentration below which, it is believed, nearly all individuals could be exposed for up to one hour without experiencing or developing irreversible adverse or other serious health effects or symptoms which could impair an individual's ability to take protective action.

EPRG – 3: The maximum airborne concentration to which nearly all individuals could be exposed for up to one hour without experiencing or developing health effects more severe than sensory perception or mild irritant, if relevant.

4.2.2 Explosion

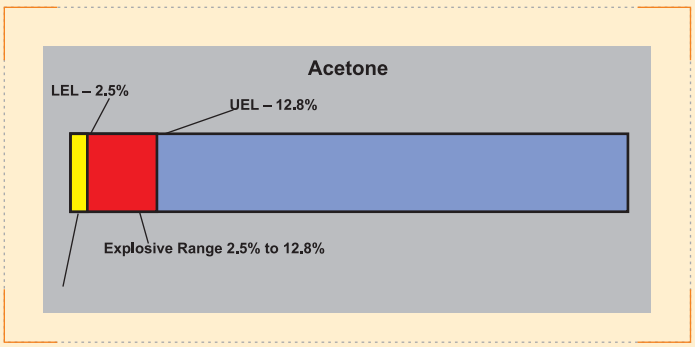
The most basic definition of an explosion is a sudden, intense release of energy that generates a pressure wave because of rapidly expanding gases and is often accompanied with a loud noise, high temperatures and flying debris. Industrial explosions involving hazardous chemicals can be of many types and the causes and effect of the explosion also varies with the type. There can be three primary hazards that should be considered when dealing with an explosion: thermal radiation, overpressure, and hazardous fragments (flying debris/missiles).

Explosions can be principally of two types: Thermal and Non–thermal. From the point of view of damages that may be caused by explosion in a chemical facility, thermal explosions are more relevant.

Explosions involving flammable gases are of particular concern in industrial facilities and are termed as Confined Vapour Cloud Explosions (CVCEs) or Unconfined Vapour Cloud Explosions (UVCE) depending on the nature of the hazardous chemical and the degree of confinement in which the explosion is triggered. Explosions involving a certain chemical can occur if a mixture of flammable gas and air within the flammable range is ignited and is influenced by the upper and lower explosive limits of the chemical in air as is explained in Box 4–4. The magnitude of overpressure developed as a result can be strongly influenced by factors such as the degree of confinement, size of the cloud, degree of turbulence, combustion property of the gas and the location of the ignition source relative to the cloud. The UVCEs have often far less power than the explosions in confinement, but sometimes UVCEs can cause widespread damage, if the amount of explosive mixture involved is high.

Box 4–4: Flammability limits (UEL and LEL)

Flammability limits, give the proportion of combustible gases in a mixture, between which limits this mixture is flammable. The lower flammable limit (LFL) or Lower Explosive Limit (LEL) describes the leanest mixture that still sustains a flame, i.e. the mixture with the smallest fraction of combustible gas, while the upper flammable limit (UFL) or upper explosive limit (UEL) gives the richest flammable mixture.



Most authentic source for UFL and LFL is MSDS where limits are expressed as a volume %. This can be easily converted into concentration (ppm). A straightway relation is LFL 1% is equal to 1000ppm and ULF of 5% is equal to 5000ppm.

Source: Chemical Hazard Communication Training Kit;
The Washington Department of Labor and Industries (L&I), WISHA Services

Explosion overpressure and endpoints

One of the major hazards associated with any explosion is overpressure. Overpressure, also called a blast wave, refers to the sudden onset of a pressure wave after an explosion. This pressure wave is caused by the energy released in the initial explosion and travels at the speed of sound radiating outward like a large burst of air with its strength weakening as it moves away from the source. If the pressure wave has sufficient power it can cause widespread damage to both human life and property. A high intensity pressure wave can lift people off the ground and throw them up against nearby

buildings and trees; at lower intensity, it can also affect pressure–sensitive organs like ears and lungs. In addition, explosions can cause substantial damage to buildings and property as can be seen in Table 4–1. Especially at risk are buildings with weak structures or kaccha /shanty houses.

Table 4–1: Explosion damage and endpoints

Overpressure (psig[3])	Expected damage
0.15	Typical pressure for glass failure.
0.30	Some damage to house ceilings; 10% window glass breakage.
0.40	Limited minor structural damage.
0.50–1.0	Windows usually shattered: some window frame damage.
1.0	Partial demolition of houses; made uninhabitable.
1.0–4.0	Range for slight to serious injuries due to skin lacerations from flying glass and other missiles.
2.0	Partial collapse of wall and roofs of houses.
2.0–3.0	Non–reinforced concrete or cinder block walls shattered.
2.3	Lower limit of serious structural damage.
2.5	50% destruction of home brickwork.
3.0–4.0	Frameless steel panel building ruined.
4.0	Cladding of light industrial buildings ruptured.
5.0	Wooded utility poles snapped
5.0–7.0	Nearly complete destruction of houses.
7.0–8.0	8–12 in thick non–reinforced brick fail by shearing of flexure.
9.0	Loaded train box cars demolished
10.0	Probable total building destruction.
14.5–29.0	Range for 1–99% fatalities among exposed populations due to direct blast effects.

Source: F P Lees (1980) Loss prevention in process industries

[3] Psig represents "pound–force per square inch gauge" and is a unit of pressure relative to the surrounding atmosphere. At sea level, Earth's atmosphere actually exerts a pressure of 14.7 psi. Humans do not feel this pressure because internal pressure of liquid in their bodies matches the external pressure. If a pressure gauge is calibrated to read zero in space, then at sea level on Earth it would read 14.7 psi. Thus a reading of 30 psig on a tire gauge represents an absolute pressure of 44.7 psi.

4.2.3 Fire

A fire caused by inflammable chemical is a complex chain reaction where a fuel combines with oxygen to generate heat, smoke, and light. Thermal radiation is the primary hazard associated with industrial fires. However, if it goes out of control, such fire hazards can also result in an explosion. In addition, as fire is a chemical reaction that mainly yields smoke and soot, it may also result in the formation of a number of gaseous by–products which can be hazardous or toxic.

A fire hazard in an industry that stores or processes inflammable substances can be triggered by one of the following ignition sources: sparks, static electricity, heat, or flames from another fire. Additionally, if a chemical substance is above its auto–ignition temperature, it will spontaneously catch fire without an external ignition source. There are several chemical properties like volatility, flash point and flammability limits (upper and lower) which indicate how easily or how readily a flammable chemical substance will catch fire and continue to burn. It is also important to remember at all times that once the chemical catches fire, three things need to be present to keep the fire going: fuel (the chemical), oxygen and heat. This is often referred to as the fuel triangle and is represented in Figure 4–3. If anyone of these components is eliminated, then the fire will stop burning.



Figure 4–3: Fuel Triangle

Source: http://www.calpaclab.com/ Fire–Triangle–s/793.htm

Types of industrial fires

Industrial fires can be categorized:

- Pool Fire: A pool fire occurs when a flammable liquid forms a pool on the ground and catches fire. In some cases, if the pool fire cannot be controlled, heat from the pool fire may weaken the leaking tank and cause it to fail completely or cause a Boiling Liquid Expanding Vapour Explosion (BLEVE).
- Jet Fire: A jet fire, also referred to as a flame jet, occurs when a flammable gas or gas liquefied under pressure is rapidly released from an opening in a container and immediately catches on fire.
- Flash Fire: When a flammable vapour cloud encounters an ignition source, the cloud can catch fire and burn rapidly in what is called a flash fire. In such cases, the flammable area is bounded by the Lower Explosive Limit (LEL) and the Upper Explosive Limit (UEL) for the chemical substance.
- BLEVE: Many fireballs are due to the phenomenon known as a 'boiling liquid expanding vapour explosion' or BLEVE. These mostly involve liquefied flammable gases stored under pressure. Most BLEVEs occur due to a storage vessel being subjected to flame impingement above the liquid level. Hot spots can develop resulting in substantial weakening of the metal to such an extent that it is no longer capable of containing the internal pressure leading to a violent rupture resulting in a large fireball and producing intense thermal radiation for short duration that can cause considerable damage to people exposed to it.

Fire radiation endpoints

Thermal radiation emanating from industrial fires can cause damage to both life and property in its immediate surroundings. Thermal radiation is normally measured as an energy flux and expressed in units of power per unit area. However, the potential to cause damage is measured by the dosage of thermal radiation that a receptor or person is exposed to and is a combination of the intensity of radiation and the time of exposure. The Table 4–2 lists the known effects of thermal radiation on bare skin as a function of exposure level and time.

Table 4–2: Fire damage and endpoints

Radiation intensity (kW/m²)	Time for severe pain (sec)	Time for 2nd degree burn (sec)
1	115	663
2	45	187
3	27	92
4	18	57
5	13	40
6	11	30
8	7	20
10	5	14
12	4	11

Source: Handbook of Chemical Hazard Analysis and Procedures; FEMA

4.3 Risk assessment

According to the framework adopted in this manual (following ISO 31000), accounting for the regulatory and planning practices, the risk assessment process for hazardous industrial areas like RiskCity can be logically divided there stages: risk identification, risk analysis and risk evaluation. The last step of risk evaluation is based on a risk tolerability criterion agreed upon with all stakeholders, and should result in a spatial risk map that form the basis for adoption of appropriate risk reduction measures. The three stages are briefly described in the subsequent sections.

4.3.1 Risk identification

Risk identification is the process of finding, recognizing and describing risks. It can be looked upon primarily as a screening exercise which should be able to answer three main questions:

- Where serious accidents can occur (risk objects)?
- What the threats may be (hazards)?
- Which types of accident can occur (risk types)?

Acting as a preliminary step for subsequent risk analysis, risk identification involves finding and recognizing likely hazards and significant consequences to the communities, environment and economy in collaboration with various risk actors. In order to be able to do this for an industrial area like RiskCity, a well–planned exercise has to be initiated to review existing information available with regulatory authorities, surveying industries with information checklists and questionnaires, identifying elements at risk around the hazardous facilities and brainstorming over credible risk scenarios that can arise from such facilities which can be analysed in the next step.

GIS provides tools for storage and manipulation of spatial (ex. storage location for hazardous chemicals) and non–spatial data (ex. MSDS of chemicals) and can play an important role in risk identification. If data from multiple sources can be systematically stored and updated in a geo–database, it can assist planners, decision makers and the general public in identifying location of hazardous chemicals in their neighbourhood and understand their spatial disposition in an industrial town like RiskCity, determine type and quantities of chemicals present at any time and also find out about safety measures and controls that have been installed by the industries to reduce risk levels.

It should be noted though that not all risk scenarios identified in a risk identification exercise can be analysed in greater detail as a part of risk analysis – for RiskCity itself, there could be more than 100 risk sources which can give rise to a toxic release, fire or explosions. These sources can again give rise to scores of possible accidents, small and large, with varying degrees of probability of occurrence. Considering thousands of such scenarios and their probable impacts would make such risk assessments an extremely laborious activity. Therefore, for undertaking a practical risk assessment that will depict reality, a limited number of scenarios need to be considered out of all possible risk situations. As a result, it is important to arrive at a consistent and agreed upon benchmark which can help in short –listing of credible scenarios that can cause a certain level of impact to the surrounding community. With such guidelines for scenario selection at the National or State level, it may not be possible for risk assessments to be consistently compared across different industrial clusters in the country and risk tolerability criteria to be drawn up.

Material Safety Data Sheets

Material Safety Data Sheet in short called MSDS provides vital information for identifying a chemical and it physical and chemical properties. Generally it comprises of an information sheet provided by a chemical manufacturer describing physical data (melting point, boiling point, flash point, etc.), toxicity, health effects, first aid, reactivity, storage, disposal, protective equipment, and spill handling procedures.

An MSDS for a substance is not primarily intended for use by the general consumer, but focusing instead on the hazards of working with the material in an occupational setting. Also the same can be utilized by the local administrative bodies to initiate primary level emergency measures in case, the hazard encompasses the nearby sensitive receptors like hospitals, schools, market complexes etc. based on the type of hazardous chemicals and the type of accidents, provided the MSDS is readily made available to the administrative authorities concerned. The MSIHC Rules require all industrial users of hazardous chemicals to maintain properly structured safety data sheets at their premises. A typical template of a MSDS is shown in Figure 4–4.

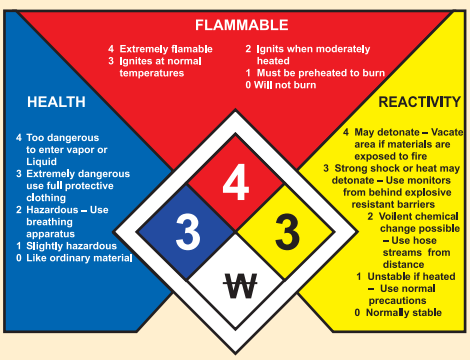


Figure 4–4: Template of a MSDS

Source: http://www.saltawayproducts.com/MSDSPage.htm

Box 4–5: Hazard identification standards – NFPA guidelines

The NFPA (National Fire Protection Authority) standard provides a readily recognised, easily understood system for identifying specific hazards and their severity using spatial, visual, and numerical methods to describe in simple terms the relative hazards of a material. It addresses the health, flammability, instability, and related hazards that may be presented as short–term, acute exposures that are most likely to occur as a result of fire, spill, or similar emergency.



Source: http://en.wikipedia.org/wiki/NFPA_704

The system is characterized by the "diamond shape" that is actually a "square–on–point" shape. It identifies the hazards of a material and the degree of severity of the health, flammability, and instability hazards. Hazard severity is indicated by a numerical rating that ranges from zero (0) indicating a minimal hazard, to four (4) indicating a severe hazard. The hazards are arranged spatially as follows: health at nine o'clock position, flammability at twelve o'clock position, and instability at three o'clock position. In addition to the spatial orientation that can be used to distinguish the hazards, they are also color–coded as follows: blue for health, red for flammability, yellow for instability and white for special parameters like Water Reactive (W), Oxidizing Agent (ox) etc.

EXERCISE 4A



To understand how to identify hazards using hazard classification labels as prescribed by the Department of Transportation (DoT) and National Fire Protection Authority (NFPA) guidelines, please refer to EXERCISE 4A in annexure.

EXERCISE 4B



Hazard identification and prevention using MSDS is shown in EXERCISE 4B in annexure.

EXERCISE 4C



For an appreciation of how web–GIS applications can help in identifying potential hazards, please refer to EXERCISE 4C in annexure.

4.3.2 Identification and development of accident scenarios

After the risk is identified, the logical next step in risk assessment involves the development of scenarios taking into consideration how an event may initiate and then systematically determining how the incident will develop. The scenario so developed specifies the nature of the release and determines the subsequent chain of consequences. This is to say that there could a number of possible outcomes arising from each initiating event, which will depend on several factors: condition of storage, nature of failure that occurs, mitigation and protection measures available at site, location of ignition sources, meteorological conditions, etc. At the same time, it is important to reduce the number of scenarios from an infinite set of potential releases to a plausible range of reference scenarios, which may be arranged into a limited number of groups of similar nature.

There are several tools which help in defining and then logically analysing a scenario. Most common is to represent it through an event tree which demonstrates through several consequence chains of the escalation of an event. The final outcomes are generally defined as a flash fire, vapour cloud explosion or a toxic cloud. Subsequently, in order to estimate damage, it is necessary to model each of the sequences in a step–wise fashion to finally calculate the possible consequences from the outcome of each consequence chain. The Figure 4–5 shows a typical event tree that may evolve for a release involving LPG.

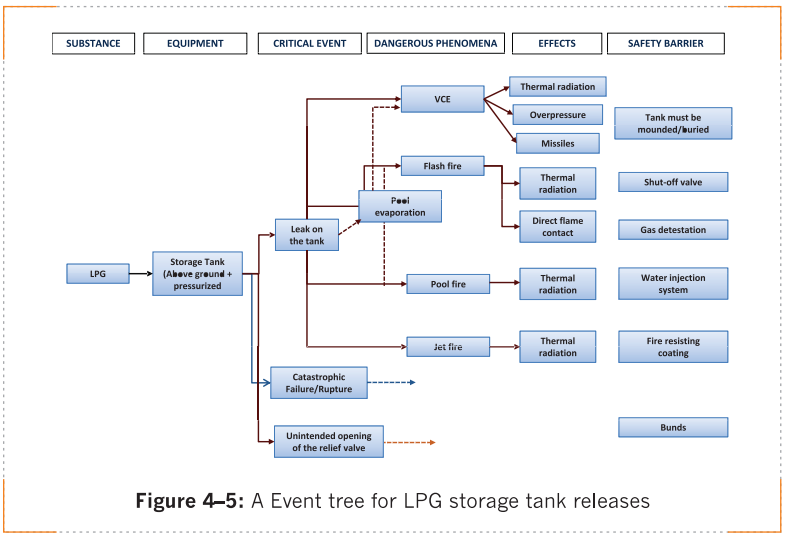


Figure 4–5: A Event tree for LPG storage tank releases

Source: Christou M.D., Gyenes Z. et al.(2011); Risk assessment in support to land–use planning in Europe

In doing scenario analysis, a special emphasis should be given in defining the Maximum Credible Loss Scenario (MCLS) which is the "credible" accident that is believed to be possible and can cause the maximum damages or having the largest effect distance. number of foreseeable factors need to be considered in identifying the MCLS and the potential effects it can have on plant, people and the environment including review of all possible event tree outcomes, and accounting for abnormal process conditions, failure of control measures, etc.

4.3.3 Risk analysis

Risk analysis is the process to comprehend the nature of risk and to determine the level of risk. For every risk and risk scenario identified in the previous risk identification stage, the risk analysis process carries out a detailed estimation of the probability of its occurrence and the severity of the potential impacts. The assessment of the probability of an event or hazard should be based, where possible, on the historical frequency of events of similar scale and available statistical data relevant for an analysis of the main drivers. The assessment of the level of impact should be in quantitative terms and can involve the quantification of a certain threshold of damage that may be caused by a particular accident involving a risk source.

When possible, it is preferred to quantify the level of risk supported by empirical evidence. Several such measures are available as a part of the practice of Quantitative Risk Assessment (QRA). QRA methods entail consequence and vulnerability calculation using deterministic prediction techniques to arrive at numerical values for individual or societal risk. However, it should also be kept in mind that there are always a number of assumptions and estimates which will have to be used–some of which may be rather uncertain. These assumptions and estimates should always be clearly identified and substantiated so that stakeholders can understand (and agree) to the results of such risk assessment. A typical QRA based risk assessment can be represented Figure 4–6.

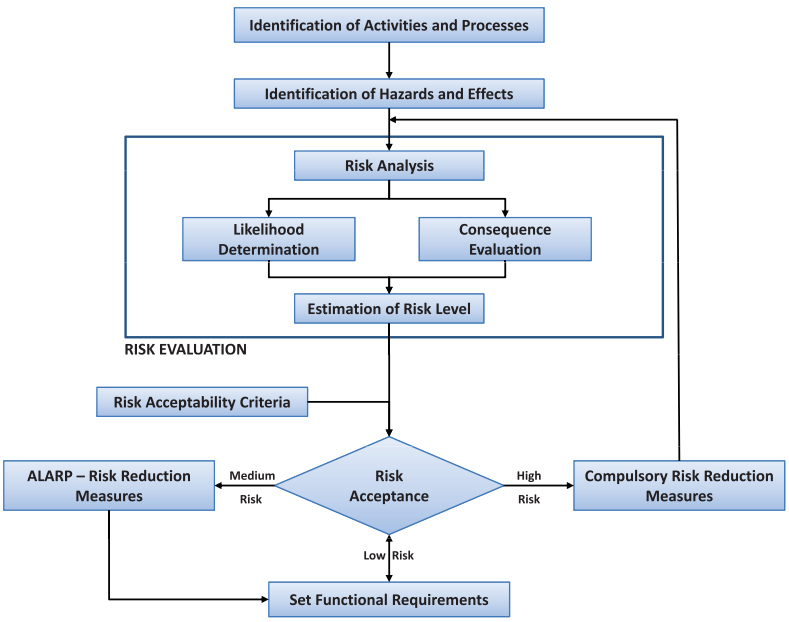


Figure 4–6: Flowchart of a QRA based risk assessment

Source: Own compilation

For the purposes of this manual, the risk assessment exercise for RiskCity would consider the geographical boundaries of the industrial area within its scope; exact locations of the storages which have been identified using high–resolution satellite imagery and based on information provided by the hazardous industries concerned and a few credible scenarios arrived at based on expert opinion.

Consequence Analysis

Consequence analysis forms a vital component in the process of risk analysis that may be used as a basis for identifying ways of reducing or eliminating significant hazards. Typically, once the accident scenarios have been established through risk identification, mathematical prediction models are used as a part of consequence analysis to estimate the physical effect that may be caused by the incident and the potential impact it may have in terms of injury or fatalities, damage to property or

damage to the biophysical environment. Consequence analysis assists in quantifying the potential damage that may be caused by an accident and the analysis is done independent of the likelihood of the occurrence of the accident.

The physical phenomenon involved in an accident being considered (mainly, toxic release, fire or explosion) depends on numerous issues. These include prevailing atmospheric conditions, nature of chemicals involved, storage conditions (ex. temperature and pressure), etc. In order to calculate the degree of damage and spatial extent of impact that may result from the accident, computations have to be undertaken in several stages. While such determination of consequences can be done using established algorithms and equations based on laws of physics, often such computation assume complex proportion, thereby needing the support of computer programes.

Such programs are generally called consequence analysis models which can be of different types:

- discharge models;
- effect models; and
- damage models which sometimes have to be applied sequentially to get a measure of the consequence.

However, it should be noted that for arriving at a deterministic estimate of the consequences, a number of assumptions are made which may introduce considerable uncertainty into the consequence analysis process. The user of such models should therefore not adopt a ‘black box’ approach to modelling consequences and should be aware of the uncertainties associated with the assumptions made. In addition, assumptions should usually be made on a 'conservative best estimate' basis to reduce uncertainties and prevent underestimation of consequences. In the case, computerised modelling tools are utilised, sufficient care must be taken in selecting and using such software and appreciating the limitation that it may be having. Though describing in sufficient detail the theory and practice involved in consequence assessment is beyond the scope of this manual, an effort will be made to explain basic modelling approaches using mathematical equations and through the use of the ALOHA consequence analysis model applied to real life exercises.

After consequence levels are calculated and probability ascertained, the risk from an accident scenario can be estimated in numerical terms and be presented in terms of metrics like individual and societal risk respectively. The concept of these risk metrics is briefly explained in Box 4–6.

Box 4–6: Risk metrics – individual and societal

When considering the risk of harm to populations exposed to hazards, it is helpful to consider two derivatives to risk.

Individuals amongst the population who could be affected by such an accident will not usually be exposed equally. This distribution of the risk is illustrated by considering the likelihood of particular individuals being affected, known as the Individual Risk. In this case, the undesired event in our definition of risk is harm to a specific individual (or person living at a particular location). Individual risk can, of course, be used in the limiting case where only one individual could be affected in an accident.

In cases where the potential is large, many factors dictate the severity, which might be realised, and there is a wide spectrum of possible harmful outcomes with associated likelihood's. This is known as the Societal Risk. In this case, the undesired event in our definition of risk is an accident, which can affect a group of people. This is usually quantified as an F–N curve.

Source: IChem Manual

EXERCISE 4D



Learn how to calculate hazard end–point distances using US EPA's RMP Off–Site Consequence Analysis guidance equations, through EXERCISE 4D in annexure.

EXERCISE 4E



Undertake consequence analysis for vapour cloud explosion, using MS–Excel, through EXERCISE 4E in annexure.

4.3.4 Risk evaluation and risk mapping

Risk evaluation is the process of comparing the results of risk analysis with risk criteria to determine whether the risk and/or its magnitude is acceptable or tolerable. Risk criteria are the terms of reference against which the significance of a risk is evaluated. The risk criteria may include

associated costs and benefits, legal requirements, socioeconomic and environmental factors, concerns of stakeholders. Risk evaluation is used to make decisions about the significance of risks whether each specific risk should be accepted or treated.

When quantitative models and additional variables and factors increase complexity without, at the same time, improving certainty (in terms of reliability, prediction and robustness), the use of more qualitative assessments which intrinsically capture expert opinions through setting of criteria and weights may be the better choice. Not only will it be more efficient to undertake, it will add to the level of transparency involved in the risk estimation method.

A risk matrix is another common way to undertake semi–quantitative risk evaluation. A risk matrix relates the two risk dimensions (likelihood and impact) through a graphical representation of different risks in a comparative way. The matrix can be used as a visualisation tool when multiple risks have been identified to facilitate comparing the different risks.

The likelihood of an major accident is based on the history of conditions and controls at the facility, consideration of any unusual environmental conditions (e.g., areas in flood plains), or the possibility of simultaneous emergency incidents (e.g., flooding or fire hazards resulting in the release of hazardous materials). Based on an assessment of industry data from accident databases, the following likelihood categories have been drawn up as in Table 4–3:

Table 4–3: Frequency ranking

Ranking	Definition
4	Higher than 10–2 occurrence / year
3	Between 10–2 to10–4 occurrences / year
2	Between 10–4 to10–6 occurrences / year
1	Lower than 10–6 occurrences / year

The consequence or severity should consider, for each identified hazard, the result of the hazard occurring i.e. what effect it may have on an exposed individual or population. It is anticipated that the range of consequences will fall between those that are negligible and self–limiting and those that would be severe, either having an immediate and serious effect or possibly leading to long term, permanent harmful consequences. Consequence ranks are shown in Table 4–4.

Table 4–4: Consequence ranking

Ranking	Definition
4	More than 90% fatalities to people offsite
3	Fatalities to 50% of people exposed offsite
2	Fatalities to 10% of people exposed offsite
1	Injuries to people exposed offsite, but no fatalities

The risk which is a multiplicative factor of likelihood and consequence can be evaluated as in Table 4–5.

Table 4–5: Risk ranking

Ranking	Definition
2	Negligible
3–6	Minor
7–12	Moderate
>12	High

The representation of risk can then be presented through a risk matrix as in Figure 4–7.

Once the overall evaluation of chemical risks in a community has been carried out, it is important to present the information to the decision makers in a manner that they can comprehend the severity of the risk scenario and can thereby formulate appropriate plans to bring the risk down to "acceptable" limits. It thus assumes significance that the overall results of the analysis and most important information be presented on an overall "risk map" together with associated threatened elements at various times. A concept of a risk map along with a figure showing contours of individual risk and grid based social risk levels originating from a hazardous facility (red dot) and overlaid over high resolution satellite imagery is shown in Box 4–7. We will discuss this aspect further in Learning Unit 6.

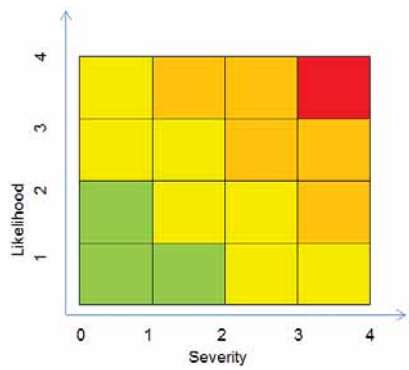
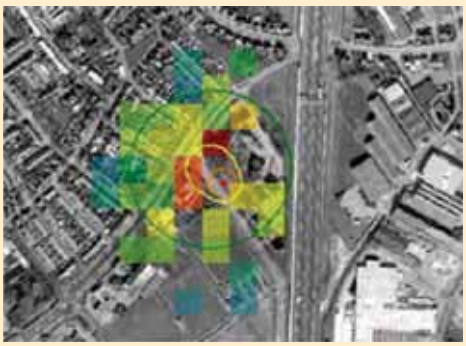


Figure 4–7: Risk matrix

Box 4–7: Risk map



Maps can be important tools to show information about hazards, vulnerabilities and risks in a particular area and thereby support the risk assessment process and overall risk management strategy. They can help set priorities for risk reduction strategies. Maps also have important roles to play to ensure that all actors in risk assessment have the same information about hazards and in the dissemination of the risk assessment results to stakeholders. Finally, risk mapping could also be useful in the broader context of land–use planning. Preparing risk maps is a complex process. They are normally part of the results of a risk analysis and follow on from steps to map the hazards and vulnerabilities over a local area (RiskCity) or a region/territory.

EXERCISE 4F

Learn how to use a GIS tool to prepare a risk map for a chlorine accident scenario through EXERCISE 4F in annexure.

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5

LEARNING UNIT 5 EMERGENCY MANAGEMENT

5.1 Introduction

Emergency management deals with long term mitigation plans along with short term preparedness and response strategies within the frame of risk management that can help the administration and communities to deal with an emergency situation. In the perspective chemical risk, this would mean accidents like a toxic release, fire or explosion originating from a hazardous industry. Emergency management is considered to be multi–disciplinary and requires a close interplay between science/technology and planning/management to effectively mitigate damage, prepare for and respond to situations that may be caused by a risk event. Generally, several organisations at local and higher levels need to collaborate and coordinate during emergency management.

Chemical emergencies typically emerge quite rapidly and requires a complex decision making process for the managers of the emergency. The problem set generally involves:

- obtaining an understanding of a potential accident scenario;
- estimating consequent impacts;
- giving guidance on possible response strategies;
- monitoring the effectiveness of response measures; and
- continuing to take decisions for bettering the response as the event progresses.

Before we go on to understand how such emergencies can be managed and what role GIS can play, let us develop the theoretical background on emergency management.

5.2 Emergency management process

Emergency management is generally organised as a cycle of four, often overlapping, phases based on the temporal dimension. A brief description the phases and what it may mean in context of a chemical emergency is:

Mitigation and prevention: involves actions that are taken to eliminate or reduce the probability or the degree of long term risk to human life and property from a particular hazard. From the chemical risk perspective this will include:

- identification of hazards industries;
- obtaining information on the nature and quantity of chemicals stored;
- finding out about vulnerability of population and property in the neighbourhood;
- risk mapping;
- land–use planning and zoning restrictions to be applied in the vicinity of hazardous industries; and
- risk reduction measures like improving safety of process and equipment at plants.

Preparedness: involves actions that are taken before an emergency to develop operational capabilities and facilitate an effective response to an emergency. This will cover:

- formulation of emergency management plan by government and organisations;
- establish coordination mechanisms and communication channels between various organisations / agencies who need to collaborate on emergency response actions;
- allocation of resources and equipment that will facilitate emergency teams to respond to an accident;
- communicating on probable effects of a risk event to the community; and
- educating them on protective actions;
- undertaking mock drills.

Response: Involves actions that are taken immediately before, during or directly after an emergency occurs, to save lives, minimise damage to property and enhance the effectiveness of recovery efforts. It will comprise of:

- actual efforts by respond team to deal with the cause of the emergency (fight a fire or plug the source of leakage of a toxic gas);
- stabilise the situation to reduce probability of secondary damage (cascading effects that may make the situation more acute);
- guide people to take appropriate protective action or assist them to evacuate from an area; and
- providing medical aid and antidotes to injured people.

Recovery: Involves short and long term activities that are aimed at bringing life back to normal or to improved levels. Recovery actions will cover aspects like

- rebuilding of residential buildings or infrastructure like roads which may be damaged because of the risk event;
- restoring power and utility connections;
- remediation of contamination; and
- clean–up actions.

The overall process, including each of these phases is called the emergency management cycle and is represented in the Figure 5–1. It must be noted that the actual risk event is positioned between the preparedness and response phases.

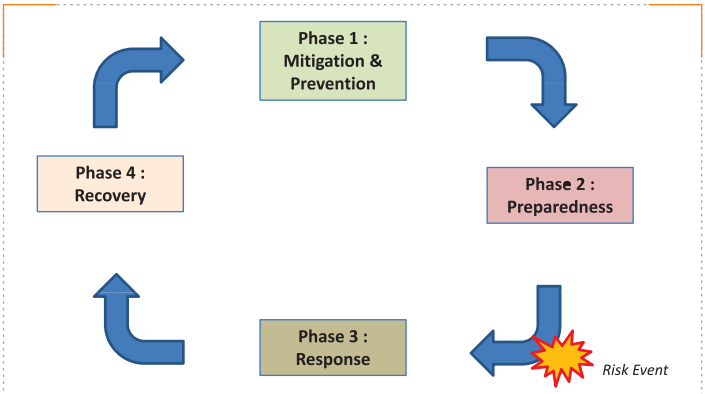


Figure 5–1: Emergency management cycle

Source: Own compilation

5.3 Emergency management and information requirements

Providing timely and useful information to appropriate parties concerned at respective stages of the emergency management process is critical to successful emergency management. Such information may pertain to:

- the details on the hazard like location, nature and quantity of chemical involved, type and intensity the accident;
- knowing about the vulnerabilities ex. how many people can be impacted;
- the meteorological conditions that are prevailing at the time;
- location of sensitive receptors like schools, hospitals;
- understanding how well equipped the response agencies are and how soon can they respond to the incident, and
- what protective actions are to be taken to reduce damage.

Therefore, the emergency managers can be confronted with several key questions:

- What is the information need of different parties before, during and after and emergency?
- What sources of data needs to be accessed to obtain such information?
- How can such data be integrated and consolidated at one place and then distributed to the emergency actors at the time they require it?
- What amount of error or uncertainty can be considered acceptable in such information provided?

It can be reasoned that such information has to be collated from multiple sources and preferably consolidated at a single point, to be able to find the right answers during an emergency situation which generally evolves very fast – generally in a matter of hours. It is also unlikely that emergency managers would have the luxury to search and retrieve such information from documents and reports under conditions of stress. The fact that the information has to be supplied on time and where errors can have serious consequences, will accord unique demands on any system developed to deliver the information. Computer aided systems therefore will have a key role for gathering and analysing information in order to aid the emergency decision making process. Several such Management Information Systems have been designed and implemented worldwide.

5.4 Emergency management and GIS

The capabilities of GIS to consolidate spatial and attribute data from several sources, collate and manipulate them based on requirements of emergency actors, making it available through a map–based visualization interface, providing scope for sharing of information between agencies all make it a valuable tool for emergency management. In addition, many of the issues that arise while managing an emergency scenario have an inherent spatial component. The predicting of the extent of hazard resulting from a chemical accident, understanding spatial disposition of vulnerabilities, pin–pointing the location of a susceptible receptor, identifying safe evacuation routes or the planning of land–use during mitigation all have a strong spatial components. As a result, GIS can play a crucial role in facilitating reasoning about many of the problems that may arise in the context of emergency management. Therefore, the value of GIS in emergency management arises directly from the benefits of implementing problem solving environment that is capable of dealing with and guiding spatial decisions.

A graph with three axes will illustrate the use of GIS for emergency management (see Figure 5–2).

- The first axis represents the various kinds of hazards ranging from natural hazards like earthquakes, floods, volcanoes to chemical ones involving toxic gas releases, fire, explosions and radiological incidences;
- The second axis represents time and can characterise actions which are taken pre–event (proactive – risk assessed), during the event (reactive – response) and post event (reactive – recovery);
- The third axis delineates action taken based on application of GIS to the different phases and activities in the emergency management process viz. risk assessment, emergency preparedness planning, response and management actions.

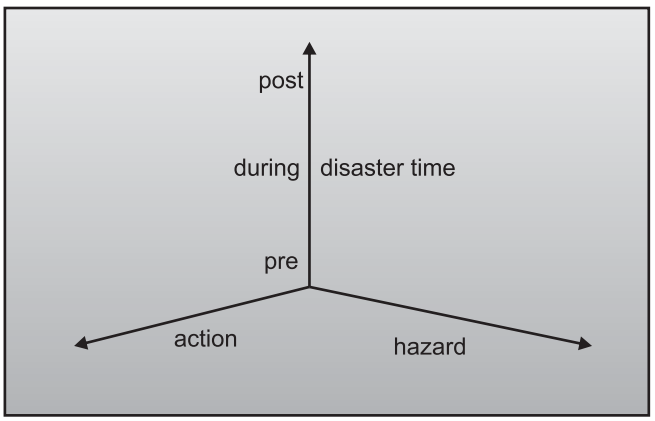


Figure 5–2: Emergency Management Paradigm

Source: Radke J., Cova T.J., Sheridan M.F., et al. (2000). Application Challenges for Geographic Information Science.

Now that we understand the role that GIS can play in emergency management, it is may be interesting to find out how GIS can contribute to each of the phases of emergency management. Following section discusses the application of GIS in each emergency management phase:

Mitigation and prevention: GIS can play several useful roles during this phase. They include:

- identifying the specific location of hazards like storage tanks, pipelines, corridors transporting hazardous chemicals;
- mapping of vulnerabilities (high population areas, susceptible receptors), infrastructure (streets, water and electric utilities, etc.);
- undertaking spatial analysis of risk resulting in a 'risk map' or 'hotspots'; and
- display of information and reports, thereby assisting planners in considering appropriate mitigation plans, land–use zones and safety buffers.

Further, addition of attribute data to respective spatial features can help emergency actors with a host of information they may need to manage an emergency situation. For example: What is the nature and content of a storage tank in a particular locality? or How many students study in a school located in a vulnerable area and what are the school timings? or What resources are available with the police and fire brigade?

Preparedness and response: GIS can answer questions like: Where to locate a new fire station so that appropriate response time to reach hazardous industries in an industrial cluster can be worked out[4]? What are the evacuation routes, if a toxic cloud blows in a certain direction based on the current prevailing meteorology? Which evacuation centres are nearest to reach for a vulnerable population? Which response team is closest and should be able to respond to an emergency situation? GIS based tools can also play a key role in training people on emergency preparedness and act as a simulator for mock drills, giving a visual sense to the team to understand possible impact of different hazard scenarios. In addition, state–of–the–art and web based GIS tools can also assist in communicating vital information like the results of simulation model to a response team so that they can fine–tune their response strategies on the ground and establish effective coordination between different agencies.

Recovery: GIS can assist in both short and long term recovery efforts. In short–term it can play a role in assessing the type and extent of damage that may have been caused by an accident, and establish priorities for action. It can help in planning for future recovery efforts, optimise emergency distribution centres for food, medicine and antidotes. GIS can also play a role in preparing longer term rehabilitation planning and tracking or monitoring of plan and inventorying and displaying re–building efforts.

5.5 Emergency management tools

Integrated emergency management tools can play an important role in preparedness and response phase by assisting in simulation of the accidents footprint and estimating the elements at risk who may need sheltering or evacuation. When an accident situation is evolving, by knowing parameters with regard to the incident (amount of release and nature of accident), meteorological variables and information on hazard endpoints, a hazard modelling tool like ALOHA can predict a hazard footprint. The model output can then be exported to a GIS tool as a spatial layer and can support further enquiry in terms of estimating damage to elements at risk as has been conceptually represented in Figure 5–3.

[4] Note: having a fire station near to a hazardous facility may ensure quicker response when an accident occurs; but at the same time there is a probability that the fire station can fall within the hazard footprint of the accident, thus immobilizing it. So, it may be prudent to locate a fire station in a low risk zone having good connectivity to the hazardous industries

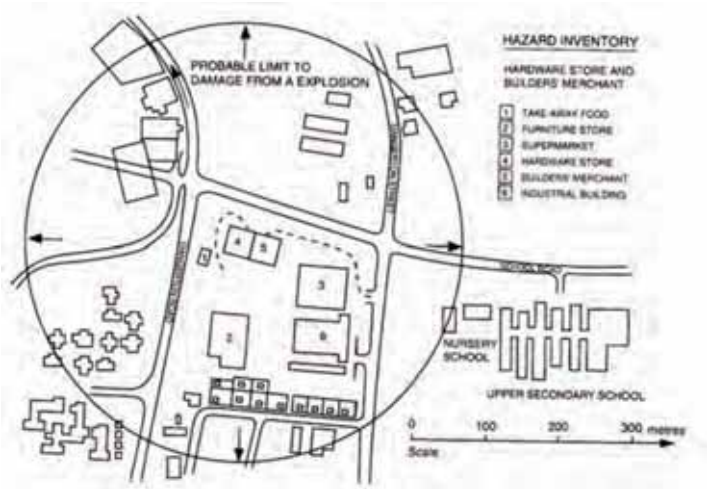


Figure 5–3: Modelling of consequences

Source: UNEP (1998). Hazard Identification and Evaluation in a Local Community.

5.5.1 ALOHA

ALOHA (Areal Locations of Hazardous Atmospheres) is a computer program designed especially for use by people responding to chemical releases, as well as for emergency planning and training. ALOHA was developed jointly by the National Oceanic and Atmospheric Administration (NOAA) and the Environmental Protection Agency (EPA) in the United States. ALOHA is capable of modelling models key hazards viz. toxicity, flammability, thermal radiation (heat), and overpressure (explosion blast force) – related to chemical releases that result in toxic gas dispersions, fires, and/or explosions.

ALOHA originated as a tool to aid in emergency response. It has evolved over the years into a tool that is used for a wide range of response, planning, and academic purposes. ALHOA models three hazard categories: toxic gas dispersion, fires, and explosions. ALOHA employs several different models, including an air dispersion model that it uses to estimate the movement and dispersion of chemical gas clouds. From this model, ALOHA is able to estimate the toxic gas dispersion, the overpressure values from a vapour cloud explosion, or the flammable areas of a vapour cloud. ALOHA uses additional models to estimate the hazards associated with other fires and explosions. ALOHA can solve problems rapidly and provide results in a graphic, easy–to–use format. This can be helpful during an emergency response or planning for such a response.

ALOHA runs quickly on desktop computers and is designed to be easy to use so that you can operate it successfully during high–pressure emergency situations. It has an in–built chemical library containing information about the physical properties of approximately 1,000 common hazardous chemicals. However, users should know that its computations represent a compromise between accuracy and speed. ALOHA has been designed to produce good results quickly enough to be of use to responders and consequently the prediction models used are not very refined.

ALOHA can display a threat zone plot, showing one or more areas where a hazard–toxicity, flammability, thermal radiation, or damaging overpressure–may exceed key Levels of Concern (LOCs) and pose a threat to people and property as shown in Figure 5–4. ALOHA displays the threat zones in red, orange, and yellow. The red threat zone represents the worst hazard while the orange and yellow threat zones represent areas of decreasing hazard. ALOHA can also display the threat zone plot on an electronic map of any location using MARPLOT®, and ALOHA's threat zones can also be exported to GIS systems as shown in Figure 5–5.

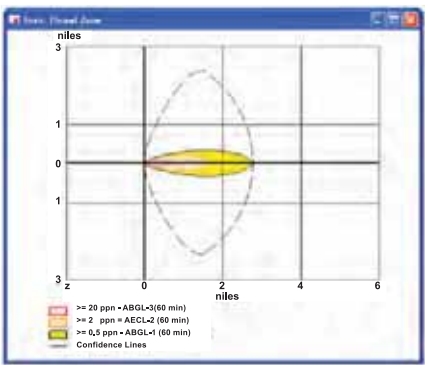


Figure 5–4: Toxic Threat Zone modelled by ALOHA

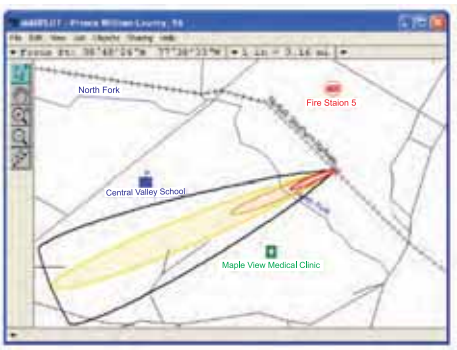


Figure 5–5: ALOHA threat zone overlaid on GIS map using MARPLOT

Source: ALOHA User's Manual

EXERCISE 5A

Learn how to use simulation modelling tools like ALOHA to calculate hazard footprints for a vapour cloud explosion scenario through EXERCISE 5A in annexure.

EXERCISE 5B

Learn how to use simulation modelling tools like ALOHA in combination with QGIS to determine the total population affected in a toxic release of ammonia through EXERCISE 5B in annexure.

5.5.2 Web–GIS based emergency management tool– EMDSS

The Emergency Management Decision Support System (EMDSS) is a web–GIS application built on top of the Risk Management Information System (RMIS). The EMDSS provides for intrinsic integration with models and expert systems through its web–GIS interface for viewing information and running simulation models as shown in Figure 5–6. EMDSS can act as a fast and effective tool for decision makers when an emergency situation has evolved because of an accident in a hazardous industry.

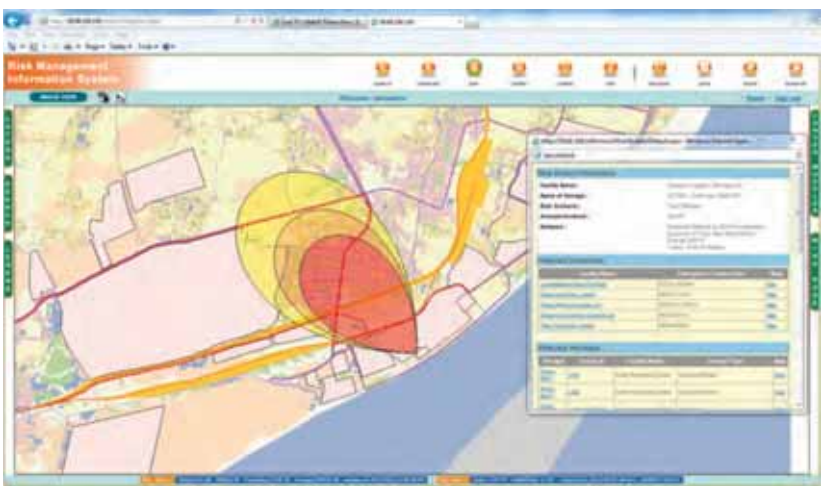


Figure 5–6: Web–GIS enabled emergency management decision support interface of the RMIS

Source: Own compilation

A key aspect of the EMDSS is that it can access information on chemicals, storages, meteorology and other pertinent data from the centralised RMIS database and also model the potential consequences of an accident to pre–defined end–points. For modelling of accident consequences, the EMDSS has embedded consequence analysis models. These models are based on relatively simple, but standard algorithms that are capable of modelling effects of toxic gas dispersions, pool fires, boiling liquid expanding vapour explosions (BLEVE) and vapour cloud explosions (VCE). These models calculate distance to a pre–defined endpoint for toxic gas concentration, radiation or overpressure levels and can dynamically overlay a spatial footprint to the endpoint on a base map. Given its close coupling with GIS, the application can also calculate the potentially affected population, roads which may get blocked and sensitive receptors (schools, old age homes, etc.) that may need priority evacuation because of an accident.

EXERCISE 5C



To know how specialized risk management applications like the RMIS can facilitate in modelling hazard scenarios and determining population vulnerability, please refer to EXERCISE 5C in annexure.

5.6 Emergency evacuation

Emergency evacuation: One of the most effective response strategies available to emergency managers during an emergency is the evacuation of the affected population to safer areas. A key spatial concept that can assist in drawing up a modelling approach for evacuation planning is the notion of a credible emergency planning zone (EPZ). An EPZ outlines who needs to be evacuated (population in the zone) and how they need to be routed to reach safety (outside the zone).

An EPZ can be drawn up from an evacuation vulnerability map that represents the most difficult evacuation that may occur in a region, defined as the population involved in the evacuation over the number of lanes connecting the population to the rest of the network. It can be formulated with this relation:

Evacuation difficulty = population / number of exit lanes

With this definition, we can try to find out about the worst case evacuation scenario that the residents assigned to a particularity section might experience (maximum difficulty), but excluding the global

worst case scenario that involves evacuating an entire urban area. With a limit on the size of an evacuation, it is possible to reveal local variation in evacuation vulnerability from node to node. The maximum difficulty value for a given node and given evacuation size is referred to as a node's spatial evacuation vulnerability. The Figure 5–7 shows three potential evacuations that all contain the node labelled A: each node has 100 people, and each link has one lane in each direction. The nodes involved in the evacuation are shown in black and the exits are shown as bold arrows. The population assigned to each node is shown with dashed lines. Population in the shaded zones needs to be evacuated in each case.

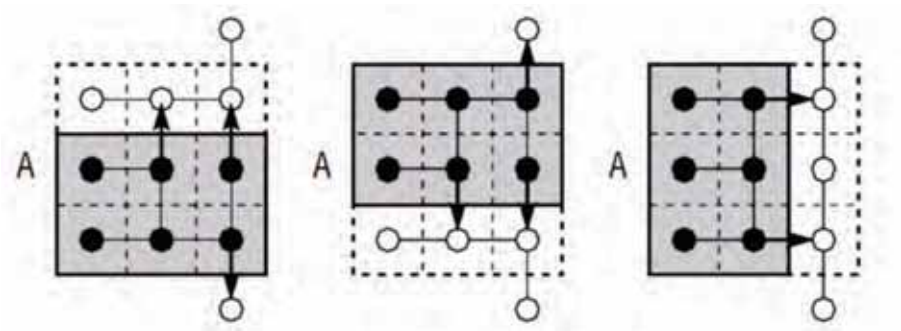


Figure 5–7: Evacuation difficulty model

Source: Cova T.J., Church R.L. (1997). Modelling community evacuation vulnerability using GIS.

EXERCISE 5D

Learn how to calculate evacuation vulnerabilities during a chemical disaster through EXERCISE 5D in annexure.

5.7 India emergency management perspective

In order to establish a structured emergency planning system, the MoEF notified the Chemical Accidents (Emergency Planning, Preparedness and Response) Rules to complement the Manufacture, Storage and Import of Hazardous Chemicals Rules on accident prevention and preparedness and response. The regulation provides statutory backup for setting up of 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. The most pertinent in this regard is the role of the District and Local Crisis Groups which is supposed to play a direct role in emergency management in an industrial area. The District Crisis Group (DCG) set up by the District Collector will serve as the apex body at the district level and shall meet every 45 days. This group shall review all On–Site Emergency Plans prepared by the occupiers of MAH installations for the preparation of District Off–Site Emergency Plan which will also include hazard due to the transportation of hazardous chemicals both by road and by pipeline. The district chairperson shall conduct at–least one full scale mock–drill of the District Off–site Emergency Plan at a site each year. Powers under Section 10 of the Environment (Protection) Act for entry and inspection are also made available to the Central/State and District Crisis Group members. The district authority is responsible for the Off–Site emergency plan and it shall be equipped with up–to–date MAH units, website, control room etc., with provisions for monitoring the level of preparedness at all times.

In practice however, many states are yet to form or make operational State Level Crisis Groups or if present, they are not in a position to deliberate on planning, preparedness and mitigation of chemical accidents or review the adequacy of all the off–site emergency plans for adequacy. The functioning of the District and Local Crisis Group are plagued with deficiencies.

With the lack of sufficient capacity building and training, the District Authorities do not often have the knowledge base to tackle a chemical emergency situation. Rather, the approach adopted is mostly in tune with the disaster response capabilities that have inherently been built into the district departments from their experience in managing natural disasters.

A common and consolidated pool of updated information on industry hazards and their potential impacts are often not available because of the lack of any central database. Wherever it exists, there are issues of getting proper and fast access to the data and without having knowledge of their validity.

In many industrial clusters, mock drills are often not held on a periodic basis. Even if they are conducted, often the feedback and learning from mock drills do not lead to any interventions to improve the system.

Box 5–1: GIS based Emergency Planning and Response System

As a part of an initiative supported by the Ministry of Environment Forests (MoEF), the National Informatics Centre (NIC) has developed a GIS based Emergency Planning and Response System (GEPRS) has been developed for Major Cluster of Industries in selected industrialized states in the country. The program which was earlier made available on CD ROM can be considered to be user–friendly and can be used along with district level offsite emergency plan not only for planning and mock trials of major chemical emergencies but also during actual emergency. Recently, a web–based version of the program is also being developed.

The program has the capability to display seamless digitized district maps of each industrial pocket with an extent to cover all the MAH industries along with MCL scenarios, police stations, fire stations and hospitals. Data on all the chemicals stored at MAH industries has been compiled. Based on the MCL scenarios computer modelling has been done using ALOHA and ARCHIE for consequence analysis. Outcome is made compatible to complete software package and for display on digitized maps. Outcome of the entire relevant scenario are stored in data base in the form of shape files and can be displayed on digitized maps in separate layers as per the user's requirement. Users can view the district map on their screens – these are digitized maps in layers superimposed on relevant sets of SOI toposheets for ease of use.

However, at the same time the system has certain limitations and it is not being used in many industrial clusters. As per information available, certain refinements are being presently made to the system.

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6

LEARNING UNIT 6 RISK AND LAND–USE PLANNING

6.1 Introduction

Land is a finite resource. Land availability is only about 20% of the earth surface. Worldwide, land is increasingly becoming a scarce resource with increasing demands from multiple sectors like agriculture, industry, mining, urban and other developments. Pressures on land allocation are being increasingly felt in emerging countries like India which has over 17% of world's population living on 2.6% of the world's geographical area. India has relatively high population density and at the same time is witnessing fast paced development that can potentially lead to rapid changes in land–use.

It is increasingly being realised by policy makers that following the current growth trajectory, without addressing key environmental and risk related considerations arising from the use of land would not lead to sustainable development in the long run. As a result, it is imperative that a more holistic understanding of land–use as an underlying and integral aspect of a complex environmental and socio–economic fabric must emerge. At a global level, this has been highlighted through the chapter 10 of Agenda 21 which calls for adoption of an integrated approach to planning and management of land resources for achieving sustainable development and where required, consider the reorganizing and strengthening of decision–making structures.

Box 6–1: Managing land from a holistic perspective

Sustainable land–use is that which meets the needs of the present while, at the same time, conserving resources for future generations. This requires a combination of production and conservation: the production of the goods needed by people now combined with the conservation of the natural resources on which that production depends so as to ensure continued production in the future (FAO).

In this context, given the multi–functionality and complexity of land–use, judicious planning at the regional and local levels would be almost impossible if consensus is not reached on trade–offs between economic, environmental and social dimensions of land utilisation that may arise from competing and often conflicting needs.

For example in RiskCity, the growth of petrochemical and allied industries for the last two decades has spurred an immense requirement for land for setting up new industries, supporting facilities and infrastructure and is emerging as an area of critical concern. Given the high density of population and the primary dependency on agriculture for a large percentage of the population in the area, allocation of land for industrial development has become a key issue with far reaching ramifications from the point of view of attaining economically robust, environmentally sustainable and socially acceptable growth. In addition, a concentration of potentially hazardous industries contributes to high levels of cumulative risk to the residential population staying in the urban area of RiskCity.

In India, the industrial development, apart from urbanization, is the major driver of economic growth. As envisioned by the Government of India, industrialisation is inevitable and will accelerate. The industrial growth rate targets are set at 12 to 14% in the medium run and contribution of industrial sector to national GDP at 25%. The industrial development is seen in the form of industrial estates, special economic zones, specialised industrial parks, investment zones, National Manufacturing Investment Zones, special investment regions (SIRs), PCPIRs (petroleum, chemicals and petro chemical investment regions) and industrial corridors that occupy a lot of land. The industrial development is associated with supportive development, viz. housing areas, transport, trade & commerce areas, waste/waste water treatment & disposal areas etc., which also require considerable amounts of land.

Land–use planning plays a very important role in planning industrial development as well as dealing with chemical risks. At the time of planning industrial or other activities that deal with chemicals, their location could be appropriately planned taking disaster risks into consideration. Or even when industrial or other activities that deal with chemicals that exist in an area, their risks could be

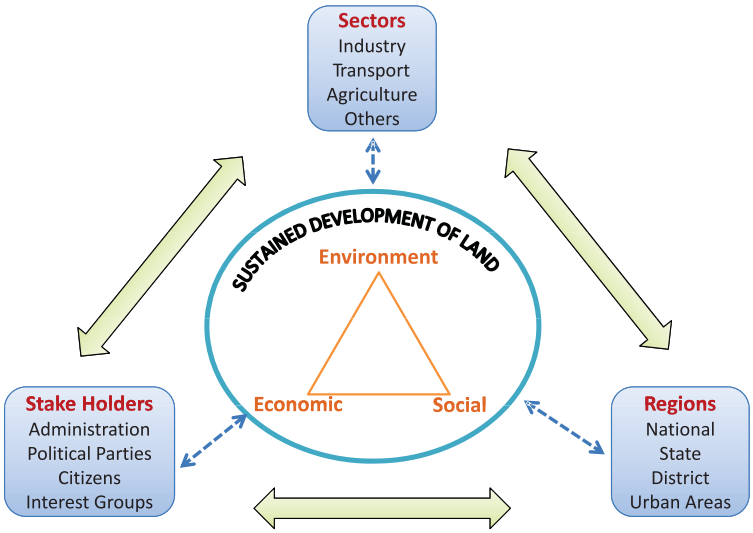


Figure 6–1: Sustainable land management paradigm

Source: Own compilation

assessed, vulnerable areas identified and the land uses regulated so as not to allow those land uses that would be affected, residential areas should not be allowed in a risk prone area.

The present situation can be visualized through a scheme in the Figure 6–1 and can be used to identify potential choice conflicts in land–use management with respect to chemical risk, such as:

- Whether the interest of industrialists or government development agencies to create more industries in an area correspond to the interest of real estate developers to create more residential settlements in an urbanised industrial area or that of farmers in the semi–urban area involved in agricultural activities?
- Whether the requirements to industrialise an area is compatible with social perception of risk and its acceptance by communities living in the area?
- If heightened chemical risk can be compensated by improving the abilities of decision makers to take up appropriate risk mitigation measures and preventive actions to minimise damage from a probable accident?

6.2 Land–use planning – fundamentals

6.2.1 What is land–use planning?

The main objective of land–use planning is to create the prerequisites required to achieve a type of land–use, that is sustainable, environmentally compatible, socially desirable and economically sound. When initiated, land–use planning is expected to set in motion social processes of decision making and consensus building concerning the use and protection of private, communal or public areas and land–uses.

Normally undertaken by government agencies, land–use planning generally comprises of a process to identify, evaluate and decide on different options for the use of land, including consideration of long term economic, social and environmental objectives and the implications for different communities and interest groups, and the subsequent formulation and promulgation of plans that describe the permitted or acceptable uses.

The land–use planning involves studies and mapping of geographical data; mapping and analysis of economic, environmental and hazard data; formulation of alternative land–use possibilities; and development of detailed plans for different geographical and administrative scales within the given planning area. Prudent land–use planning decisions can therefore play a key role in reducing risk from natural and man–made disasters by discouraging settlements and construction of key installations in hazard–prone areas.

Proper planning of land and its resources allows for rational and sustainable use of land catering to various needs, including social, economical/developmental and environmental needs. Proper land–use planning based on sound technical procedures and land utilisation strategies, supported by participatory approaches empowers people to make decisions on how to appropriately allocate and utilize land and its resources comprehensively and consistently catering to the present and future demands.

6.2.2 Land–use planning system – scale and nature of planning

Land–use planning can be undertaken at various scales and decisions can be taken at various levels of the government. The methods of planning and nature of plans formulated may differ to consider the policies and planning priorities at the level concerned. In India, the levels can be categorised as National, State, District and Local. At the same time, there has to be close coordination and interaction between the levels – preferably the flow of information both ways.

However, in India, the planning process is predominantly guided by centralised planning and allocation of resources through the 5–Year plans. The Planning Commission has recently focused on laying out a broad spatial development strategy for the country that aims to reduce regional disparities and harmonise growth in relatively underdeveloped areas. In line with this evolving planning approach, the Planning Commission has also laid down a set of 23 target indicators from the 10th Plan onwards with the objective of measuring socioeconomic development and sustainability. In addition, the sectoral policies and plans drawn up by the line ministries of the Government of India also provide necessary planning direction and drive development based on developmental priorities.

There is lack of comprehensive and integrated land use planning in the country, which enables rationale and optimal land utilisation. A systematic and scientifically based land use planning in the country is inadequate at local, regional as well as at state levels. In the area of land–use planning or its utilisation, there is no single approach currently being followed across the country. Various sectors at central level such as urban, rural, industrial, transport, mining, agriculture etc. follow their own approaches.

The Constitution (Seventy–fourth Amendment) Act, 1992 provides for District Planning and Metropolitan Area Planning that consolidates plans of both Panchayats and municipalities having regard to spatial (land use) planning. The District Plans prepared currently do not cover spatial (land), environmental as well as urban concerns. For the urban areas, the Urban Development Plans Formulation and Implementation (UDPFI) Guidelines (1996) recommended urban development planning system, which consists of a set of the following four inter–related plans:

a) Perspective plan: A long term (20–25 years) policy plan of spatio–economic development of the settlement.

b) Development plan: Conceived within the framework of the approved Perspective Plan, it is a medium–term (generally five years co–terminus with the term of the local (authority) comprehensive plan of spatio–economic development of the urban centre.

c) Annual plan: Conceived within the framework of Development Plan, it is a plan containing the physical and fiscal details of new and on–going projects that the local authority intends to implement during the respective financial year.

d) Plans of projects/schemes: Conceived within the framework of approved development plan/annual plan, these are detailed working layouts for execution by a public or private agency.

Master Plans and Development Plans are prepared for urban areas, metropolitan areas and sometime Regional Plans such as for Delhi National Capital Region.

For the industrial areas, the National Manufacturing Policy (Nov 2011) of the Government of India, promotes integrated industrial townships, known as the National Investment and Manufacturing Zones (NIMZs) with at least 5,000 Hectare area and calls for preparation of environment friendly development plans. Major environmental aspects are required to be taken care of in the NIMZ in the beginning itself by having proper zoning during master planning. The state level/local level authorities such as industrial development corporations and infrastructure development boards are identifying locations for industrial estates, special economic zones, investment zones/regions and industrial corridors and preparing development/master plans for such areas. For example, the Gujarat Infrastructure Development Board is preparing an elaborate Development Plan for Dholera Special Investment Region, which is a part of the Delhi–Mumbai Industrial Corridor. Such plans guide future land use.

For the "Eco Sensitive Zones", which are notified under the Environment (Protection) Act, 1986, there is a requirement of preparation of Zonal Master Plans or Zonal Development Plans that guide further development in the area. "Eco Sensitive Zone" may be defined as area(s) which contains a natural feature with identified environmental resources having 'incomparable values' (water resource, flora & fauna etc.) requiring special attention for their conservation. The Eco Sensitive Zones will include protected areas such as National Parks, Wildlife Sanctuaries, Conservation Reserves and Community reserves (total number: 659), which covers about 4.79% of the total geographic area of the country. The areas other than protected areas such as landscape areas, areas with historical value also are covered under Eco Sensitive Zones.

Within this evolving land–use planning system in India, there is a need for integrating the aspect of chemical risks as a preventive approach, whether planning for urban areas or industrial areas or eco sensitive areas etc. In addition to the areas/zones where land use planning started in the country, the major chemical hazard vulnerable areas could be identified and declared as such and land use planning undertaken.

6.2.3 Land–use planning perspective

Over the years, the approaches to planning has gradually evolved taking into account the governance structures and socio–political realities that enable the implementation of plans. Such changes have been reflected in the approach adopted towards planning as also from the point of application of information science. Table 6–1 maps the progress of planning since the early part of last century, when it got established as a practice:when it got established as a practice:

Table 6–1: Planning paradigm and application of information systems

Era	Planning paradigm	Application of information systems
Till 1920's	Planning as design – urban designers and planners create our cities	No role
1920's	Planning as regulation– zoning and control is the core of government action	No role
1940's	Planning as applied science – scientific, economic policy analysis guide planning solutions	No role
1960's	Planning as politics – social movements and political action affect planning decisions	Data oriented information Systmes
1970's	Planning as communication – public information / participation broaden planning perspectives	Information management systems
1980's	Planning as collaboration – stakeholders engaged to reason together and own up planning decisions	Knowledge based and Decision Support Systems
2000 onwards	Planning as integration of policy, science, design and collaboration – information revolution and rebirth of design innovation informed by science, policy and collaboration	Intelligent systems that allow for collaboration between stakeholders

Source: Adapted from Randolph, Environmental Land Use Planning and Management, 2004

6.3 GIS and land–use planning

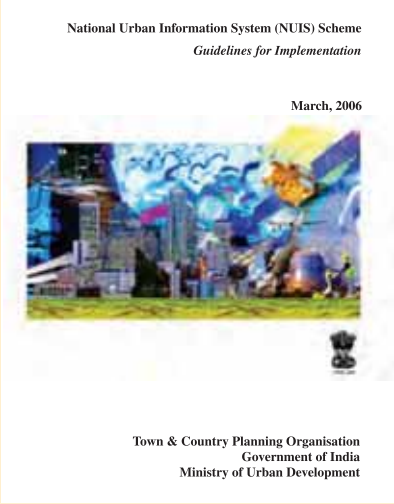
GIS is a useful tool for land–use planning and decisions. With its capabilities for integrated analysis of the spatial and associated attribute data and scope for storing, manipulating and displaying of maps that can allow the planner to take a graphical and composite view of a specific area. She/he can evaluate the suitability of land for specific developmental purposes and accordingly make suggestions of different land–use options. Another key distinguishing feature of GIS that enables land–use planning is its ability to handle map–based spatial data and its ability to harmonise data emerging from heterogeneous sources through the adoption of common geo–coordinates and projection systems thus allowing them to be overlaid over each. For example, to undertake risk informed land–use analysis of RiskCity, the spatial datasets to be handled include parcel level land–use, location and nature of hazardous chemicals stored in industries, distribution of population, presence of specific vulnerabilities to chemical risk, proximity to hospitals which can provide relief, etc. had to be sourced from different agencies and collated together into a common geo–spatial database.

However, it should also be kept in mind that GIS is only a tool for planners to consolidate, analyse and query/visualize information dealing with developmental issues in their respective planning areas. The successful application of GIS hinges crucially on the ability to gather and collate necessary information (spatial and attribute) in a useful form keeping in mind the planning objectives. If the information is acquired without assigning focused objectives, setting of standardised data collection and processing methods, many of these data would not be compatible for any further analysis – voluminous data may result in the phenomenon of 'garbage in, garbage out (GIGO)' in terms of the analysis results leading to weak information output that may lead to constraints and uncertainties in the planning process. In addition, in a dynamic planning environment where data changes with time (land–use, population, etc.), it is important to have proper mechanisms for updating data in a standardised database, so that the information analysed by GIS stays relevant to the planning problem at hand. Some of the key information that may need to be developed in such a database includes:

- Land information, land cover, cadastral data and property boundaries;
- Resource maps and development constraints including water catchments, fertile agricultural areas, environmentally sensitive areas like coastal regulation zones (CRZs) or forests, slope, areas prone to natural or man–made hazards;
- Building information, building outline, type, structure, building form, height, floor areas
- Development plans and approvals, structure plans, land–use control and zoning plan, infrastructure development plans;

Box 6–2: National Urban Information System

One of the key problems associated with urban planning in the country pertains to the application of rigid conventional methods and procedures that provide little scope for adapting to dynamic situations. Accordingly, in order to promote the optimal use of modern ICT enabled tools and methods for urban planning, the Central Government launched a scheme for preparation of a National Urban Information System (NUIS). Implementation of the NUIS is expected to enhance the management of urban settlements through the use of modern planning techniques through the following:



- Development of urban indices based on generation, storage and manipulation of spatial and attribute data bases;
- Standardization of GIS databases, methodologies and procedures to enable easy integration and sharing of information;
- Build capacity among town planning and allied departments who are proficient in using modern automated methods.

More information, please refer to the NUIS website:http://urbanindia.nic.in/programme/lsg/nuis.htm

The level of land–use analysis that can be undertaken using GIS depends on one side on the sophistication of the tool and methods being used, but on the other also on the proficiency and understanding of the planner to use them for the planning task at hand. At a basic level, GIS can mimic the manual overlay process used by planners and facilitate the combining individual suitability maps layers which can then be analysed to obtain an overall suitability map. At a higher level, method like cartographic modelling can be applied to land–use suitability analysis. This will involve the use of map algebra techniques involving boolean operations, interpolation techniques, spatial modelling involving multi–criteria analysis which are almost impossible to undertake without computer assisted mapping as shown in Figure 6–2.

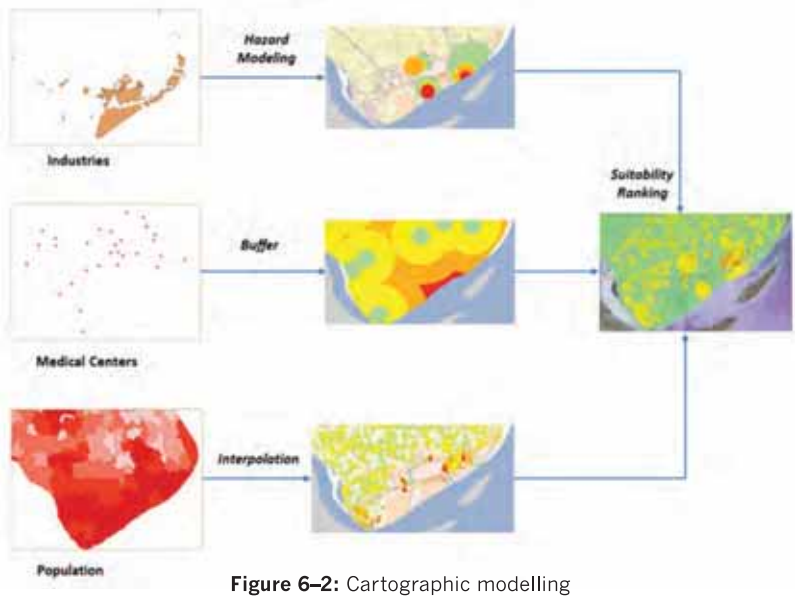


Figure 6–2: Cartographic modelling

Source: Own compilation

At a more advanced level, GIS can also assist the decision makers with a module evaluate several alternative land–use planning scenarios based on opinions received from different stakeholders associated with the planning process to evaluate the pros and cons of each scenario before agreeing to preferred scenarios based on planning priorities. Such modules have the ability to integrate decision modelling tools like Multi–Criteria Decision Analysis (MCDA) as add–ons to normal GIS tools and are called Spatial Decision Support Systems (SDSS). GIS–based MCDA can be thought of as a process that combines and transforms spatial and non–spatial data into a resultant decision (output). The MCDA procedures define a relationship between the input maps and the output map. The procedures involve the utilization of geographical data, the decision maker's preferences and the manipulation of the data and preferences according to specified decision rules. Accordingly, two considerations are of critical importance for spatial MCDA:

- GIS capabilities of data acquisition, storage, retrieval, manipulation and analysis, and MCDA capabilities for combining the geographical data and the decision maker's preferences into uni–dimensional values of alternative decisions.

- A number of multi–criteria decision rules have been implemented in the GIS environment for tackling land–use suitability problems and they can be classified into multi–objective and multi–attribute decision making methods. While the multi–objective approaches are mathematical programming model oriented methods, the multi–attribute decision making methods rely on a data oriented approach.

Figure 6–3 shows a schematic diagram on how SMCE can be applied from a decision–making perspective to land–use planning. The matrix A contains the criteria in one axis (C_1 to C_n), and a list of possible alternatives, from which a decision has to be taken on the other axis (A_1 to A_m). Each cell in the matrix (a_{ij}) indicates the performance of a particular alternative in terms of a particular criterion. The value of each cell in the matrix is composed of the multiplication of the standardised value (between 0 and 1) of the criterion for the particular alternative, multiplied by the weight (W_1 to W_n) related to the criterion. Once the matrix has been filled, the final value can be obtained by adding up all cell values of the different criteria for the particular alternative (e.g. a_{11} to a_{1n} for alternative A_1). Using this method, a composite risk index map can be prepared using several criteria maps by applying a decision rule and then calculating the performance of all cell values of the different criteria (a_{ij}) for the particular alternative.

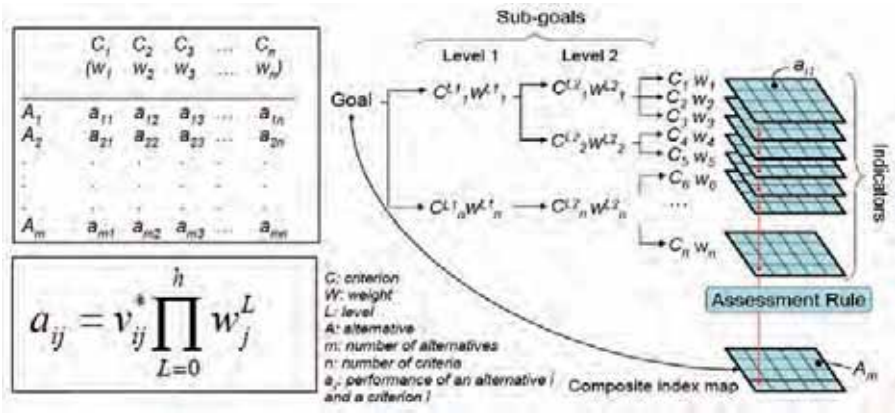


Figure 6–3: Schematic procedure for spatial multi–criteria evaluation based on AHP

Source: ITC (2001). ILWIS 3.0 Academic – User's Guide.

6–4 Risk informed land–use planning

High extent of damage caused by several industrial accidents in the past like Bhopal, Mexico City, Toulouse can be attributed to inappropriate land–use in the vicinity of highly hazardous facilities. On several occasions, either the siting of an industrial facility had been undertaken without taking into consideration proximity to existing settlements or because demographic pressure had led to the migration of population around the hazardous industry at a later time due to ineffective land–use plans or lax regulatory restrictions leading to heightened risk to society. After assessing the damage caused by such accidents and undertaking studies to analyse risk in the vicinity of hazardous installations, often it is resorted to maintaining a certain separation distance between such hazardous facilities and communities living in the surrounding. While creating sufficient separation distance between such facilities and residential areas can provide for a straightforward resolution of the problem, such decisions are often difficult to implement in areas having high population densities and where use of land is constrained.

Consequently, judicious planning of land–use around hazardous facilities or deciding on the siting of new hazardous facilities is internationally accepted to be an important risk reduction or mitigation measure for managing risk that may arise from development of industrial areas and have been implemented through directives and legal instruments. Considering the damages caused by Bhopal and Mexico disasters, the European Union brought about amendments to the Seveso Directive that aims at prevention of major chemical accidents in Europe and limit potential consequences to man and the environment. Changes brought through the incorporation of Article 12 of the Seveso II Directive requires European Member States to use land–use planning as a key instrument to provide a high level of protection to the community from chemical risks. The UNISDR also recognises that carefully designed and rigorously implemented land–use planning can be one of the most useful approaches to manage risk arising from either man–made or natural hazards. However, at the same time, it also recognises this aspect to be challenging, given the conflicting views that is held by different stakeholder on the issues of land and its use for productive purposes.

Box 6–3: Article 12 of Seveso II Directive

Article 12 of the amended Seveso II Directive reads as follows:

1. Member States shall ensure that the objectives of preventing major accidents and limiting the consequences of such accidents are taken into account in their land–use policies and/or other relevant policies. They shall pursue those objectives through controls on:

   a) the siting of new establishments;

   b) modifications to existing establishments covered by Article 10;

   c) new developments such as transport links, locations frequented by the public and residential areas in the vicinity of existing establishments, where the siting or developments are such as to increase the risk or consequences of a major accident.

   Member States shall ensure that their land–use and/or other relevant policies and the procedures for implementing those policies take account of the need, in the long term, to maintain appropriate distances between establishments covered by this Directive and residential areas, buildings and areas of public use, major transport routes as far as possible, recreational areas and areas of particular natural sensitivity or interest, and, in the case of existing establishments, of the need for additional technical measures in accordance with Article 5 so as not to increase the risks to people.

2. Member States shall ensure that all competent authorities and planning authorities responsible for decisions in this area set up appropriate consultation procedures to facilitate implementation of the policies established under paragraph 1. The procedures shall be designed to ensure that technical advice on the risks arising from the establishment is available, either on a case–by–case or on a generic basis, when decisions are taken.

Source: JRC (2006). Land–use planning guidelines in context of Article 12 of Seveso II Directive

However, the solution to the problem may not be as easy as it may look like. On one side, land–use planners have to account for the safety of surrounding population in an industrial area while on the other they have to consider options to exploit land in the best possible manner accounting for socio–economic considerations like employment opportunities, benefits to local community from operation of an industry and objectives for area level industrial development. Related to such divergent objectives, different stakeholders including industry, administration, employees, communities and interest groups have different priorities and values which need to be considered in the decision making process pertaining to land–use planning. The risk assessment method should therefore be designed in

a manner that its output can guide the land–use planning process through a set of risk based planning criteria. For example, a risk map of RiskCity showing high, medium and low risk areas can guide land–use planners on whether to allow another new hazardous industry in the area or to evaluate future development options for vacant land in the vicinity of a cluster of hazardous industry.

As discussed in the earlier sections, several approaches to risk assessment from hazardous industries currently exist and they vary from the purely quantitative to semi–quantitative and qualitative. The choice of an appropriate method should take into account its acceptability to risk actors and preferably supported by the regulatory framework for risk assessment. Methods for quantitative assessments have evolved into an established practice and make an attempt to calculate a numeric value of risk based on the hazard potential of industries and the potential for damage to population present in the neighbourhood. It is often represented in the form of metrics like individual and societal risk and the conception of such metrics is exhibited in the first example cited in the Box 6.5. Based on such calculations, policy makers can then delineate risk acceptability or tolerability criteria which in turn can be used for setting the criteria for land–use planning decisions. On the other hand, there also exist more normative processes which aim to provide a qualitative representation of risk through a composite index, rather than trying to calculate a numeric value of risk based on likelihood and severity of possible accidents.

Within the group of quantitative methods, two distinct approaches for risk characterisation exist and it is important to understand them to get a correct picture on how it can influence land–use planning. The first approach called the **"consequence oriented approach"** is based on the assessment of the consequences from potential accidents with no attempt to quantify the likelihood of accidents. The main concept driving this approach is the relative uncertainty involved in ascertaining the frequency of accidents and in some ways this method is akin to the analysis of "worst case scenarios". The justification being: if there are enough measures to protect population from the consequence of a worst case accident scenario, enough protection will be in place for any other scenario that could result in lesser effects. But then, this method will also provide for larger safety or exclusion distances where planning restriction have to be imposed and may not be suitable for densely populated areas.

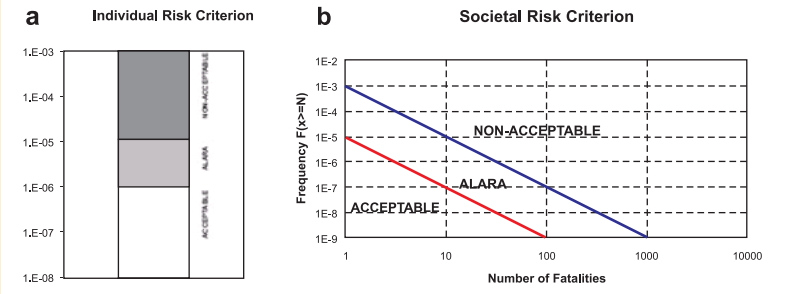
The second approach is called the **"risk oriented approach"** and is more known as Quantitative Risk Assessment (QRA). In this approach, the objective is to evaluate both the severity of potential accidents as well as estimate the likelihood of their occurrence. This method is more complete in analysing risk, and especially holds good for areas which have sever land–use constraints and high population densities. But, at the same time it is quite complicated, needs a host of information and as well as making assumptions on the frequencies of initiating events and subsequently their probable fallout based on other factors. This method is also widely used as a part of planning practice in the Netherlands, Germany and the UK.

Box 6–4: National examples on risk guided land–use planning approaches

The Netherlands

For example, in the Netherlands, the measure of individual risk is used to estimate risks from hazardous installations and risk contours showing the spatial disposition of risk around a hazardous facility is used to facilitate land–use planning decisions. For populated areas, the Dutch Ministry of Housing, Spatial planning and Environment (VROM) has set the following standard i.e. IR < 10–6 (per year). In addition, societal risk values are also taken into account before any new development is undertaken in an area, where risk sources are present.

Individual and societal risk criteria in the Netherlands

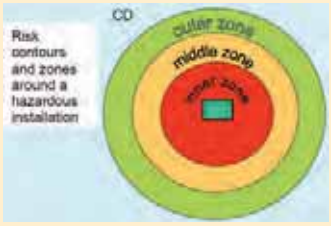


Source: Christou M.D., Gyenes, Z. et al. (2011). Risk assessment in support to land–use planning in Europe: Towards more consistent decisions?

United Kingdom

The aim of HSE with regard to health and safety advice for land–use planning is to mitigate the effects of a major accident on the population in the vicinity of hazardous installations, by following a consistent and systematic approach to provide advice on applications for planning permission around such sites. The HSE advises the Local Planning Authority (LPA) on the nature and severity of the risks presented by a hazardous installation to people in the surrounding area based on a structured set of criteria arrived at through risk analysis. The recommendations are given due weight by the LPA when making its decision for a proposed new development.

Risk criteria in the UK



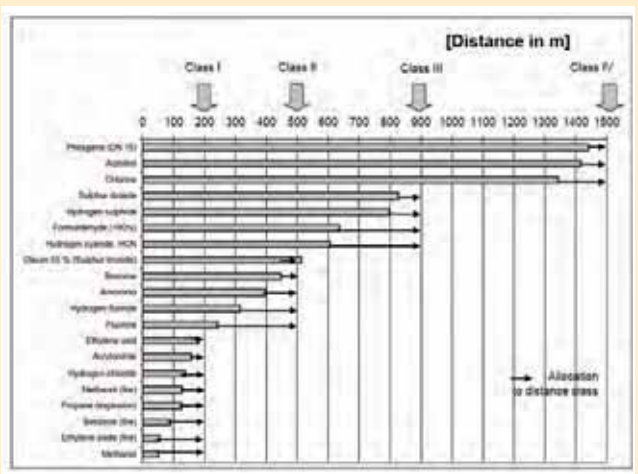
Level of sensitivity	Development in Inner Zone	Development in Middle Zone	Development in Outer Zone
1	DAA	DAA	DAA
2	AA	DAA	DAA
3	AA	AA	DAA
4	AA	AA	AA

Sensitivity Level 1 - Example: Factories
Sensitivity Level 2 - Example: Houses
Sensitivity Level 3 - Example: Vulnerable members of society e.g. primary schools, old people's homes
Sensitivity Level 4 - Example: Football ground/Large hospital
DAA means **D**o not **A**dvise **A**gainst the Development
AA means **A**dvise **A**gainst the Development

Source: UK HSE

Germany

In Germany, the land–use planning criteria for locating hazardous industry is decided based on safety distances that separate areas of different use. The safety distances are specified after assessment for hazard of each type of installation based on a consequence oriented approach that takes into account the maximum credible of a hazardous substance getting involved in an accident. The damage level is linked to an injury criterion – higher damages like death and sever injury are not accepted. Local authorities are responsible for preparing land–use plans taking into account such safety distances and restrict the use of land within such areas. A typical chart that provides guidance on safety distances for hazardous industries handling different chemicals is shown in the adjoining figure.



Source: SFK/TAA Working Group "Land–Use Planning", 2011

6.5 Indian perspective on risk and land–use planning

In India, the Environmental Impact Assessment (EIA) Notification under the Environment (Protection) Act, 1986 regulates the setting up of highly polluting or hazardous industries within the country. Projects involving high risk are expected to obtain environmental clearance from an appraisal committee based on systematic assessment of environmental impacts and risk. However, the elaboration with which such risk assessments are undertaken and the extent to which siting criteria consider risk aspects remain a question. Also, EIA being a project based approval system, decision makers may not be able to consider cumulative risk involved in an industrial cluster before according clearances to new projects. Further, in general, there are no zoning restrictions adopted in the vicinity of existing hazardous facilities to prevent the development of residential areas which will be exposed to high risk.

From the regulatory point of view, Section 41A of the Factories Act require state governments to set up site appraisal committees which can then consider applications for siting of hazardous industries or expansion of existing industries and provide a decision based on the merits of the case. However, no objective process is outlined in the regulation based on which such an evaluation would be carried out and the appraisal of a case is left to the wisdom of the committee members. The absence of any standardized risk assessment process may result in high amount of subjectivity in such decision making.

In order to ensure proper siting of newly planned industries, taking into account environmental considerations, a project called the **"Zoning Atlas for Siting of Industries[5]"** has been implemented through the apex pollution control authority in the country – the Central Pollution Control Board. The project lays down a methodology of preparing thematic maps at district level factoring aspects like prevailing air, water and ground water quality and undertaking criteria based sensitivity analysis for assessing suitability for new industries in an area. Using a standard methodology, zoning atlas maps for several districts in the country have been prepared and are available as hardcopies from the CPCB. However, it should be noted that these Atlases have not taken chemical hazard risks into consideration.

At this time, use of a Zoning Atlas for planning of new industrial areas has been inadequate. Zoning Atlas tools and methods have not so far been mainstreamed with the planning process or adopted by developmental / planning authorities at the state and district levels.

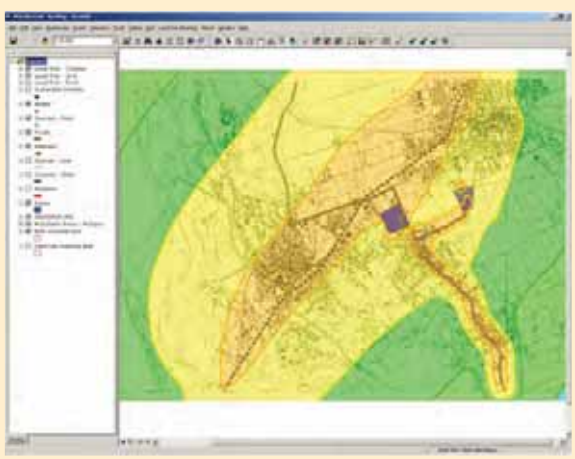
[5] The project was supported by the Indo–German Cooperation and the World Bank

6.6 Risk based land–use planning techniques and tools

GIS has had an intricate linkage for supporting land–use planning in general and also when incorporating specifics aspects like chemical risk, primarily because of the complexity of the task of risk mapping. At present, many of the planning tools that are used for undertaking chemical risk assessment are designed based on QRA based methods whose final outcome is a risk map, which is then overlaid on a base map using GIS, principally for visualization purposes. Several techniques and tools like SAFETI, RISKCURVES and ARIPAR have been developed since the 1980's for generation of risk maps and are able to facilitate land–use related decision making in various degree, incorporating the chemical risk aspect. Sometimes, the use of these tools for generating risk contours/maps has been made mandatory by country level regulations, as the use of SAFETI is mandatory in the Netherlands. However, except for a few cases, the acceptance of such tools and techniques by the land–use planning community has historically been low. This is principally because of the inability of decision makers and land–use planners to comprehend the scientific logic and assumptions that go into generating the risk maps. In addition, often many of these tools exhibit an inadequate level of integration with GIS – the principal use of the GIS interface is for visualization purposes without any scope for undertaking any further level of dynamic spatial analysis.

Box 6–5: Risk based land–use planning – ARIPAR tool

First significant steps towards factoring chemical risk inland–use planning were taken up in Europe in the early eighties because high population densities, together with a high degree of industrialization had forced decision–makers to develop methods for evaluating and managing the risks. Area based risk studies were carried out in Canvey Island (UK), Rijnmond (Netherlands) and Ravenna (Italy) to develop



methods for quantifying cumulative risks originating from a number of hazardous facilities located in an industrial area and then formulate criteria based on which risk can be considered for land–use planning. In Italy, the Italian Department for Civil Protection, together with Regione Emilia Romagna, started the ARIPAR project (Analysis and Control of the Industrial and Harbour Risk in the Ravenna Area) in 1988.The main outcome of the ARIPAR project was the development of a methodology and the related software tool for area risk assessment. Specifically, this tool incorporated the analytical knowledge the existing situation in the Ravenna area with respect to risk sources, vulnerability resorts and emergency control centres, and it produced quantitative estimate of the risks in the Ravenna area through the development of an "area risk reassembling module" to quantify the risk connected with storage, process and transportation of dangerous substances present on site. Subsequently, the ARIPAR tools has been further refined and presently research is being undertaken to improve its capabilities.

Source: ARIPAR – getting started manual, JRC

In parallel, another set of methods and tools based on the principles of indicators and hinging more on collaborative decision making that accounts for views of stakeholders. These techniques and tools focus more on structuring a land–use situation specifying objectives to cover relevant elements of the decision making process in order to fulfil the goals of the community (Grønberg 1999; Papazoglou, Bonanos et al. 2000). If well designed, such a comprehensive indicator based system can condense technical information on risk determining factors as well as account for the perceptions of the community which can then be synthesized into a composite risk index providing for a representative and acceptable picture of the levels of risk prevailing in an area. A prominent feature of these normative approaches also involved widening of the focus on vulnerability which receives limited attention in QRA based approaches and leading to the conceptualization of vulnerability models and the use of indices that can result in easy interpretation and understanding of vulnerability factors contributing to risk.

6.6.1 Semi–quantitative method for calculating cumulative risk

The Risk Guided Planning Support System (RGPSS) is a web–GIS based application built on the Based on the individual methods that have been discussed earlier in the GIS Basics and Risk Assessment Modules, we now attempt to combine them in order to formulate a semi–quantitative methodology for calculating the cumulative risk originating from a number of hazardous industries and estimate the spatial distribution of risk across the entire industrial area.

1. Level of hazard, determined through consequence analysis and spatially represented through a hazard potential map;
2. Predicted frequency of the accidental event;
3. The distribution of population in the area represented through a grid based interpolated population map.

At first, we use quantitative values and calculations for hazard analysis, estimation of probability and population distribution and then convert them into ranks based on a logical set of criteria. The criteria for hazard and probability ranking will be the same as is defined in Risk Assessment section. The population density values (calculated in each 100 X 100 m cell) are ranked based on the criteria shown in Table 6–2:

Table 6–2: Population density ranking

Ranking	Population density (range in number of persons per hectare)
4	> 150 per hectare
3	> 80 < 150 per hectare
2	> 25 < 80 per hectare
1	< 25 per hectare

The three factors are then combined to obtain a measure of risk to society through the following calculation:

Hazard Potential = Hazard Probability X Hazard Consequence

Cumulative Area Risk = Hazard Potential X Population Density (grid wise)

The measure of cumulative risk is calculated based on multiplication of ranks, which is subsequently categorised into 3 risk levels (high, medium and low) based on the evaluation criteria shown in Table 6–3:

Table 6–3: Risk ranking criteria

Ranking	Definition
<= 8	Low
9–24	Moderate
>= 24	High

The level of risk can then be represented spatially on a map thereby providing for a spatial disposition of chemical risk over an industrial area.

6.6.2 Web–GIS based planning support system for risk management

The Risk Guided Planning Support System (RGPSS) is a web–GIS based application built on the Risk Management Information System (RMIS) platform and is capable of generating composite risk maps through spatial multi–criteria analysis (SMCE) of several hazard and vulnerability based factor maps, taking into consideration the preferences and priorities of the decision maker. The user can select factor maps that he/she considers to be relevant from a set of standardised maps which have been prepared by experts and stored in the RMIS spatial database – such maps include the hazard map,



Figure 6–4: Interface of the SMCE based planning support system within RMIS

Source: Own compilation

evacuation difficulty map, population density map, distance to hospital map and a host of others. For undertaking SMCE, each of these factor maps can be given a certain weight age based on which, a final composite risk map (Figure 6–4) can be prepared by the system. This risk map can then be used by stakeholders to understand the present risk scenarios and also to assess suitability of setting up of new industries or arrive at decisions to reduce risk in a particular neighbourhood.

EXERCISES 6A and 6B



Considering cumulative risk over an area, learn how to use GIS tools for preparing risk maps and subsequently use them for developing zoning plans (both risk based and consequence based approaches)through EXERCISE 6A and EXERCISE 6B in annexure.

EXERCISE 6C



Experience how spatial multi–criteria analysis is implemented through a web–GIS tool like the RMIS in order to identify land for setting up new hazardous industries in EXERCISE 6C in annexure.

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GLOSSARY

Chemicals and Petrochemicals Investment Regions (PCPIRs)	PCPIR is a specifically delineated Investment Region planned for the establishment of production facilities for petroleum, chemicals and petrochemicals. A PCPIR would be a combination of production units, public utilities, logistics, environmental protection mechanisms, residential areas and administrative services. It would have a processing area, where the manufacturing facilities, along with associated logistics and other services, and required infrastructure will be located, and a non– processing area, to include residential, commercial and other social and institutional infrastructure. The minimum processing area for the PCPIR will be about 40% of the total designated area, i.e., around 100 km². The processing area may or may not be contiguous.
EIA	Environment Impact Assessment is a planning tool that is now generally accepted as an integral component of sound decision–making. The objective of EIA is to foresee and address potential environmental problems/concerns at an early stage of project planning and design. EIA/EMP should assist planners and government authorities in the decision making process by identifying the key impacts/issues and formulating mitigation measures.
EMP	Environment Management Plan (EMP) comprehensively covers all aspects of the natural and human environment so that adverse impact, if any is taken care of and the project does not create any hazard or affect the quality of life for generations. The plan also indicates the details as to how various measures have been or are proposed to be taken including cost components as may be required.
Environmental Protection Act (EPA), 1986	Most comprehensive Act relating to Environmental Protection. Objective is to implement the decisions made at the U.N. Conference on the Human Environment at Stockholm, June 1972. It is an umbrella Act which covers various issues of air, water, land, human beings and other living creatures and property.
Event Tree Analysis	Event tree analysis is a logical evaluative process which works by tracing forward in time or forwards through a causal chain to model risk. It does not require the premise of a known hazard. An event tree is a inductive investigatory process.

Hazard	Potentially damaging physical event, phenomenon or human activity that may cause loss of life or injury, property damage, social and economic disruption or environmental degradation.
Hazardous chemical (HAZCHEM)	Chemical substances which are in solid, liquid or in gaseous form and used in many processing industries in India causes acute or chronic health effects on the individuals exposed to these chemicals. The chemicals causing the health hazard are carcinogenic, toxin or highly toxic agents, irritants, corrosives and these agents can damage the lungs, skin, eye or mucous membranes are called as hazardous chemicals.
Industrial disaster	Industrial disasters are disasters caused by chemical, mechanical, civil, electrical or other process failures due to accident, negligence or incompetence, in an industrial plant which may spill over to the areas outside the plant causing widespread damage to life, property and environment.
Chemical accident	Refers to an event resulting in the release of a substance or substances hazardous to human health. Such events may include fires, explosions, leakages or releases of toxic or hazardous materials that can cause people illness, injury, disability or death. Accidents, if properly managed, need not lead to an industrial disaster.
Land–use Planning	Land use planning means the scientific, aesthetic, and orderly disposition of land, resources, facilities and services with a view to securing the physical, economic and social efficiency, health and well–being of urban and rural communities. Land–use planning has been defined as "the systematic assessment of land and water potential, alternative patterns of land use and other physical, social and economic conditions, for the purpose of selecting and adopting land–use options which are most beneficial to land users without degrading the resources or the environment, together with the selection of measures most likely to encourage such land uses" (FAO, 1999).
Major Accident Hazard (MAH)	Unit means isolated storage and industrial activity at a site handling (including transport through carrier or pipeline) of hazardous

	chemicals equal to, or in excess of the threshold quantities specified in COLUMN 3 OF SCHEDULE 2 and SCHEDULE 3 of EPA Act respectively.
Material Safety Data Sheet	(MSDS) or internationally known as Safety Data Sheet (SDS) also known as PSDS, Product Safety Data Sheet is an important component of workplace safety. It is intended to provide workers and emergency personnel with procedures for handling or working with that substance in a safe manner, and includes information such as physical data (melting point, boiling point, flash point, etc.), toxicity, health effects, first aid, reactivity, storage, disposal, protective equipment, and spill–handling procedures.
MCA	Maximum Credible Accident (MCA) is a postulated accident that a facility must be designed and built to withstand without loss to the systems, structures, and components necessary to assure public health and safety.
Risk	Probability of harmful consequences or expected loss (deaths, injuries, property, livelihoods, economic activity disrupted or environment damaged) resulting from interaction between natural or human–induced hazards and vulnerability in a particular spatial and temporal condition. Risk = Hazard X Vulnerability
Special Economic Zones (SEZs)	A Special Economic Zone (SEZ) is a geographical region that is designed to export goods and provide employment. SEZs are exempt from federal laws regarding taxes, quotas, FDI–bans, labour laws and other restrictive laws in order to make the goods manufactured in the SEZ at a globally competitive price. Currently, there are about 143 SEZs (as of June 2012) operating throughout India and an additional 634 SEZs (as of June 2012) that have been formally/principally approved by the Government of India.
Vulnerability	The conditions determined by physical, social, economic and environmental factors or processes, which increase the susceptibility of a community to the impact of hazards.

HANDS–ON EXERCISES

Geoinformatics Application in Chemical Risk Management

1

EXCERCISES FOR LEARNING UNIT 2

Need: Managing and interpreting geographic data is a key element in chemical risk management. As a result, it is important that risk actors acquire basic knowledge on geographical information system (GIS) and the functioning of GIS tools for being able to take informed decisions.

Exercise 2A: Exploring spatial data using QGIS

Objective: Participants are introduced to the QGIS software tool and its various options for viewing, exploring and interacting with spatial data. The exercises are aimed at familiarizing the user with QGIS fundamentals, GIS data types and subsequently undertaking spatial analysis for decision making.

1. Introduction to GIS application software

In this exercise we will explore the QGIS Browser to learn how it is used within the QGIS software environment. The first part of the exercise is meant to become familiar with the user interface. The other parts deal with specific functions such as browsing and exploring data, setting coordinate systems, etc. Only basic functions of QGIS Browser will be covered in this exercise. Additional functions, if necessary, will be introduced later in the course.

Data for this exercise can be found in exA>Data Folder.

☞ **Start QGIS Browser**

Windows Start Menu>Programs>Quantum GIS Lisboa> Quantum GIS Browser (1.8.0)

When the QGIS Browser starts, the Standard Toolbar appears by default. The interface is divided into two distinct window panes: the left pane provides options for browsing through folders and the right pane provides options to get information on or preview geographic datasets. Figure 2A–1 shows the QGIS Browser interface and identifies the key elements.

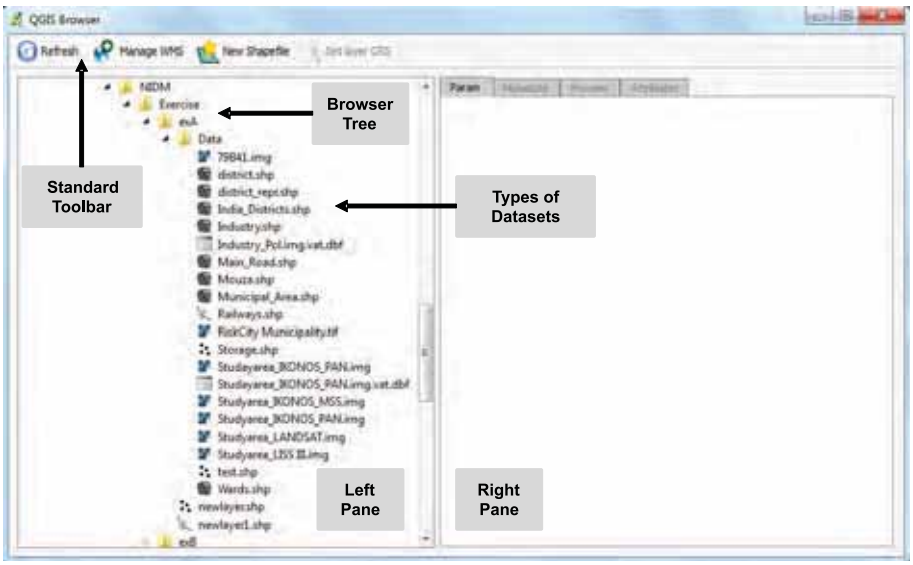


Figure 2A–1: QGIS Browser Interface

Source: Own compilation

1.1. Why use QGIS browser?

QGIS Browser allows you to manage, access and explore existing geographic data irrespective of the format in which the data is stored or its location, whether on the local discs or elsewhere on the organizational network (through mapped network drives). As such, you can compare it with Windows Explorer, but specifically tailored for Geospatial data. You can also create geographic data and connect to an existing geo–database.

In this exercise we will primarily focus on the exploratory part of QGIS Browser.

1.2. Browse for maps and data

Similar to Windows Explorer, you can view the contents of a folder on the left pane of the QGIS Browser. For the purpose, navigate to the folder containing data for this exercise and click on the small arrow on the left side of the folder. Different types of geographic datasets with specific icons uniquely identifying each data type e.g. polygon, point, line, etc. will be displayed below the folder. Upon selecting the folder, a listing of the folder contents (geographic data files and along with supporting documents) will be displayed on the right pane e.g. filename, filesize, date, etc. under the Param tab. Figure 2A–2 shows interpretation of the items displayed through the QGIS Browser interface.

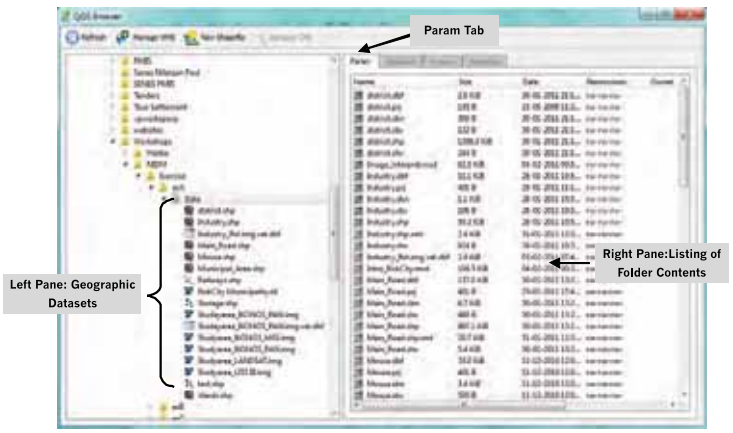


Figure 2A–2: Preview of various types of geographic data which can be managed with QGIS Browser

Source: Own compilation

1.3. Explore the data

For a general understanding of the geographic extent of the data, the left pane display of geographic data will serve the purpose. However, to examine the geographic data more closely, select the desired data file on the left pane and click the Preview tab on the right pane of the browser. This is a quick way to determine how the dataset looks before opening it in QGIS Desktop. Figure 2A–3 shows the usage of the preview tab.

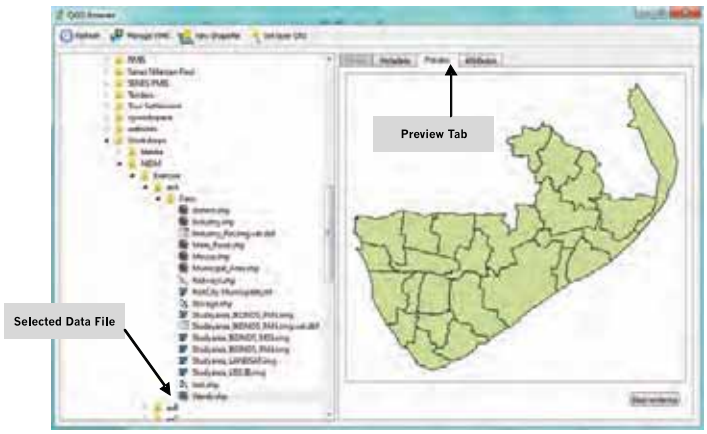


Figure 2A–3: Preview of the geographic data

Source: Own compilation

You can also click on the Attributes tab to view and browse through the attribute table of the selected data file. Figure 2A–4 shows the contents of an attribute table.

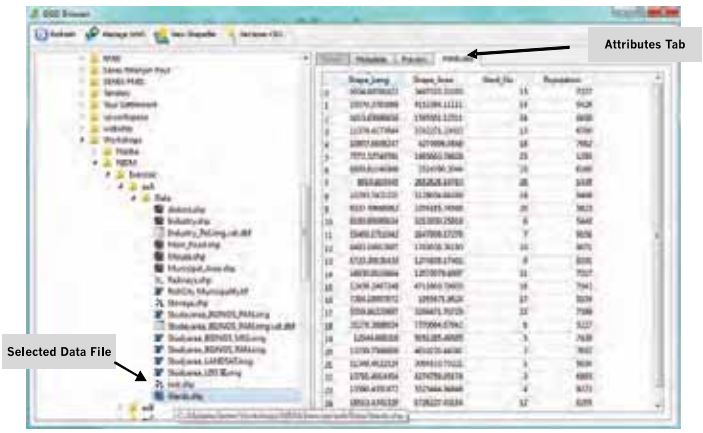


Figure 2A–4: Preview of attributes associated with geographic data file

Source: Own compilation

To quickly gather basic information about the selected data file e.g. geometry type, number of features, projection, datum, etc. click on the Metadata tab. Figure 2A–5 shows contents of the Metadata tab.

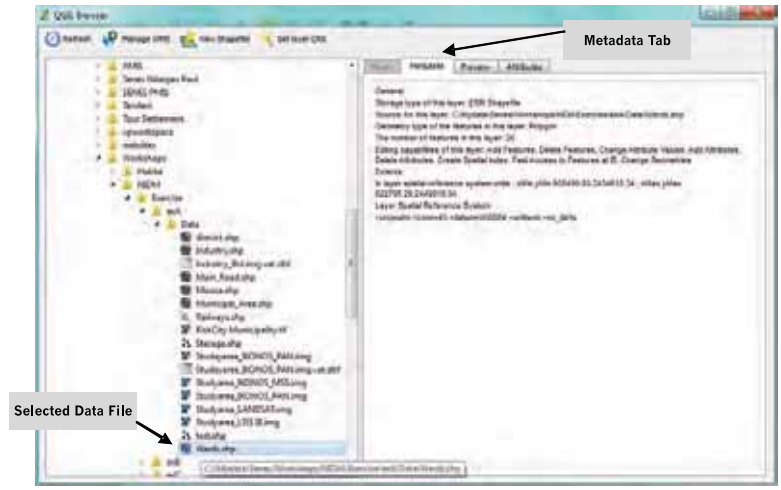


Figure 2A–5: Preview of metadata associated with geographic data file

Source: Own compilation

Assessment

Open the data folder for this exercise using the QGIS Browser tree. Now let us have a closer look at the contents of the folder:

1. Select a geographic data file and preview its contents. For the selected data file:
   - What is the geometry type?
   - What is the total number of features?
   - What is the datum?
2. Select the mouza.shp datafile and navigate to the Attributes tab. What is the Mouza–Name in the 16th row of the table?

3. Tick the geometry type that each one of the following geographic data files contain:

Layers	Point	Line	Polygon
Municipal Area			
Main Road			
Industry			
Storage			

1.4. QGIS Browser as a gateway to QGIS Desktop

So far we have briefly explored some of the most important functions of QGIS Browser. But the purpose of QGIS Browser is data browsing and basic data management. When you need to edit geo–spatial data, analyse it or create map layers you will need to use another application of the QGIS Application Suite: QGIS Desktop. From here onwards, most of the exercises will be dealing with the basics of geo–information processing using the functions of QGIS Desktop. Figure 2A–6 shows the QGIS Desktop application interface.

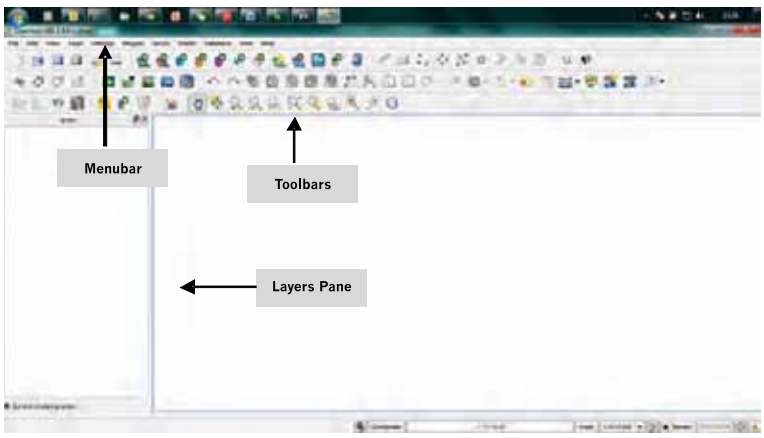


Figure 2A–6: QGIS Desktop Interface

Source: Own compilation

1.5. Use QGIS desktop

Launch QGIS Desktop from Windows Start Menu>Programs>Quantum GIS Lisboa>Quantum GIS Desktop (1.8.0).

The QGIS Desktop GUI (Graphic User Interface) will be displayed as shown in Figure 2A–7. Select File > Open Project and navigate to the exB>Data folder. For the purpose of this exercise you will select the file "Intro_RiskCity.qgs" (notice that saved QGIS map projects have the file extension .qgs) and click the Open button.

Now your screen should show a map like the one in Figure 2A–7.

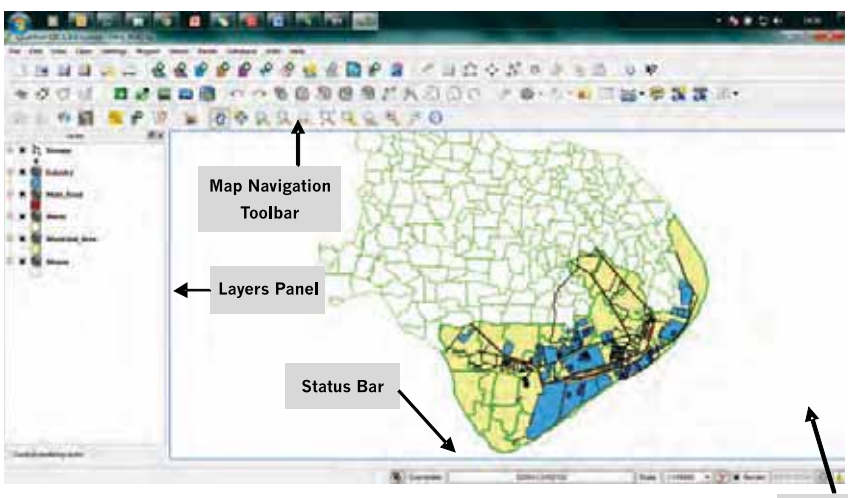


Figure 2A–7: Map showing RiskCity Database

Source: Own compilation

The large window currently displaying the layers of RiskCity is called the Map Window. The smaller window on the left side is the Layers Panel. It shows which layers are loaded in the Map Window. The Layers Panel also shows the legend (e.g. colour) used to display the features of a layer in the map. The check box next to each layer indicates whether or not the layer is active in the map.

1.6. Moving around the in Map Window

The Map Navigation toolbar helps you to move around within the map window and perform basic map navigation tasks. The tools that are mostly used in map navigation are discussed below.

Click the Zoom Out button on the toolbar. Using the mouse, draw a rectangle on the map and release. The map will be redisplayed at a smaller scale within the map window.



Click the Zoom In button on the toolbar. Using the mouse, draw a larger rectangle on the map and release. The map will be redisplayed at a larger scale within the map window.



Click the Pan button on the toolbar. Pan tool helps to move the map in all directions within the map window. Click on the map and move the mouse in any direction. Notice the map moves in the direction of your mouse movement.



Find out the Zoom Full button on the toolbar. Once you locate the correct button, click the same to see the entire map within the map window.

From the Layers Panel, list out the name of the layers loaded in the Map Window. What is the geometry type of the layers?

Layer Name	Geometry Type

1.7. Understanding the data in your map

Information about the data cannot always be explored simply by looking at a map. Many times you will need to find out specific information about geographic features and examine the attributes of a map layer.

Click the Identify Features button on the toolbar. Select the industry layer on the Layer Panel and click on an industry on the map. The Identify Results Window will display information on the selected industry as shown in Figure 2A–8.

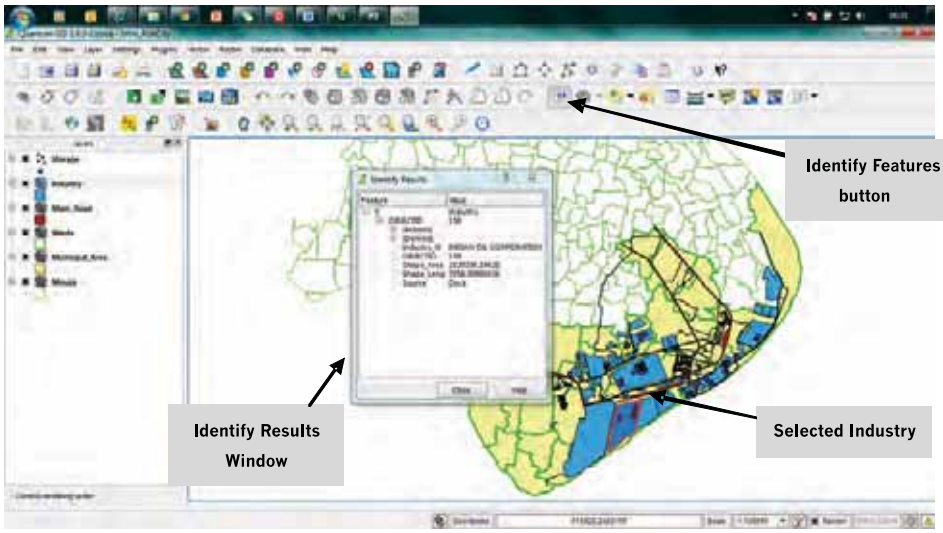


Figure 2A–8: Identify features on a map

Source: Own compilation

Select the industry layer and click Open Attribute Table button. Click the Industry_N field to sort the industry names in alphabetical order. Search for Industry XY01 under Industry_N field and select the record. You will notice that the record is highlighted both in the table and the industry is highlighted on the map as shown in Figure 2A–9.

You can also select multiple industries in the table (using the ctrl key on your computer keyboard) which will subsequently be highlighted on the map.

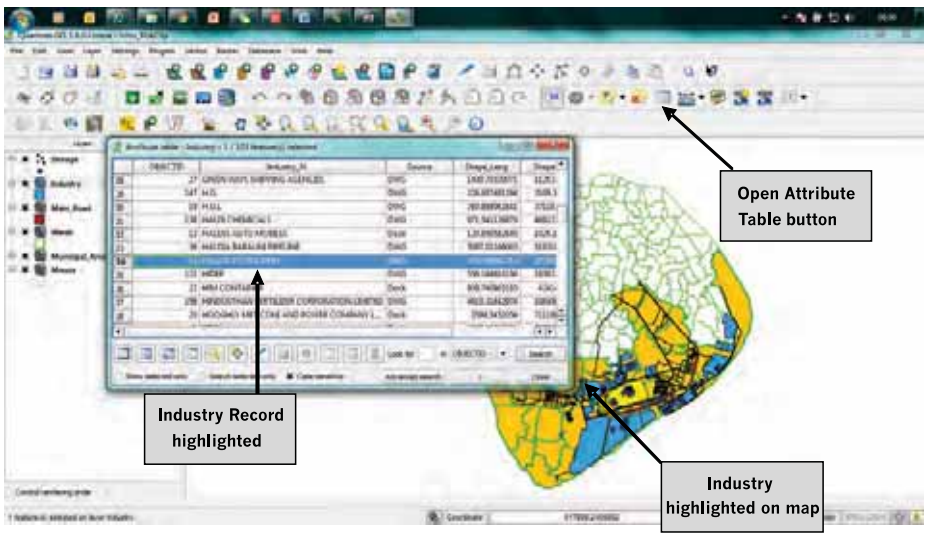


Figure 2A–9: Identifying features using attribute table

Source: Own compilation

2. Create new layer/shapefile file for digitization points and polygon features

- Remove all open layers from the Layers Pane.
- From the QGIS menubar select Layer>New>New Shapfile Layer or click the icon.
- In the New Vector Layer dialog, select Type as Point.
- Select CRS as WGS84 / UTM zone 45N and click the OK Your screen should look like Figure 2A–10.

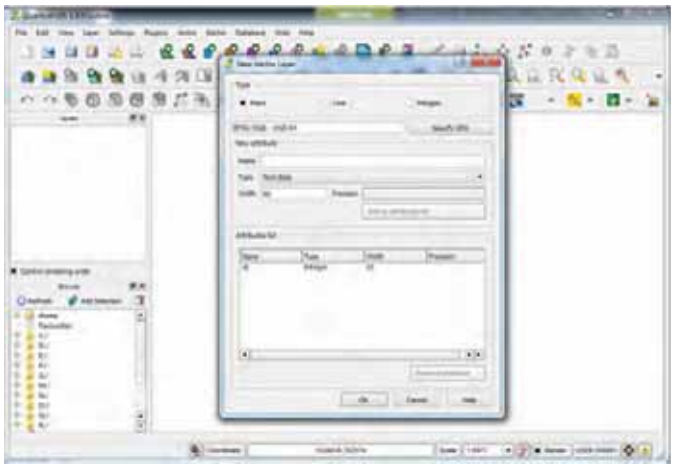


Figure 2A–10: Creating a new vector layer window in QGIS

Source: Own compilation

- Name the file storage_pt and click the Save button. Save the file in the ExB>Data folder.
- Now open the Studayarea_IKONOS_PAN.img from ExA>Data folder and zoom in on one of the industries.
- Digitize five storage tanks from the image as points on the storage_ptshapefile as below:
  - Select storage_pt.dbf on the Layers Pane
  - Click the Toggle Editing tool on the QGIS Desktop toolbar
  - Now zoom in to the image to locate industry storage tanks
  - Once you have located a cluster of storage tanks, click the Add Feature tool on the QGIS Desktop toolbar
  - Click on a storage tank on the image and provide its id. Click OK button to add the storage tank to the storage_ptshapefile
  - Once digitization of the five storage tanks are over, click the Toggle Editing button to Save the changes
- Your screen should look like Figure 2A–11.

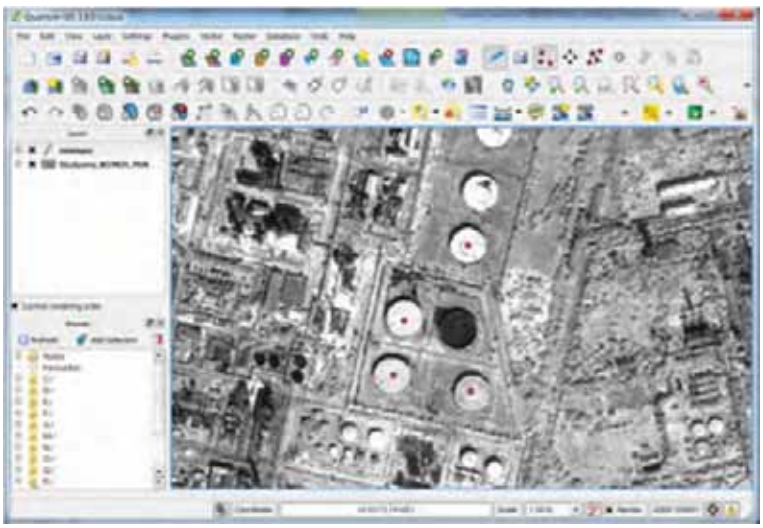


Figure 2A–11: Digitization of a new point layer

Source: Own compiation

- Create a new shapefile by the same method as described above. This time, choose the type as Polygon and provide the same coordinate system as mentioned above.
- Name the layer ward_poly and save in ExB>Data folder.
- Now open the RiskCityMunicipality_Georef.tif from ExB>Data folder and digitize ward numbers 9 and 10 on the ward_poly shapefile following the above described digitzation steps.

2.1. Attaching new attributes to layers

- From the Layers Pane, right click on the ward_poly shape file and select Open Attribute Table.
- From the tools at the bottom of the Attribute Table dialog box, click the Toggle editing mode button.
- Now click on the New column button as showing in Figure 2A–12.



Figure 2A–12: Digitization of a new point layer

Source: Own Compilation

- In the Add Column window, add two new fields Ward_No and Population of Type Text (String) and Width 10.
- Click OK when done.
- Add the ward no. and population data in the respective fields as per information given in the table below.

Ward No.	Population
9	1234
10	1098

- Once done, click the Toggle editing mode button to Save the changes.

2.2. Editing layer attributes

- From the Layers Pane right click on the ward_poly shape file and select Open Attribute Table.
- From the tools at the bottom of the Attribute Table dialog box, click the Toggle editing mode button.
- Now we will edit the population of ward number 16. In the Look For field, type 16 and from the in list select Ward_No field. Click Search. You screen should look like Figure 2A–13.

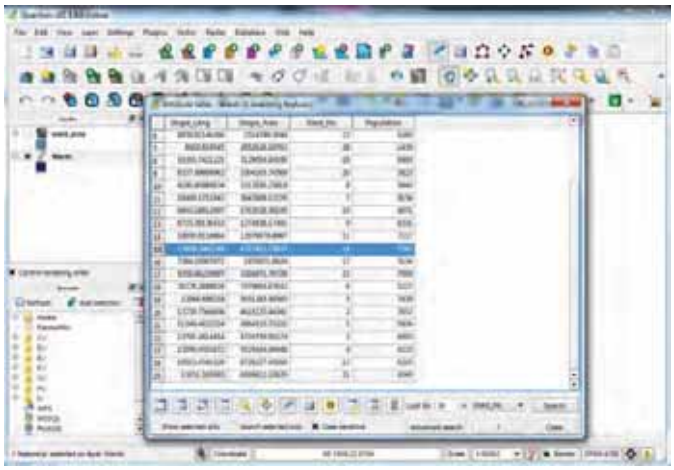


Figure 2A–13: Searching for attribute data

Source: Own compilation

- The row corresponding to ward number 16 will be highlighted. Select the population field and replace the value 7542 with 1441. Press enter to save the change.
- Click the Toggle editing mode button to Save the changes.
- Click Close button to close the Attribute table.

2.3. Select features by querying the attribute table of a layer

- Remove ward_poly from map window.
- Now add the vector layer 'wards' to map window. Right click on the layer in Layers Pane and view the attribute table. Can you identify the ward with the highest population? Also identify ward with the lowest area.
- Now we will display the data according to population density. Right click on the wards layer in Layers Pane and click Properties>Style tab.

- Change Single Symbol option to Categorized. Select column as Population.
- Click Classify button to add ward wise population values.
- Click the Labels tab and select Display labels. Click OK once done. Find out which ward has the highest population density?
- Can you query to find out the population of ward 11? Can you identify the reason why the population of such a large ward is on the lower side?

Exercise 2B: Fundamentals of Remote Sensing

Objectives: Understand the fundamentals of remote sensing, spatial resolution of satellite data, georeferencing, visual image interpretation, applying QGIS for viewing satellite data and creating shapefiles.

1. Viewing Satellite Data

- Open the Image_interpret.qgs file from folder ExA>Data. Can you see the districts of the state of West Bengal?
- Now add the image Studyarea_LISSIII.img to your map window. In the Layers Pane, drag the image below the districts layer.
- With the Identify Features button click on an area on the image and identify the districts whose image is visible in the window.
- Right click on Studyarea_LISSIII.img in the Layers Panel and view the image metadata through Properties>Metadata tab. Scroll down the box under the Abstract section and note the values within the subheading Pixel Size. What do you think is the resolution of the image?
- In the image, is it possible to identify a peninsula like area just south of the meeting point of two major rivers? If yes, zoom on to the area – can you identify any significant features in it?
- Now add the image Studyarea_Landsat.img to your map. From the Box 2B–1, can you note down the resolution of this image? Can you also note down how many bands this image has?

System	Landsat-7
Orbit	705 km, 98.20 inclination sun-synchronous, 10:00 AM crossing, 16-day repeat cycle ETM+ (Enhanced Thematic Mapper) 185 km (FOV = 15")
Off-nadir viewing	No
Revisit time	16 days
Spectral bands (μm)	0.45–0.52 (1), 0.52–0.60 (2), 0.63– (3) 0.76–0.90 (4), 1.55–1.75 (5), 10.4–12.50 (6), 2.08–2.34 (7), 0.50-0.90 (PAN)
Spatial resolution	15 m (PAN), 30 m (bands 1–5,7), 60 m (band 6)
Data archives at	earthexlorer.usgv.gov edcimswww.cr.usgs.gov/imswelcome

Box 2B–1: Searching for attribute data

- Zoom in to the peninsula area you had homed on earlier and see if you can identify objects/features better than what you had seen in Studyarea_LISSIII image? Can you identify an urban or industrial area in the image? At which scale can you identify the urban/industrial area?
- Is it possible to identify any roads or transportation corridors in this area from the image?
- Now open the topographic sheet (79B41.img) and see if you can identify any road in it? From Properties>Transparency tab make the topographic sheet 50% transparent and see whether the road alignment matches with that of the Landsat image? Remove all layers from the map pane.
- Open images Studyarea_IKONOS_Pan.img and Studyarea_IKONOS_MSS.img in you map. From image properties, identify the resolutions of each image. Scan through them separately, compare and identify the differences that you can see in them.
- The Figure 2B–1 provides a visual comparison between a high resolution and low resolution image. Notice that from the IKONOS image on the left you can clearly identify the houses and the smaller roads lying within the residential area.



IKONOS (1m resolution) showing the Durgachak Residential Area



Landsat (30 m resolution) showing the Durgachak Residential Area

Figure 2B–1: High and low resolution image comparison

Source: Own compilation

2. Georeferencing a raster image

A major issue in any GIS application is the correct geometry of the maps. Raster data is commonly obtained by scanning existing paper maps or obtaining aerial photographs and satellite images of the study area. Scanned map datasets don't normally contain spatial reference information (either embedded in the file or as a separate file). Also, with aerial photography and satellite imagery, sometimes the location information delivered with them is often inadequate, and the data does not align properly with other data you may have. Thus, in order to use some raster datasets in conjunction with your other spatial data, you often need to align it or georeference it to a map coordinate system.

A map coordinate system is defined using a map projection (a method by which the curved surface of the earth is portrayed on a flat surface). When you georeference your raster dataset, you define its location using map coordinates and assign a coordinate system. Georeferencing raster data allows it to be viewed, queried, and analysed with other geographic data.

2.1. Viewing scanned map

- Open the IKONOS satellite image (Studyarea_IKONOS_PAN.img) from the ExA>Data folder. The image will appear as a black rectangle on the Map Window.
- Right click on the image in the Layers Pane and select Properties>Style tab.
- In the Single band properties section, select the Use Standard Deviation radio button.
- In the Contrast enhancement section at the bottom of the tab, select the Stretch to MinMax option from the dropdown box. Click OK
- Overlay the scanned ward map (RiskCityMunicipality.tif) file on the image from the ExB> Data folder.
- Find out whether the scanned ward map is overlaying properly on the satellite image? If not, then what can be the reason?

2.2. Assigning coordinates to a scanned map

Following section demonstrates the procedures to assign coordinates to a raster image (e.g. scanned ward map of RiskCity Municipality.tif) by means of a number of control points, and making it ready for vectorization.

The Georeferencer tool is needed for georeferencing. Click the Georeferencer icon in the QGIS toolbar. 

- Click the Open Raster button on the toolbar and add the scanned ward map (RiskCityMunicipality.tif from ExB>Data folder).
- A Coordinate Reference System Selector window will be displayed on the screen. Select WGS84 / UTM zone 45N as the coordinate system list and click OK The ward map will be added to the Georeferencer window.
- Can you see the four bright yellow circles on the map?
- Zoom into each of these circles starting with the one on the top left side corner.
- Click the Add Point button on the toolbar and then Click at the centre of the red dot inside Circle A.

- Now enter the X and Y co–ordinates against Point A from the table below in the Enter map coordinates dialog and click the OK

Point	Input X	Input Y
A	607401.825	2443157.316
B	611768.070	2440172.915
C	617324.238	2440729.492
D	617700.286	2442220.493

- Repeat the last two steps for points B, C and D.
- Once done, click Start Georeferencing button on the toolbar. A dialog window will prompt you to set the transformation type. Click OK
- The transformation settings dialog will open. Fill information against each field as given in the Figure 2B–2 and click the OK button. Remember to save the Output raster file in the ExB>Data folder.



Figure 2B–2: QGIS Transformation settings window

Source: Own compilation

- Close the Georeferencer window. When prompted to save the GCP points, click Save button. The GCP points file will be saved in the same folder as the georeferenced image. You will be able to load the GCP points later, if required.
- In QGIS Desktop, open the Studayarea_IKONOS_PAN.img from ExA>Data folder. Make necessary changes to the image to make it visible. Now add the georeferenced ward file.
- From the Layers Pane, right click on the RiskCityMunicipality_Georef.tif file and select Properties. Select the Transparency tab on the layer properties window and change the transparency level to 50% under the Global transparency option.
- Verify whether the scanned ward map is overlaying properly on the satellite image.
- Now the ward map image is ready for vectorization.

Exercise 2C: Spatial analysis

QGIS Desktop can be used to undertake spatial analysis, a technique that manipulates the topological or geometric properties of multiple spatial datasets for taking informed decisions.

In this exercise, we will spatially analyse two sets of geographic data for determining to what extent the population of a municipal ward matches the census information. For the purpose, two polygon layers have been prepared – the wards layer contains ward–wise population data and the PopGrid_2001_rank layer contain grid (100 m x 100 m) based census data prepared through spatial interpolation techniques. You can check the attribute tables of both the layers to view the population data – relevant fields in the Wards layer are Ward_No and Population while in the PopGrid_2001_rank layer it is the SUM_pop_pa field. Our target ward for the analysis is ward number 1.

To perform spatial analyses, follow the following steps:

1. Remove all layers, except the Wards layer, from the Layers Panel using the Remove Layer(s) tool. 
2. Select the Wards layer and use the Labelling tool to display the ward number of each ward on the map as shown in Figure 2C–1. 

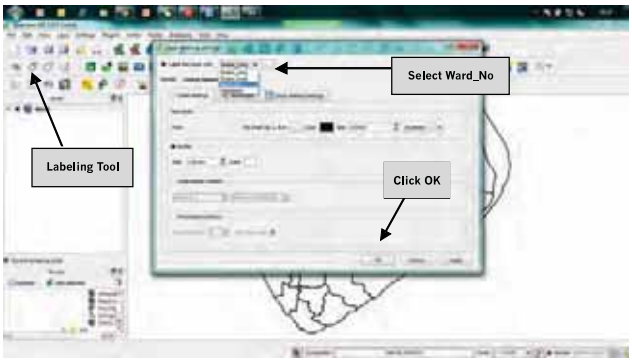
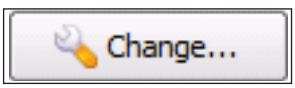


Figure 2C–1: Enable Layer Labels

Source: Own compilation

3. Click the Add Vector Layer tool, navigate to ExB>Data folder and add the PopGrid_2001_rank layer. Notice that the new layer sits on top of the wards layer and makes it almost invisible.

4. Next we will change the PopGrid_2001_rank layer symbology. Right click on the PopGrid_2001_rank layer in the Layers Panel and select Properties option. The Layer Properties window will open. On the Style tab click the Change... button which will open the Symbol Properties window.



5. Under Symbol layer properties section, select the dropdown box next to Fill style option, choose No Brush. Similarly change the value next to Border width option to 0.10 and click the OK as shown in Figure 2C–2.

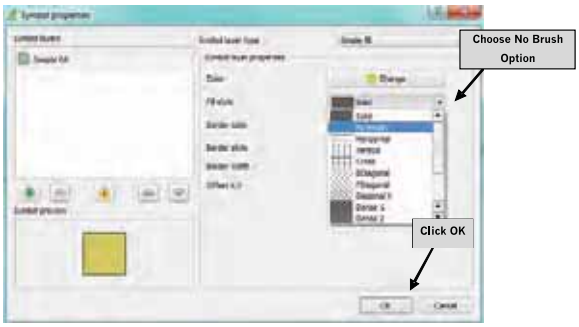


Figure 2C–2: Changing layer symbology

Source: Own compilation

6. Notice that the map now displays both the layers clearly. Next we will start spatial analysis.

7. From the QGIS Desktop Menu Bar, click Vector>Geoprocessing Tools>Intersect. This will bring up the Intersect operation window. Select PopGrid_2001_rank as the Input vector layer and Wards as the Intersect layer. Specify a filename as PopGridWardIntersect for the Output shapefile, click Browse and navigate to the ExB>Data folder to specify its saving location and click the Save button. Next, click the OK (Figure 2C–3 for details).

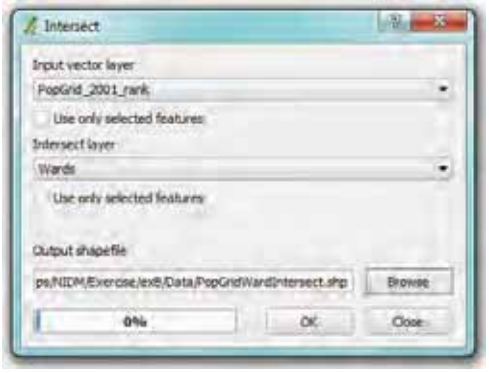


Figure 2C–3: Intersect operation window

Source: Own compilation

8. Subsequently, QGIS Desktop will combine both the layers and confirm creation of the PopgridWardIntersect layer. It will also prompt to add the new layer in the Layers Panel. Click Yes button to confirm addition and Close button to close the Intersect operation window.

9. Deselect PopGrid_2001_rank layer in the Layers Panel to view only the PopgridWardIntersect layer and the Wards layers. Select the PopgridWardIntersect layer and open its attribute table. Notice how the values in the Sum_pop_pa field are distributed against the Ward_No field.

10. We will now spatially isolate ward number 1 from the new layer and retrieve its population statistics. Right click on the PopgridWardIntersect layer in the Layers Panel and select Query option. This will bring up the Query Builder window.

11. Under the Fields section, double click Ward_No. Under Operators section click = operator. Notice that both the selections have appeared in the SQL where clause section. Place the mouse cursor next to the = operator in the SQL where clause section and type 1. Click OK (Figure 2C–4 for details).

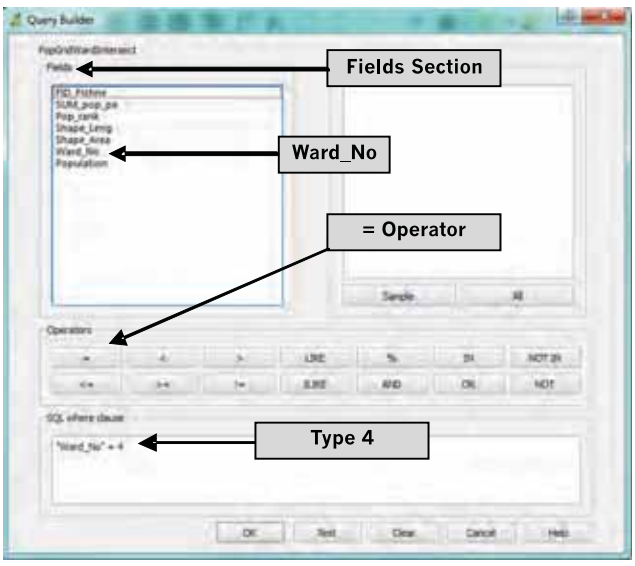


Figure 2C–4: Query builder window options

Source: Own compilation

12. Notice that ward number 4 is now isolated and displayed on the Map Window in a different colour. Next, from the QGIS Desktop Menu Bar, click Vector>Analysis Tools>Basic statistics. This will bring up the Basic statistics window. Select PopgridWardIntersect as the Input Vector Layer and Sum_pop_pa as the Target Field. Click OK The Statistics output window display Statistical Parameters and corresponding Values. The value against the Sum Parameter displays the total population figure as per census data for ward number 4 (Figure 2C–5 for details).

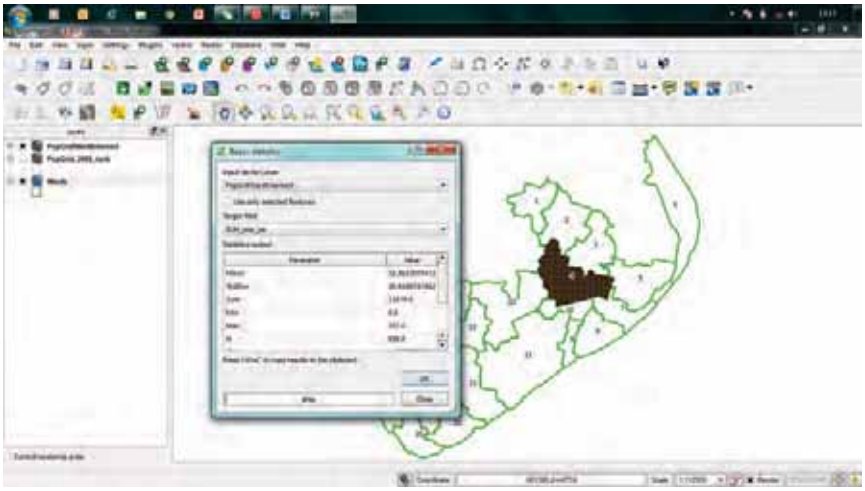


Figure 2C–5: Layer Statistics Window

Source: Own compilation

13. Now check the population figure for ward number 4 from the Wards layer attribute table. Do find any difference between the two figures? If yes, what could be the possible reason(s) for the difference?

2

EXCERCISES FOR LEARNING UNIT 3

Objective: Appreciation of regulatory and institutional frameworks related to manufacture, storage and handling of chemicals is essential for decision makers to understand and identify potential chemical risks that could arise from a hazardous industry.

The exercises in this series have been designed to make the participant aware of the key aspects of the MSIHC Rules, its application in identifying potentially hazardous industries and siting of hazardous industries from the risk planning point of view. Participants are also shown how to apply GIS tools to understand whether hazardous industries meet the regulatory requirements and subsequently derive their own judgement regarding interventions that might be required to ensure safety of the community and property.

Exercise 3A: Regulatory Criteria for Hazardous Industries

Whether an industry/facility comes under MAH category is guided by the regulations, in this case, the MSIHC Rules. Further, the levels of regulatory control is decided upon based on the quantity of chemical stored as specified in Schedules 2 and 3 respectively (exC>C2>Annex> MSIHC_Rules1989.pdf). For flammable substances, the threshold quantities as specified in the MSIHC Rules are summarized in the Table 3 A–1:

Table 3A–1: Threshold quantities of flammable substances

	Schedule 2*	Schedule 3*
Flammable gas	50	15
Extremely flammable liquids	5000	1000
Very highly flammable liquids	7000**	1500
Highly flammable liquids	10000	2500
Flammable liquids	15000	5000

*Complete Schedule II and Schedule III of MSIHC Rules are presented in (exC>C2>Annex>MSIHC_Rules1989.pdf) for your reference

**All amounts in MT.

- Scan the following table of Industries that stores hazardous chemicals and identify which ones are MAH facilities. In addition, can you find out if any of these industries qualify for meeting the High Level requirements as per MSIHC Rules?

Table 3A–2: RiskCity Industry Chemical Storage Inventory (partial)

Storage Name	Quantity (MT)	Chemical	Hazardous Property
Industry XY 1			
XY 1– TK01	1950	Unleaded Petrol	Extremely Flammable
XY 1– TK02	1920	Naptha	Very Highly Flammable
XY 1– TK03	2270	Kerosene (SKO)	Highly Flammable
XY 1– TK04	10590	Hi Speed Diesel	Highly Flammable
XY 1– TK05	10680	Hi Speed Diesel	Highly Flammable
XY 1– TK06	2900	Furnace Oil	Flammable
XY 1– TK07	2900	Furnace Oil	Flammable
XY 1– TK11	7560	Unleaded Petrol	Extremely Flammable
XY 1– TK12	7350	Naptha	Very Highly Flammable
XY 1– TK13	2465	Hi Speed Diesel	Highly Flammable
XY 1– TK14	2175	Kerosene (SKO)	Highly Flammable

Storage Name	Quantity (MT)	Chemical	Hazardous Property
XY 1– TK15	6760	Furnace Oil	Flammable
XY 1– TK16	6740	Furnace Oil	Flammable
XY 1– TK17	9450	Naptha	Very Highly Flammable
Industry XY 2			
XY 2– B001	12	LPG	Flammable Gas
XY 2– B002	10	LPG	Flammable Gas
XY 2– UT01	40	Hi Speed Diesel	Highly Flammable
Industry XY 3			
XY 3– T001	6375	Hi Speed Diesel	Highly Flammable
XY 3– T002	6375	Hi Speed Diesel	Highly Flammable
XY 3– T003	6375	Hi Speed Diesel	Highly Flammable
XY 3– T004	6375	Hi Speed Diesel	Highly Flammable
XY 3– T005	730	Motor Spirit	Very Highly Flammable
XY 3– T006	730	Motor Spirit	Very Highly Flammable
XY 3– T012	3280	Kerosene (SKO)	Highly Flammable
XY 3– T013	3280	Kerosene (SKO)	Highly Flammable
XY 3– T014	5340	Furnace Oil	Flammable
XY 3– T015	2670	Furnace Oil	Flammable
XY 3– T016	5340	Furnace Oil	Flammable
XY 3– T017	1460	Motor Spirit	Very Highly Flammable
XY 3– T018	1460	Motor Spirit	Very Highly Flammable

Exercise 3B: Finding safe distance from storage tanks

Hydrocarbon processing and handling plants are inherently hazardous. Todays trend of large and complex plants present a substantial risk potential. The hydrocarbon industry over the years learnt lessons from fires and explosions throughout the world and wherever explosion or fire hazards exist, proper plant layout and adequate spacing between hazards as well as elements at risk are essential for loss prevention and control. In India, the plant safety norms including inter–distances between facilities and their relative locations for the petroleum industry are delineated as per regulatory provisions stipulated in the Petroleum Rules, 2000. The minimum inter–distances between storage tanks storing Class A petroleum of volume more than 5000 KL is provided in form XV of the Petroleum Rules (Article 6 of the First Schedule) and is presented in the following table.

Table 3B–1: Inter–distances between storage tanks

The minimum distance of such storage tanks to the fencing is stipulated in the Table 3B–2:

S. No.	Item	Floating Roof Tanks	Fixed Roof Tanks (Class A & B Petroleum	Class C Petroleum
1.	All tanks with diameters upto 50 metres	(D + D+)/ 4	(D + d)/4	(D + d) / 6
2.	All tanks with diameters exceeding 50 metres	(D + d) / 4	(D + d) / 3	(D + d) /4

Note :

1. This table is applicable for installations where aggregate storage capacity of class A and class B petroleum stored above grade exceeds 5000 m^3. or where the diameter of any such tank for the storage of petroleum exceeds 9 m.
2. Distances given are shell to shell in the same dyke.
3. Notation :

   "D" – diameter of larger tank in metres

   "d" – diameter of smaller tank in metres
4. If the inter–distance (for class A & B) calculated as above are less than 15 m, then minimum of 15 m or 0.5 "D" or "d" shall be followed.
5. Inter–distance between class A/B storage tanks and class C storage tanks shall not be less than 6 meters.

Table 3B–2: Distances from boundary fences

S. No.	Installation	Minimum Distance from Boundary fencing around Installation
1.	Storage filling shed for Petroleum Class A or Class B	15
2.	Storage filling shed for Petroleum Class C	10
3.	Tank vehicle loading/unloading area for class A & B petroleum	20
4.	Tank vehicle loading/unloading area for class C petroleum	10

Note :

1. All distances are in metres.
2. This table is applicable for facilities in an installations where total quantity of petroleum class A & B stored above above ground in bulk exceeds 5000 m^3. or where the diameter of any such tank for the storage of petroleum exceeds 9 m.
3. Notation :

   "D" – diameter of larger tank in metres
4. Above table is based on the assumption that property beyond the boundary line is either protected or adequate green belt is provided as a safety buffer where no structure exists. Property beyond property line is deemed protected if it is within the jurisdiction of public Fire Brigade or plant's own Fire Brigade.

   i) Distance from Floating roof tank to boundary fencing for stable and boil–over liquids, having protection or exposure shall be "D/2" (minimum 20 m).

   ii) For tanks with weak roof–to–shell joint :

   The above distance shall be "D/2" (minimum 20 m) for tanks having approved foam or interting system and the tank diameter not exceeding 50 m.

GENERAL CLASSIFICATION OF PETROLEUM PRODUCTS

Petroleum products are classified according to their closed cup FLASH POINTS as follows:

Class "A" Petroleum:
Liquids which have flash point<23°C.and <65°C.
Class "B" Petroleum:
Liquids which have flash point>=23°C and <65°C.
Class "C" Petroleum:
Liquids which have flash point>=65°C. and <93°C.

In RiskCity, Facility XY1 stores different Class "A" Petroleum products in two fixed roof tanks viz. Tank No. 11 and Tank No. 12 respectively in addition to other storage tanks. The total storage volume, diameter, products stored in these two tanks are provided in the following table.

Table 3B–3: Storage tank details

Storage Name	Volume (KL)	Chemical Name	Facility Name	Tank Diameter (m)	Category
TK11	10800	Unleaded Ptrol	XY 1 Facility	40	Class A
TK12	10500	Naptha	XY 1 Facility	40	Class A

- In ExC>C2>Annex, you will find a scaled site map of the facility. Calculate the inter–distance between tanks 11 and 12 (using a centimetre scale) and assess whether they meet the regulations. Also, measure the distance between the tanks and the fencing wall to the east, north and south to see whether distance from the boundary fence is sufficient.
- Now open file XY1_Facility_Image.mxd from ExC>C2>Data and zoom on to the area indicated by the yellow outline. Can you identify XY facility and the tanks in the high resolution imagery? To what extent does the printed site map matches with imagery? Can you observe any difference?
- Measure the same distances using the Measure Line tool from the QGIS toolbar and compare with the earlier distances measured. Hint: The Measure Line tool looks like a graduated measuring scale.
- Can you observe any green belt abutting the boundary wall on the eastern side? Do you see some unplanned habitation just next to the eastern boundary wall? Do you think these habitations should have been allowed?

Exercise 3C: Finding risk information from risicokaart.nl

Use Internet Explorer to open the site: http://risicokaart.nl/en/

In the search bar, on top right side of the screen, type Europoort (one of the largest ports in Europe with large storages of hazardous chemicals) and Search Studying to the legend, how many BRZO facilities can you identify?

Take Note

Now, the left pane on the risk map, click on the dropdown for provinces and select "Zeeland". In the map that is returned by the search, identify the hazardous industry that is shown in the middle of the map. Also study the risk contours and write down you understanding, after studying the legend to the right.

3

EXCERCISES FOR LEARNING UNIT 4

Objective : Chemical Risk Management is a specialized domain that requires understanding of different hazard types, identification of potential risks in line with regulatory frameworks, understanding chemical properties for consequence analysis in the event of a hazard situation and generating hazard footprints to understand the extent of damage. GIS can play a crucial role in hazard identification and generation of risk maps to understand the effect of a hazard scenario.

The exercises in this series begin with making the participant familiar with different types of hazards based on hazardous chemicals classification, understanding chemical properties and exposure mitigation from MSDS, using GIS tools for hazard identification, calculating hazard end–point distances using manual methods as well as established modelling tools, undertaking consequence analysis and using GIS tools for preparing scenario based risk maps.

Exercise 4A: Hazard identification from labels

This exercise aims at identification of hazardous chemicals by using standard classification labelling guidelines. The Department of Transportation (DOT) determines what items are hazardous and categorizes them into different classes. There are eight specific categories of materials, each with a varying number of sub categories.

This classification labels are used mainly for transportation purposes but for fixed installations the same would give sufficient clarity in maintaining precautionary measures. The hazard classification labels are given in the following table.

Table 4A–1: Hazard classification Label

Class 1 Explosive substance or article	
Class 2 Gases	
Class 3 Flammable liquids	
Class 4.1 Flammable solids, self–reactive and desensitised explosive	
Class 4.2 Substances liable to spontaneously combust	
Class 4.3 Substances which, in contact with water emit flammable gases	
Class 5.1 Oxidizing substances	

Class 5.2 Oxidizing peroxides	
Class 6.1 Toxic substances	
Class 6.2 Infectious substances	
Class 7 Radioactive material	
Class 8 Corrosive substances	

Activity 1

Open **MsTank.png** image from ExC>C1>Data folder using windows explorer.

Using this image and above mentioned table, classify the type of chemical stored in the tanks shown in the image.

The Type of Chemical stored in the tanks should be _____

Activity 2

Open **Tank_NFPA.jpg** image from ExC>C1>Data folder using windows explorer.

Using this image and above mentioned Chemical hazard Label, identify the hazards of the chemical stored in the tank. The identified hazard parameters of the chemical stored in the tanks are:

Health: _____

Flammability: _____

Reactivity: _____

Special: _____

Exercise 4B: Identification of chemical hazards and its preventions using MSDS

MSDS is short for Material Safety Data Sheet. It is an information sheet provided by a chemical manufacturer describing physical data (melting point, boiling point, flash point, etc.), toxicity, health effects, first aid, reactivity, storage, disposal, protective equipment, and spill handling procedures.

An MSDS for a substance is not primarily intended for use by the general consumer, focusing instead on the hazards of working with the material in an occupational setting. Also the same can be utilized by the local administrative bodies to initiate primary level emergency measures in case, the hazard encompasses the nearby sensitive receptors like hospitals, schools, market complexes etc. based on the type of hazardous chemicals and the type of accidents, provided the MSDS is readily made available to the administrative authorities concerned.

Activity 3

- Study the MSDS provided in exC>C1>Annex >Atofina LPG MSDS.pdf.
- Does the MSDS match the standard template that is prescribed in the MSIHC Rules (exC> C1>Annex>Industry XY01?
- Can you identify the constituents which make this chemical?
- What kinds of hazards are associated with the chemical?
- What kind of preventive measures will be required to handle the chemical or prevent any harmful exposure from it?

Exercise 4C: Risk identification using GIS application

GIS provides powerful tools for storage and manipulation of spatial (ex. storage location for hazardous chemicals) and non–spatial data (ex. MSDS of chemicals) and can play an important role in risk identification. When such data is systematically stored and updated in a geo–database, it can assist planner, decision makers and the general public in identifying location of hazardous chemicals in their neighbourhood and understand their spatial disposition in an industrial town like RiskCity, determine type and quantities of chemicals present at any time and also find out about safety measures and controls that have been installed by the industries to reduce risk levels.

In this exercise we will find the location of a MAH industry within the RiskCity and also locate hazardous flammable chemical storages of more than 10000MT.

- Open the RMIS application from the URL: http://27.251.71.139/rmisnew and login with the given username and password.
- Click the search tab and select industry to search for MAH industries.
- From the Industry Name dropdown list, select Industry XY01 and click Search button.
- RMIS will display the industry on the map and its related information on a separate window as shown in Figure 4C–1.

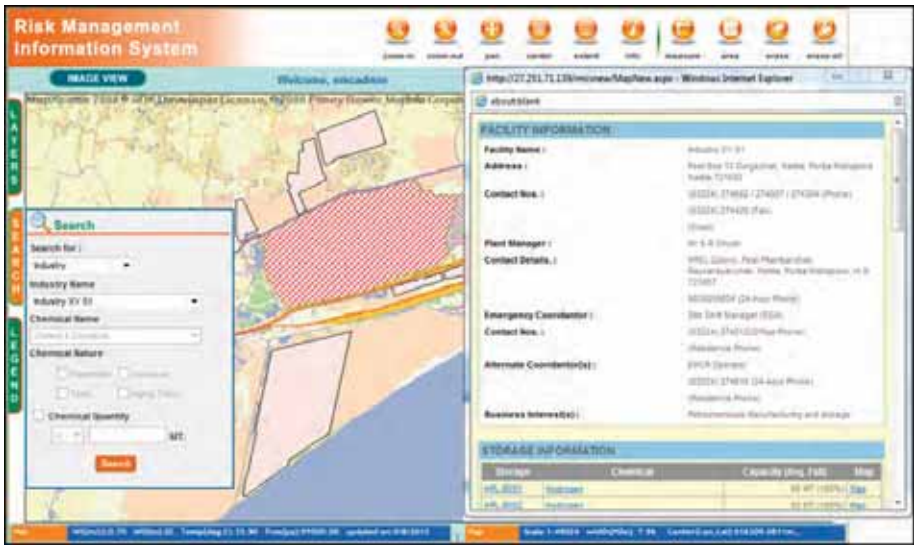


Figure 4C–1: RMIS risk identification interface

Source: Own Compilation

- Now we will try to locate chemical storages storing flammable materials in excess of 10000 MT. From the search tab, select Chemical Nature and then select the Flammable property. Under Chemical Quantity select > and enter 10000 in the value field. Your search screen should look like Figure 4C–2.
- Which chemicals and industries have been listed by the query? Prepare a note on what you think could be potential accidental scenarios that can arise from any one of the listed industries.

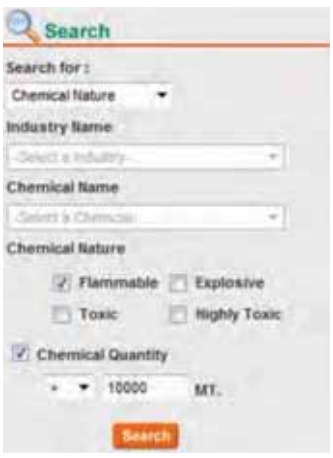


Figure 4C–2: RMIS risk identification query

Source: Own Compilation

Exercise 4D: Calculation of Hazard End–point for Pool Fire using Equations

A valve failure on the loading pipeline to Tank No. 11 of XY 1 Facility leaks, resulting in a spill of 75 KL of motor spirit from the tank. The spill is contained within a secondary containment which has an area of about 100 sq metres and catches fire accidentally initiating a pool fire scenario. In order to set up an exclusion area and prevent people from getting burn injuries, the safety distance from the fire needs to be calculated.

A simple way to do this is by using the US EPA's RMP Off–Site Consequence Analysis Guidance equations. The EPA equation is based on factors for estimating the distance to a heat radiation level that could cause second degree burns from a 40–second exposure. This heat radiation level was calculated to be 5,000 watts per square meter.

The equation for estimating the distance from pool fires of flammable liquids with boiling points above ambient temperature is:

$$X = H_c \sqrt{\frac{0.0001\,A}{5000\,\Pi\,(H_v + C_p\,(T_B - T_A))}}$$

where:

X = distance to the 5 kilowatt per square meter endpoint (m)

H_C = heat of combustion of the flammable liquid (joules/kg)

H_V = heat of vaporization of the flammable liquid (joules/kg)

A = pool area (m^2)

C_p = liquid heat capacity (joules/kg–°K)

T_b = boiling temperature of the liquid (°K)

T_a = ambient temperature (°K)

Using the above equation and the values for the above parameters which are mentioned in the MSDS for Motor Spirit, calculate the end point distance from this fire. Alternately use Table 4D–1.

.Table 4D–1: Chemical properties of motor spirit

Chemical	Hc (joules/kg)	Hv (joules/kg)	Cp (joules/kg–K)	Tb (K)	Ta (K)
Motor Spirit	4.78E+07	300513	2198	398.7	298.7 (ie. 25.7°C)

Exercise 4E: Consequence Analysis– generating the hazard scenario for vapour cloud explosion

This exercise aims at the assessment of a hazard scenario in RiskCity to be able to predict the consequence in terms of hazard end points. We would expect you to undertake a realistic hazard assessment using spread sheet calculation (MS Excel) techniques. The generation of the base data for hazard analysis generally require the careful description of a probable risk event, as a result of which a risk scenario can be drawn up to simulate the real life accident and wherein the potential to cause damage be ascertained through standard consequence assessment models.

Case Study: Facility XY 2 in RiskCity is owned by a large oil company in the country and provides need based supply of the petroleum products and intermediaries to the neighbouring industries and for retailing through Petrol Pumps in the region. Facility XY 2 houses a storage terminal currently houses 7 tanks storing Superior Kerosene Oil (SKO), HSD, Motor Spirit (MS) and other intermediaries.

This accident occurs when facility personnel were preparing for pipeline transfer (PLT) operations to transfer Motor Spirit (MS) from Tank XY 3 – TK 17 which has the capacity to store about 1460 MT (which is about 2000 KL) to the storage tank of nearby installation of Facility XY 1. During the preparations to the PLT operations, there was huge leakage of MS from a valve in the outlet line of the TK–17 tank of the facility which continued uncontrolled for about an hour. This massive loss of containment of MS resulted generation of significant quantities of petroleum vapour to escape into the atmosphere and form a vapour cloud which spread across the entire installation and the neighbouring area, in the downwind direction. This vapour cloud probably found a source of ignition, possibly in a motorbike exhaust pipe which was kick started giving rise to sparks, and resulted in a severe vapour cloud explosion (VCE). The blast was so powerful that it completely destroyed the facilities and building within the Terminal and also caused significant damage to nearby installations and habitations in the vicinity. Through the set of exercises that follow, we will try and make an assessment of consequences using standard techniques.

The amount of chemical involved in the vapour cloud explosion was predicted to be about 825 MT with an average release rate of 15 MT/min (55 min of release). The outside temperature was about 30^0 C and it was a bright sunny day with the wind blowing towards the North West direction at a speed of 2 meter/sec. The liquid is released from a hydrostatic head at a height of 12 meter as was later reported by some ground personnel who witnessed the incident. When a large amount of flammable vaporizing liquid like Motor Spirit is rapidly released, a vapour cloud forms and disperses in the surrounding atmosphere. If this cloud is ignited before the cloud is dispersed to below its lower flammability limit (LFL), a VCE or flash fire may occur. For modelling the main consequence of a VCE, the damage is considered to be because of overpressure (with endpoint measured 1 psi) which could pose a significant damage to life and property in the vicinity of the facility.

Read carefully the case study presented above. Identify the values of the parameters which will be used for the formulation of the hazard scenario. Write down the values of the following parameters:

Name of chemical: _____

Quantity of chemical involved: _____ (kgs)

Heat of combustion of material: _____ j/kg

Release rate of the material: _____ (kg/s)

Wind direction (to) and speed: _____ _____ and _____ (meters/sec)

Cloud cover: _____ (Clear/Partly Cloudy/ Cloudy)

Ambient temperature: _____ ^{0}C

Release/source height: _____ (meters)

Upper flammability limit: _____ ppm

Lower Flammability Limit: _____ ppm

Note:

You can use MSDS_MS.pdf file for referring to the chemical properties, if required. It can be found in your C:\ExC folder. 1MT = 1000kg

Once required parameters for the hazard modelling are identified, the next step is to use those values in evaluating the end point distance of the hazard effects.

Open VCE Calculation.xls file from exC folder. This file contains the steps to perform the hazard analysis based on the case study given above.

Carefully read the steps defined and provide the required parameters to complete the calculation

Carefully note what are the important parameters used in the analysis. You will use the values identified earlier.

Please enter the analysis results **after the calculation** for the following:

Flammable area of vapour cloud: _____ meters

Explosion endpoint of vapour cloud with 1 psi overpressure: _____ meters

Exercise 4F: Preparing risk map using chlorine scenario

The purpose of this exercise is to evaluate potential risk from failure of a chlorine tank in the RiskCity. For the purpose, we will calculate the hazard potential considering the catastrophic rate of failure of a chlorine tank and the severity/magnitude of its consequence.

Based on review of Major Hazard Assessment Unit Handbook, the frequency of failure of a 1 metric ton of chlorine tank per year is 4.10–6. We will consider that a chlorine tank in the XYZ Facility has undergone catastrophic rupture releasing one metric ton of the gas into the atmosphere for 20 minutes. The atmospheric conditions during the accident were: Wind Speed – 3 m/sec, Air Temperature – 35^{0}C and Atmospheric Stability Class – D.

The percentage of human fatality vis–à–vis concentration thresholds of chlorine has been derived based on probit functions and is given in the following table where the effect distances from the accident source have been calculated using ALOHA.

Table 4F–1: Effect distances from accident sources

Fatality (%)	Consequence category	Chlorine concentration (mg/m3)	Effect distance (m)
50	4	870	763
20	3	470	1000
10	2	340	1200
1	1	160	1600

The information in the above table has been used to generate a GIS shapefile (Grid100_CL.shp) show the effect distance on a 100m x 100m grid. The shapefile is located in

- Open the ConsAnalysis.qgs file from the exD>D2 folder.
- This will open the Grid100_CL.shp file which displays the consequence of the accident categorised using five distinct colours.
- Open the attribute table of the layer.
- The table displays the consequence categories (column name Cons_Cat) and the probability or likelihood of the accident happening (column name Prob_Cat).
- Now we will calculate the hazard potential (consequence x probability/likelihood) using the above information and in line with the concept of risk as discussed in previous sections. The hazard potential will be calculated in the HazPot column.
- To calculate hazard potential:
    - Double Click on the Cons_Cat column to arrange the values in descending order.
    - Click the Toggle editing mode button at the bottom of the attribute table.
    - Click on the Open field calculator button to bring up the field calculator dialog.
    - Select Update existing field option and from the dropdown list below it, select the HazPot column.
    - From the Function List window, double click on Fields and Values option.

- Double click the Cons_Cat column, followed by a click on the multiply operator (*) and then double click the Prob_Car column. The expression will be reflected in the Expression window.
- Your screen should look like Figure 4F–1.

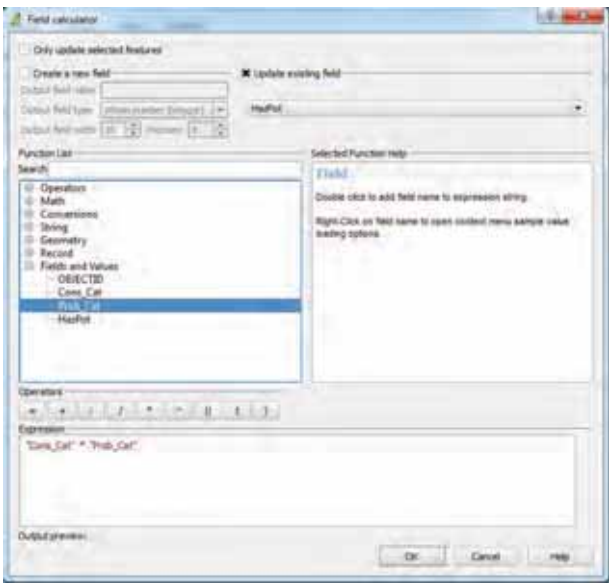


Figure 4F–1: QGIS Desktop – Field Calculator Dialog

Source: Own Compilation

- Click OK
- Notice that the HazPot column displays the results of the field calculation operation.
- Click the Toggle editing mode button again to save the results.
- Right click on the Grid100_CL layer in Layers Pane and click Properties>Style tab.
- From the dropdown list next to Columns option select HazPot.
- Click the Delete all button below the symbols window.

- Click the Classify button to add the unique values for the HazPot column based on which the hazard potential will be represented on the map.
- Now we will refer to the risk matrix (Figure 4–7 in the training manual) and change the symbol colours on the map, according to the colours shown for the consequence values on the X axis.
- Double click on the symbol next to the value 0. This will open the Symbol selector dialog.
- Click on Change button and select the White colour. Click OK
- Similarly change the colours for the remaining values as shown in the risk matrix.
- For the symbol with no values, change the colour to White.
- Finally click the OK The Risk Map for chlorine is now displayed on the screen.

- Now add the Studyarea_IKONOS_PAN image from the exA>Data folder.
- Drag the image below the Grid100_CL layer on the Layers Pane.

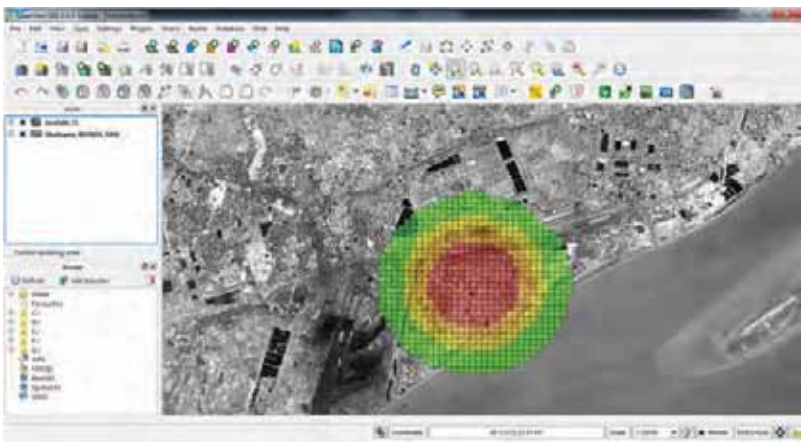


Figure 4F–2: Chlorine risk map

Source: Own compilation

- Right click the Grid100_CL layer, select Properties and make the layer 50% transparent. the purpose, you will have to select each colour symbol. Once done, your screen should look like Figure 4F–2.
- Can identify any residential areas which may be affected because of the accident? If yes, in which municipal ward(s) do they fall?

4

EXCERCISES FOR LEARNING UNIT 5

Objective : Understanding a potential accident scenario and being able to predict its possible impact is important information that helps a decision maker to develop emergency management plans as well as targeted response strategies to manage and mitigate an emergency situation. Specialised modelling tools used together with GIS applications can assist decision makers to estimate consequences of chemical accidents so that the information can be used to plan for emergency management and response.

The exercises in this series will introduce participants to ALOHA, a modelling tool for simulating accident scenarios and generating hazard footprints. Subsequently, GIS tools will be used to analyse such footprints to understand their impact on vulnerable receptors. In addition, participants will be introduced to GIS enabled specialised applications that integrate modelling tools and provide support for dynamic risk scenario generation and vulnerability analysis. Finally, participants will also learn how to apply GIS in evacuation planning and emergency response.

Exercise 5A: Estimating hazard footprint for vapour cloud explosion using ALOHA

Refer to the case study in EXERCISE 4E as the basis for this exercise

- Go to Desktop and click on the ALOHA shortcut menu.
- ALOHA will initiate the application with an initial confirmation box.

- Click on the menu bar, select Setup>Chemical.
- This will open a window with a predefined list of chemicals. If you don't find your chemical, then click on the "Add" button.
- Enter Chemical name and associated parameters and click OK
- The chemical will get listed on the existing list. Select the chemical. This will raise a warning message; ignore the message by clicking OK
- On menu bar select Setup>Atmospheric>User Input.
- Here you can enter the required atmospheric parameters. Please leave any field unmodified, if you don't have the data for it.
- Please observer carefully that your stability class is B. Click OK
- On menu bar select Setup>Source>Direct.
- Enter required parameters in this window. Carefully select the proper unit for values.
- Select Continuous Source and enter the rate of release here. Please leave any field unmodified, if you don't have the data for it.
- On menu bar select Display>Threat Zone.
- From the next window select Flammability Area (for Flammable Area of Vapour Cloud) and click OK
- In Flammable Level of Concern (LOC) window, note that the LEL value is listed as one of values for LOC. Select the LEL Value in Red Threat Zone. Make all other threat zones none. And Click OK
- ALOHA will generate the hazard footprint (in graphical form) like the Figure 5A–1 and the endpoint distance in the "Text Summary" window. Note the value.

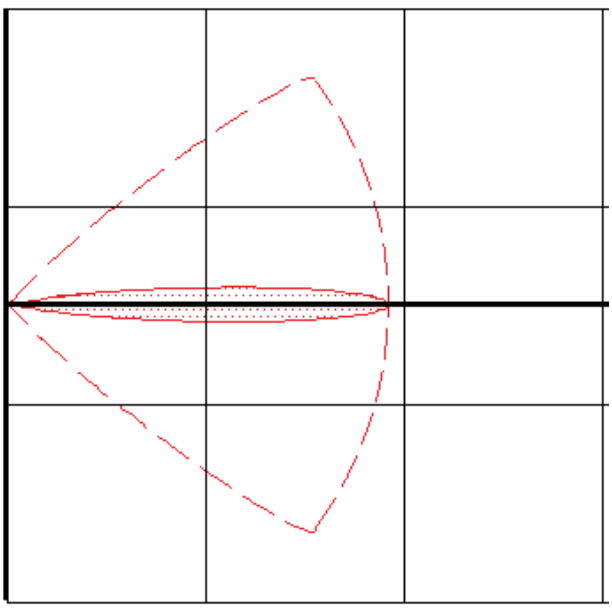


Figure 5A–1: ALOHA hazard footprint representation for vapour cloud

Source: Own compilation

Flammable Area of Vapour Cloud: _____ meters.

- On menu bar select Display>Threat Zone.
- From the next window select Blast Area of vapour Cloud (for explosion endpoint) and click OK
- In the vapour cloud explosion parameters window leave every filed unmodified and click OK
- In select Overpressure Level of Concern (LOC) select 1psi against Red Threat Zone and rest threat zones should be set as none. click OK
- ALOHA will generate the hazard footprint (in graphical form) like the one shown in Figure 5A–2 and the endpoint distance in the "Text Summary" window. Note the value.

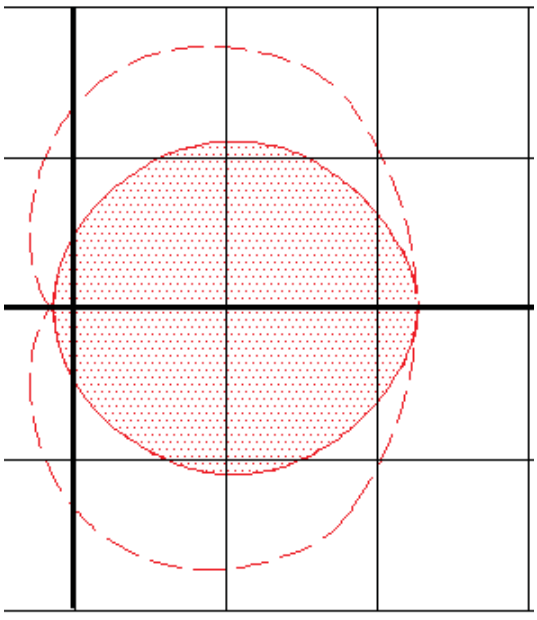


Figure 5A–2: ALOHA hazard footprint representation for explosion

Source: Own compilation

Explosion Endpoint of Vapour Cloud: _____ meters.

Compare the end point values generated during Activity 2 and Activity 3 and comment.

Exercise 5B: Using a simulation model like ALOHA to determine the number of affected population from a toxic release.

- Go to Desktop and click on the ALOHA shortcut menu.
- ALOHA will initiate the application with an initial confirmation box.
- Click on the menu bar, select Site Data>Location.
- This will open a new window with a predefined list of sites. Select RiskCity, India from the list.
- Click on the menu bar, select Setup Chemical.
- This will open a window with a predefined list of chemicals. If you don't find your chemical, then click the "Add" button to add a new chemical.
- Select Ammonia from the existing list.
- On menu bar select Setup>Atmospheric>User Input option.
- Here you can enter the required atmospheric parameters from the scenario. Please leave any field unmodified, if you don't have the data for it. Click OK to go to the next screen.
- Enter the Atmospheric Temperature from the scenario and Override the stability class to C. Click OK to save changes.
- On menu bar select Setup>Source>Direct.
- Select source strength unit as tons. Select Continuous release and enter values of 15 tons of release for 25 min.
- Enter source height as 15m. Click OK to save the changes. Subsequently, click OK on any warning messages that appear.
- On menu bar select Display>Threat Zone. From the Hazard to Analyse window, select Toxic Area of Vapour Cloud and click OK
- In the Toxic Level of Concern window, select the User Specified option under each of the Threat Zones add toxic levels of concern as follows: red – 220 ppm, orange – 150 ppm and yellow – 100 ppm. Note that the IDLH of Ammonia is 220 ppm.

- Under the Show Confidence Lines option select for each threat zone.
- ALOHA will generate the hazard footprint (in graphical form) and the endpoint distances in the Text Summary window as shown in Figure 5B–1.

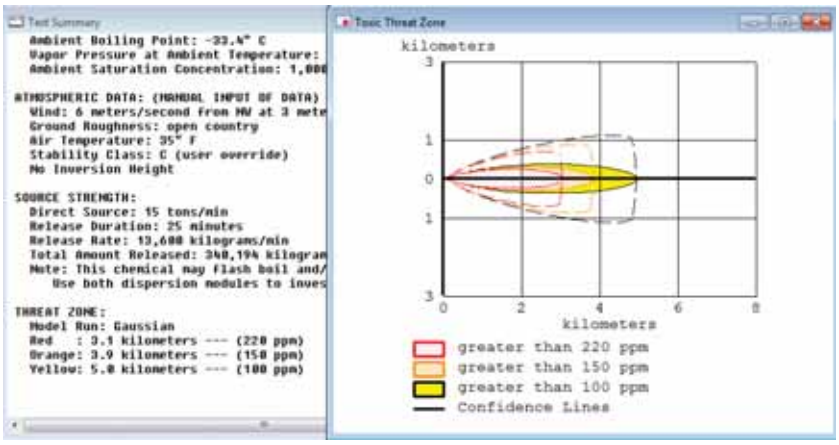


Figure 5B–1: ALOHA hazard footprint and end–point distances for ammonia

Source: Own compilation

- Note the endpoint distance values. What is the toxic endpoint to IDLH of ammonia in meters?
  - Go to Sharing>MARPLOT>Go to Map.
  - In MARPLOT, go to File>Import as overlay object and select storage.shp from Exercise A data folder. The storage layer should show up on the map window. Zoom to the required level to identify Storage 91 and click on the pointer and then in ALOHA menu select "set source point at click point".
  - Now click again on the ALOHA menu and select "export ALOHA objects to KML" and save the KML file in the desired location.
  - Open Google Earth, go to File>Open and load the saved KML file. You will go to the desired location of the footprint.

After knowing the possible footprint and its spatial disposition, the next step find out about the number of people who might be affected by a toxic release of ammonia, so that suitable protective

actions can be initiated for their safety. We have already calculated the end–point distances for this scenario and the spatial representation of the red zone has been created in the form of a layer file. We need to find out the municipal wards and population that might get affected from this hazard scenario.

- Open QGIS Desktop and load the Pop_Vilnerability.qgs file from exE>Data.
- Now add the Pop_grid100 layer from exE>Data folder. Change the layer's Fill style property to No Brush.
- Next add the footprint_redzone.shpfrom exE>Data folder. Change the layer's Colour property to Red and the Transparency to 50%.
- Now right–click on the footprint_redzone.shp layer and select the Zoom to Layer Extent option to identify the municipal wards, industries and storages that are affected. Once identified, go back to the full extension of the map. Your screen should look like Figure 5B–2.



Figure 5B–2: QGIS map showing hazard footprint overlaid on affected area

Source: Own compilation

- In order to understand the population that is affected, we have to intersect the footprint_redzone.shpand the Pop_grid100 layers.
- From the QGIS Desktop menu bar, select the Vector>Geoprocessing Tools>Intersect option.

- In the Intersect dialog, select footprint_redzone.shpas the Input vector layer. Select Pop_grid100 as the Intersect layer. Give the Output shape file name as Popvul.shp and click OK to save the new layer.
- Once the intersect operation is done, click Yes to add the new layer to the map. Click Close button to close the Interest dialog.
- Change the new layers colour property to red and make the layer 50% transparent.
- Unselect the Pop_grid100 layer from the Layers Pane. You will be able to see the intersected layer on the map window more clearly. Your map should look similar to Figure 5B–3.

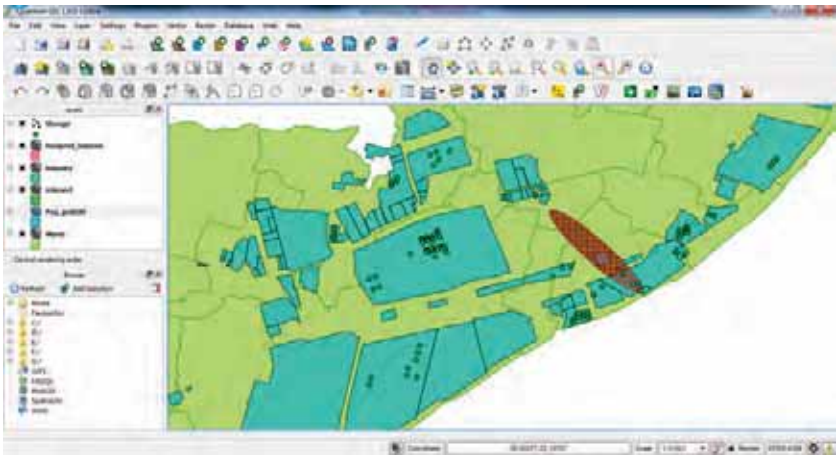


Figure 5B–3: QGIS map showing hazard footprint intersected with population information over the affected area

Source: Own compilation

- Now, from the QGIS Desktop menu bar, select the Vector>Analysis Tools>Basic Statistics option.
- Select Popvul as the Input Vector Layer and the Target Field as Sum_pop_pa. Click OK and notice the value against the Sum field. What is the total number of population that is affected by the scenario?

Exercise 5C: Using RMIS to determine the number of affected population from a toxic release.

It has been discussed earlier that the release of a toxic gas and formulating an appropriate response to mitigate it, involves a dynamic decision environment where variables may change quickly over time. As a result, emergency responders should be able to adapt their plans based on best information available at that time. Taking the earlier example for Ammonia release, we will now consider a situation where the wind direction has changed after 30 minutes, from the time when the accident was notified and after initial response was commissioned. Now, instead of blowing from south–east to north–west, the local meteorological station provides a feed showing the wind to be blowing from the south–west to the north–east. Under the changed circumstances, we will find out the number of people affected and compare it with the earlier scenario. However, we will do this exercise using the RMIS tool.

- Open the RMIS application from the URL: http://27.251.71.139/rmisnew and login with the given username and password.
- Click the Hazard Modeller tab on the right side of the screen. The RMIS provides a wizard based interactive user interface for capturing basic information about an accident, model the scenario and subsequently display the results on a map.
- Click the Atmospheric Data tab and change the wind direction from South–West to North–East using the direction needle.
- Select Feed Data from User; next, enter 6 in the Wind Speed field and 35 in the Temperature field.
- Under Cloud Cover option select Partly Cloudy which is equivalent to stability class C.
- Click the Set Parameters button to save the changes. Your screen should look like Figure 5C–1.



Figure 5C–1: RMIS hazard modeling – setting atmospheric parameters

Source: Own compilation

- Now we will model the accident scenario. Click the Scenario Builder tab and select Sanjana Industry XY03 under industry name field. The atmospheric parameters that you specified earlier are now displayed under Chemical Source and Risk Event window.
- Next, select the storage name and the risk event. Click the next button.
- Under hazard scenario, select Alternative Case. You can scroll the Chemical Source and Risk Event window to see how some the scenario and chemical parameters are being displayed automatically from the integrated chemical database and the scenario rule–base. Click the next button.
- Enter the following values for Amount of Chemical: 6, Release Time: 25, and Release Height: 15. Click the next button.
- Enter the following values for orange: 150 and yellow: 100. Note that the IDLH of ammonia (210) is pre–populated from the integrated chemical database of the RMIS and cannot be changed. Click Generate Hazard Footprint button. Your screen should look like Figure 5C–2.



Figure 5C–2: RMIS Hazard Modeling – generating the hazard footprint

Source: Own compilation

- The RMIS displays the hazard footprint on the map and the underlying vulnerability information is shown in a separate window. Your screen should look similar to Figure 5C–3.



Figure 5C–3: RMIS Hazard Modeling – hazard footprint and underlying vulnerabilities

Source: Own compilation

- Which industries are affected by the scenario that you have just modelled? How many people are affected?

Exercise 5D: Calculating evacuation vulnerabilities as a measure of emergency response preparedness

We will consider that accidents have occurred near two habitations within the RiskCity. For the purpose of this exercise, habitations within the RiskCity have been clustered into larger entities on the basis of their accessibility to larger roads and highways and proximity to nearby habitats.

- Open the Evac.qgs file from exE>Data folder
- Open the attribute table of the EvacVuln layer.
- Scan the FID_SU_Hab column to find values 0 and 6. Next, with the shift key pressed, click the mouse on the rows one after the other, to select them together.
- Now, click the Zoom map to the selected rows button at the bottom of the attribute table window. The map will zoom to the extent of the selected habitations. Click the Close button.
- Change properties of the EvacVuln layer to display the FID_SU_Hab field as label. The procedure for displaying layer labels has been demonstrated in earlier exercises.
- Next, zoom in to one of the habitations and count the number of roads that uniquely connect one habitation to another or unique roads within a habitation that connect to a major road leading outside that habitation. Use the Identify Features button to note the total population of the habitat (Sum_po field) and the habitation number (FID_SU_Hab field).
- Similarly, count the roads, note down the habitation number and the value in Sum_po field for the other habitation also.
- Open the attribute table of the EvacVuln layer again and click the Toggle editing mode button at the bottom of the attribute table window.
- Now click on the RdOut column for the habitation number 0 and enter the number of roads. Next, click the Evul column to enter the value for evacuation vulnerability (Evacuation Vulnerability = Sum_po / Number of Roads).
- Similarly enter the values for number of roads and evacuation vulnerability for the other habitation also. Once complete, click the Toggle editing mode button to Save the changes. Click Close button to close the attribute table window.

- Now we will change the style of the EvacVuln layer to represent the vulnerability visually.
  - o Right click on the EvacVuln layer and select Properties>Style tab.
  - o Change Single Symbol to Categorized. Select the Evul column from column list.
  - o Select YlOrRd from Colour Ramp option. Click Classify button to add the evacuation vulnerability values for the two habitations.
  - o Under Symbols, select the one with no values and double click on it. Change the colour to blue.
  - o Click OK to close the properties window.
- Finally click the Deselect Features from All Layers button on the toolbar. Your screen should look like Figure 5D–1.

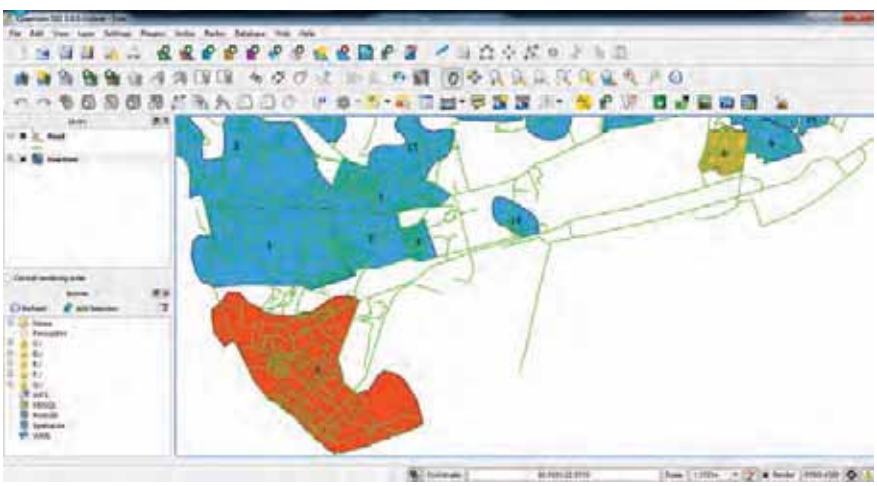


Figure 5D–1: Evacuation Vulnerability displayed on QGIS map inteface

Source: Own compilation

- The map now displays the affected habitats in varying intensities of their evacuation vulnerabilities. The unaffected habitations are displayed in blue colour.

5

EXCERCISES FOR LEARNING UNIT 6

Objective : Risk based land–use planning is an emerging concept in India and relates to effective management and allocation of land for sustainable development. GIS tools play a significant role in risk based land–use analysis and can provide the necessary decision support to planners, land administrators and decision makers in the industrial development process.

The exercises in this series are aimed at showing how GIS tools can be effectively used to identify high risk areas within an industrial town, plan possible rehabilitation of affected community to low risk zones and at the same time identify land suitable for further industrial development.

Exercise 6A: Establishing zoning plans (risk based approach)

The objective of this planning exercise is to establish the basis for appropriate zoning plans which may lead to the gradual rehabilitation of population living in the high risk areas of risk city as a way of risk reduction. The exercise will try and calculate the number of people who may need to be rehabilitated and also the area of land where such rehabilitation has to be brought about.

The intent is to development a risk map of the populated downtown area of the RiskCity, taking into consideration reference scenarios from the three MAH facilities which are located in close proximity to the area. The scenarios are given in the following table:

Table 6A–1: Accident scenarios with hazard distances

Accident scenario	Installation	Frequency (y^{-1})	Accident description	Hazard distances for % fatality			
				50%	20%	10%	1%
A	Atmospheric tank	$5.\ 10^{-6}$	VCE	0m	0m	2400m	2500m
B	Tonner	$4.\ 10^{-6}$	Toxic Release	763m	1000m	1200m	1600m
C	Horton Sphere	$9.\ 10^{-7}$	BLEVE	529m	607m	652m	768m

For the purpose, we will take into account the potential impact of the accidents on population living in the facilities' surroundings and delineate the areas which are under high risk. The methodology takes from the earlier method for risk calculation (Chlorine Exercise) and also adds population to calculate societal picture of risk prevailing in the area.

The grid–wise population density over RiskCity, as discussed in earlier example, is ranked into the following categories as shown in the following table.

Table 6A–2: Population criteria

Ranking	Population density (range in number of persons per hectare)
4	> 150 per hectare
3	> 80 < 150 per hectare
2	> 25 < 80 per hectare
1	< 25 per hectare

- Open the Studyarea_IKONOS_PAN image from the exA>Data folder and the CumulativeRisk layer from the exF>Data folder. Arrange the layers in a way that the image is visible below the risk layer.
- Now, change the Style properties of the risk layer to Categorized, so that it displays the hazard potential (column name HP) of the areas concerned. Make all symbol colours 50% transparent so that you can understand the possible impact on the habitations by analysing the map. Your screen should look like Figure 6A–1.

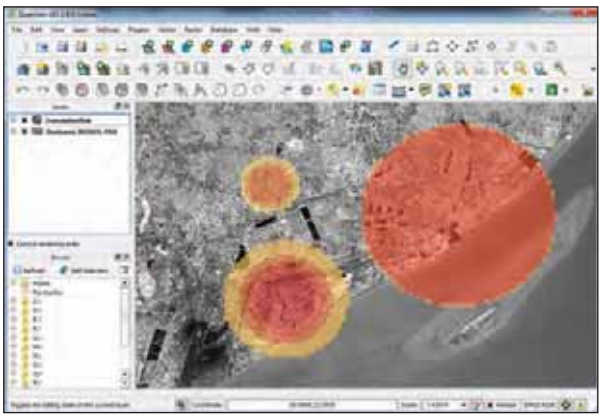


Figure 6A–1: Hazard Potential displayed using QGIS

Source: Own compilation

- Next, open the Pop_grid100 layer from ExB>Data folder and run a spatial query to display population density that has been ranked between 1 and 4 (Querystring: "Pop_R">= 1 AND "Pop_R"<= 4). Change the style properties of the population layer to select a blue colour. Your screen should look like Figure 6A–2.

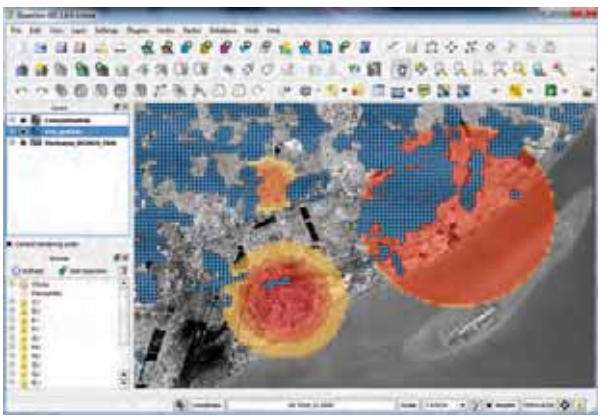


Figure 6A–2: Hazard Potential displayed according to population density

Source: Own compilation

- Can you identify populated areas with high hazard potential? Now, change the style properties of the population layer to categorized and select blues from the colour ramp to visualize highly populated areas on the map. Your screen should look like Figure 6A–3.

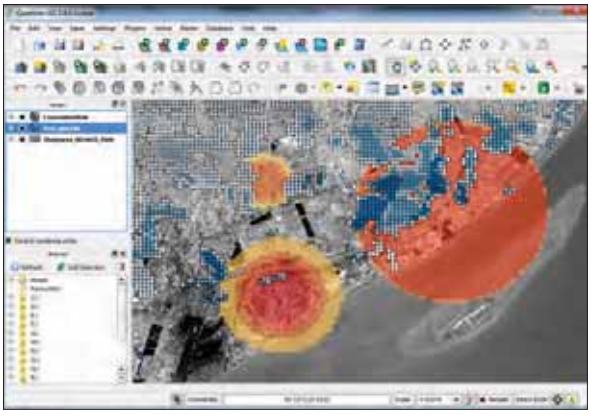


Figure 6A–3: Hazard Potential in highly populated areas

Source: Own compilation

- Can you identify population that are under high, moderate and low risk based on population ranking? Do these areas match with your earlier analysis of highly populated areas identified from the hazard potential point of view?
- Next, we will multiply the hazard potential of each grid cell with the population rank to determine the cumulative risk of that grid cell. For the purpose, open the attribute table of the Cumulative Risk layer and click the Toggle editing mode button. Next, click the Open field calculator button and update the CumRisk field with the following formula: "HP" * "Pop_R". Click the Toggle editing mode button and Save the changes. We will use the cumulative risk information in the forthcoming steps.
- Referring to Risk Ranking Criteria Table given in the manual, use the CumRisk column to visually display the cumulative risk. [Hint: Change the layer style to graduated and select CumRisk as the column name. Click the classify button. Then change the classes to 3 and manually edit each data range according to the range given in Risk Ranking Criteria Table (Table 4–5 in

training manual). Finally change the colours to Green, Yellow and Orange according to low, medium and high risk. Your screen should look like Figure 6A–4.

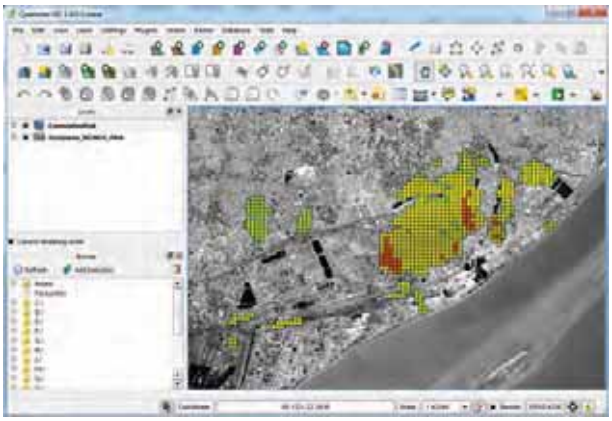


Figure 6A–4: Cumulative Risk displayed using QGIS

Source: Own compilation

- From the above calculation can you estimate the land area falling under moderate to high risk category? [Hint: one grid cell represents .01 km^2]

Exercise 6B: Establishing zoning plans continued (consequence based approach)

This is a variation of the earlier exercise. A new layer has been created keeping the probability constant at 1 x 10^{-4} (consequence oriented method). You will now calculate cumulative risk once again using the same method discussed above. Name of the new layer is CumRisk_FProb.shp and is located in ExF>Data folder.

- Open the CumRisk_FProb.shp layer and its attribute table.
- Check the values in the Prob_Comb column to ensure that it reflects the probability rank for 1x 10^{-4}.
- Now using Field Calculator, as shown in the earlier exercise, update the Hazard Potential column by multiplying the Cons_Comb and Prob_Comb columns.
- Next, use the new values for hazard potential to update the Cumulative Risk column, in a similar way, by multiplying the HP and Pop_R columns.
- Run a spatial query on the CumRisk column to extract grid values falling within each risk category, using Table 6–3 in the training manual as reference. Tally the affected population figures with your earlier findings and note the difference.

Exercise 6C: Identifying land for industrial development

The objective of this exercise is to find a tract of land where a new hazardous industry can be set up. The exercise will use the RMIS Risk Modeller tool, which implements multi–criteria analysis, to generate a composite risk map taking into account several hazard and vulnerability factors. The risk map will be used to look for the ideal location for the new MAH industry. Also, the new industry should not put existing population to high risk.

- Open the RMIS application from the URL: http://27.251.71.139/riskmce and login with the given username and password.
- Click the Risk Modeller tab to start multi–criteria analysis. The Risk Modeller provides a wizard based interactive interface for capturing different parameters required to perform the multi–criteria analysis. For this exercise, select the Hazard Potential, Population Density, Evacuation Vulnerability and Road Density as factors based on which the multi–criteria analysis will be done. You can also click on the Factor Map link to see the risk thresholds for each factor. Your screen should look like Figure 6C–1.



Figure 6C–1: Multi–criteria analysis using RMIS Risk Modeler – Selection of Factors

Source: Own compilation

- Next the selected factors need to be ranked according to individual weights assigned to them. For weightage calculation select the Point Allocation method. Click Next button. Your screen should look like Figure 6C–2.



Figure 6C–2: Multi–criteria Analysis using RMIS Risk Modeler – Ranking of Factors

Source: Own compilation

- Allocate points to each of the factors selected in the earlier stage to create a comparison matrix. Click Next button.
- Based on the values assigned to each of the factors, the priority vector / normalized Eigen vector of the comparison matrix created in the earlier step will then be displayed.



Figure 6C–3: Multi–criteria Analysis using RMIS Risk Modeler – Risk Map

Source: Own compilation

- Click the Finish button to generate the Risk Map. Your screen should look similar to Figure 6C–3.
- Use the risk map to find the ideal location(s) for the siting the new MAH industry. Share your findings, with reason, with the other participants.

About NIDM



National Centre for Disaster Management (NCDM) set up under the Department of Agriculture and Cooperation, Ministry of Agriculture in March 1995. NCDM has been upgraded into full–fledged National Institute of Disaster Management in October 2003. Under the Disaster Management Act, 2005, the Institute has been entrusted with the nodal national responsibility for human resource development, capacity building, training, research, documentation and policy advocacy in the field of disaster management.

NIDM is steadily marching forward to fulfil its mission to make a disaster resilient India by developing and promoting a culture of prevention and preparedness at all levels. Both as a national Centre and then as the national Institute, NIDM has performed a crucial role in bringing disaster risk reduction to the forefront of the national agenda. It is our belief that disaster risk reduction is possible only through promotion of a "Culture of Prevention" involving all stakeholders.

We work through strategic partnerships with various ministries and departments of the central, state and local governments, academic, research and technical organizations in India and abroad and other bi–lateral and multi–lateral international agencies.

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About the Indo–German Environment Partnership (IGEP) Programme

IGEP builds on the experience of the predecessor Advisory Services in Environment Management (ASEM) programme but at the same time strengthens its thematic profile in the urban and industrial sector, up–scales successful pilots and supports the environmental reform agenda and priority needs of India.

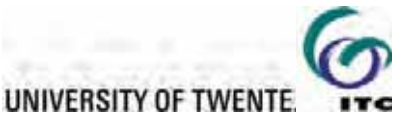
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SENES Consultants (India) is one of the largest consultancy organizations in the country providing a broad range of specialized environment management services to clients including the government, corporates and funding agencies. In operation for more than 12 years, SENES has developed a strong portfolio in risk and disaster management – this includes implementation of projects related to risk assessment and hazard analysis of MAH facilities, hazardous site remediation, HSE audits, emergency management, urban and socio–economic planning, GIS mapping and spatial analysis, management information systems, training and capacity building. SENES had also been the principal technical consultant to the Indian Chamber of Commerce to assist in implementing the European Commission supported Environmental Risk Reporting and Information System (ERRIS) project. The knowledge base and experience gained from the project was used to design and develop a cutting edge web–GIS enabled platform – the Risk Management Information System that can assist key stakeholders in managing technological risks.

University of Twente



The Faculty of Geo–Information Science and Earth Observation of University of Twente, better known as ITC, provides international postgraduate education, research and project services in the field of geo–information science and earth observation using remote sensing and GIS. The aim of ITC's activities is the international exchange of knowledge, focusing on capacity building and institutional development in developing countries and emerging economies. In doing so, considerable attention is paid to the development and application of geographical information systems (GIS) for solving problems. ITC is especially active in the fields of disaster management, environmental assessment, climate change, sustainable agriculture, food security, biodiversity, water management, land use planning and land administration. With about 200 staff members, more than 20,000 alumni and more than 10 partnership programs, ITC has a worldwide presence and an extensive network in geo–information and related fields.



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Anandita Sengupta is a PhD student of the University of Twente, the Netherlands. Through her research, she is focusing on the challenges that lie in the way of introducing a risk guided land use planning framework in the country (India) in order to minimize the potential consequences from chemical accidents. Presently, she is also working as a researcher in the Major Accidents Hazardous Bureau (MAHB), Institute for the Protection and Security of the Citizen (IPSC) of the Joint Research Centre, European Commission in Italy. She is currently responsible for testing, comparing and interpreting the results of different risk assessment tools and using their outcomes for informing land–use policy decisions using regional case studies. Previously, she has worked on the Environmental Risk Reporting and Information System (ERRIS) project for the Indian Chamber of Commerce, Kolkata and contributed to the development of GIS based methods for guiding risk based land–use decisions in the industrial town of Haldia in eastern India. She holds Master's degree in Geo–information Science from the International Institute of Geo–information Science and Earth Observation (ITC) jointly with Indian Institute of Remote Sensing (IIRS) followed by Master's degree in Geography from Banaras Hindu University, India.



Debanjan Bandyopadhyay

Debanjan Bandyopadhyay is presently pursuing his research on risk information and decision support systems as a part of a PhD program at the University of Twente, the Netherlands. He also has a MBA degree in Information Systems and a Post Graduate Diploma in Environment Management from the University of Calcutta. Through his current research, he is trying to advance a body of work focusing on the design and development of GIS based risk information systems for hazardous industrial clusters in India which was initially undertaken as a part of the Environmental Risk Reporting and Information System (ERRIS) project and supported by the European Commission. He was responsible for the conceptualization and management of the project leading to the setting up of the first distributed web–GIS based risk information system in two industrial towns located in eastern India. Professionally, Debanjan presently heads the Environmental and Social Risk Management vertical for SENES Consultants (India) and has 16 years of experience on implementing diverse projects in areas like environmental information systems, impact assessment, risk analysis, audits, environmental policy and planning at the regional and national levels in India. In course of his career, he has also worked in several other countries like Sri Lanka, Bangladesh, Bhutan, Myanmar, Maldives and Botswana.



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Nilanjan Paul has 15 years of professional experience in GIS based data analysis and interpretation, risk assessment studies using multi–criteria analysis models and development of GIS based information systems. He has obtained a MBA degree in Information Systems from the University of Calcutta and has been trained in application of decision support system tools from International Institute of Geo–information Sciences and Earth Observation (ITC) in the Netherlands. He has experience of working with the latest GIS based information technologies including the development of geo–databases and distributed web based spatial information systems. He was the principal architect in designing the web–GIS based risk information software under the Environmental Risk Reporting and Information System (ERRIS) project for hazardous industrial clusters in India. Presently, he leads the GIS & IT division of SENES Consultants (India) and In course of his professional career has worked on a number of multilaterally funded projects for agencies like the DFID, JBIC, UNDP and USAID related to the development of information systems. In course of his career, he has also worked in several other countries like the Netherlands, Thailand and Botswana.



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Dr. Anil K. Gupta, Head of Policy Planning Division and Training Section, joined the National Institute of Disaster Management in 2006 as Associate Professor. His areas are disaster management, climate-change adaptation and NRM, with focus on risk/vulnerability assessment, planning and management. He did his Post-Doctoral work at NEERI Nagpur (CSIR) and received Young Scientist Award in 1996. He is Fellow of Earth Scientists Society. He was Reader & Head of Department of Environment & NRM since 2003 and founder Director of Institute of Environment & Development Studies at Bundelkhand University. Earlier he worked at the Ambedkar Central University of Lucknow, Disaster Management Institute (Govt. of MP, Bhopal), National Mineral Development Corporation, and CICON Environment Technologies. He has supervised several Ph.D. and PG research, has over 100 publications including 3 books, 4 training modules and 44 papers in refereed journals. He implemented several research/coordinated projects supported by GIZ Germany, UNDP, UNEP, CDKN, ICSSR, and MoEF, focussing on drought, floods, climatic-risks, coastal hazards, DM planning, environmental knowledge and legislation. He has 23 experiences of research including 17 years teaching/training and 8 years administrative experience.



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Sreeja S. Nair is Assistant Professor at National Institute of Disaster Management since 2007. She is disaster management professional having more than 12 years of experience in the field. Her areas of research, documentation and training activities at NIDM include geoinformatics applications in disaster management, environmental law, disaster data and information management, ecosystem approach to disaster risk reduction and chemical disaster management Ms. Nair published 10 papers in national and international journals, authored 3 training modules and edited 2 books and 2 proceeding volumes. She is the coordinator of Indo German Cooperation on Environmental Knowledge for Disaster Risk Management and co–principal investigator of ICSSR research project on drought vulnerability and mitigation analysis. She is also involved as a technical expert in the GIZ–European Union pilot project on integrating climate–change adaptation with disaster management planning process coastal Andhra & Tamil Nadu.

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