Technological (Industrial) Risk Assessment

by
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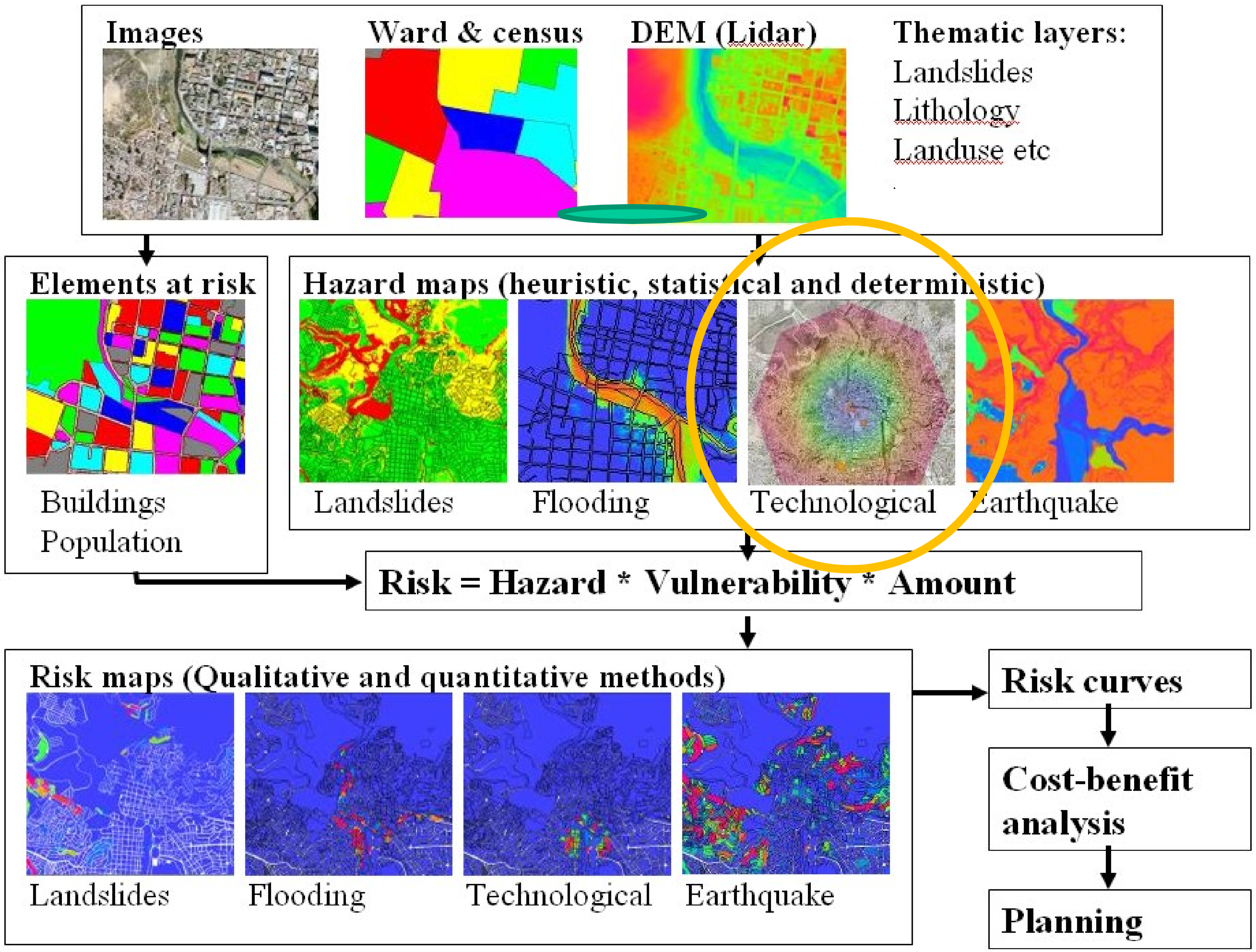
Multi hazard risk assessment



Lecture Overview

- Fundamentals of technological risks
- Different methods for technological risk assessment
- Use of Geo-information for technological risk assessment - various tools and the ERRIS project
- Industrial risks and land use planning – Haldia case study
- Demonstration & exercises

ITC

What is an Industrial hazard?

UNTAMED INFERNO

- Fire At Jaipur IOC Depot Raging, Army Called In
- 5 Confirmed Dead, 40 IOC Staff Untraced
- Tanker Blast Causes Tremors At 2.3 Richter
- Areas Around Sitapura Evacuated, Students Shifted

Arvind Sharma

Oil tankers on fire at the IOC depot at Sitapura industrial Area in Jaipur on Thursday night

What is an Industrial hazard?

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"A hazard originating from technological or industrial conditions, including accidents, dangerous procedures, infrastructure failures or specific human activities, that may cause loss of life, injury, illness or other health impacts, property damage, loss of livelihoods and services, social and economic disruption or environmental damage"

(UNISDR, 2009)

Risk sources and types

Sources of Technological Risks

- Hazardous Industries mainly Chemical and Petrochemicals
- Chemical Warehouses and Storages
- Transportation of Hazardous Substances
- Pipelines

Types of Technological Risks

- Toxic Releases
- Fires
- Explosions
- Spills
- Radiation

Natural & Technological Risks…..

Natural Causes

Technological Disasters

Human Causes

Refinery ablaze as aftershocks rattle Japan

Tokyo
September 29, 2003

Strong aftershocks jolted the Japanese island of Hokkaido two days after an earthquake measuring eight on the Richter scale, while a new fire broke out yesterday at an oil refinery where the tremor had caused a major blaze.

An oil storage facility is ablaze at a refinery in Tomakomai on Japan's northern island of Hokkaido.
Picture: Reuters

"A fire started at a naphtha tank shortly before 11am (1200 AEST)," said an official at the Idemitsu Kosan Co Ltd refinery in the Pacific Coast city of Tomakomai, Hokkaido island. Nobody was believed to be injured.

It was the second fire to hit the refinery. The powerful quake on Friday caused a major blaze at a crude oil storage tank that took seven hours to put out.

It is unclear whether the new fire was linked to aftershocks, the official said.

The tank for naphtha, used as raw material for petrochemical products, has a storage capacity of more than 30,000 kilolitres, she said.

An earthquake measuring 5.3 on the Richter scale hit Hokkaido around 7:23am

Bhopal Gas Tragedy(2nd and 3rd Dec,1984)

The Bhopal Disaster of 1984 was the worst industrial Disaster in the history of the world.

Events leading to the disaster

- Accidental release of 40 metric tons of Methyl Isocyanate (MIC) from the storage tank.
- Seepage of water(500) Litres into the MIC storage tank.
- Water reacted with the escaping toxic gas and formed a deadly chemical mixture

Impact

- 15000 people died immediately and over 500,000 people suffered from injuries
- At least 200,000 people fled Bhopal during the week after the accident.
- Many died due to delayed medical treatment
- Estimates of the damage vary widely between $350 million to as high as $3 billion.

Enschede Fireworks Explosion (May 13, 2000)

The Enschede fireworks disaster was caused by a fire which broke out in the S.E Fireworks depot in Enschede.

Events leading to the disaster

- **Fire broke out in the central warehouse storing 900 kg of fireworks**
- **The fire extended to two full containers placed illegally outside of the building and exploded shortly afterwards.**
- **A chain reaction of explosions led to the destruction of the firework bunker.**

Impacts

- **22 people killed**
- **Almost 400 houses were reduced to their foundations and another 1,000 damaged.**
- **The loss was estimated at 0.5 billion euros**

Pilot’s snapshot


Just after

Source: Paul Hofstee ITC

Technological Risk Management : Country Level Regulations

Seveso II

The Seveso Directive on the major accident of certain industrial activities was adopted by the Council of the European Union in 1982 and was aimed at prevention and control of accidents involving dangerous substances and the limitation of their consequences for man and the environment.

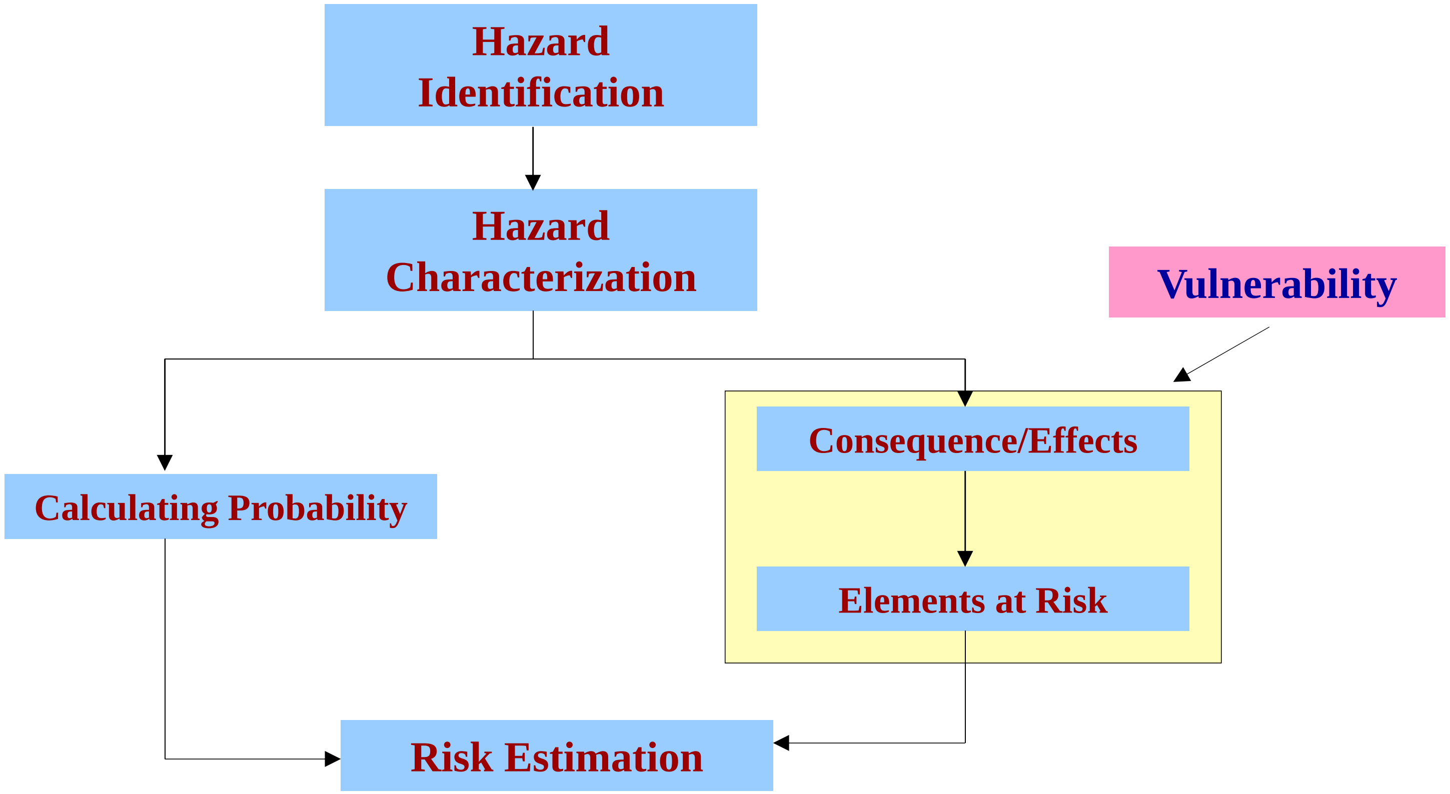
Emergency Planning & Community Right to Know Act

EPCRA was enacted by United States Congress as the national legislation on community safety. This law was designated to help local communities protect public health, safety, and the environment from chemical hazards

Manufacture, Storage and Import of Hazardous Chemicals Amendment Rules, 1989

The Manufacture, Storage and Import of Hazardous Chemicals Rules were notified in India with the objective of prevention of major accidents arising from industrial activities and limiting the effects of such accidents both on man and on the environment

General Approach to RA



Formula used for Risk Estimation :

R = Probability X Vulnerability (Effects + Elements at Risk) X Amount

Hazard Characterization

- Type of Hazardous Chemicals – Toxic, Flammable, Explosive, Corrosive
- Amount of Hazardous Chemical present at a particular time
- Type of the Storage (or Process)
- Storage / Process Parameters

Getting Information on Hazardous Chemicals

MSDS

- Material safety data sheets or "MSDSs" are information sheets on products that:
  - tells what chemicals are in the product
  - what the hazards of the chemicals are
  - how to protect yourself from the hazards

Product / Hazard Labels

- The manufacturer
- The name of the product
- a hazard warning
- a list of hazardous ingredients

Properties of Hazardous Chemicals

- A hazardous chemical is any chemical that can do harm to the human body or the environment.

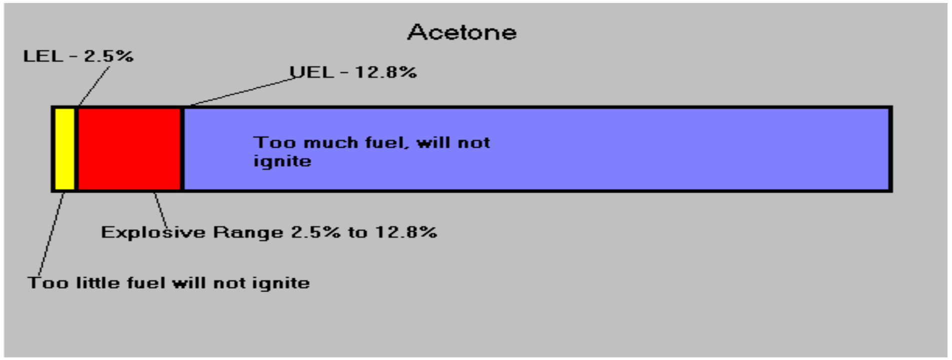
Toxic Chemicals

- Toxicity – depends on total intake of a chemical to body (dose) and generally measured in terms of concentrations in air
- Allowable limits are expressed in terms of "PELs" or "TLVs" or "IDLH" and is based on 8-hour average exposur or ceiling or peak levels
- Chemicals can have Chronic Toxicity or Acute Toxicity – In risk assessment, generally we look at acute toxicity meaning doses that make you sick if you get an 'acute" o high dose all at once.
- In addition toxic chemicals can also be carcinogenic, teratogens or mutagens.

Properties of Hazardous Chemicals

Inflammable Chemicals

- The vapor of a flammable liquid ignites and causes fire or explosion – not the liquid itself.
- The flammability of a liquid depends on its physical properties:
  - Vapor Pressure
  - Flash Point
  - Limits of Flammability
  - Vapor Density



Explosives

- Substances which by themselves or in mixture with other substances can explode under certain circumstances.

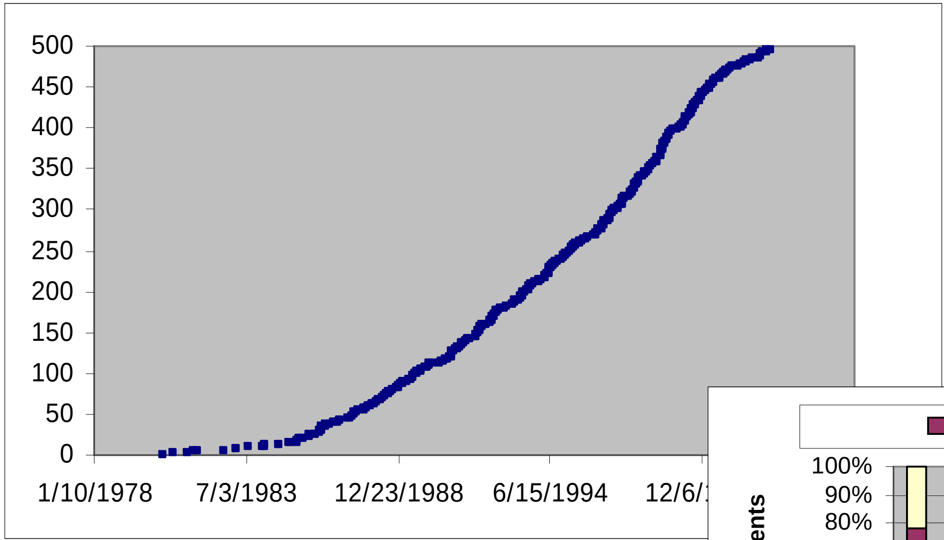
Calculation of Hazard Probability

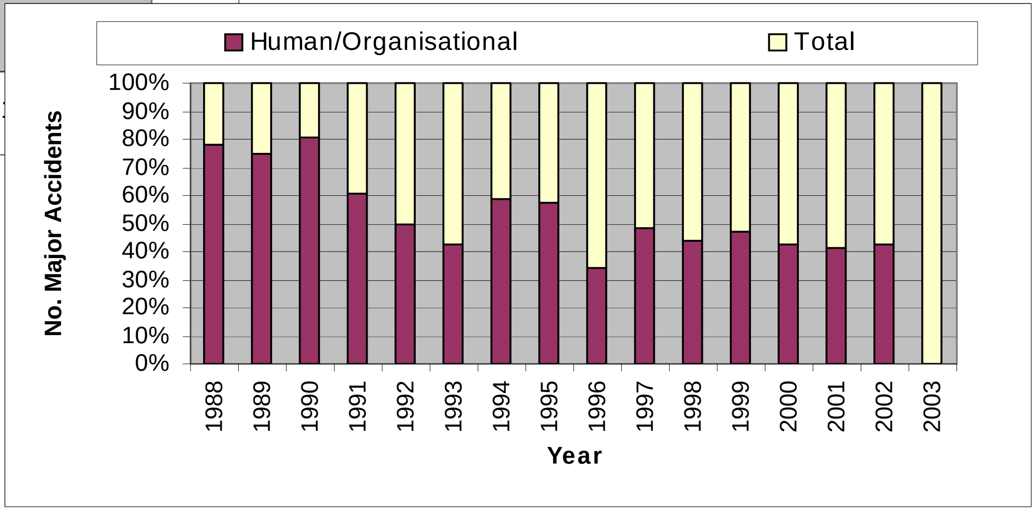
- Methodologies include:
  - Historical Accident Analysis
  - Decision Trees (Quantitative)
  - Failure Mode Effects Analysis (FMEA) studies

- Example of Typical Failure rates (US)
  - Pipelines : 1.5×10^{-3} / miles – year
  - Double Walled Storage Tanks : 1×10^{-4} / tank – year
  - Warehouse Contaniners : 1×10^{-3} / tank – year

- Important to note that calculation of exact proability is next to impossible – objective is to get a fair estimate of the probability of a event happenning to resulting in prioritization of risks.

Accidents Statistics

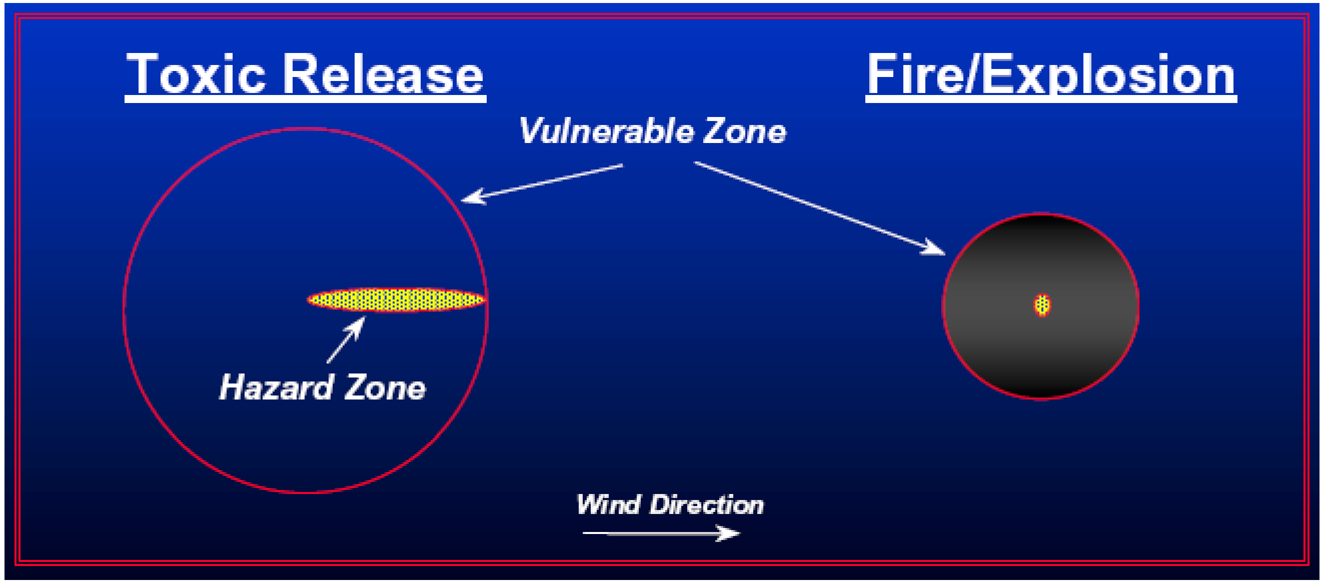




Analysis shows a reduction in the proportion of accidents caused by human/organisational failures (improvement of safety mngt)

Calculation of Consequence/Effects

- Consequence or Effects modeling is used to estimate the size of a hazard zone in case of Maximum Credible Loss Scenario (MCLS) or other alternative accident scenarios.
- Is used to predict end points of a toxic release, fire or a explosion
  - Toxic Release : Distance downwind to IDLH / TLV concentrations of gas in mg/m^3 or ppm
  - Fire : Intensity of radiation measuring to 5 Kw/m^2 which can cause second degree burns for a 40 sec exposure
  - Explosion : 1 pounds per square inch (psi) which can cause partial demolition of houses



Types of Consequence/Effects Models…..

Toxic Release

- Vapour Cloud Dispersion
- 2 Phase Release followed by Dispersion
- Evaporating Pools followed by Dispersion
- Run-off to soil / water

Fires

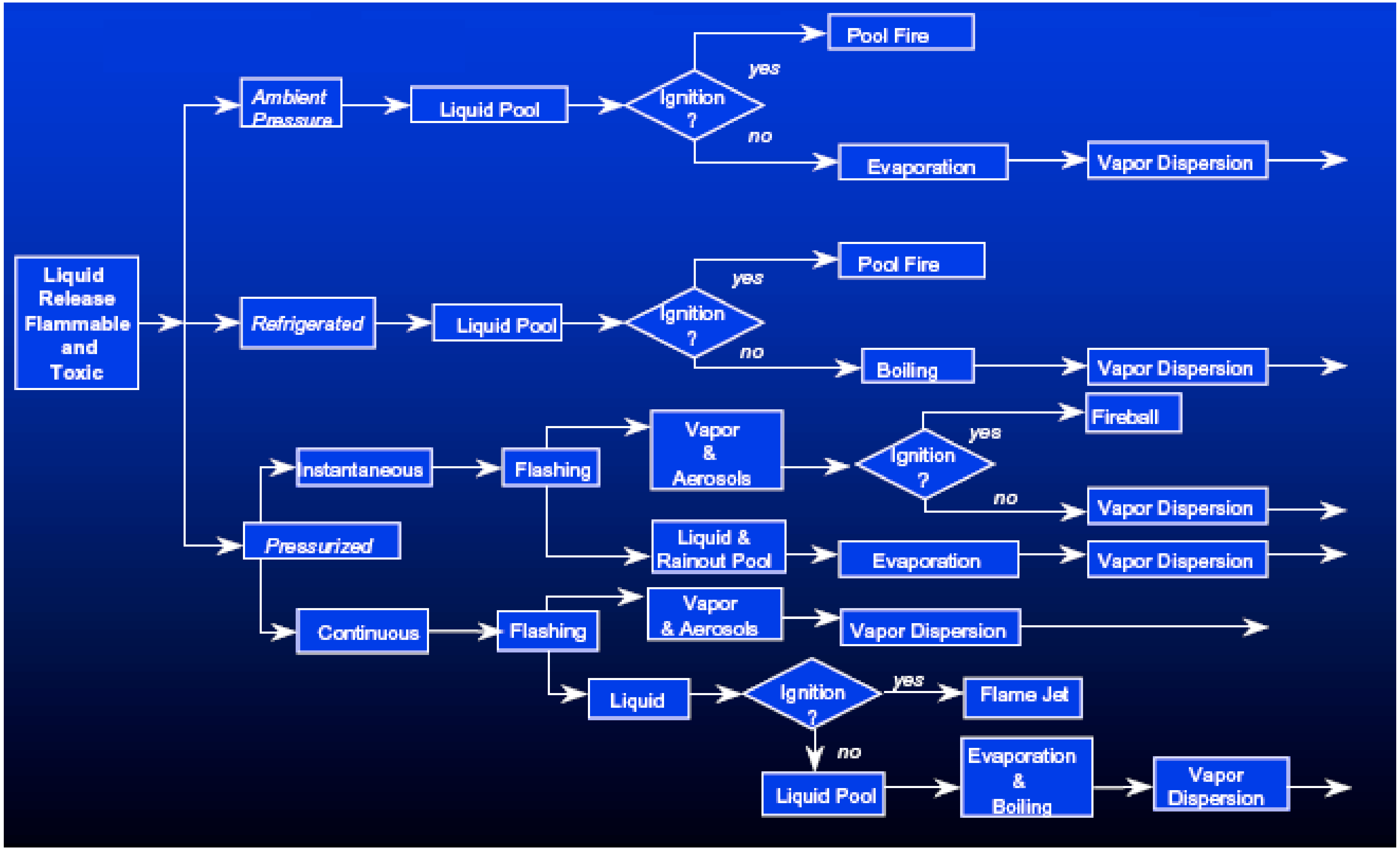
- Pool fires
- Vapour Cloud Fires
- Flame Jets
- Flares
- Fireballs

Explosions

- Unconfined Vapour Could Explosions
- Vented Explosions
- Condensed Phase Explosions
- Projectiles
- "Knock-on" effects

Understanding Release Scenarios…..

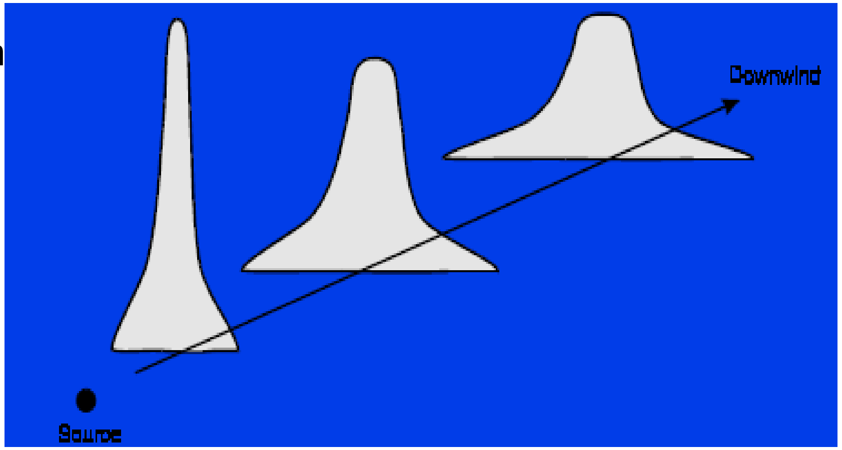
- Flow diagram for identifying appropriate models for liquid releases



Calculation of Endpoint Distances

Toxic Gas Dispersion

- Variety of approaches and methodologies for calculating dispersion end-points
  - Gaussian Models
  - Box Models (dense gases)
  - 3 D models or K models
  - Computational Fluid Dynamics (CFD) models
- Gaussian models are only valid for simple cases
  - Neutrally buoyant gases (not dense, not positively buoyant)
  - Uniform flow field
  - Applicable only for wind speeds greater th
  - No obstacles, no terrain



Calculation of End-point distances

Fire and Explosion

- Hazard Zone for BLEVE : Distance to 5 KW / m2 :

$$X = \sqrt{\frac{2.2\ t_a\ R\ H_c\ W_f^{\ 0.67}}{4\,\Pi \left[\frac{3.42\ \mathrm{x}\ 10^6}{t}\right]^{0.75}}}$$

R = radiative fraction of the heat of combustion (assumed to be 0.4)
ta = atmospheric transmissivity (assumed to be 1)
Hc = heat of combustion of the flammable liquid (joules/kg)
Wf = weight of flammable substance in the fireball (kg)
t = duration of the fireball in seconds (estimated from the following equations)

- Hazard Zone for Vapour Cloud Explosion : Distance to 1 psi :

$$X = 17\left(0.1\ W_f\ \frac{H_{Cf}}{H_{CTNT}}\right)^{1/3}$$

X = distance to overpressure of 1 psi (meters)
Wf = weight of flammable substance (kg)
HCf = heat of combustion of flammable substance (joules/kg)
HCTNT = heat of combustion of trinitrotoluene (4.68 E+06 joules/kg)

Risk Measures

Individual Risk

Individual risk is the risk of fatality or injury to any **identifiable** (named) individual who lives within the zone impacted by a hazard, or follows a particular pattern of life, that might subject him or her to the consequences of a hazard.

Societal Risk

Societal risk is the risk of multiple fatalities or injuries in the society as a whole, and **where society would have to carry** the burden of a hazard causing a number of deaths, injury, financial, environmental, and other losses.

ITC

How to express risk?

- Suppose: What is the risk of flying by airplane? Is it higher than driving a car?

  - What are the risks from driving an automobile?
  - There are 15,000,000 accidents per year, 1 in 300 of which result in death, there are 250,000,000 people

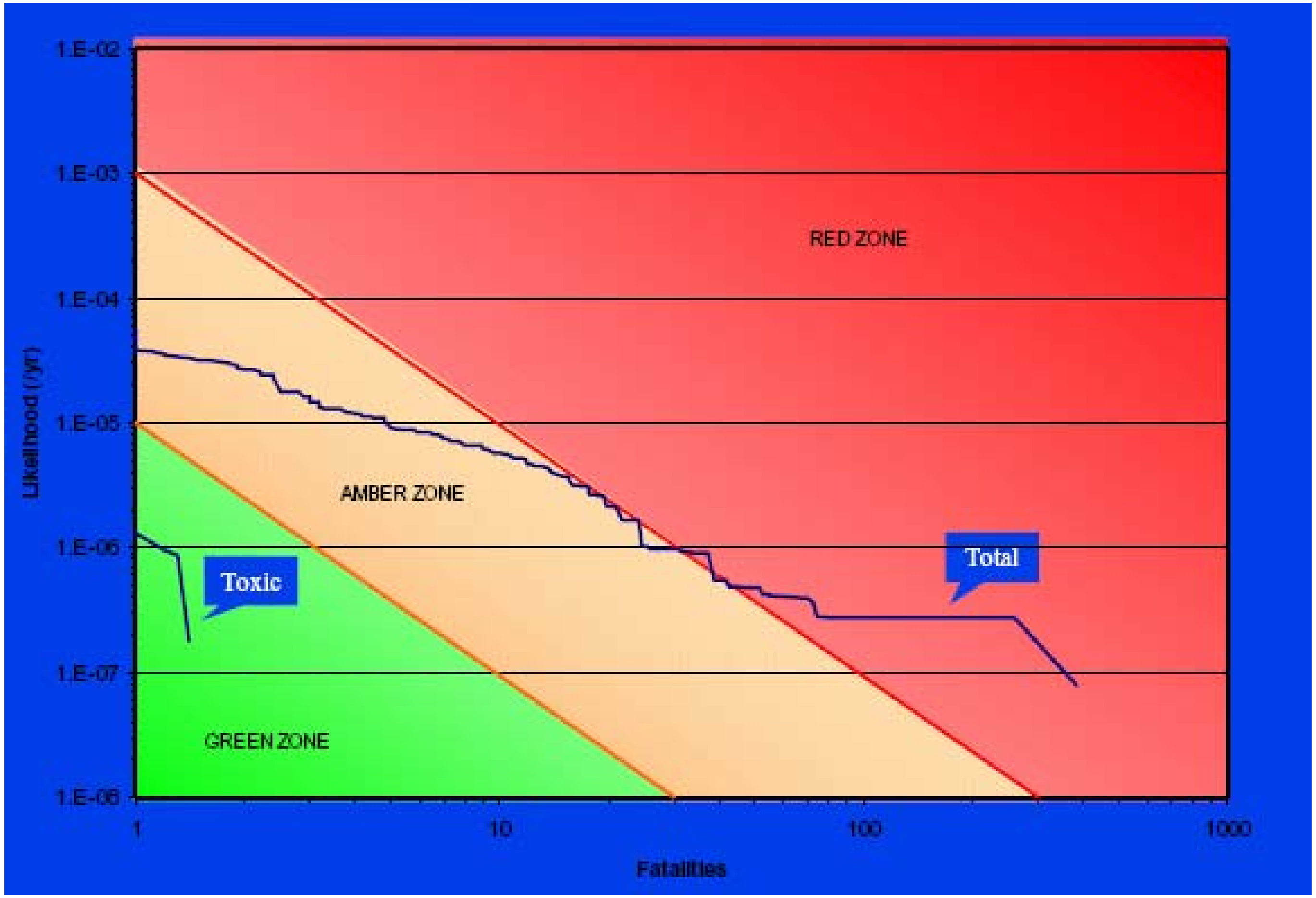
$$Societal\ Risk = 15{,}000{,}000 \frac{accidents}{year} \times \frac{1}{300} \frac{accidents}{year} = 50{,}000 \frac{deaths}{year}$$

$$Individual\ Risk = \frac{50{,}000\ deaths / year}{250{,}000{,}000\ people} = 2 \times 10^{-4} \frac{deaths}{person \cdot year}$$

$$Lifetime\ Risk = 2 \times 10^{-4} \frac{deaths}{person \cdot year} \times 70\ years = 0.014 (1\ in\ 70)$$

Risk Evaluation

- Example F/N Curves for Fatalities



Acceptable Risk

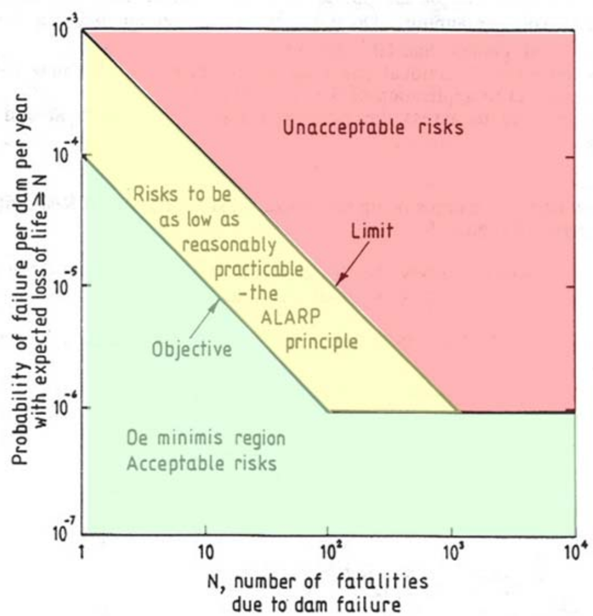
Acceptable risk: a risk which the society or impacted individuals are prepared to accept. Actions to further reduce such risk are usually not required unless reasonably practicable measures are available at low cost in terms of money, time and effort.

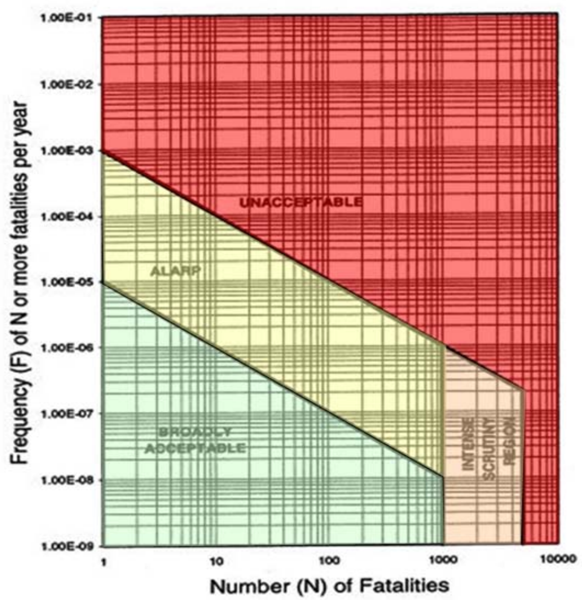
Tolerable risk: a risk within a range that society can live with so as to secure certain net benefits. It is a range of risk regarded as non-negligible and needing to be kept under review and reduced further if possible.

ALARP (As Low As Reasonably Practicable) principle: Principle which states that risks, lower than the limit of tolerability, are tolerable only if risk reduction is impracticable or if its cost is grossly in disproportion (depending on the level of risk) to the improvement gained.

The definition of acceptability levels is a responsibility of the national or local government in a country.

	Individual acceptable risk level
UK Health and Safety Executive Board	< 10-4 /year
Iceland, Ministry for the Environment	> 3 x 10-4 / year
Switzerland (BUWAL, Swiss agency for the Environment, Forests and Landscape)	< 0.3x10-4 / year
Hongkong (Geotechnical Engineering Office)	Existing developments: <10 –4 / year New developments: <10-5 /year
Netherlands	< 1.4 × 10-5/year





Acceptable risk in the Netherlands

- North and South Holland (the area with the highest concentration of population) 1 per 10,000 years
- Rest of the country at risk from sea flooding 1 per 4,000 years
- Netherlands risk acceptability criteria for technological risk :
  - Individual – 10^{-5} / year
  - Societal – 10^{-3} / N^2

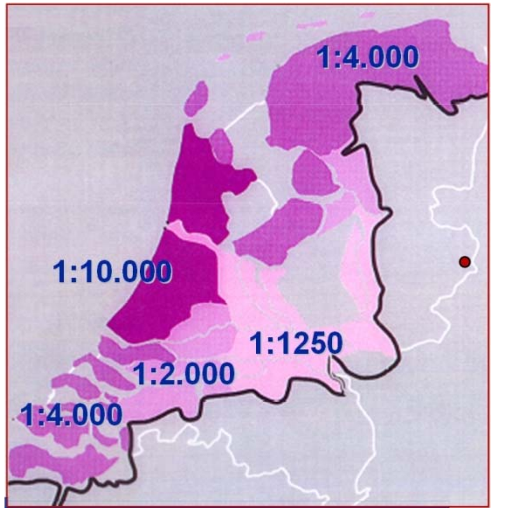
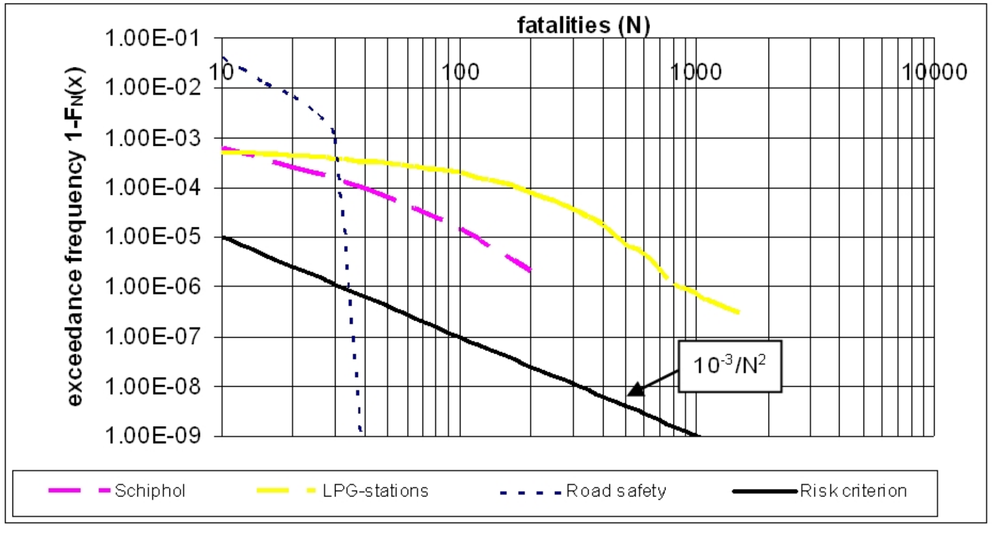


Figure 7.8: Safety standards with respect to flooding in the Netherlands



Industrial Risk Assessment

Purpose of Industrial Risk Assessment

- To ensure that the level of risk on which the population is exposed is not high ("is tolerable")
- To identify weak points and to contribute to the rational management of risk
- To evaluate risk reduction measures
- To compare establishments and/or other hazardous activities in order to decide which ones are the most hazardous (and therefore deserve more attention / higher priority)
- To help better understanding the risk

ITC

Industrial Risk Assessment Methods

- Index methods (DOW, MOND, ISPESL, …, CEI)
- Rapid Ranking method
- Deterministic approach
- Consequence-based approach
- Qualitative approach
- Quantitative approach (“probabilistic” or “Risk-based”)
- Semi-Quantitative approach

DOW Index Method

Purpose:

- Screening of the various units within an establishment (for prioritization reasons)
- Rough estimation of the Probable Property Damage

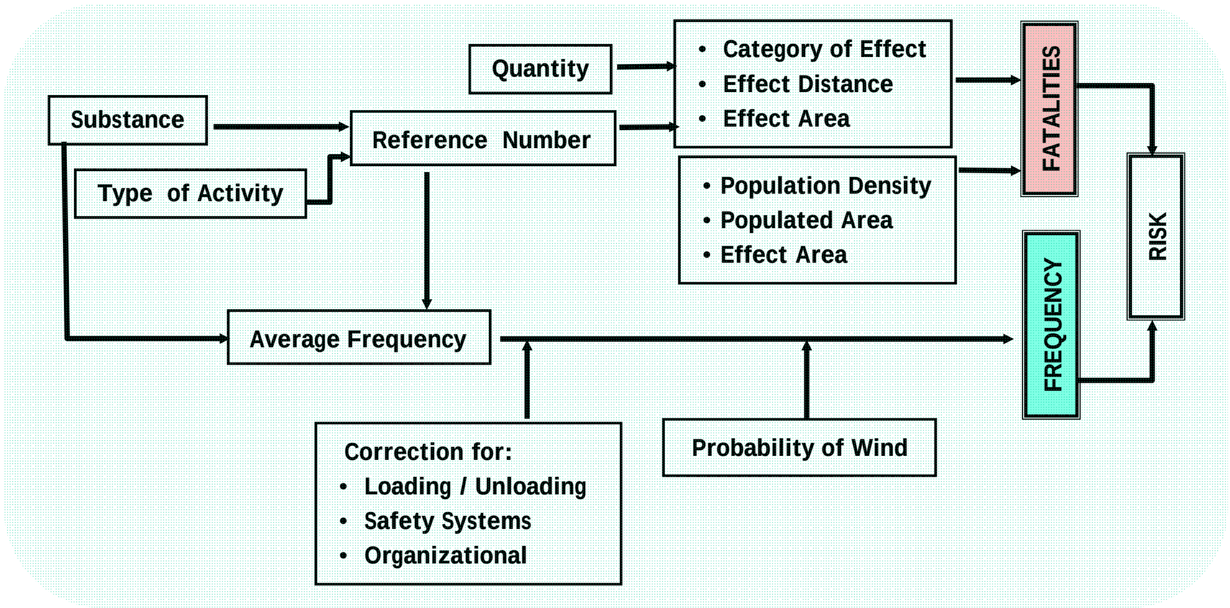
Principles:

- Only Fire and Explosion hazards
- Depends on the process (Unit Hazard Factor)
- Depends on the substances characteristics (Material Factor)
- Takes into consideration safety systems (credit factors)
- Provides a hazard index (F&E Index) and an estimation of the property damage (percentage of the unit likely to be damaged)

Rapid Ranking Method

Principles:

- Rough assessment of the consequences of major accidents in terms of fatalities and the relevant frequency.
- Acceptability or prioritization is considered either in terms of frequency, or in terms of fatalities, or both



Deterministic Approach

Steps:

- Prescribe technical details
- Prescribe procedures
- Check that all prescriptions have been followed

Advantage: “clear” and “easy” in application

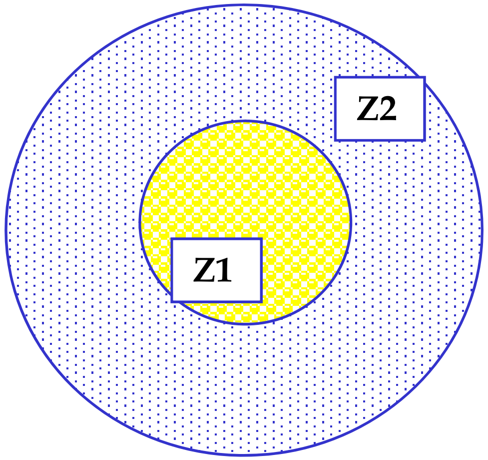
Disadvantage:

- Cost usually increased
- “absolute” results in terms of ‘safe’ or ‘unsafe’

Consequence based Approach

Method:

Distances corresponding to certain levels of consequences (thresholds), representing the *lethal* and of *irreversible* effects. Assessment of consequences of a small number of 'reference' accident scenarios. Their likelihood is taken into consideration only implicitly.

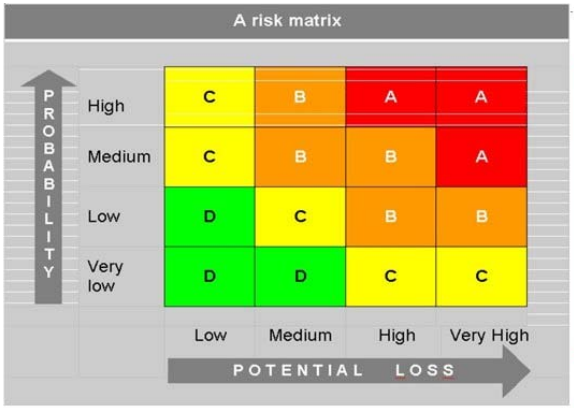


Some examples of threshold values for different effects:

- LC1% and IDLH for toxic releases
- the thermal radiation for fire
- certain overpressure level for explosions

Qualitative Approach

- Risk matrix
- Define probability classes
- Define loss classes
- Define the combination of the two as risk classes
- Alternatively: define risk matrix with vulnerability and hazard classes



Risk levels

- A: Very high. Frequent events causing very high losses, or moderate frequent events causing very high losses
- B: High. Frequent events with moderate losses/ moderate & low frequent events causing (very) high losses
- C: Moderate. Frequent events with low losses or very low frequent events causing (very) high losses
- D: Low. Low frequency events with low losses

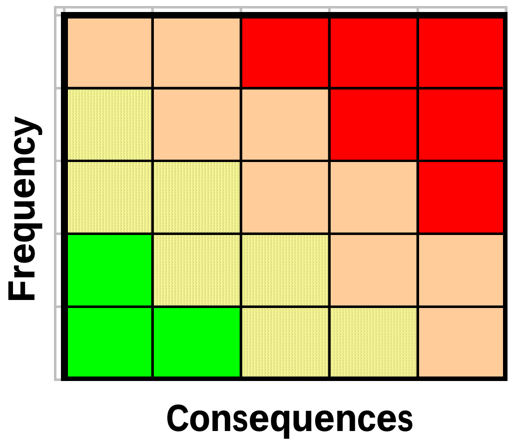
Loss

Based on the potential by taking into account elements at risk

- Fatalities
- Injuries
- Impact on facilities, critical services and infrastructure
- Property damage
- Business interruption
- Environmental/ Economic impact

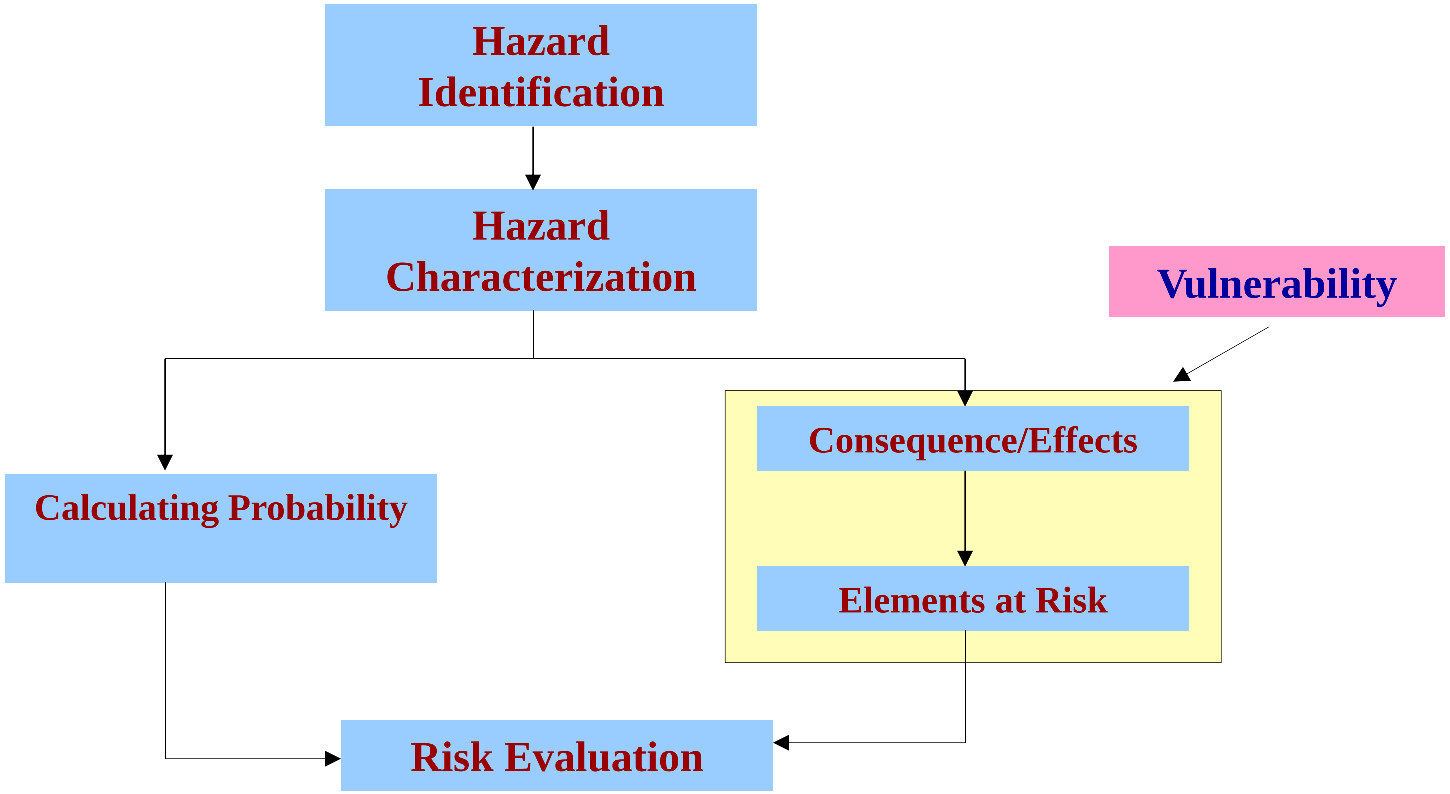
Probability

High	Events that occur more frequently than once in 10 years
Moderate	Events that occur from once in 10 years to once in 100 years
Low	Events that occur from once in 100 years to once in 1000 years
Very Low	Events that occur less frequently than once in 1000 years



- **For Consequences:**
  - Minor
  - Serious
  - Very serious
  - Major
  - Catastrophic
- **For Frequency:**
  - Likely
  - Possible, but not likely
  - Unlikely
  - Very unlikely
  - Remote

Semi-quantitative approach to RA



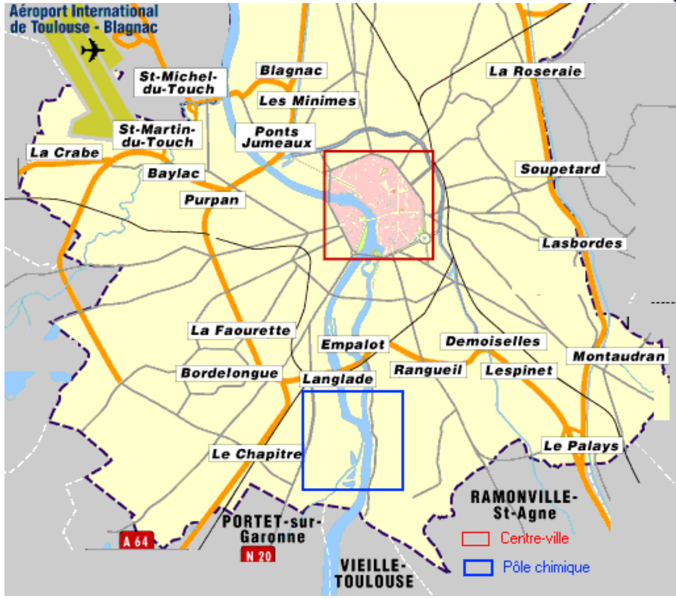
Formula used for Risk Estimation :

R = Probability X Vulnerability (Effects + Elements at Risk) X Amount

Tools for Technological Risk Assessment

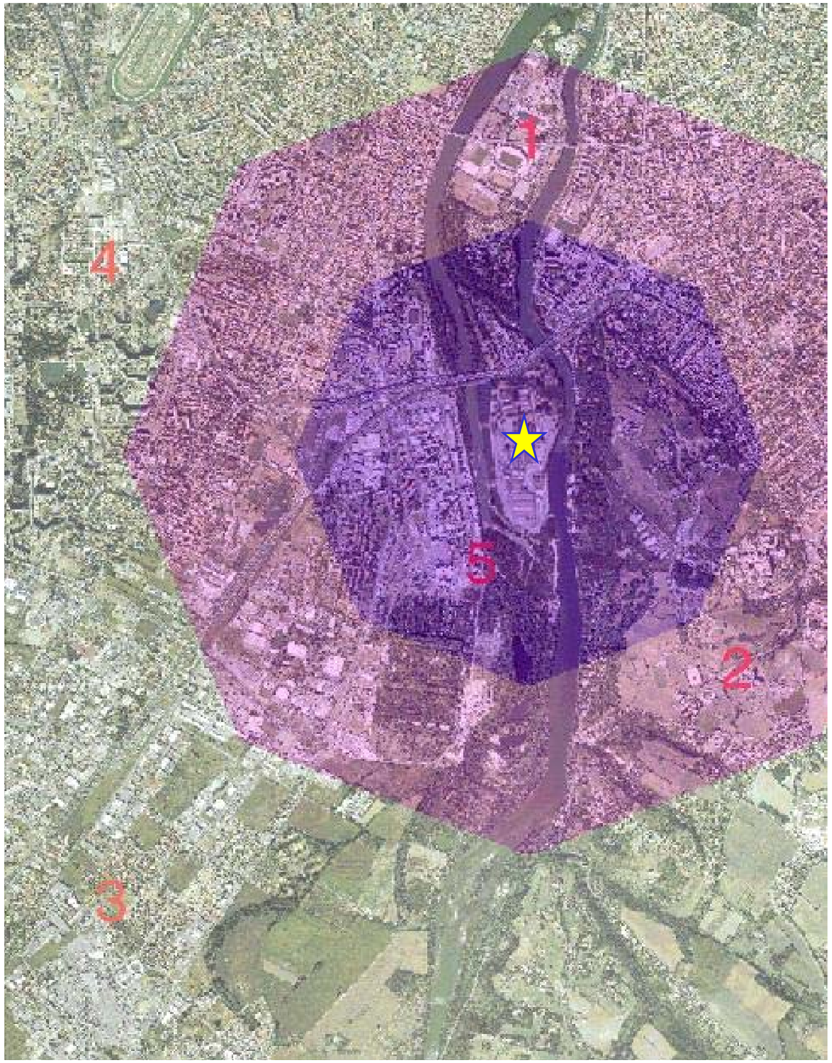
GIS case study using ILWIS

- Case study of AZF Factory Explosion in Toulouse – France
- The disaster occured on the 21 th of September 2001, when a fertiliser factory containing ammonium nitrate storage facilities exploded.
- The factory employed 470 persons and was located 3 km from the center of Toulouse
- 30 people were killed
- 2500 persons were injured
- 30000 Buildings were damaged within a radius of 1500 meters (1/3 heavily)
- Financial consequences amounts 2.5 billion €

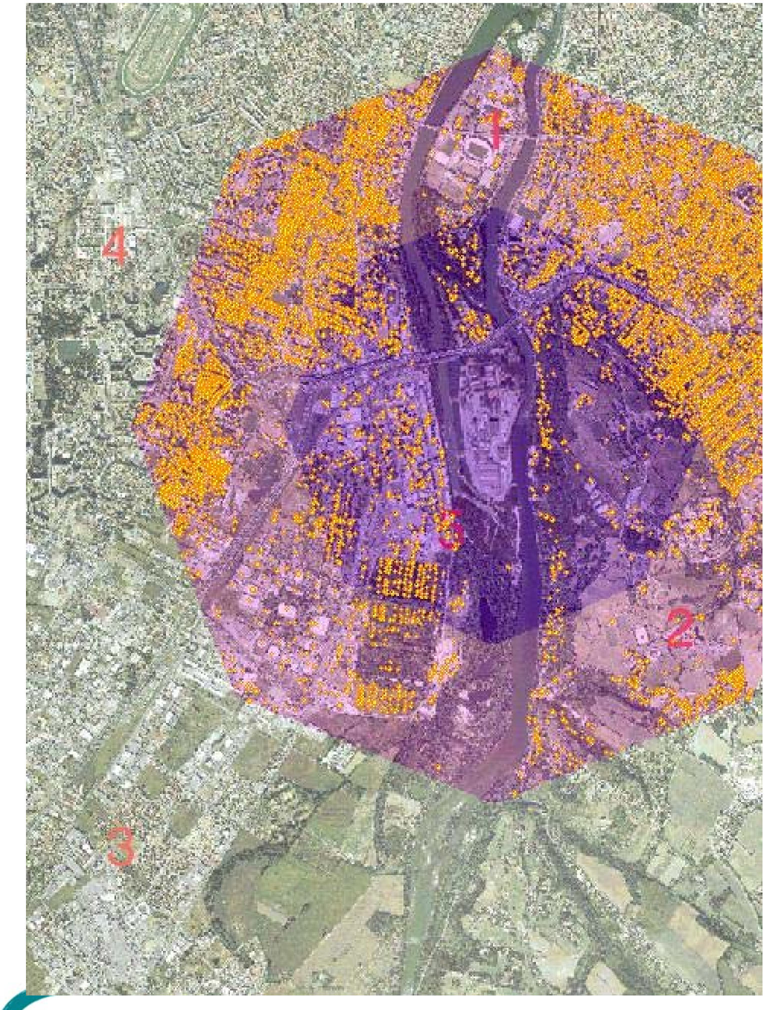


Overlay of Hazard Zones on Map

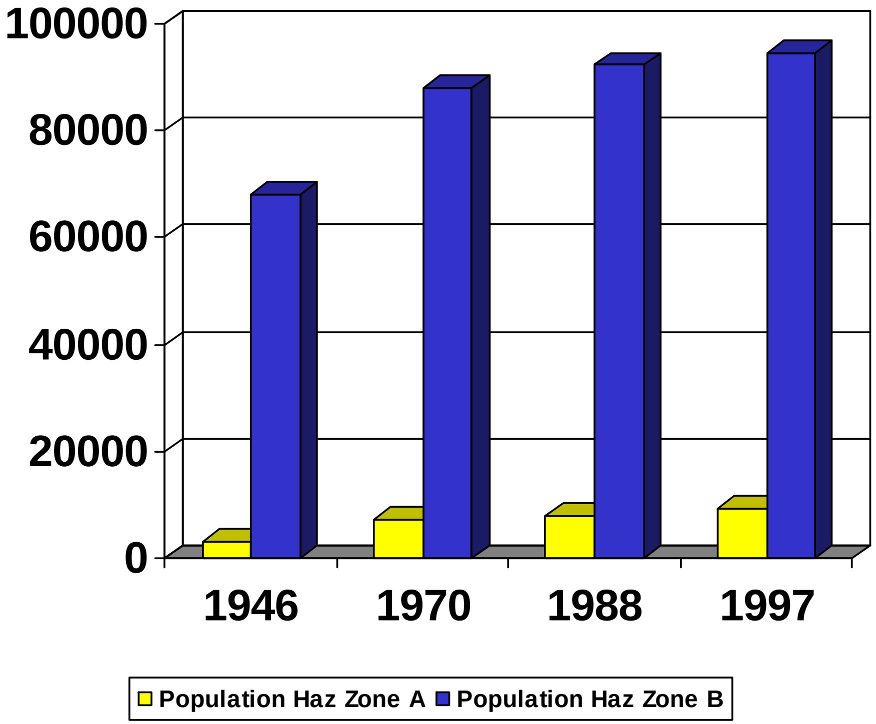
- Creation of point map for the “AZF Plant”;
- Calculation of radial distances of Haz Zone A & B using Distance Calculation Option;
- Generation of two raster maps for the respective Haz zones
- Overlaying of maps on the Toulouse image



Increase in risk over time

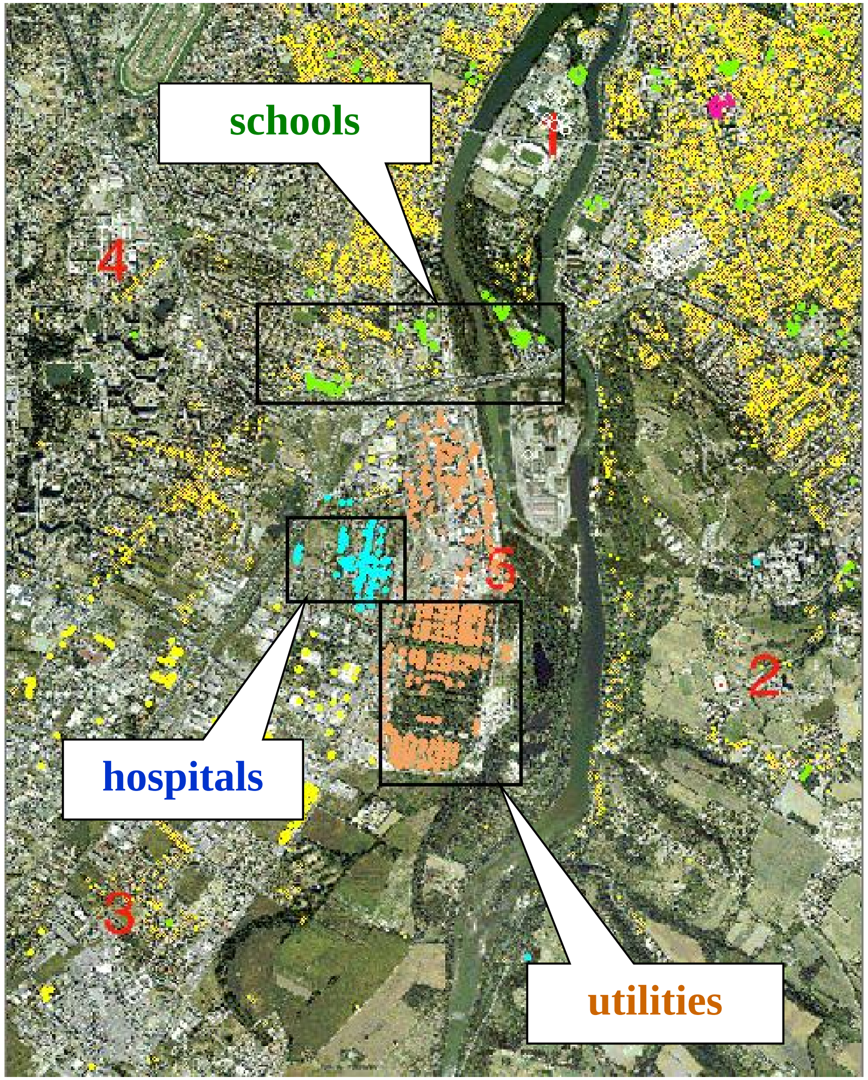


	1946	1970	1988	1997
Pop. Haz. Zone A	3212	7438	8016	9281
Pop. Haz. Zone B	68017	88008	92170	94517



Other Aspects of Calculating Vulnerability using GIS

- Temporal vulnerability – gradual growth in population through last few decades called *'honeypot'* effect.
- Spatial vulnerability - receptors in the vicinity including critical facilities, utilities, sensitive receptors (inadequate land use zoning)
- Other hazardous industries which may lead to Cascade-Domino effects



ARIPAR Project

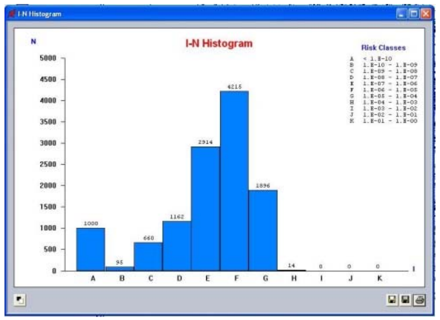
Analysis and Control of the Industrial and Harbour Risk in the Ravenna Area *(Analisi e controllo dei Rischi Industriali e Portuali dell'Area di Ravenna)*

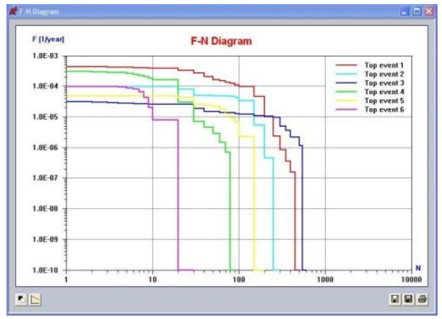
Main Objective:

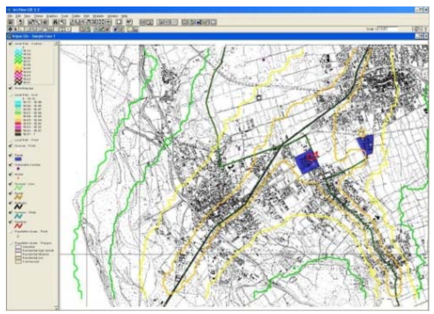
- To develop a methodology and the related software tool for area risk assessment.

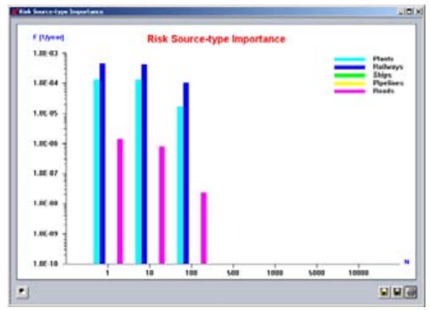
Key Features :

- Local Risk (Risk contour)
- Individual Risk
- Societal Risk (I-N Histogram, F-N Curves)
- Importance of different risk source types









ARIPAR Methodology

IMPACT AREA DATA

- Impact Area Map
- Vulnerability Centres
- Meteorology
- Population

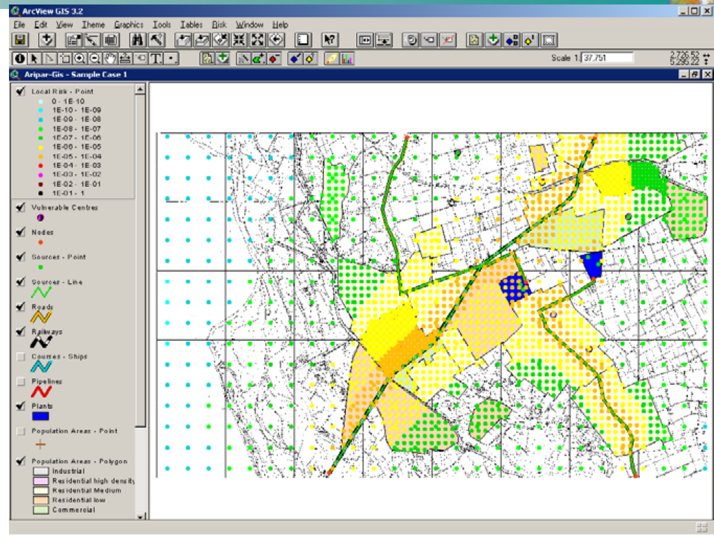
SOURCE AREA DATA

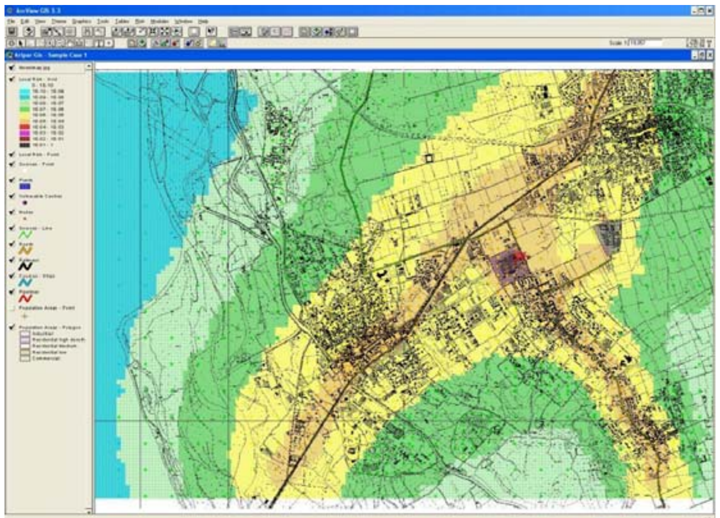
- Plant
- Transport

OFF LINE ANALYSIS

- Frequency Estimation
- Consequences Analysis

AREA RISK ASSESSMENT





Geo-information for Technological Risk Assessment

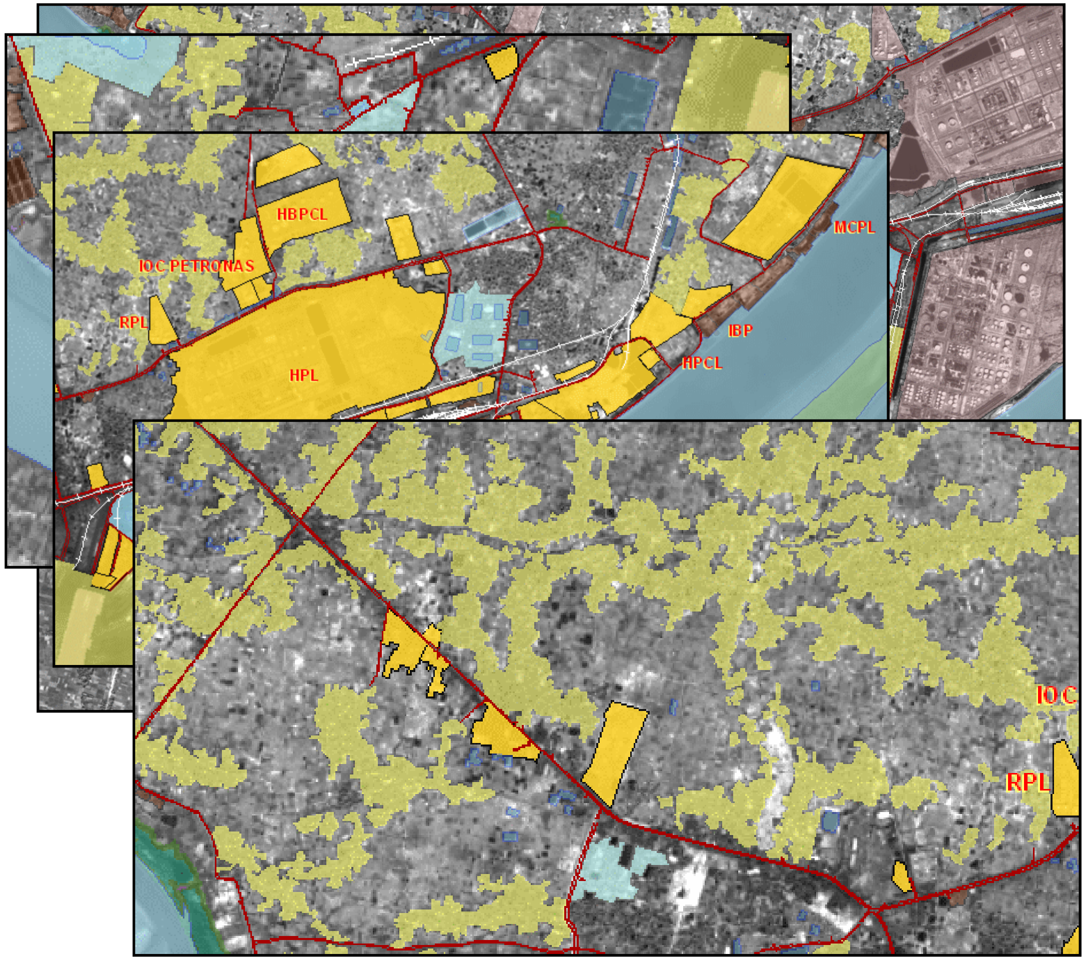
Case Study Town : Haldia

West Bengal

East Midnapur

Haldia Industrial Area

Haldia : Overview



- Haldia town has developed in a haphazard and unplanned manner;
- The land-use is mixed and varied comprising of agricultural land, residential areas, villages and slum clusters, industrial areas, forests and greenbelts, ponds, wetlands and rivers;
- Some typical land-use patterns :
  - Planned residential
  - Industrial
  - Unplanned mix of residential, agricultural and rural

Haldia: Elements at Risk

Kuchha house bordering the hazardous (MAH) industries

Large number of squatters and shanties along the canal in between hazardous industries

Passenger railway network passes through hazardous industries

Pipelines running along the roads and settlements

ERRIS Overview

Environmental Risk Reporting and Information System

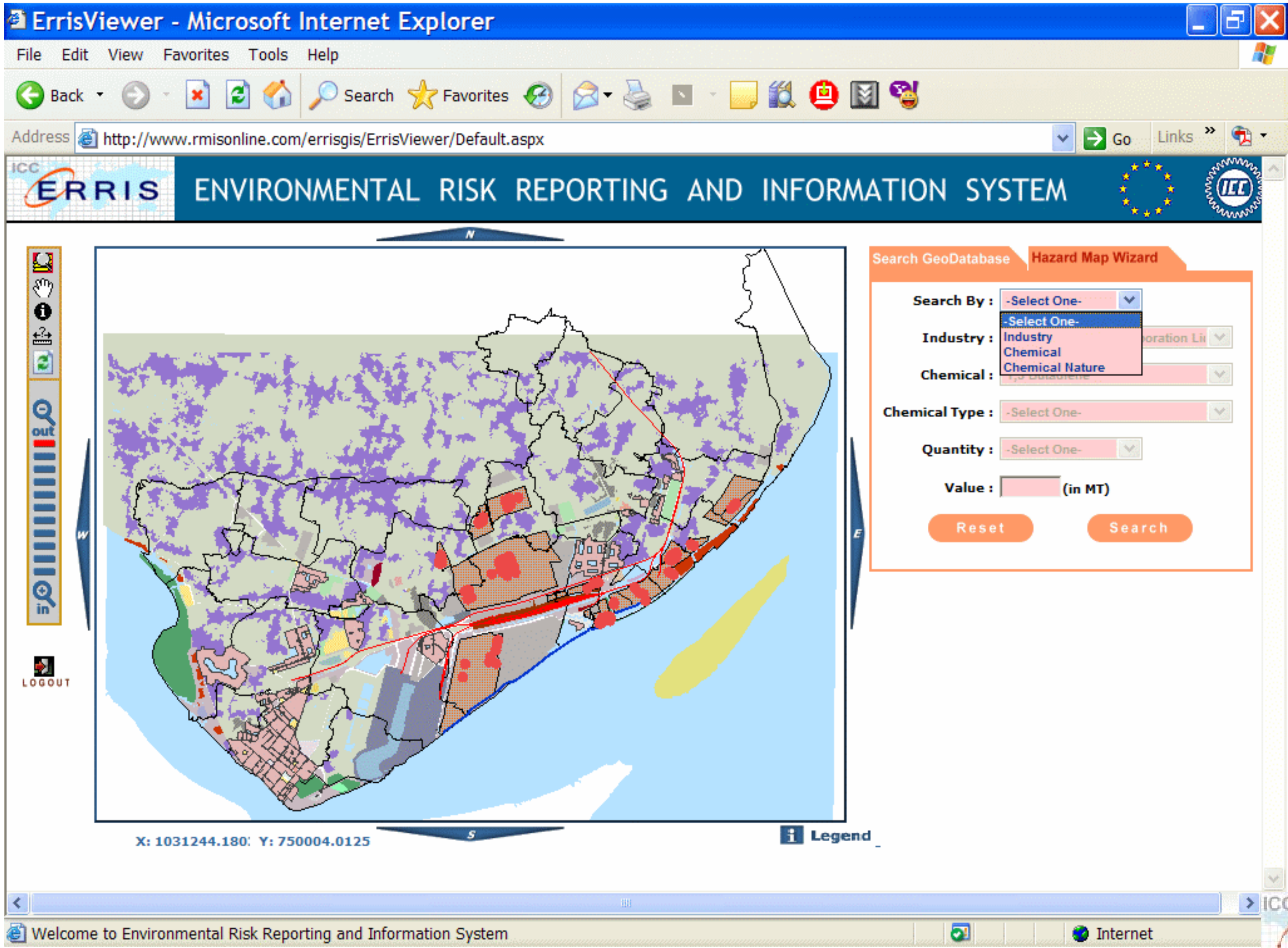
ERRIS Objectives :

To formulate a voluntary system for reporting of risks and develop a spatial GIS based information system to store and make available risk related information to the stakeholders.

Key Features :

- Centralized web server based database providing spatial and other related information on hazards and vulnerability
- Easy to access and update from remote locations
- Security of information ensured through selective access

ERRIS



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Hazard Map Wizard
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Chemical Type :
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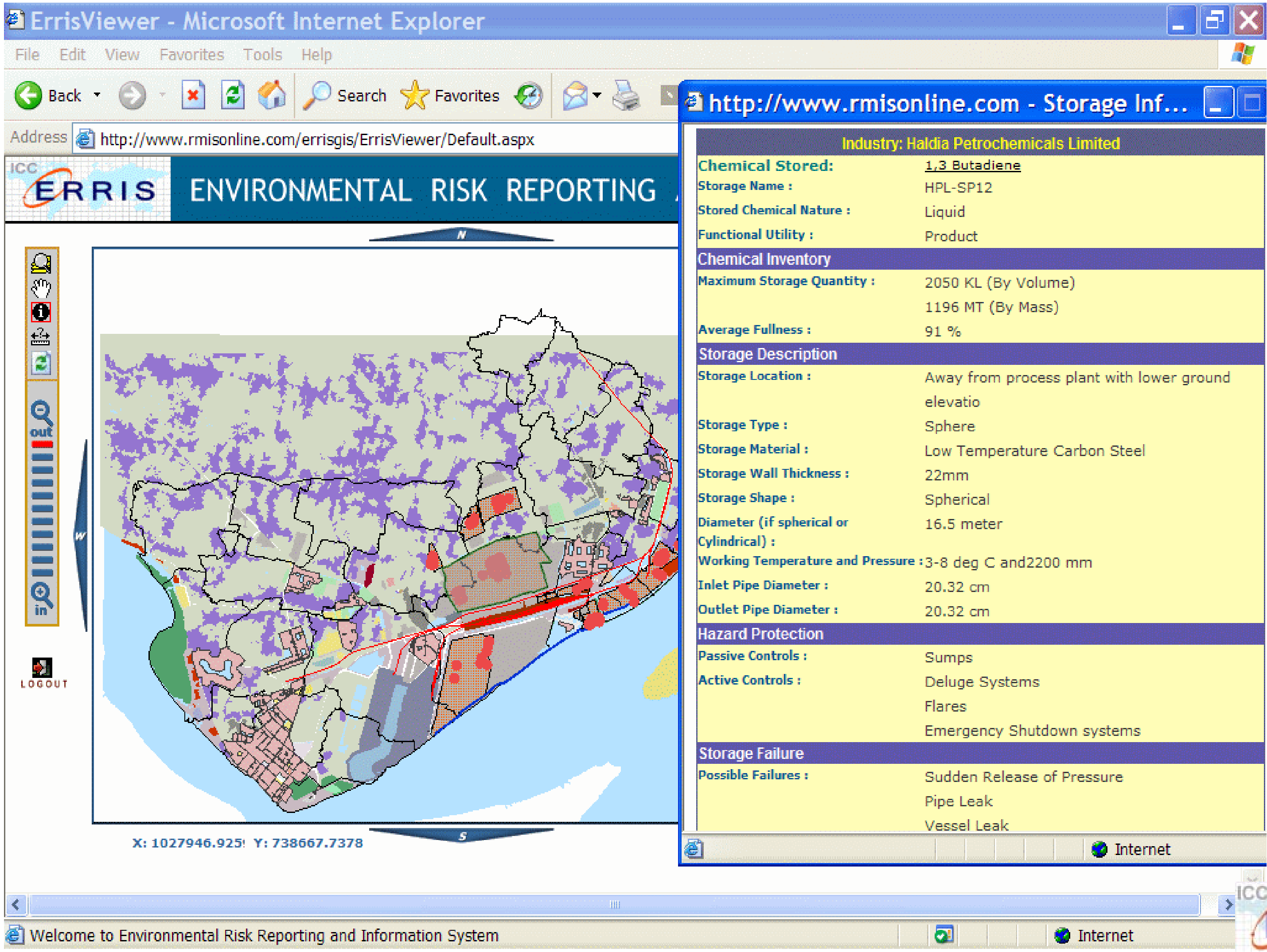
Welcome to Environmental Risk Reporting and Information System
Internet

ERRIS



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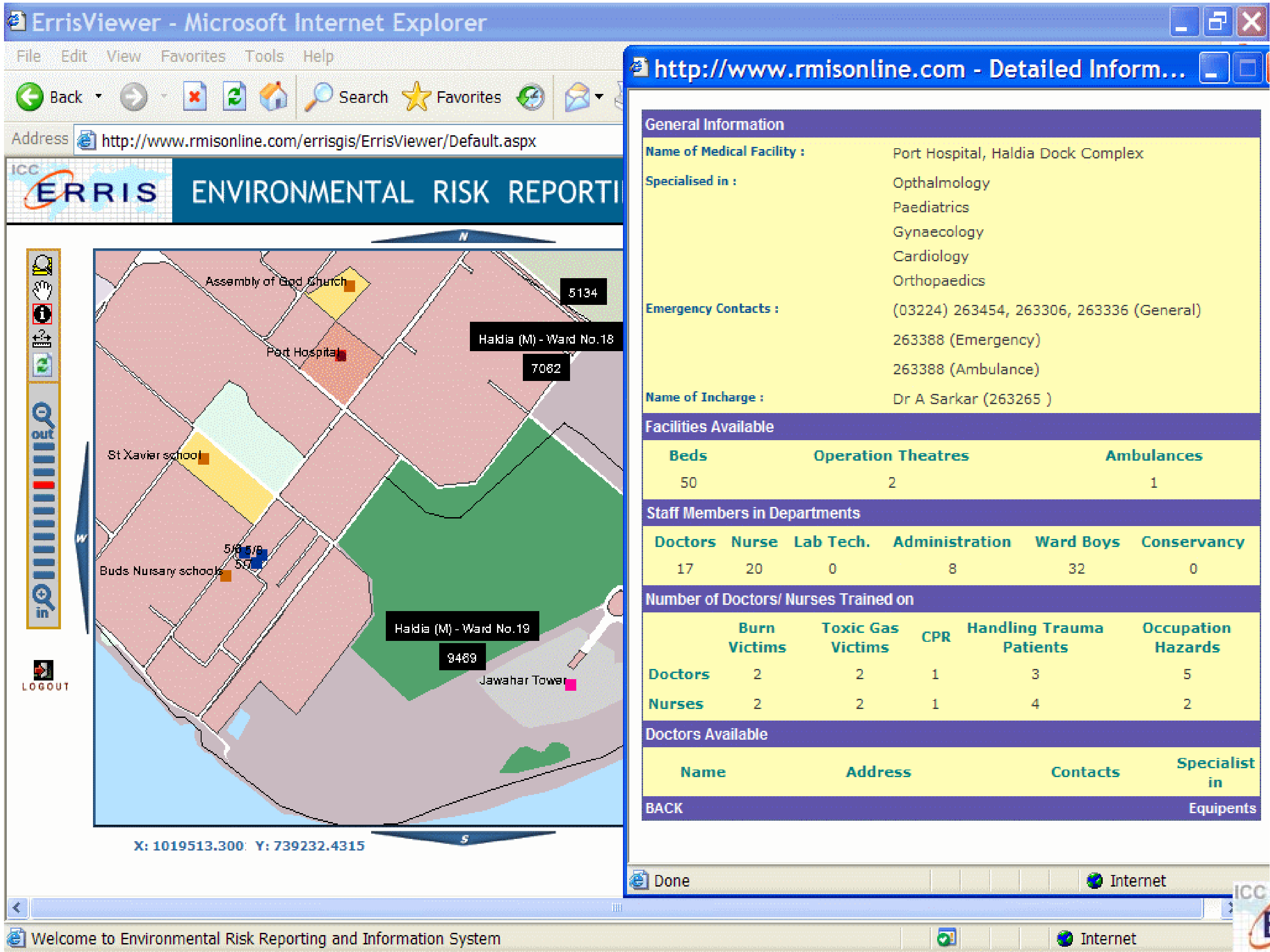
LOGOUT
X: 1027946.925! Y: 738667.7378
Welcome to Environmental Risk Reporting and Information System
Internet
http://www.rmisonline.com - Storage Inf...
Industry: Haldia Petrochemicals Limited
Chemical Stored: 1,3 Butadiene
Storage Name : HPL-SP12
Stored Chemical Nature : Liquid
Functional Utility : Product
Chemical Inventory
Maximum Storage Quantity : 2050 KL (By Volume)
1196 MT (By Mass)
Average Fullness : 91 %
Storage Description
Storage Location : Away from process plant with lower ground elevatio
Storage Type : Sphere
Storage Material : Low Temperature Carbon Steel
Storage Wall Thickness : 22mm
Storage Shape : Spherical
Diameter (if spherical or Cylindrical) : 16.5 meter
Working Temperature and Pressure : 3-8 deg C and2200 mm
Inlet Pipe Diameter : 20.32 cm
Outlet Pipe Diameter : 20.32 cm
Hazard Protection
Passive Controls : Sumps
Active Controls : Deluge Systems
Flares
Emergency Shutdown systems
Storage Failure
Possible Failures : Sudden Release of Pressure
Pipe Leak
Vessel Leak
Internet

ERRIS



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Assembly of God Church
Port Hospital
St Xavier school
Buds Nursary schools
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Haldia (M) - Ward No.18
7062
Haldia (M) - Ward No.19
9469
Jawahar Tower
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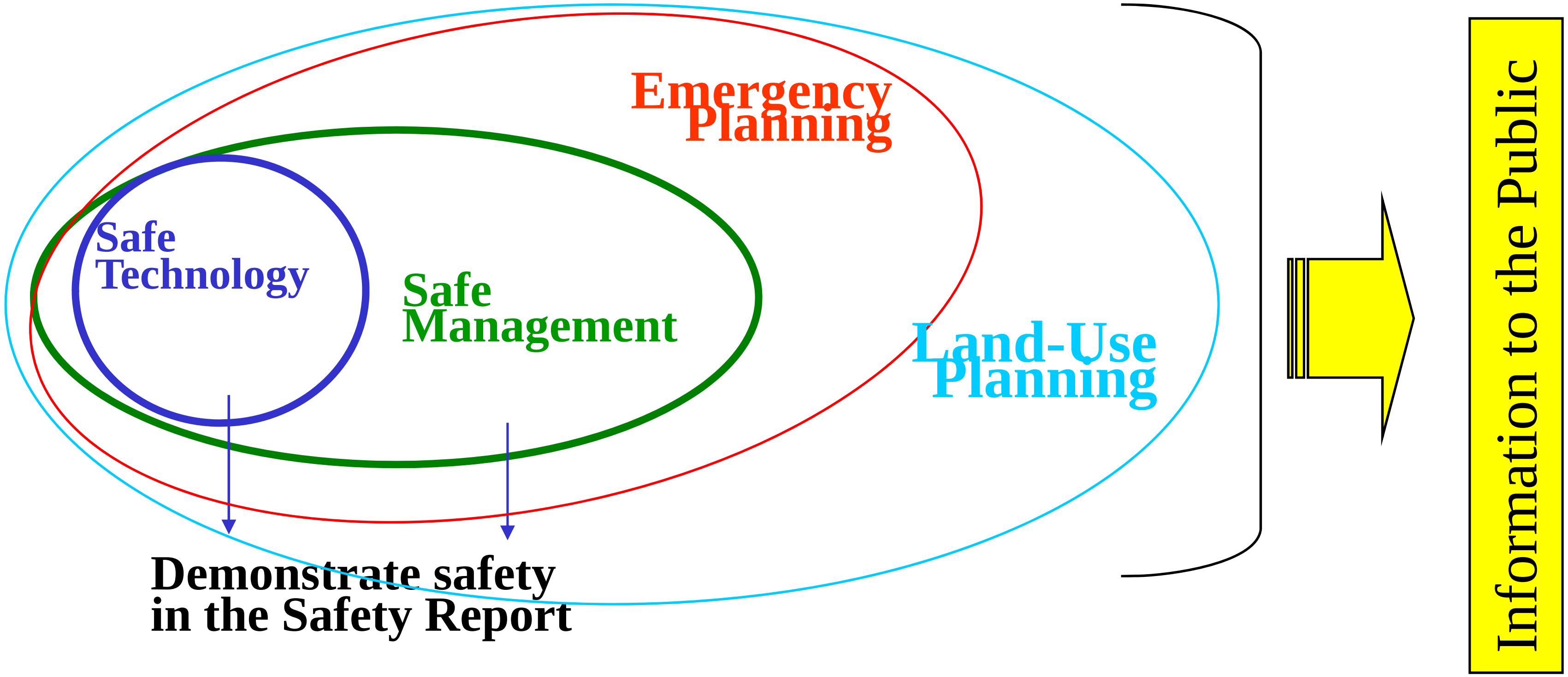
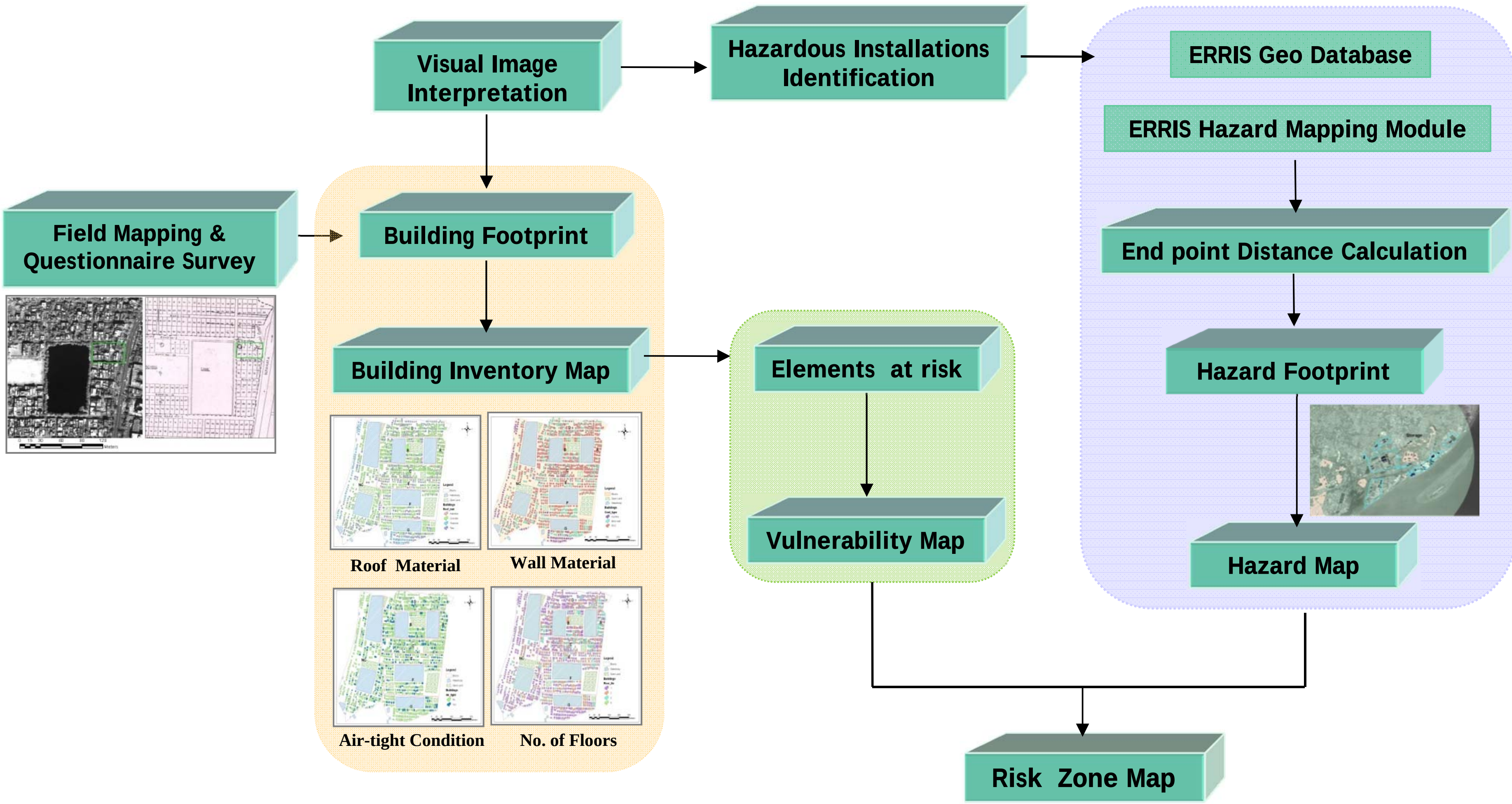
Welcome to Environmental Risk Reporting and Information System
Internet
http://www.rmisonline.com - Detailed Inform...
General Information
Name of Medical Facility : Port Hospital, Haldia Dock Complex
Specialised in : Opthalmology
Paediatrics
Gynaecology
Cardiology
Orthopaedics
Emergency Contacts : (03224) 263454, 263306, 263336 (General)
263388 (Emergency)
263388 (Ambulance)
Name of Incharge : Dr A Sarkar (263265)
Facilities Available
Beds 50
Operation Theatres 2
Ambulances 1
Staff Members in Departments
Doctors 17
Nurse 20
Lab Tech. 0
Administration 8
Ward Boys 32
Conservancy 0
Number of Doctors/ Nurses Trained on
Burn Victims, Toxic Gas Victims, CPR, Handling Trauma Patients, Occupation Hazards
Doctors 2 2 1 3 5
Nurses 2 2 1 4 2
Doctors Available
Name Address Contacts Specialist in
BACK
Equipents
Done
Internet

Haldia Case Study – Land use Zoning

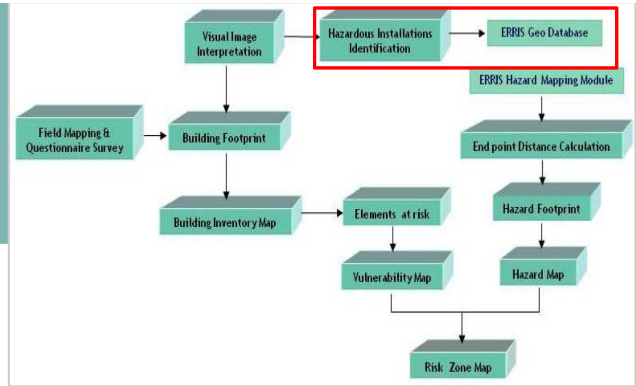
Philosophy for Land use Zoning

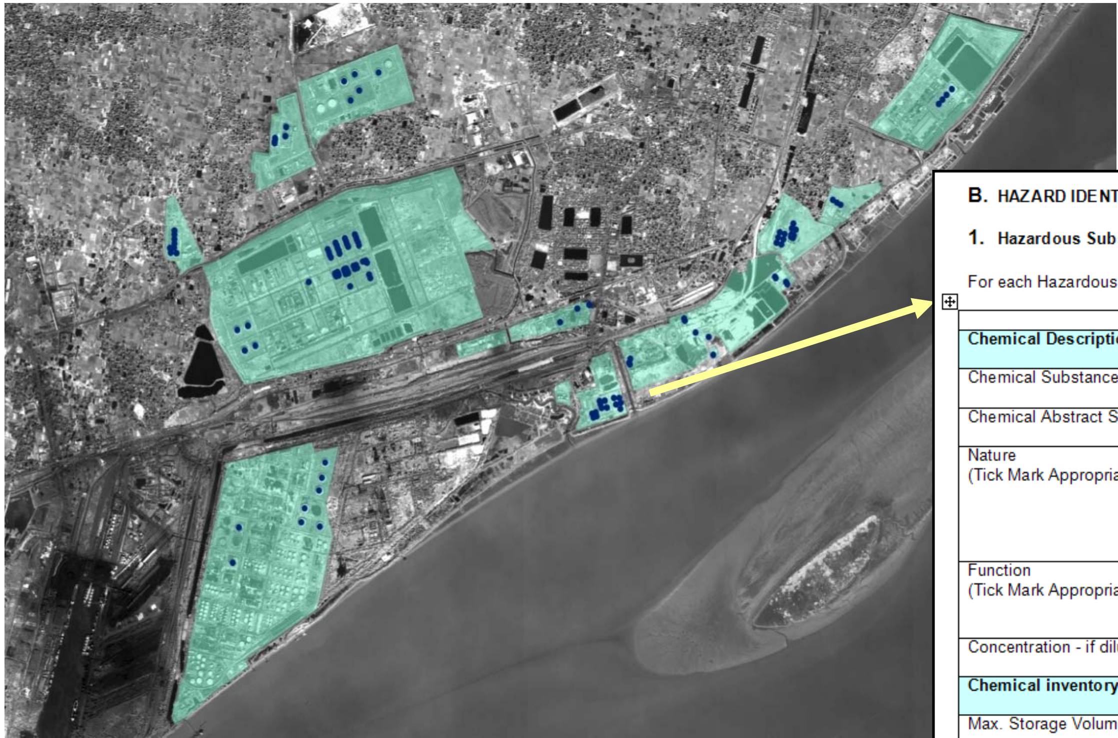


Methodology for Land use Zoning



Hazardous Installations





Source: ERRIS Project

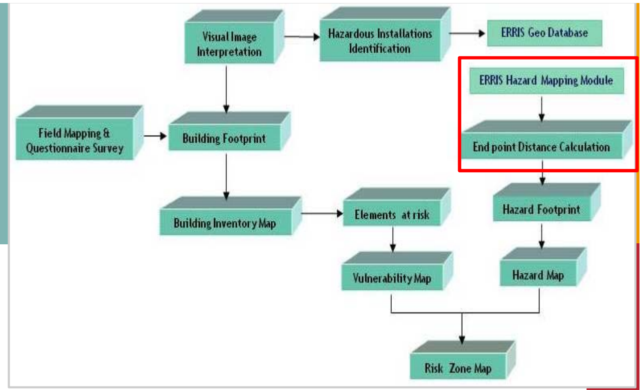
B. HAZARD IDENTIFICATION

1. Hazardous Substance Inventory

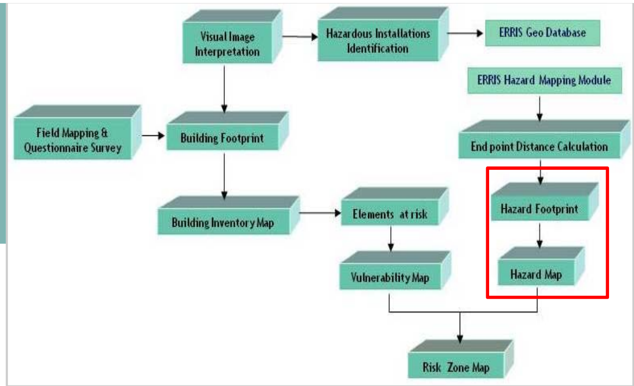
For each Hazardous Chemical Storage furnish the following information :

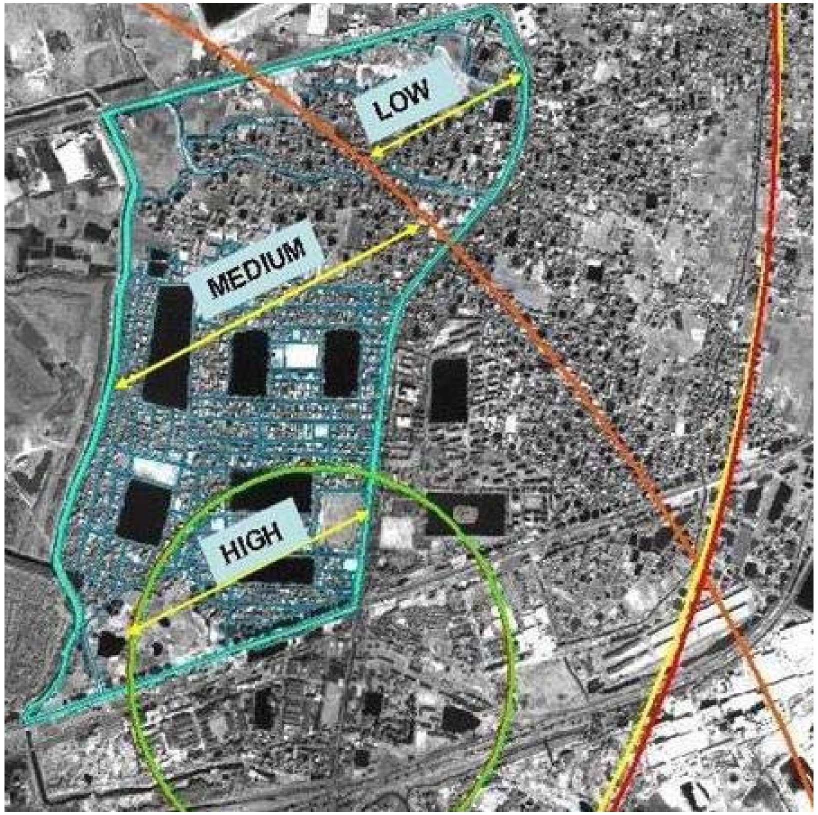
	Storage Container A	***Storage Container B***
Chemical Description		
Chemical Substance Name		
Chemical Abstract Service (CAS) No.		
Nature (Tick Mark Appropriate)	☐ Pure ☐ Mixture ☐ Solid ☐ Liquid ☐ Gas	
Function (Tick Mark Appropriate)	☐ Raw Material ☐ Intermediate ☐ Product	
Concentration - if diluted with Water (%)		
Chemical inventory		
Max. Storage Volume (m^3)		
Max. Storage Quantity (in tons)		
Average Fullness (%)		
Maximum Daily Amount		
Storage Description		
Storage Location (Description of area within 30 words)		
Storage / Container Type		
Material of Construction		
Wall thickness		
Shape		
Diameter (if cylindrical / spherical)		
Working Temperature		

Hazard Footprints



Hazard Zonation Maps





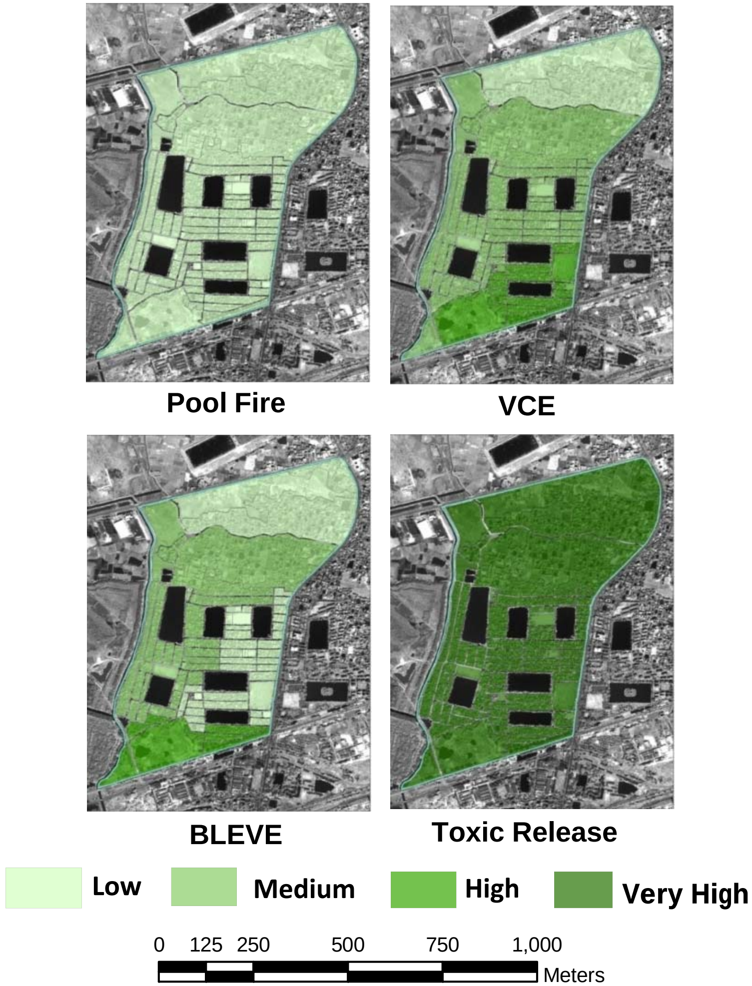
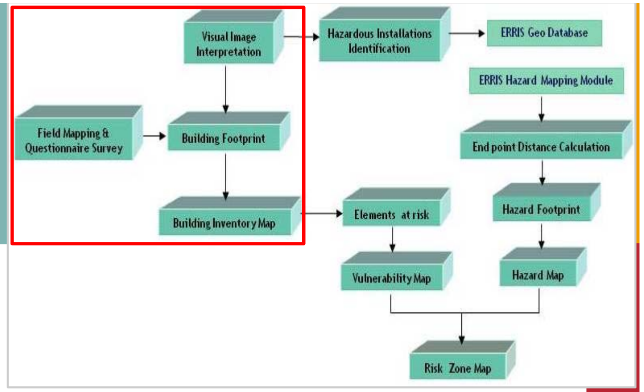


Table: Number of MCLS Footprints

Hazard Score	No. of MCLS Foot prints	Category
4	More than 6	Very High
3	5 - 6	High
2	3 - 4	Medium
1	Less than 3	Low

Database Preparation



Building Data

Block	A
Plot ID	1
Building ID	10/A/1/1
No. of Floors	2
Age (Years)	12
Construction Type	RCC
Roof Material	Concrete
Air Tight	Yes

Population Data

8 AM – 6 PM	6
6 PM – 8 AM	4

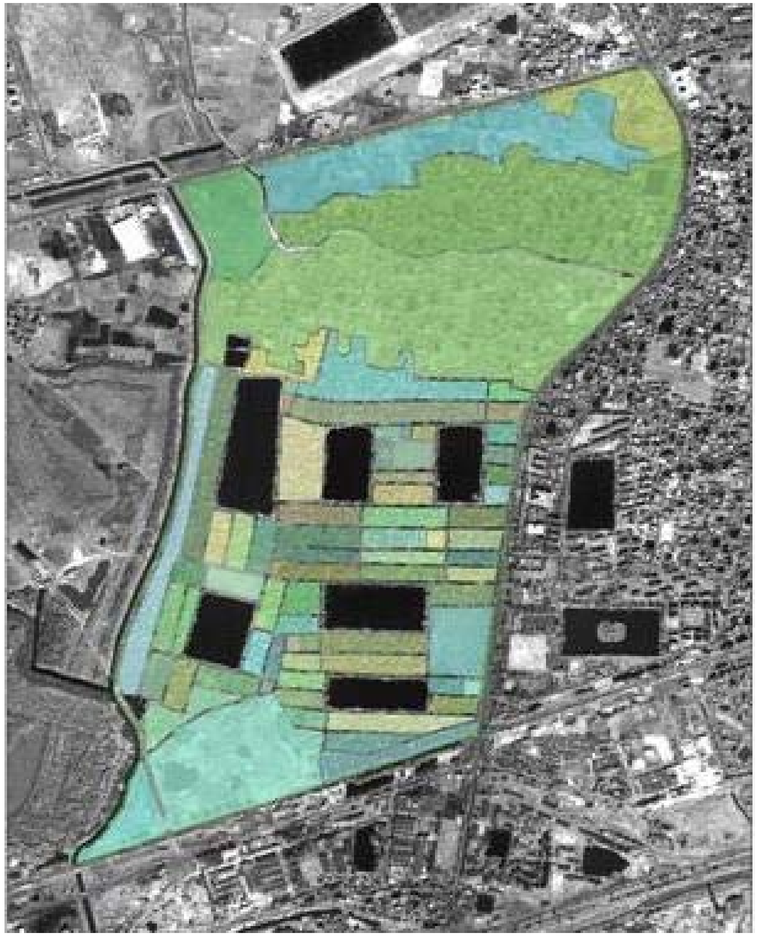

Kuchha House


Thatched wall

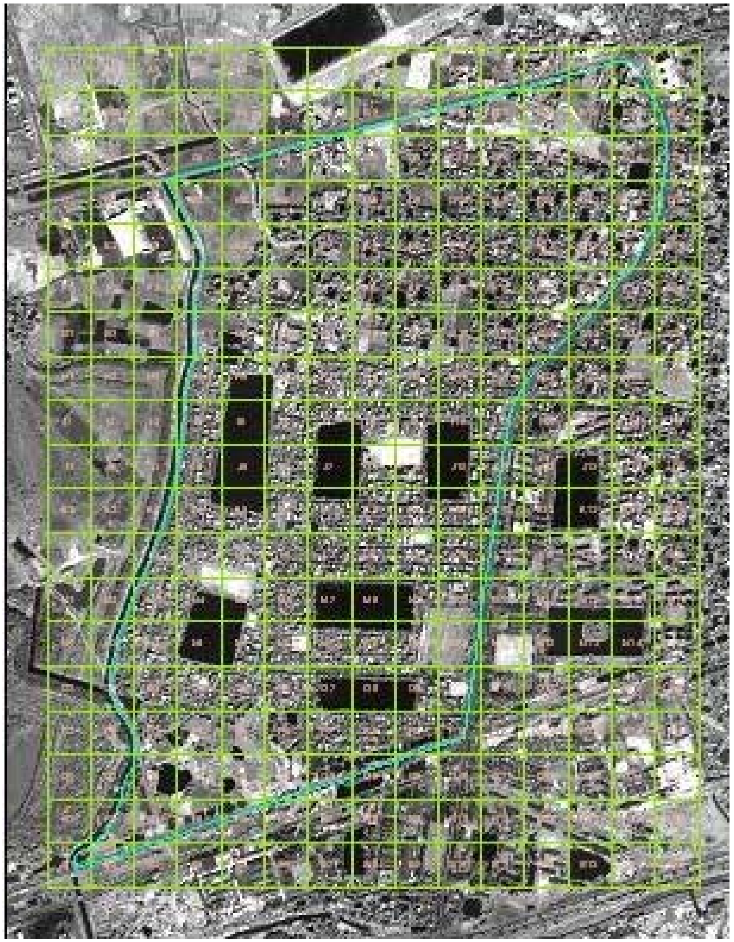

Brick walled tiled roof


Bamboo wall

Approaches for Assessment

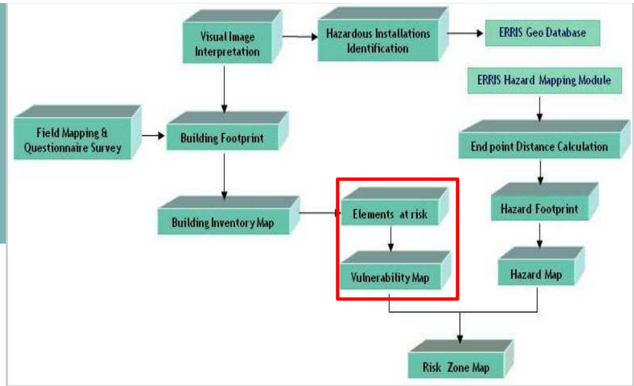


Mapping Unit Approach



Grid Approach

Building Vulnerability



- Different Building Parameters considered
  - Roof Material (RM)
  - Construction Type (CT)
  - Number of Stories (S)
  - Airtight Condition (AT)
- Ranks (R) assigned based on their vulnerable characteristics
- Weights (W) assigned with respect to impact of hazard on building parameters
- Individual building vulnerability assessed using MCE
- Based on estimated vulnerability, buildings categorized
  - Low
  - Medium
  - High
  - Very High

Table: Ranks assigned to different Building Characteristics

Building Characteristics	Types	Vulnerability Ranks
Roof Material	Thatched	4
	Tiles	3
	Asbestos / Tin	2
	RCC	1
Construction Type	Kuchha	4
	Brick Walled	3
	RCC	1
Number of Stories	Three / Four	4
	Two	2
	One	1
Air Tight Conditions	No	4
	Yes	1

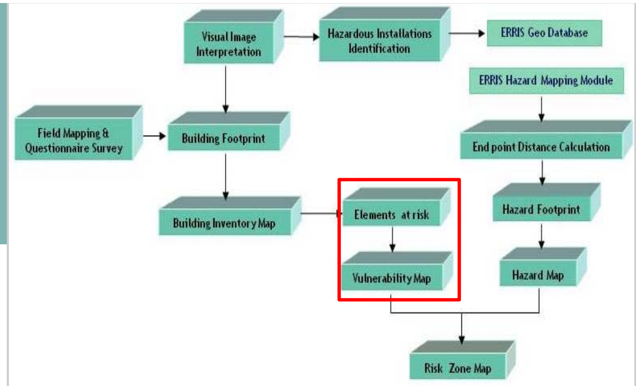
Table: Weights assigned for different hazards

Building Characteristics	Pool Fire	VCE	BLEVE	Toxic Release
Roof Material	0.5	0.2	0.2	0.1
Construction Type	0.3	0.4	0.4	0.1
Number of Stories	0.1	0.3	0.3	0.3
Airtight Condition	0.1	0.1	0.1	0.5

Building Vulnerability = [W of RM*(R of RM)]+[W of CT*(R of CT)]+ [W of S*(R of S)]+[W of AT*(R of AT)]

ITC

Vulnerability Assessment



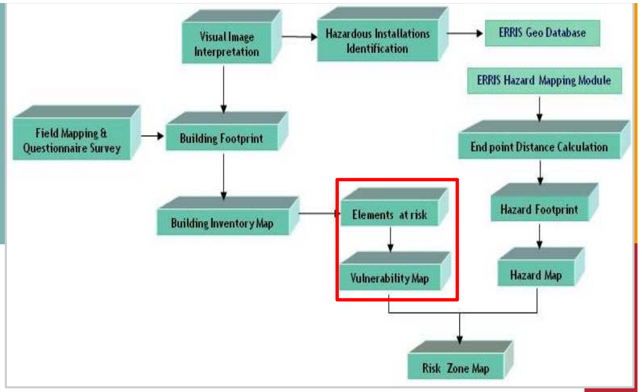
Using MCE, building vulnerability and population (inside) combined together to assess vulnerability of Mapping Unit or Grid

Table: Criteria for Vulnerability Assessment based on a Grid Approach

Vulnerability Score	Vulnerability Criteria
4	Number of Population at a particular time is higher than 200
	More than 50% buildings have vulnerability score 4
3	Number of Population at a particular time is higher than 100
	More than 50% buildings have vulnerability score 3 & 4
2	Number of Population at a particular time is higher than 50
	More than 50% buildings have vulnerability score 2 & 3
1	Number of Population at a particular time is less than 50
	More than 50% buildings have vulnerability score 1

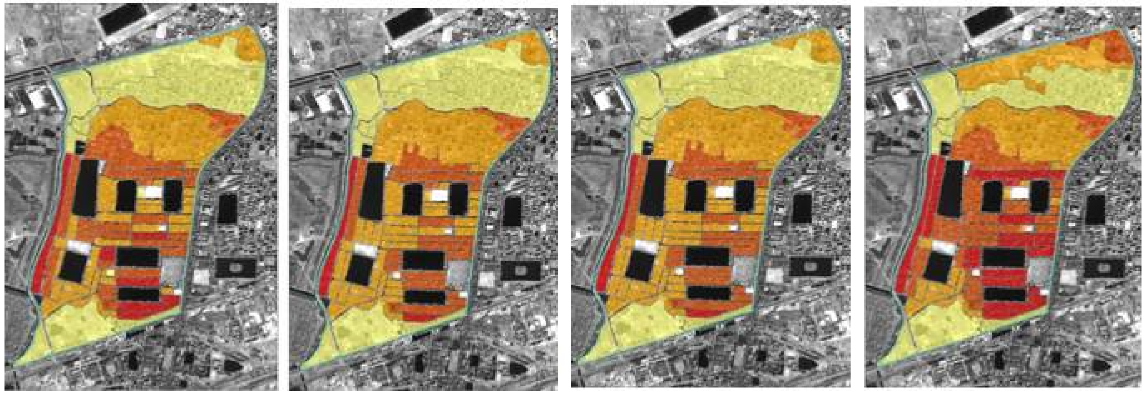
ITC

Vulnerability of Mapping Units



Day Time Scenario:

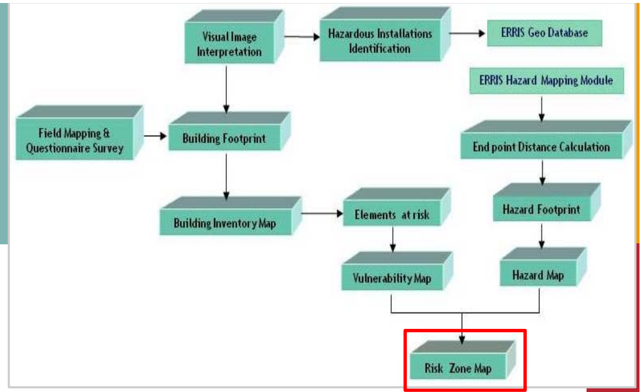
Night Time Scenario:



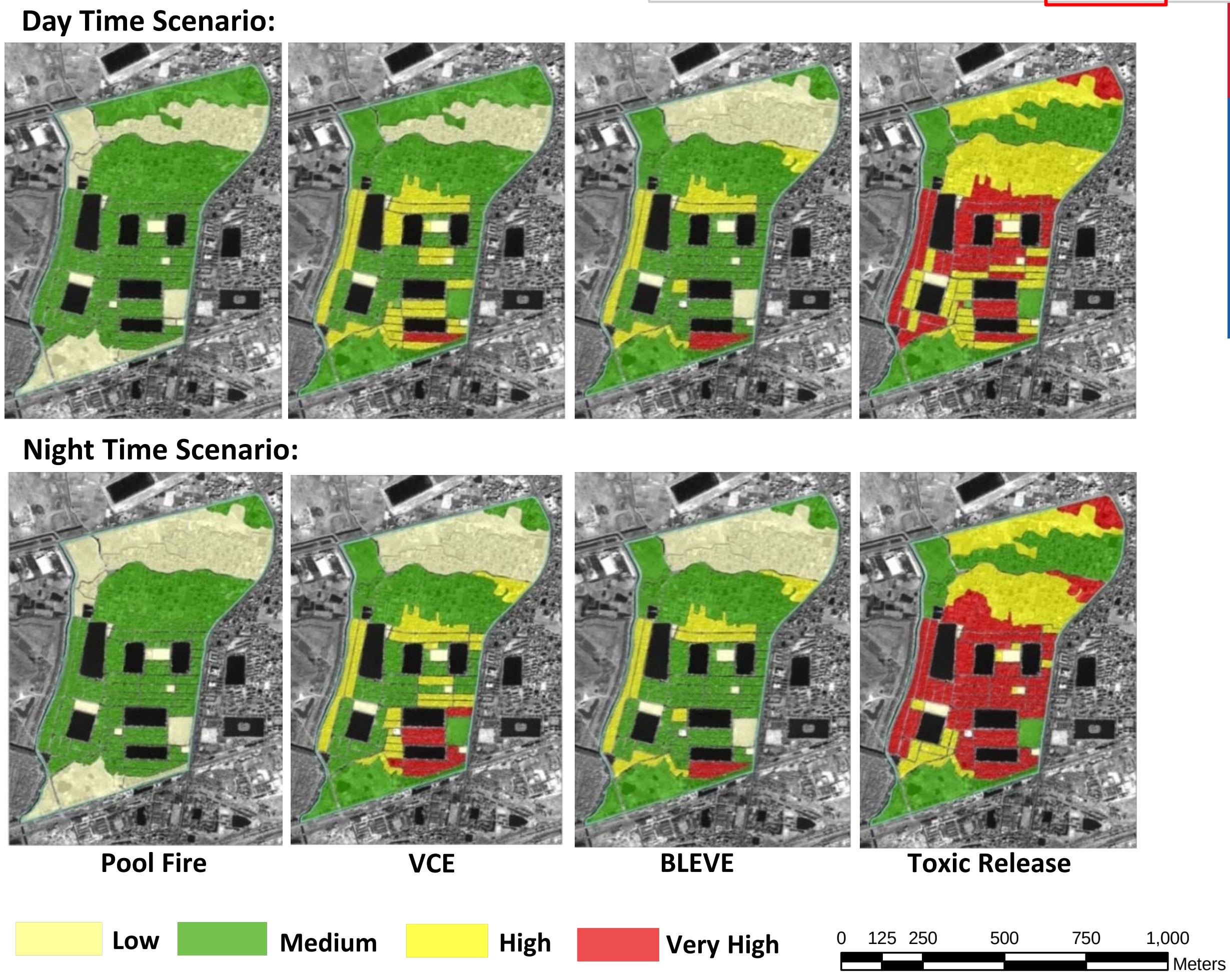
Pool Fire VCE BLEVE Toxic Release

Low Medium High Very High

Risk Zonation of Mapping Units



LIKELIHOOD \ CONSEQUENCE	1	2	3	4
4	4	8	12	16
3	3	6	9	12
2	2	4	6	8
1	1	2	3	4



Thank you!