# PART B

# TECHNICAL GUIDANCE

# I Technical aspects on safety and land-use planning with regard to the siting and modification of hazardous activities

Land-use planning is a framework through which land-use monitoring and compatibility evaluation decisions as well as planning adjustment are implemented. This involves a range of technical, administrative and legislative processes for the purpose of selecting areas and deciding/adopting the type of development within these zones (compatible with adjacent land use). All of these processes are consistent with either national applicable laws, regulations, policies and legislation or international agreements such as conventions and protocols. The land-use planning structure and approach depends also on the history of the country, its industrial and economic development, the available scientific and technical expertise and the risk/safety culture of its population.

This chapter describes land-use planning methods (and risk acceptance criteria) and best practices in relation to land use planning for, or in the vicinity of, major hazard establishments within the UNECE and EECCA countries considering transboundary effects.

Disclaimer: the following information is included in this Guidance only as a demonstration of the land-use planning approaches used in the countries. This information should not be taken as a recommendation by the UNECE to use any of these approaches.

## 1.1 Land use planning approaches

The UNECE countries rely on technical and scientific advice to support their land use planning decision making a part of which is based upon the used risk assessment methodology and risk acceptance criteria. Risk consideration is one amongst the several other aspects/components that contribute to the decision making process such as economic development, nature protection and heritage preservation. Hence, different outcomes are possible depending on the risk methodology used and other aspects considered in the decision making. The approaches can be grouped under four categories reflecting their main (dominant) characteristics of the used risk approach:

1. *deterministic approach*: defines so-called “generic distances” which are derived from the kind of hazardous activity considered, operational acquired experience, environmental impact and expert judgement in general;
2. *consequence-based approach*: identifies one or more accident scenarios, assesses their consequences and evaluates the resulting effects for instance on individuals in terms of fatalities and injuries;
3. *risk-based approach*: assesses both consequences and probabilities of the accident scenario occurrence and evaluates the resulting individual and/or societal risk;
4. *semi-quantitative (or semi-probabilistic) approach*: method based on a quantitative consequence evaluation of an accident scenario and qualitative estimation of its frequency occurrence.

It must be stressed out that hybrid approaches combining two or more of the methods above are also used.

### 1.1.1 Deterministic based approach

The deterministic approach is straightforward method that relies on expert judgment for defining generic distances between areas occupied by hazardous activities and the surrounding zones used for other community purposes. This judgment is based on experience derived from operating similar hazardous facilities previous events such as accidents, incidents, near-misses, environmental impact and historical data. The pre-defined generic distances depend on the types of hazardous substances and activities present in the hazardous facility and that potentially can be involved in an accident. Hence, these distances are not related to risk or based on a detailed analysis of the hazardous facility. According to this approach, one should:

1. apply the most recent prevention and mitigation measures so that the consequences of any possible event, based on predefined scenarios and threshold values (e.g. 0.1 bar, ERPG2[54]), have no impact beyond the hazardous facility perimeter;
2. propose a gradual land zoning by which incompatible areas (such as industrial and residential areas) are not close to each other.

This method can provide a certain separation between the developments and the hazardous activity and can be considered by a country that is not using either a consequence or a risk assessment approach. In Germany the deterministic approach is used and a "table of distances" is defined for several hazardous substances to look up the minimum distances from facilities involving these substances. For instance, ammonia (400 m), hydrogen sulphide (800 m) and chlorine (1350 m).

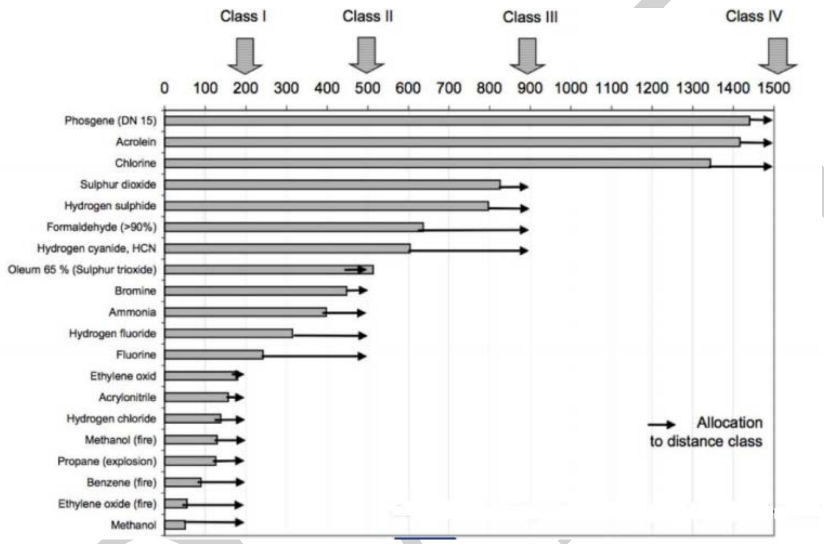


Figure 1 Safety distances for hazardous substances according to the German legislation (graph taken from Guidance SFK/TAA-GS-1 [55])

### 1.1.2 Consequence (-effects) based approach

The consequence based approach is based on the assessment of the consequences of credible worst accidents only and does not require evaluating the frequency of occurrence of these accidents. The concept of worst case relies on the assumption that when sufficient measures are in place to protect the population from the worst accident then also sufficient protection exist for any less serious accident.

The consequences are associated with their corresponding thermal radiation, overpressure and toxic concentration effects and compared with approved damage thresholds values. These threshold values indicate the beginning of the undesired effect (expressed as fatalities, irreversible effects, reversible effects) after receiving a dose for a given exposure period. Examples of damage thresholds values for the three type of consequences are outlined in Table 4. An illustrative example of threshold values for chlorine continuous release is visualised in Figure 2 and Figure 3.

Table 4 Examples of damage thresholds values for determining distances

[54] ERPGs are developed by the Emergency Response Planning committee of the American Industrial Hygiene Association and estimate the concentrations at which most people will begin to experience health effects if they are exposed to a hazardous airborne chemical for 1 hour (website http://www.aiha.org/get-involved/aihaguidelinefoundation/emergencyresponseplanningguidelines/Pages/default.aspx)

[55] Guidance "SFK/TAA-GS-1 produced the German Hazardous Incidents Commission (SFK) and the German Technical Committee for Plant Safety (TAA), 2005

| Consequence | Effect-Distance |
|---|---|
| Thermal effects | determination of a distance corresponding to a thermal radiation which, for a given exposure period, can cause burns likely to be lethal or cause serious injury; |
| Explosion | determination of a distance corresponding to an overpressure likely to be lethal or cause serious injury (e.g. burst eardrums). |
| Toxic release | determination of a distance corresponding to a lethal toxic dose or serious injury (e.g. LCl %, that is the Lethal Concentration corresponding to the "first death" or lethality 1 %); |

Hence consequence distances from the hazardous facility are estimated based on the damage thresholds values. Typically the "lethal" and "irreversible" effects thresholds are used for defining two zones around the hazardous facility.  The inner zone is characterised by lethal effects and therefore any urban development is not allowed.  In the outer zone the irreversible effects occur, hence the presence of vulnerable population and population growth are forbidden.  Such an approach was used in France before the 2001 Toulouse accident and is used in other countries

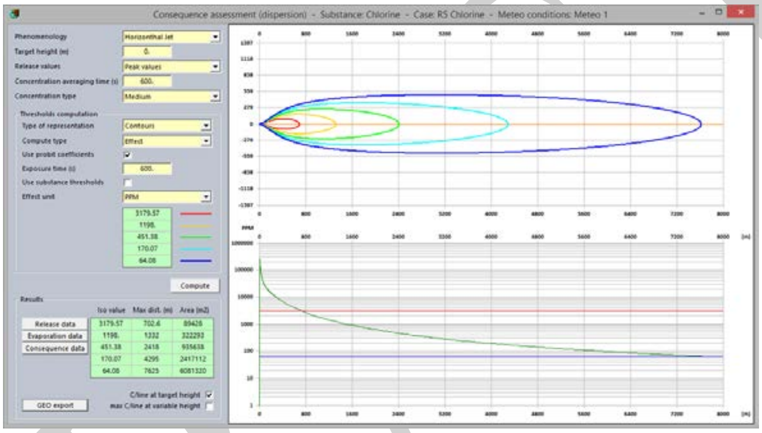


Figure 2 Example of Chlorine continuous release by ADAM 1.0 (MAHB) (graph courtesy DG JRC MAHB)

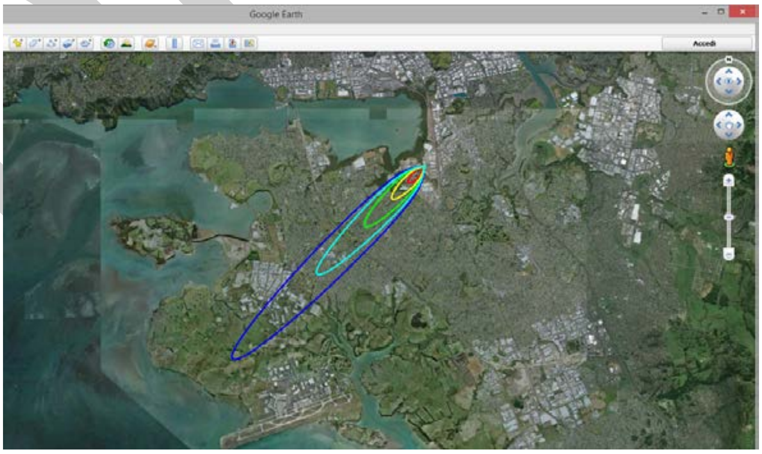


Figure 3 Example of Chlorine continuous release by ADAM 1.0 (MAHB) represented in google Earth (graph courtesy DG JRC MAHB)

### 1.1.3 Risk based approach

In the risk-based approach a quantitative risk assessment method is used to calculate both the consequences of the identified accident scenario and its expected frequency of occurrence. This method requires collecting or having access to large amounts of data such as reliable failure frequency data, effect endpoints values, population and environmental data and models for calculating the consequences and effects. Although being more thorough, this method more complicated, more time-consuming and more expensive (and results can be questioned because of the uncertainties associated with the frequencies used). A risk assessment consist of five elements which are:

- hazard identification;
- probability/frequency estimation of the potential accidents occurrence (taking into account the existing safety/preventative measures and systems);
- consequence estimation of the accidents;
- overall risk indices integration;
- calculated risk comparison with acceptance/tolerability criteria.

The two risk measures that are usually calculated are the individual risk and societal risk which are respectively represented under the form of risk contours, societal risk curves and societal risk maps.

The land-use zoning decision is based upon specific risk individual risk and societal tolerability criteria. As shown in Figure 4 after calculating the risk in a point this value is compared with the tolerability value associated to that point. Hence, overlapping of the individual risk map with the area map enables obtaining the zone compatibility of every sensitive area element (i.e. houses, vulnerability centres).

This approach has been adopted by The Netherlands, United Kingdom and Spanish Autonomous Region of Catalonia. The Netherlands evaluate the land-use compatibility also through societal risk (i.e. F-N curves) and societal risk maps the latter being easier to understand by the public.

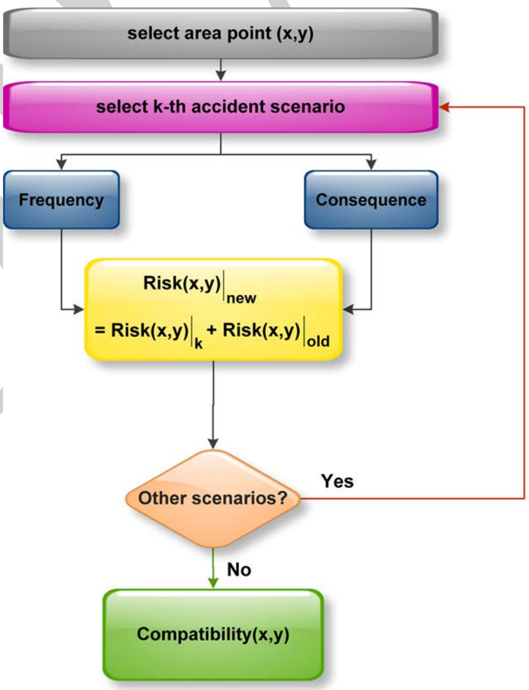


Figure 4 Process for calculating the risk in a generic point of the area and verifying whether it is compatible with the proposed land-use (graph courtesy Lorenzo van Wijk)

### 1.1.4 Semi-quantitative approach

The semi–quantitative (or semi-probabilistic) approach uses a hybrid method that is based on a quantitative consequence evaluation of an event and qualitative estimation of its frequency occurrence. Often the event is chosen from a set of credible accident scenarios and represents the worst-case credible accident scenario. Also in this case the quantitative assessment needs data such as reliable failure frequency data, effect endpoints values, population and environmental data and models for calculating the consequences and effects. As explained in Section 1.1.2 also in this case the consequence assessment outcome can also be presented as an effect thresholds values. Frequency is estimated by means of defined probability classes.

A qualitative compatibility matrix is obtained by associating a compatibility threshold value to each combination of vulnerability/effects thresholds value and frequency. Hence, the land-use zoning decision is based upon comparing the found compatibility value in a point with the most restrictive compatibility value associated to that point as shown in Figure 5. This approach is used in Italy and France.

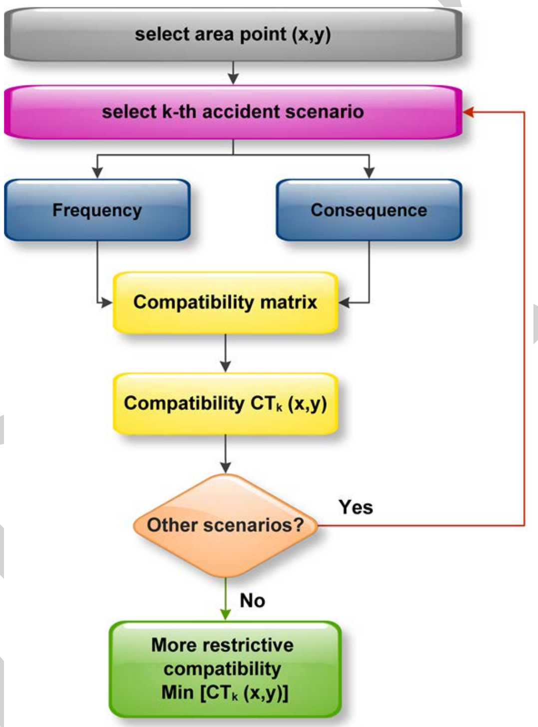


Figure 5 Semi-quantitative process for verifying that the calculated compatibility in a point of the area is compatible with the proposed land-use (graph courtesy Lorenzo van Wijk)

## 1.2 Land use planning and control

There are several formal definitions of land-use planning but all of them have the common understanding of a decision process about the optimal use of land so as different socioeconomic activities, i.e. agriculture, housing, industry, recreation and commerce, should take place to create a healthy and sustainable environment to the benefit of the local community. Hence the land use decision must also account for all sources of risk, both natural and man-made.

Urban planning is a well consolidated process which guided the development of cities and towns for years. However, with the advent of new legislations (e.g. Seveso II/III) these plans must be re-considered to explicitly include the risk posed by existing or future hazardous activities. The presence of risk sources makes the land-use planning problem more difficult due to the need to consider the safety of the population, the related economic aspect and the environmental protection.

The land-use planning problem involves public competent authorities at all levels, national, regional and local, whose particular duties depend on the specific country legislation and organisation. In a hypothetical country where it can be supposed that there is a national, a regional and local authority, the national authority sets up policies to make the presence of hazardous installations compatible with the urban development, i.e. to define the compatibility criteria; the regional authority is responsible for defining the land-use planning analysis procedure; finally the local authority is responsible for the implementation of the land use plan in respect to existing norms and legislation. Such plan should be "dynamic" i.e. periodically revisited to account for new compatible developments.

Obviously, in real situations, the organization and the interrelationships among the various stakeholders is more complex, but the simplification made of a hypothetical country is useful to describe the main concepts.

A land-use planning process in areas where hazardous substances are present requires the implementation of the following steps:

1. Description of the area and of the land use defined before the new legislation on LUP takes place. A set of maps describe the land uses as e.g. residential (high density, medium and low density areas), industrial, commercial, agricultural. Maps of transport networks such as roads, rails, channels, hydrogeology, i.e. surface water, ground water, areas of particular interest, e.g. forest, recreational, parks, coasts.
2. To this set of maps another information needed for the LUP analysis is the map of vulnerable places, i.e. locations where more vulnerable people are present (e.g. hospitals, elderly houses, schools, parks) or where a considerable number of people may be present from time to time (e.g. churches, shopping centres, theatres, railways stations).
3. Description of industrial risk sources, considering both plants and transport of dangerous substances. The source of information is constituted by the safety reports produced by the manufacturers. Depending on the risk analysis approach adopted by the country, safety-distances/accident-effects/individual-risk maps are made available. Other maps can be produced for transport of hazardous substances.
4. By superimposing the maps of the existing land uses with the maps safety distances or accident consequences or risk maps (depending on the approach), it is possible to evaluate the compatibility of industrial activities with land uses around them (according to the criteria defined by the national authority). This study is not so simple since it involves different stakeholders (authorities, industry and population) with different interests. Hence, similar to the risk acceptability issue, the solution of the LUP problem must be conceived as more a consensus building process rather that the application of an algorithm. The consensus building may be greatly facilitated by the use of modern risk analysis tools based on Geographic Information Systems platforms, which are able to represent all georeferenced maps and spatial risk data in a single environment, allowing to rapidly verifying (by re-running the risk model) the result of new assumptions or the use of new data. The final result is the new land use map in which the industry is compatible with the land use.

### 1.2.1 For new hazardous industrial activities

The evaluation of the compatibility of a new industrial activity, such as the request of an industry to build a new plant or to increase the quantity of hazardous substances requires a new Safety Report. The risk posed by the new potential activity is added to the existing risk map. Should the increased risk be not acceptable, then the authorities can ask the industry to possibly reduce the risk level through proper design upgrading.

The applications of the compatibility criteria to the new situation allow stakeholders to draw conclusions about the acceptance/rejection of the new activity or, if possible, the modification of the involved land use.

### 1.2.2 For existing hazardous industrial activities

In the case of existing hazardous activities the problem of land-use planning is different and also more complex to address. There are two kind of controls that need to be exercised under such circumstances. One relates to modifications occurring within the hazardous facility whereas the other one refers to new developments, such as residential areas or public transport (e.g. airports, railway stations), in the vicinity of the existing hazardous facility.

A hazardous facility can modify a chemical process, the amount of hazardous substances, equipment or the safety systems. Before proceeding the operator of the hazardous facility informs the authorities about the planned modifications. This can occur through the Safety Report prepared the operator of the hazardous facility. The authority will assess whether these modifications increase the risk to human or off-site consequences/effects of an accident in the zones around the facility. It is worth noting that national legislation establishes the criteria under which a modification should be considered as significant. For instance, Table 5 presents the criteria defined by the UK HSE for establishing the type of modifications that could have significant repercussions on the levels of risk to the people and the environment.

To maintain safety distances in the long term between hazardous activities and other zones, such as those assigned for residence, public spaces and services as well as areas with culture heritage and natural sensitivity characteristics, requires having policies that capture this aspect of preserving these distances. This should also describe the procedure for establishing when a proposed development can be considered in the vicinity of the facility. One approach is defining a consultation distance or zone based on individual risk or damage effects considerations and which defines whether a development is within or outside the consultation zone. Another way is organising the land-use in clear separate zones such as industrial, service and residential zones.

In both cases the aim is fulfilling the compatibility criteria with the land-use of the zones. Authorities may request the existing hazardous facility to take measures that can reduce the level of risk in the zones with an assigned land-use that have become incompatible.

Building consensus becomes more difficult to achieve and may come at a cost. For example, a final decision of the authority can be relocating the hazardous facility or moving people, living in an area with unacceptable risk level, to a safer location.



Table 5 Examples of changes that could have significant repercussions (from UK HSE[56])

| Change | Description of change |
|---|---|
| SMS changes | Reorganisation of the management structure.<br>Contractorisation, delayering, demanning, or multi-skilling in relation to the operation or maintenance of the establishment.<br>Changes in health and safety policy, procedures, standards, aims, objectives or priorities, including<br>changes to the MAPP or SMS.<br>Inclusion of an environmental management system (EMS) within the SMS and all changes to the EMS. |
| Modifications | A change in the quantity of a dangerous substance.<br>A change in the phase of a dangerous substance, for example, a change from liquid to gaseous chlorine.<br>The introduction of new dangerous substances or removal of existing dangerous substances.<br>New processes.<br>Changes to storage facilities.<br>Changes to the control systems.<br>Changes to containment systems (both secondary and tertiary).<br>Changes to the mode of deliver y or transport of dangerous substances.<br>Changes to the design or location of control rooms and/or the number of people present within them.<br>Changes to the location of occupied buildings and/or the number of people present within them. |

56 Revised guidance for operators of top tier - COMAH establishments, Review and revision of COMAH safety reports, COMAH, HSE R01

| Change | Description of change |
| --- | --- |
| | Changes to the original design parameters such as process operating conditions or practices, changed throughput, design life extensions or removal of safety-critical plant.<br>Construction of a new installation on an existing site.<br>A small modification which could have large consequences, such as a change to the valve type used in a particular line.<br>Introduction of temporary and/or mobile equipment.<br>Repairs to structures or any plant and equipment.<br>Decommissioning of plant and installations.<br>Changes to flood warning procedures, and response to flooding incidents where appropriate. |
| New facts/ knowledge | A substance which is present on site, but not previously classified as a dangerous substance, is reclassified as dangerous (or the reverse).<br>A change in the risk phrases assigned to a dangerous substance.<br>Advances in knowledge about the behaviour of dangerous substances.<br>Incidents which reveal potentially hazardous reactions or loss of control scenarios not previously considered.<br>Non-COMAH substances found to be capable of creating a major accident hazard.<br>Recommendations made following a public inquiry or major incident.<br>Lessons from worldwide incidents.<br>Advances in technology that might render parts of the safety report out of date very rapidly (though in general, steady advances in technical knowledge can be accommodated at the five-year review stage).<br>Advances in design standards.<br>New scientific or technical research, or other advances (such as reduction in the cost of safety measures) that may affect the decisions previously made about which measures are necessary.<br>Ageing plant and associated performance.<br>Population changes on and off site.<br>Changes in the land-use of surrounding areas.<br>Changes in the conservation designation of surrounding land.<br>Classification or re-classification of surrounding land as environmentally sensitive areas. |

### 1.2.3 For transport corridors

Although there is a range of legislations and regulations that deal with the off-site transport of hazardous substances, in general ensuring land-use compatibility nearby transport corridors remains a difficult issue in land-use planning. The off-site transport of hazardous substances by road, rail, pipelines and inland waterways represents in terms of uncontrolled releases a risk similar to the ones found with storage tanks. However addressing the transport of hazardous substances requires different methods of control because it is a risk source moving between land-use zones unlike the storage tanks which are static risk sources. In this context, it is important to note that the Industrial Accidents Convention only covers transportation on the site of the hazardous activities (art, 2, para. 2 (d) (ii)).

The risk assessment should demonstrate that the vehicles transporting hazardous substances use dedicated roads or transport at specific hours of the day times as well as that the transport corridor will not generate significant adverse effects within the land areas crossed. Also, an emergency management plan should be setup detailing emergency preparation and response measures aiming at minimising the risk of adverse effects on the people and the environment. In the case of pipelines the planning control are similar to those applied to fixed hazardous facilities.

### 1.2.4 Areas that could be affected by the transboundary effects of an industrial accident

Past accidents have shown how the off-site effects of a hazardous facility in one country can have disastrous effects in neighbouring countries on their people, environment and property, including surrounding land-uses. Well known past accidents are those that occurred in Switzerland (1986) and Romania (2000).

On the 1st November 1986, a major environmental disaster, caused by a fire in a warehouse, occurred at the Sandoz agrochemical storehouse in Schweizerhalle, near Basel, Switzerland. Fire brigades sprayed millions of liters of water to extinguish the fire, but the volume of water was too great for existing catch basins. Consequently, thousands of cubic meters of water, mixed with insecticides and other chemicals, entered the Rhine through the Sandoz sewer system[57]. On the 30th January 2000 a tailings dam overflowed at the Aurul Mine in Romania and released 100,000 cubic metres of effluent containing cyanide into the Tisza River and which successively reached the Danube River. A very low level of cyanide was still detected in the river water when it reached the Black Sea[58].

The risk of having a transboundary event for instance in the EU/EEA is not negligible since in 2015 according to the EU SPIRS (Seveso Plant Information Retrieval System) there[59] were 2,295 out of 10,340 Seveso establishments (22.2%) located less than 5 km from the country borders – within the scope of the location criteria of the Industrial Accidents Convention.[60] Figure 6 shows the distribution of these establishments within 5km of the EU/EEA borders: 225 EU/EAA-EU/EAA boundaries (blue) and 71 EU/EAA-External borders (red). Land-use planning aspects related to hazardous activities located at the boundaries of one country and which can be affected by the effects of transboundary accidents are addressed by the provisions contained in the Industrial Accidents Convention, which stipulate that "affected Parties" shall seek the establishment of policies on significant developments in areas which could be affected by transboundary effects of an industrial accident arising out of a hazardous activity so as to minimize the risk involved" (art. 7)."Affected Parties" are Parties capable of being affected by transboundary effects of an industrial accidents – either through air-borne or water-related releases of hazardous substances.

Countries must identify those hazardous activities that are capable of causing transboundary effects and co-operate, exchange information and take appropriate measures with the neighbouring countries to protect the people and the environment against such accidents. Transboundary cooperation is important to ensure that zoning or land use strategies are compatible. This is of particular importance not only for hazardous facilities located at the boundaries but also with respect to transport corridors (by road, rail, pipelines and waterways) used for transporting hazardous substances. Therefore, cooperation must also be extended in establishing external emergency and response plans, including undertaking restoration measures.



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57 French Ministry of the Environment - DPPR / SEI / BARPI

The Rhine polluted by pesticides on November 1st, 1986 at Schweizerhalle, Switzerland, October 2006, http://www.aria.developpement-durable.gouv.fr/wp-content/files_mf/FD_5187_schwizerhalle_1986_ang.pdf

58 Spill of liquid and suspended waste at the Aurul s.a. Retreatment plant in Baia Mare, UNEP / OCHA Report, Geneva, March 2000, http://reliefweb.int/sites/reliefweb.int/files/resources/43CD1D010F030359C12568CD00635880-baiamare.pdf

59 https://minerva.jrc.ec.europa.eu/en/espirs/content

60 The Industrial Accidents Convention covers only the "upper tier" Seveso establishments, while in these figures, both "upper" and "lower tier" establishments are considered.

Figure 6  Seveso establishments located less than 5 km from the EU/EAA Countries borders obtained from EC SPIRS system (courtesy DG JRC MAHB)

### 1.3 Typical approaches in the context to LUP in ECE Member States

Within the UNECE countries there exists different land-use planning approaches based on methods (or a combination of these) described in Section 1.1.  These approaches are the result of the different legislation and practices used.  In this Section are presented examples of land-use planning approaches in selected countries that have a long term and well-established framework for taking major accidents into account in land-use planning.  The approaches described below are based on the guidance presented in Chapter 4.5 under the Seveso guidance.

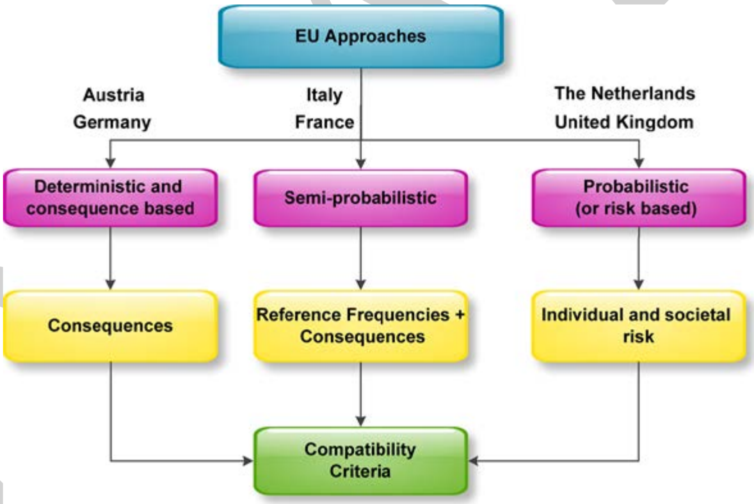


Figure 7  approaches used in different EU Member States (graph courtesy Lorenzo van Wijk)

#### 1.3.1 French approach[61]

The Toulouse accident of 2001 which caused 31 fatalities and over 3000 injured along with damages estimated at three billion Euro, highlighted the weaknesses and deficiencies of the French land-use planning approach based on the estimation of consequences generated by all representative scenarios only without considering the probability of occurrence of these events.  Following the Toulouse event, the French legislation regarding both technological and natural accidents risk prevention was reviewed and a new law on land use planning and risk quantification approved on July the 30th 2003.  The legislation was in particularly strengthened for regulating the siting of the hazardous

61 Taveau J., Risk assessment and land – use planning regulations in France following the AZF disaster, Journal of Loss Prevention in the Process Industries, 2010.

facilities and the urbanization control in their vicinity as well as the flows of information about the risk management plans between operators of the hazardous facilities, Authorities and the local community. The aim was to resolve problematic land use planning situations inherited from the past and to set the framework for future land use planning.

Under the new law, all possible accident scenarios occurring in a hazardous facility must be identified and studied and their probabilities of occurrence must be estimated in order to achieve a tolerable/acceptable safety level for the population. To achieve this, the new regulation set three requirements

- harmonizing the risk analysis approaches;
- integrating the two risk-based and consequence-based approaches;
- identifying corrective actions for existing or developing urbanization and control measures on future land use planning in the proximity of hazardous establishments.

To address the above requirements, the "Technological Risk Prevention Plans" (PPRT) was introduced to develop and manage land use planning. The land-use planning policies with regard to major accidents risk are defined by the Ministère de l'Ecologie, du Développement et de l'Aménagement Durables (MEDAD). Other three Ministries (Ministry for Industry, Ministry for the Interior and Ministry of Labour) share the responsibility for major hazards prevention and control.

Furthermore, to facilitate and standardize the process of elaboration of the Safety Reports prepared by the hazardous facilities the "General Principles for the Elaboration of Safety Reports" guidelines. The Safety Report must contain the following information:

1. description of the process and equipment;
2. hazard identification, i.e. identification of risk sources;
3. characterization of the main hazards, based on an estimate of the consequences of instantaneous release of energy and/or toxic substances (e.g. catastrophic tank rupture);
4. hazard reduction, i.e. reduction of the principal hazards based on technical and economic analysis;
5. analysis of similar past accidents to identify counter-measures/lessons learned;
6. identification of the most critical events through a preliminary risk assessment;
7. detailed risk analysis (e.g. HazOp), to assess the impact deviation of process parameters due to component failures or human errors on the system;
8. use of mathematical models to estimate the intensity of the effects of accidental events;
9. assessment of the likelihood of accidental events through the probability of initiating events and fault protection systems;
10. assessment of the potential fatalities/injuries per accident due to consequences of the event;
11. classification of accident scenarios using the national risk acceptability matrix (MMR matrix) which would be later used also for LUP purposes.

The Safety Report is paramount to the two regulatory processes involved land use planning as it provides the necessary risk information requested for assessing respectively societal risk and individual risk. Societal risk is assessed with the help of a risk matrix and is used to decide whether the permit to operate can be given to a hazardous facility. Individual risk is established with the help of so-called aléa maps which are used to setup the Technological Risk Prevention Plans for land use planning.

Under the French approach risk is estimated as a function of the three parameters (1) gravity (also called intensity or magnitude), (2) probability and (3) swiftness /kinetics of the accident.

The gravity level is determined by combining intensity of the effects on the population and the number of people exposed at a given distance from the hazardous installation. Table 6 lists the lethal and irreversible effects on the population following a certain level of intensity exposure to thermal radiations, overpressures and toxic substances. The four types of effect considered are 5% lethal effects (or significant lethal effects), 1% lethal effects (or first lethal effects), irreversible injury, reversible injury or broken glass. The gravity level is defined based upon the number of potential victims for each type of effect and five gravity levels have then been defined, as illustrated in Table 7.

Table 6 Intensity of the effects on population

| Effects on population | Fire (thermal radiation) | Explosion (overpressure) | Toxic release (individual risk) |
|---|---|---|---|
| 5% lethal effects (*) | 8 $kW/m^2$ or 1800 $(kW/m^2)^{4/3}$ | 200 mbar | LC 5% |
| 1% lethal effects | 5 $kW/m^2$ or 1000 $(kW/m^2)^{4/3}$ | 140 mbar | LC 1% |
| Irreversible effects | 3 $kW/m^2$ or 600 $(kW/m^2)^{4/3}$ | 50 mbar | IET (**) |
| Reversible effects | --- | 20 mbar | --- |

((*) of the population exposed, (**) IET=Irreversible Effects Threshold)

Table 7 Gravity levels expressed in relation to the proportion of people exposed

| Gravity level | 5% (*) lethal effects | 1% (*) lethal effects | Irreversible (*) effects |
|---|---|---|---|
| Disastrous | > 10(*) | > 100 | > 1000 |
| Catastrophic | 1 – 10 | 10 – 100 | 100 – 1000 |
| Major | 1 | 1 – 10 | 10 – 100 |
| Serious | 0 | 1 | 1 – 10 |
| Moderate | 0 | 0 | < 1 |

(*) of the population exposed

The yearly frequency of occurrence of the accidents are assessed using methods that range from quantitative to qualitative approaches. Quantitative methods are based upon reliability models such as Fault Trees whereas the qualitative approach uses five defined probability classes going from A (> $10^{-2}$/year) to E (<$10^{-5}$/year) and presented in Table 8. The qualitative frequency allows to determine the order of magnitude of the frequency of occurrence of an accident based on past events. Therefore it cannot be applied to new hazardous activities as there are no similar past accidents.

Table 8 Five probability classes based upon qualitative assessment and their equivalence with the quantitative frequency

| Frequency class | Qualitative frequency | | Quantitative frequency | Semi-quantitative frequency |
|---|---|---|---|---|
| E | Extremely unlikely scenario | Possible considering the current knowledge, but never occurred anywhere worldwide | $< 10^{-5}$ event/year | A hybrid risk-based model that takes into account factors/measures reducing the level of risk |
| D | Realistic but unlikely scenario | Possible but never occurred in a similar facility | $> 10^{-5}$ event/year | |
| C | Improbable scenario | Already occurred in a similar facility worldwide | $> 10^{-4}$ event/year | |
| B | Probable scenario | Already occurred (or supposed to have occurred) during the lifetime of the facility | $> 10^{-3}$ event/year | |
| A | Frequent scenario | Already occurred (several times) during the lifetime of the facility | $> 10^{-3}$ event/year | |

When addressing the accident scenarios, these are classified as either “fast accident” or “slow accident”. This distinction refers to the time availability to implement existing internal and external emergency measures to evacuate/shelter all people who might be affected by the accident. Hence, an explosion is a “fast accident” as there is no time to enact all emergency measures to reduce the consequences of heat radiation and overpressure on the exposed population. On the other hand a toxic release can be considered a “slow accident” since emergency measures can be implemented before the event effects reach their highest intensity level. The hazardous facility must provide all of the necessary information to justify classifying an accident scenario of the type “slow”. The method takes into consideration the type of accident when assessing the consequences and preparing the risk maps.

After establishing the frequency class and gravity level parameters for each of the identified accident scenario, these parameters are used to determine the risk level associated to the hazardous activity/facility to support land-use planning decisions according to a national risk acceptability matrix illustrated in Table 9.

The red marked cells (NO) indicate that any hazardous phenomenon is allowed therefore the operator must improve the facility safety levels in order to reduce the risk to acceptable level otherwise the hazardous activity cannot be approved as it represent an unacceptable risk. The orange marked cells (NO/MMR2) mean that no more than five dangerous phenomena after the operator has taken all measures to reduce the risk. The yellow marked cells (MMR1) indicate that permit to operate a hazardous facility can be issued after all practicable safety measures (i.e. cost-acceptable measures) have been implemented by the operator. Finally, the green marked cells (OK) means that the hazardous facility can be approved to operate without requesting any further measure or action.

Operators must demonstrate that best available techniques used to reduce the risk or that the “as low as reachable practically” principle is followed.

Table 9 French national risk acceptability matrix for land use planning evaluations and restrictions in relation to the presence of hazardous activities

| Gravity level | | Frequency class | | | | |
|---|---|---|---|---|---|---|
| | | E | D | C | B | A |
| Gravity level | Disastrous | NO MMR2 | NO | NO | NO | NO |
| | Catastrophic | MMR1 | MMR2 | NO | NO | NO |
| | Major | MMR1 | MMR1 | MMR2 | NO | NO |
| | Serious | OK | OK | MMR1 | MMR2 | NO |
| | Moderate | OK | OK | OK | OK | MMR1 |

The "aléa" concept (i.e. alert level) is employed to assess land-use compatibility. Aléa is defined as the probability that a hazardous phenomenon generates effects of a given intensity over a certain period of time in a given point of the area. These aléas are associated with land-use restrictions according to four classes of zones set out in the national technological risk prevention plans (PPRT) listed in Table 10. The different aléa levels, zoning principles and allowed land-use planning and construction measures are outlined in Table 11.

Table 10 Zoning criteria set out in the national technological risk prevention plans guide (PPRT)

| Regulated zones | Future land-use planning and construction measures | Possible real estate measures |
|---|---|---|
| Dark red | Ban on new construction | Expropriations, relinquishment ("délaissement") |
| Light red | Ban on new construction but possibly allows extending industrial buildings and infrastructure if the necessary safety measures are implemented | Relinquishment ("délaissement") |
| Dark blue | New construction possible depending upon the limitations in their use or implemented safety measures | |
| Light blue | New construction possible depending upon minor limitations in their use. No public buildings which are difficult to evacuate. | Compulsory protection measures for public buildings and industries. |

The French term "délaissement" refers to the legal approach whereby the authorities can prohibit land or buildings from being re-used once they are vacated by the existing owners/users and if the owners wish so with the obligation on the part of the authorities to acquire the property. These measures are paid using an agreement between the State, the operator and the local authorities. [Additional risk reduction measures to improve the safety of the population can be proposed through consolidation of buildings and infrastructures. These measures are paid by owners of buildings and infrastructures and their cost cannot be above 10% of the property value.]

Table 11 General rules for land compatibility for the zones around the hazardous installation

| Maximum effects on population at a given point | 5 % lethal effects | | | 1 % lethal effects | | | Irreversible effects | | | Indirect effects |
|---|---|---|---|---|---|---|---|---|---|---|
| Cumulative probability distribution of dangerous phenomena at a given point | > D | 5E to D | < 5E | > D | 5E to D | < 5E | > D | 5E to D | < 5E | All |
| Aléa | Very High (+) VH+ | Very High VH | High (+) H+ | | High H | Medium (+) M+ | | Medium M | Low | |
| Zone regulation for thermal radiation and toxic exposure effects | Dark red | | Light red | | | Dark blue | | Light blue | Light blue | |
| Zone regulation for overpressure effects | | | | | | Dark blue | | | | |

From Table 11 it can be seen that zones with aléa classified as VH+ and VH any existing houses can be subject to either compulsory purchase (i.e. expropriation) or "délaissement". Also zones with aléa classified as H+ and H are subject to "délaissement". Development of new urbanisation such as residential areas or services are generally not allowed in zones with aléa classified from VH+ to H. Urban development is subject to special conditions in zones with aléas M+ to M (for toxicity or heat radiation) and M+ to Low (for overpressure). It is also foreseen that buildings and people within the hazard zone can be protected through technical measures such as for instance installation of explosion-proof windows. However, for the zones with aléas M+ to M the cost of these measures may not exceed 10% of the exposed assets value.

For each one of the three effects of the accident, i.e. thermal radiation, overpressure and toxic exposures, an aléa map is obtained showing three curves representing the intensity of the effects on the exposed population (i.e. 5% lethal effect, 1% lethal effect, irreversible damage). A land-use compatibility criteria is obtained by overlapping separately all aléa maps referring to the same effects (thermal radiation, overpressure and toxic exposure) and summing up the frequencies of occurrence of these accidents. This can lead to a change of aléa level, for a given point of the area, from a less restrictive to a more restrictive category. Note that 10 accident scenarios of class E count as one 'D'. Also "slow accident" effects are summed separately.

Figure 8 shows an example of aléa mapping where the different effects intensities are represented by different colours.

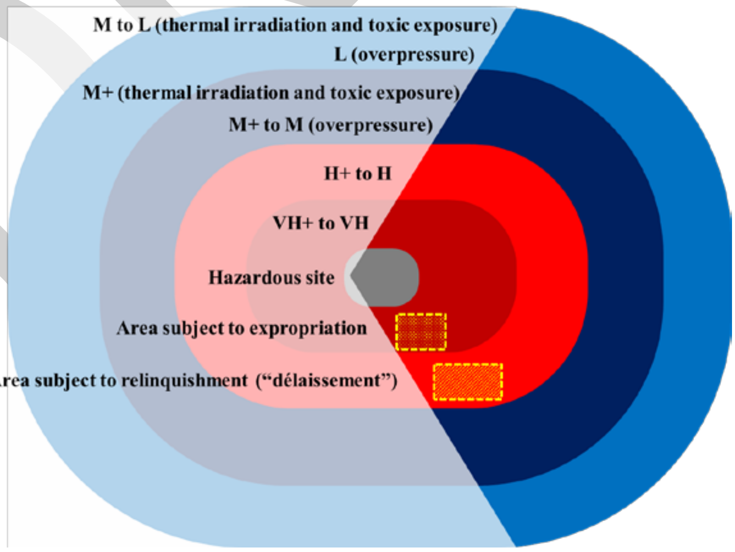


Figure 8 Example of aléa mapping for toxic release and thermal radiation and overpressure effects identifying areas subject to expropriation and relinquishment (graph courtesy Lorenzo van Wijk)

Figure 9  Example of aléa mapping for thermal radiation and toxic release obtained with ADAM 1.0 (courtesy DG JRC MAHB)

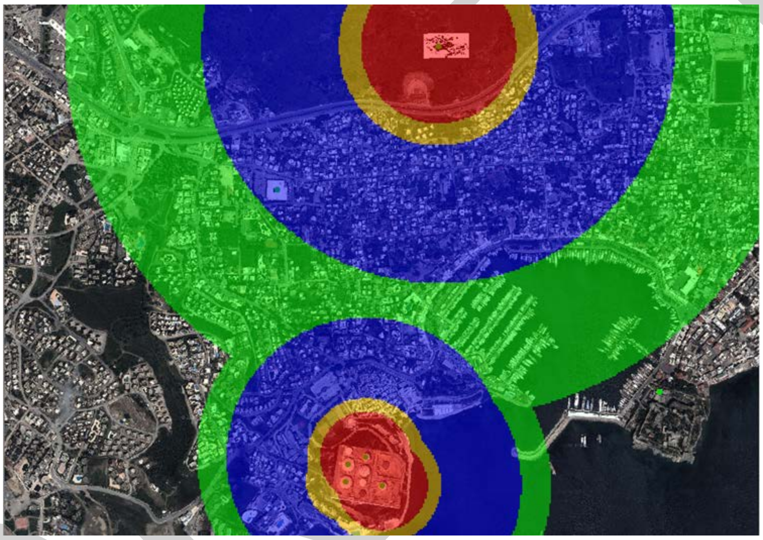

Figure 10  Example of aléa mapping for overpressure obtained with ADAM 1.0 (courtesy DG JRC MAHB)



The overlapping of aléa maps with the zone criteria allows to define land-use compatibility.  The following tables show the different criteria used in France. They differ from each other because of the type of:

- accident (thermal and toxic effects / overpressure effects);
- type of construction (new / existing buildings).

Table 12  Construction criteria for new buildings (thermal and toxic effects).

| **Aléas** | **Construction criteria for new buildings (thermal and toxic effects)** |
|---|---|
| **VH+** | Ban of new constructions. |
| **VH** | |
| **H+** | Ban of new constructions but possibility to enlarge existing industrial buildings and infrastructures, if protected. |
| **H** | |

| | |
|---|---|
| **M+** | New constructions allowed but with limitations on use or protection measures. |
| **M** | New constructions allowed but with minor limitations on use.<br>Compulsory protection measures for public buildings and industries.<br>No public building difficult to evacuate. |
| **Low** | No restrictions. |

Table 13 Construction criteria for new buildings (overpressure effects)

| Aléas | Construction criteria for new buildings (overpressure effects) |
|---|---|
| **VH+** | Ban of new constructions. |
| **VH** | |
| **H+** | Ban of new constructions but possibility to enlarge existing industrial buildings and infrastructures, if protected. |
| **H** | |
| **M+** | Protection measures for new buildings. |
| **M** | |
| **Low** | New constructions allowed with minor limitations on use.<br>Compulsory protection measures for public buildings and industries.<br>No public building difficult to evacuate. |



In case of existing constructions, buildings may be subject to expropriation or relinquishment.

Table 14 Construction criteria for existing buildings (expropriation).

| Aléas | Construction criteria for existing buildings (expropriation or relinquishment) |
|---|---|
| **VH+** | Automatic for housing buildings. To be defined for other activities. |
| **VH** | To be defined. |
| **H+** | |
| **H** | |
| **M+** | |
| **M** | |
| **Low** | |

Table 15 Construction criteria for existing buildings (relinquishment)

| Aléas | Construction criteria for existing buildings (relinquishment) |
|---|---|
| **VH+** | Automatic. |
| **VH** | Automatic for housing buildings.<br>To be defined for other activities. |
| **H+** | |
| **H** | To be defined. |
| **M+** | No |
| **M** | |
| **Low** | |

### 1.3.2 Italian approach

Following the transfer of administrative and legislative responsibilities from national to local level, national laws are implemented by the Italian Regions through their own legislation whereas the Provinces and Municipalities adopt their own statutes and regulations.  This holds in particular with crucial issues of general-interest in the areas of control of major-accident hazards, industrial safety, public health and safety, civil protection, natural resources protection and regional economic development.

With regard to aspects linked to the “Minimal Safety requirements for the urban and territorial planning in the areas subject to major accident risks” Decree[62], Regions play a central role in implementing national guiding rules and criteria for land use planning with the Provinces and Municipalities adopting their own regulations.  This Decree requires that adequate safety distances must be established between the establishment and residential areas in case of:

1. construction of new installations;
2. enlargement of existing plants;
3. new establishments or infrastructures close to the plant, which can worsen the risk level or the consequences of an accident.

Specific national decrees have been issued for LPG storages and toxic/flammable liquids storages[63].

The Regional Technical Committee provides advice under the form of a Technical Paper on land-use planning to the Municipality regarding the decision to issue a permit to build or operate a hazardous facility.

Table 16 outlines the responsibilities at national and local level in implementing land-use planning regulation.



Table 16  National and local responsibilities in land-use planning

| Administrative level | Regulation responsibilities |
|---|---|
| National (Government) | Defines the principles and objectives of national interest in the “National Urban Law” that must be implemented by all of the 20 Regions and the 2 Autonomous Regions. |
| | Transposes the EU Seveso III Directive into the national legislation |
| Region | Defines regional plans containing specific provisions regarding matters of regional interest and planning objectives for the Provinces and Municipalities. |
| | Implement national legislation through adopting regional laws and assigns responsibilities as well as ensures the enforcement of procedures. |
| Province | Defines its territorial plans and urban planning principles and controls the elements under its responsibility (i.e. transportation corridors, vulnerable areas, etc.). |

62 DM 9 maggio 2001, Requisiti minimi di sicurezza in materia di pianificazione urbanistica e territoriale per le zone interessate da stabilimenti a rischio di incidente rilevante, pubblicato su Gazzetta Ufficiale del 16 giugno 2001, n.138.

63 DECRETO LEGISLATIVO 22 febbraio 2006, n.128, Riordino della disciplina relativa all'installazione e all'esercizio degli impianti di riempimento, travaso e deposito di GPL, nonche' all'esercizio de ll'attivita' di distribuzione e vendita di GPL in recipienti, a norma dell'articolo 1, comma 52, della legge 23 agosto 2004, n. 239. Pubblicato sulla G.U.S.G. n. 74 del 29 marzo 2006

| | |
|---|---|
| | Defines zones "subject to specific regulation" and set out principles for urbanization plans. |
| Municipality | Defines its urbanization plans based on regional and provincial indications, assigns land property/use rights and discipline/controls use of elements under its responsibility. These plans are consulted by the community following its publication in the Official Journal.<br>Requires a land-use planning Technical Paper that analyses the risk generated by hazardous facilities and identifies vulnerable elements – this information is represented in a simple and clear cartographic format. Land-uses is organised taking into account on the base of this document. |

The Italian land-use planning approach is based on a semi–quantitative and is centred on three stages as described in the Decree[64]:[65]

1. identifying vulnerable territorial and environmental elements in the area of concern around the hazardous facility;
2. determining the impact area following an accident;
3. evaluating the territorial and environmental compatibility with the proposed land-use due to the presence of the hazardous facility. such as, for example, communication roads, sites open to the public, residential areas, when localisation or settlement or infrastructure may worsen the hazard level or the consequences of a relevant accident

**Step 1: identifying vulnerable territorial and environmental elements**

The vulnerable territorial and environmental elements in the vicinity of hazardous facilities are identified as follows.

*Vulnerable territorial elements*

Areas are categorised in six classes according to an urbanisation/construction index and community related characteristics as shown in Table 17. The land/zone categorisation considers the following relevant aspects:

- difficulties in evacuating vulnerable people such as children, elderly and the sick;
- difficulties in evacuating residents living in five (or more) storey buildings and crowds in public spaces due to less capability to reach emergency exits or shelters;
- minor difficulties in evacuating people living in isolated or low–rise buildings;
- activities with low vulnerability and characterised by a short term permanence of people;
- outdoor activities with higher degree of vulnerability (as opposed to indoor activities).

The above aspects all contain the element of vulnerability of the people. The Decree defines the criteria and thresholds to establish the vulnerability of each urban and natural element. One of the criteria is the ease with which people can be evacuated. . The general criterion is the one of more or less easy evacuation of the population which is characterised for instance by the building index (ratio between volume of the building and its projected surface), the number of beds in a hospital or the number of scholars in a school. For instance a zone with a building index higher than 4.5 $m^3/m^2$ (ratio between volume of the building and its projected surface) and with more than 25 beds

64 P. Colletta, R. Manzo (eds.), Governo del territorio e rischio tecnologico, Metodologie di intervento ed esperienze di attuazione del D.M. 9 maggio 2001; online, Ministero delle Infrastrutture e Trasporti, http://www.infrastrutturetrasporti.it/sites/seveso2/pages/sev_page_05.htm

65 Carpignano, G. Pignatta, A. Spaziante, Land use planning around Seveso-II installations: the Italian approach, in: Proceedings of the European Conference on Safety and Reliability, MG, Torino (I) 2001, p. 1763.

in hospital is classified A. These classes characterise the use of land based on the type of vulnerable territorial elements present in the vicinity of hazardous facilities. Transport corridors and interchange nodes as well as technological infrastructures present nearby the hazardous facility are taken into account by implementing measures aiming at reduce and mitigating the consequences of an accident occurred at the hazardous facility.

Table 17 Six classes of land categorisation

| Category | Type of land-use development |
|---|---|
| **A** | Predominantly residential areas with building land index higher than 4.5 $m^3/m^2$;<br>Housing development harbouring people with limited mobility, such as hospitals, nursing homes, schools, kindergartens (more than 25 beds or 100 people present);<br>Places subject to outdoor overcrowding, e.g. 'fixed' marketplaces or other retail stores (over 500 people). |
| **B** | Predominantly residential land with building land index between 4.5 and 1.5 $m^3/m^2$;<br>Housing development harbouring people with limited mobility, such as hospitals, nursing homes, schools, kindergartens (more than 25 beds or 100 people present);<br>Places subject to outdoor overcrowding, e.g. 'fixed' marketplaces or other retail stores (up to 500 people);<br>Places subject to indoor overcrowding, e.g. shopping centres, commercial offices, offices, schools, universities, etc. (over 500 people);<br>Areas subject to significant overcrowding, with limited periods of exposure to risk such as places for public entertainment, sport events, cultural, religious (more than 100 people present in the case of outdoor location, over 1000 indoor).<br>Railway stations and other transport nodes (with passenger movements over 1000 persons/day). |
| **C** | Predominantly residential land with building land index between 1.5 and 1m3/m2;<br>Places subject to indoor overcrowding, e.g. shopping centres, commercial offices, offices, schools, universities, etc. (up to 500 people);<br>Areas subject to significant overcrowding, with limited periods of exposure to risk such as places for public entertainment, sport events, cultural, religious (up to 100 people present in the case of outdoor location, up to 1000 indoor).<br>Railway stations and other transport nodes (with passenger movements up to 1000 persons/day). |
| **D** | Predominantly residential land with building land index between 1 and 0.5 $m^3/m^2$;<br>Areas subject to significant overcrowding, but on a monthly basis – fairs, open-air markets, cemeteries, etc. |
| **E** | Predominantly residential land with building land index lower than 0.5 m3/m2;<br>Industries, agricultural / manufacturing / livestock enterprises. |
| **F** | Hazardous facility area.<br>Area adjacent to the hazardous where no industrial elements/activities and people are present. |



*Vulnerable environmental elements*

Vulnerable environmental elements are identified by assessing the potential environmental damage based on the release of dangerous substances and the kind of accident. These elements are defined as follows:

- landscape and environmental heritage assets;
- natural protected areas such as parks and other areas identified by the regulation;
- surface water resources such as aquifers and surface water bodies in relation to the basin volume and circulation time;

- deep water (such as wells for drinking or irrigation water), protected or unprotected deep water resource and recharging water resources;
- agricultural land use such as forestry and other valuable cultivated areas.

The environmental vulnerability is also assessed on the basis of the type of accident that potentially can take place. For example, the effects of a fire or an explosion on water or subsoil can be neglected whereas the effects of toxic gas dispersion on vegetation must be considered.

**Step 2: Determining the impact area following an accident**

Accident consequence models are employed to estimate the level of damage to the people and structures for each type of effect, i.e. thermal radiation, overpressure and toxic concentration. The damage thresholds values presented in Table 18 are defined by the Decree for thermal radiation, overpressure and toxic concentration. The impact area is identified by comparing whether the calculated damage for each point in the affected area is below or above the threshold values and overlapping the impact area with the area map identifying the vulnerable territorial and environmental elements.

Table 18 Threshold values adopted in the Italian regulation

| Accident type | Elevated fatalities | Start fatalities | Permanent injuries | Reversible injuries | Structural damage |
|---|---|---|---|---|---|
| Fire (*stationary thermal radiation*) | 12.5 kW/m$^2$ | 7 kW/m$^2$ | 5 kW/m$^2$ | 3 kW/m$^2$ | 12.5 kW/m$^2$ |
| BLEVE / Fireball (*variable thermal radiation*) | Fireball radius | 359 kJ/m$^2$ | 200 kJ/m$^2$ | 125 kJ/m$^2$ | 200-800 m (storage tank type ) |
| Flash fire (*instantaneous thermal radiation*) | LFL | 0.5 LFL | - - - | - - - | - - - |
| VCE (*peak overpressure*) | 0.3 bar (0.6 bar open space) | 0.14 bar | 0.07 bar | 0.03 bar | 0.3 bar |
| Toxic release (*absorbed dose*) | LC50 (30 min exposure) | - - - | IDHL | - - - | - - - |

The frequency of occurrence of an accident event is associated with one of the four probability class defined as follows:

- < $10^{-6}$ event/year
- $10^{-4}$– $10^{-6}$ event/year
- $10^{-3}$– $10^{-4}$ event/year
- > $10^{-3}$ event/year

**Step 3 Evaluating the territorial and environmental compatibility**

*Territorial compatibility*

The Decree defines the kind of land-use in function of the land vulnerability category, accident frequency class and damage effects on the people and structures. The compatibility of the zones surrounding a hazardous facility is evaluated by means of a qualitative compatibility risk matrix presented in Table 19. However, only during the transition period of the Decree implementation and until the land-use changes were approved, more restrictive compatibility criteria were followed as can be seen from Table 20.

The process that leads to obtaining the territorial compatibility map around a given a hazardous facility is the following:

- select an accident event (fire, explosion and toxic dispersion);
- calculate the frequency of occurrence and select the probability class to which it belongs;
- calculate the effects in each point of the area (i.e. whether it is high / starting lethality, irreversible / reversible effects);
- identify the compatible building categories by using the compatibility matrix described Table 19;
- repeat the above steps for each accident event;
- select the most restrictive compatibility level for each point of the area.

Table 19 Compatibility matrix introduced by the Decree (M.D. 09/05/2001) [66]

| Probability class [events/year] | Consequence category | | | |
|---|---|---|---|---|
| | Reversible injuries | Permanent injuries | Start fatalities | Elevated fatalities |
| $< 10^{-6}$ | ABCDEF | BCDEF | CDEF | DEF |
| $10^{-4} - 10^{-6}$ | BCDEF | CDEF | DEF | EF |
| $10^{-3} - 10^{-4}$ | CDEF | DEF | EF | F |
| $> 10^{-3}$ | DEF | EF | F | F |

Table 20 Compatibility matrix during the transition period of the Decree implementation (M.D. 09/05/2001)

| Probability class [events/year] | Consequence category | | | |
|---|---|---|---|---|
| | Reversible injuries | Permanent injuries | Start fatalities | Elevated fatalities |
| $< 10^{-6}$ | BCDEF | CDEF | DEF | EF |
| $10^{-4} - 10^{-6}$ | CDEF | DEF | EF | F |
| $10^{-3} - 10^{-4}$ | CDEF | EF | F | F |
| $> 10^{-3}$ | EF | F | F | F |

*Environmental compatibility*

Land use planning policies must take into account their specific environmental context when addressing the development of new hazardous facilities or modifications to existing hazardous facilities which can increase the risk

66 DM 9 maggio 2001, Requisiti minimi di sicurezza in materia di pianificazione urbanistica e territoriale per le zone interessate da stabilimenti a rischio di incidente rilevante, pubblicato su Gazzetta Ufficiale del 16 giugno 2001, n.138.

level in the area.  For instance, seismic and hydrological/geological areas should be taken in due consideration in the risk evaluation.

The classification of environmental damage is related to the potential releases of dangerous substances and is defined by considering:

- quantity and characteristics of the substances released;
- specific measures applied to reduce and mitigate the environmental impact of an accident.

Hence, using as criterion the time necessary to restore the original state of a natural element affected by an accident the following two environmental categories are defined:

- significant damage, i.e. damage for which remediation and environmental restoration of sites contaminated as a result of the accident can presumably be completed within the space of two years from the beginning of the activities;
- serious damage, i.e. damage for which remediation and environmental restoration of sites contaminated as a result of the accident will require more than two years from the beginning of the interventions.

As far as environmental compatibility is concerned, a serious damage is always to be considered incompatible.  On the contrary, in case of significant damage, prevention and mitigation measures should be applied.

Operating permits procedure

The permit to operate is issued by the Regional Authorities (responsible for lower-tier establishments) and the Regional Technical Committee (responsible for upper-tier establishments).

The Regional Technical Committee assesses the safety report prepared by the operators of upper-tier establishments who can proceed with either building the new installations or substantially modifying the existing facility previous receiving technical approval.

Involvement of the public

The public concerned can consult the safety report of the hazardous facility and the Technical Report on land-use planning (excluded industrial, commercial or personal information and those related to public security or national defence).  The consultation procedures are defined by the planning regulation and the consultation period starts after the publication in the Official Journals of the urban plans.

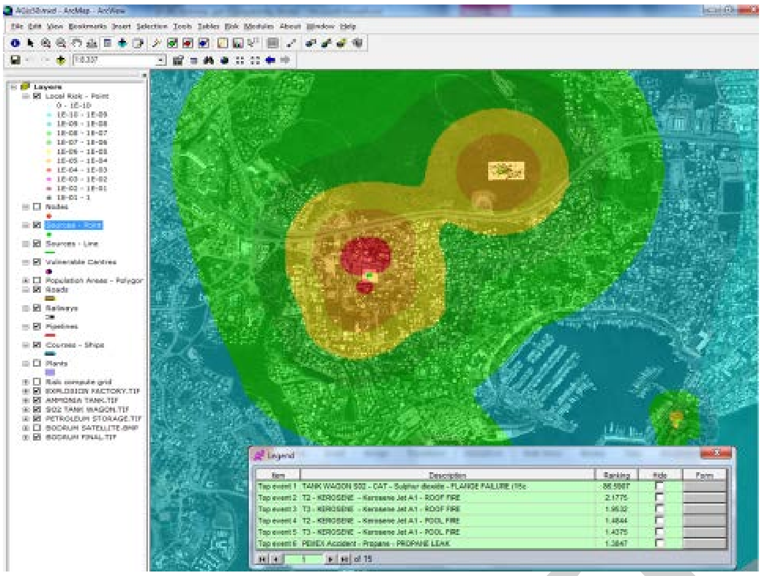

Figure 11 Example of land-use compatibility obtained with ADAM 1.0 (courtesy DG JRC MAHB)

### 1.3.3 Dutch approach[67]

The high number of inhabitants combined with the scarcity of land, as well as its vulnerability, make of The Netherlands the country with the highest population density within the EU. Large parts of the available land are below the sea level, with areas reaching 30 meters within the "Randstad Holland" agglomeration (comprising cities as The Hague, Rotterdam, Leiden, Haarlem, Amsterdam, Eindhoven, Breda, Arnhem and Nijmegen) where most of the chemical industry is concentrated. Flooding is instinctively the main concern from the safety angle.

This had led The Netherlands to develop a safety culture addressing the concept of risk and its probabilistic nature along with the need of setting acceptance levels in terms of cost-benefit thereby establishing "quantitative-based reasoning" in risk regulation before other European countries.

The Dutch risk assessment methodology approach is made of the following three elements:

- quantifying risk with a probabilistic method;
- estimating individual risk and its acceptability thresholds;
- estimating societal risk.

Table 21 presents the individual and societal risk thresholds/criteria as defined by law. The value prescribed for the individual (location-based) risk of $10^{-6}$ is legally binding for vulnerable objects, while a target value of $10^{-5}$ applies to less vulnerable objects. For the societal risk, evaluations are carried out case-by-case but no limiting values are in place. When assessing permits, the authorities must compare the calculated societal risk with the targets for risk acceptance shown in Table 21.

Table 21 Dutch individual and societal risk threshold values

| | | |
|---|---|---|
| Individual risk thresholds | New situations | $10^{-6}$ / year |
| | Existing situations | $10^{-5}$ / year |
| Societal risk | > 10 deaths | $10^{-5}$ / year |

67 Staatsblad van het Koninkrijk der Nederlanden (2004), Besluit van 27 mei 2004, houdende milieukwaliteitseisen voor externe veiligheid van inrichtingen milieubeheer (Besluit externe veiligheid inrichtingen).

| | | |
|---|---|---|
| thresholds | >100 deaths | $10^{-7}$ / year |
| | > 1000 deaths | $10^{-9}$ / year |

In the Netherlands, a full QRA is required in the phase of permit application for the installation of new establishments, as well as for modifications of existing situations. The coordination role for external safety matters has been assigned to the VROM (Spatial Planning, Housing & Environment Ministry) who decided to establish the External Safety Directorate as specific implementation body. According to current legislation, operation permit are subordinated to a fulfilment of the environmental quality defined in External Safety (Establishment) Decree.

### 1.3.4 United Kingdom approach

The two Health and Safety Executives respectively in the UK and Northern Ireland are the bodies responsible for implementing the Seveso III implementation through the "Control of Major Accident Hazards (COMAH) as well as providing guidance and giving advice to the local planning authorities of the District Councils on land-use compatibility in the vicinity of hazardous facilities.

Local planning authorities are responsible for defining the land-use planning as well as for the urban and environmental management. They must consult the HSE for any development plans regarding hazard facilities and the areas in their vicinity that falls within the so-called Consultation Distance. In this context the HSE developed the online support tool PADHI+ (Planning Advice for Developments near Hazardous Installations) to assist the local planning authorities in receiving pre-planning advice on territorial compatibility and consultation zones advice. To achieve social and economic prosperity goals and policies considered relevant, the local planning authorities can refuse a 'negative advice" from the HSE since its advice is not legally binding. However, the HSE can ask the Secretary of State to take over the decisions of Planning Authorities when considering the planned developments in the vicinity of hazardous installation to be at risk. Given the acknowledged expertise of HSE in assessing the off-site risks presented by the use of hazardous substances, the government guidelines stresses out that "any advice from HSE that planning permission should be refused for development for, at or near to a hazardous installation or pipeline should not be overridden without the most careful consideration."

The HSE conducts a risk assessment for the considered hazardous facility to evaluate its safety report by using data and information contained in the hazardous facility's permits (such as Hazardous Substances Consent data including information on dangerous substances quantities, tank sizes, pressure and temperature) and issued by the local authorities. These calculations are probabilistic for toxic substances (i.e. individual risk) and deterministic-based for fire and explosion. HSE defines three ranges of individual risk level based on the dose received and characteristics of the population. The upper limit for acceptable involuntary risk (e.g. involuntarily exposed people including employees in surrounding establishments) is set at $10^{-5}$ fatalities per year. The lower limit for individual risk to the general population is $10^{-6}$ fatalities per year as any risk below this threshold is considered insignificant in relation to everyday risk exposure[68]. In case of vulnerable people, such as elderly people or the sick, an individual risk limit of $0.3 \cdot 10^{-6}$ fatalities per year is used. Also HSE identifies three levels of effects/damage following exposure to a given amount of thermal irradiation and overpressure. These three levels of damage are summarised in Table 22.

Table 22 Criteria for the definition of consultation zones around the installation



[68] HSE (2005), PADHI – HSE's land use planning methodology. Online: http://www.hse.gov.uk/landuseplanning/padhi.pdf.

| Consultation zone | Fire (thermal radiation consequences) | Explosion (overpressure consequences) | Toxic release (individual risk) |
|---|---|---|---|
| Inner | Fireball radius | 600 mbar | $> 10^{-5}$ |
| Middle | 1000 TDU(*) | 140 mbar | $10^{-5} – 10^{-6}$ |
| Outer | 500 TDU(**) | 70 mbar | $10^{-6} – 3 \cdot 10^{-7}$ |

(*) Thermal Dose Unit = 1 $(kW/m^2)^{4/3}s$ (**) Third degree burns

Following the evaluation of the safety report, the HSE establishes a so-called “Consultation Distance” (or Zone) from the hazardous facility. Within this distance (or area) there are potentially significant consequences for human health or the environment from a major accident at the facility, including potentially significant consequences for development such as residential areas, buildings and areas of public use, recreational areas and major transport routes. Within the Consultation Distance are identified an inner, middle and outer consultation zone with the outer zone boundary delimiting the Consultation Distance. HSE is not consulted beyond this distance. The inner, middle and outer zone for each consequence are defined based upon the corresponding damage presented in Table 22. An example of three consultation zones obtained for a toxic release is shown in Figure 12.

HSE introduced both a However HSE introduced a fourth consultation zone called Development Proximity Zone (DPZ) following the Buncefield disaster of 2005[69]. This zone is defined for Large Scale Petrol Storage Sites (LSPSS) only and is the zone closest to the hazardous facility boundary. The four consultation zones are sown in Figure 13.

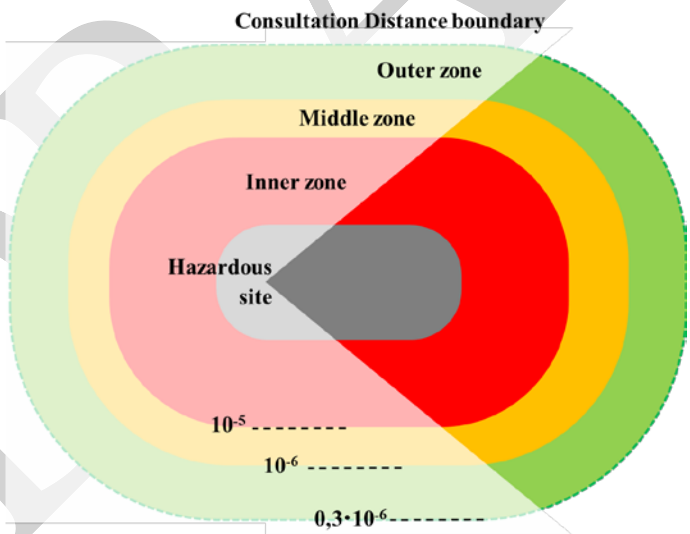


Figure 12 Three consultation zones and their individual risk consultation zones around hazard facility for toxic releases (graph courtesy Lorenzo van Wijk)



[69] http://www.hse.gov.uk/comah/buncefield/buncefield-report.pdf

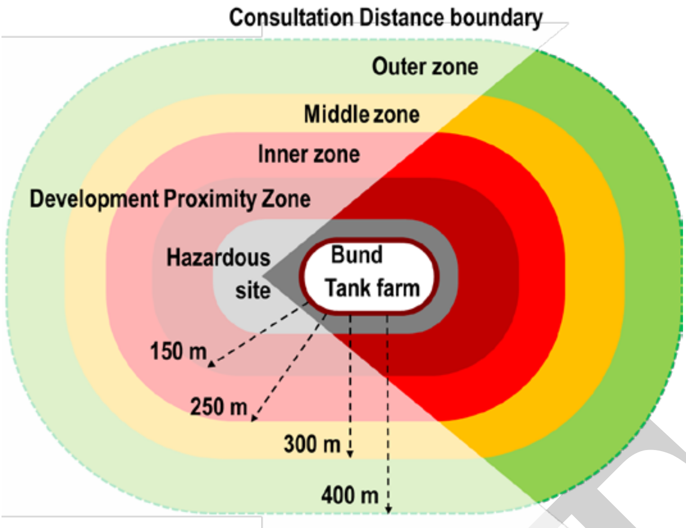


Figure 13 Four consultation zones and their distances defined by HSE around Large Scale Petrol Storage Sites (graph courtesy Lorenzo van Wijk)

Next, the HSE defined a development type matrix to assess the developments compatibility within the above consultation zones. Developments and land-use are classified by into account a number of factors related to the characteristics of the population, the buildings and the infrastructures such as:

- vulnerability of the exposed population (e.g. adults, children, elderly, disabled);
- proportion of time spent by any individual in the development (e.g. home, workplace, hospital, shopping centre, leisure centre);
- size of the building or infrastructure, i.e. number of people potentially present;
- people staying indoors or outdoors - if outdoors ease in sheltering (e.g. home, shopping centres);
- ease of evacuation or other emergency measures;
- characteristics of buildings (number of storey, materials used, ventilation system).

Based on the above factors HSE has defined four land use categories and five vulnerability levels:

- land use categories:
1. Category A: Residential area, hotel, holiday accommodation (e.g. bed and breakfast, camping)
   2. Category B: Buildings with less than 100 occupants and car parks with less than 200 vehicles (e.g. factories, warehouses, offices, non-retail plants, nurseries)
   3. Category C: Public spaces (e.g. retail, leisure centres)
   4. Category D: Highly vulnerable or very large facilities (e.g. hospital, nursing home, school, stadium)
- vulnerability levels
   1. Level 0: applicable exclusively for Large Scale Petrol Storage Sites (LSPSS);
   2. Level 1: normal working population;
   3. Level 2: general public (at home and involved in normal activities);
   4. Level 3, vulnerable members of the public (elderly, people with mobility difficulties, children)
   5. Level 4: people belonging to Level 3 and people doing outdoors activities (Level 2).

A consultation matrix is obtained by coupling each land-use development category with a vulnerability level and associating this combination with a consultation zone. An illustrative example is presented in Table 23. This consultation matrix is used for taking the planning decisions.  [This land-use compatibility is based on societal risk acceptability. If the expected frequency of an accident involving 50 or more fatalities from a single event is greater than $2 \cdot 10^{-4}$ fatalities/year than the risk is considered unacceptable.]

HSE "Advice Against" the proposed development when it considers unacceptable the risk associated to the hazardous facility and "Does not Advice Against" when risk is considered acceptable and no safety objections regarding the population have been expressed.  For instance, HSE suggests that development for land categories A and B is inadvisable when individual risk exceeds 10-5 fatalities/year and 10-6 fatalities/year for land categories C and D.

Hence, inside the inner zone are allowed industrial activities and parking lots with a day and night scarce people's presence and where safety measures can be applied with ease (note that HSE considers the presence of more than 25 people a 'significant risk').  Any other kind of development is forbidden within this zone.  Residential buildings can be present within the middle zone only if the developments correspond with Sensitivity Level 2 (i.e. no vulnerable centres).  Residential areas and small vulnerable centres are allowed within the outer zone.  Finally, in the case of Large Scale Petrol Storage Sites, developments usually unoccupied (e.g. storage facilities, long term parking) within the Development Proximity Zone (DPZ) are tolerated.  No restrictions are imposed beyond the Consultation Distance represented by the boundary of the outer zone.  However as societal risk can be relevant outside the Consultation Distance there are discussions ongoing regarding HSE's advisory role beyond this distance.]

The approach described above is used for new developments in the vicinity of existing hazardous facilities only and not for approving of existing hazardous facilities.

Table 23  HSE consultation matrix for developments around a hazardous facility

| Vulnerability level | Land-use developments | Outer zone | Middle zone | Inner zone | DPZ |
|---|---|---|---|---|---|
| 0 | Developments usually unoccupied (e.g. long term parking, storage facilities) | Not applicable | Not applicable | Not applicable | DAA |
| 1 | (A) Residential area, hotel, camping | DAA | DAA | DAA | AA |
| 2 | (B) Buildings with less than 100 occupants and car parks with less than 200 vehicles (e.g. factories, warehouses, offices, non-retail plants) | DAA | DAA | AA | AA |
| 3 | (C) Public spaces (e.g. retail, leisure centres) | DAA | AA | AA | AA |
| 4 | (D) Highly vulnerable or very large facilities (e.g. hospital, nursing home, school, stadium) | AA | AA | AA | AA |

DAA =  Don't Advise Against development, AA =  Advise Against development, DPZ = Development Proximity Zone

Figure 14  Example of consultation distances obtained with ADAM 1.0 (courtesy DG JRC MAHB)

The Local Planning Authorities consult the Environmental Agencies (in England and Wales) or the Scottish Environmental Protection Agency (in Scotland) for matters related with environmental impact since the HSE provides advice on the risk to the public.

The "Hazardous Substances Consent" procedure is followed for the siting of new hazardous facilities and issues related with the modification of existing ones.  The operator submits its application to the local Hazardous Substances Authority and the safety report of the hazardous facility to the HSE who will assess it.  The local Hazardous Substances Authority consult HSE on the development application.

Successively HSE advises the Local Authorities whether the development is compatible with respect to its surrounding land-use destinations.  Furthermore, HSE can require in case of consent that the facility implements a number of measures aiming at improving the safety of the population.

The Safety Report provided by the hazardous facility operators is not accessible to the public as is the case in Italy or France.  However, the operators must provide to the people potentially affected by the accident at the facility all the relevant information on existing safety measures at the facility and on the external emergency measures in the event of an accident without their having to request it.  Furthermore, upon request by the local authority the operator shall provide them with sufficient information to demonstrate that all necessary measures are taken to comply with the existing regulations.  The public has also a restricted access to the risk-maps provided by the HSE to Local Planning Authorities and must motivate its request to consult these risk maps.

However, the public must be consulted for the Local Plan adoption.  Hence, once the planning procedure has been completed, adequate publicity is given to the planning application by publishing in the local press and other media.  Also, all the land-use planning information becomes accessible to the public and planning meetings are open to its participation.  Further the public is entitled and given an adequate opportunity to express its opinion with respect to the land-use plans and which the local planning authority has to take into consideration.

It is worth noting that under the principle of compensation the losses bear by third parties due to planning decisions being modified or revoked shall be compensated.

### 1.3.5 Swiss approach

Switzerland uses a risk-based approach and visualises societal risk with a frequency-consequence (F-N) curve.

The severity of the accident is quantify using nine indicators: fatalities, injuries, evacuated persons, alarm factor, animals killed, area of destroyed ecosystem, contaminated area, polluted groundwater and property losses.  These indicators are given a different weight.

A "major accident index" based on the absolute number of consequence quantifies the severity of the accident on 0-1 range scale.  The acceptability of the frequency with which this index exceeds certain levels of this index is assessed with a frequency-consequence (F-N) curve

To note that independently of their frequency major accident are always acceptable when their index is low.

(note to the reader: above information found in literature which might be outdated)

### 1.3.6 Russian approach

Russia uses the risk-based approach and uses both individual and societal risk criteria.

Individual risk criterion considers the following levels of risk

- $10^{-4}$ fatalities/year or higher as considered as non-acceptable;
- $10^{-5}$ fatalities/year or lower for existing establishments
- $10^{-6}$ fatalities/year or lower for new establishments

The following societal risk criterion is considered

- for existing establishments limitations to the population density is applied for areas with individual risk ranging from zone between $10^{-4}$ and $10^{-5}$.
- for new establishments limitations to the population density is applied for areas with individual risk $10^{-6}$.

(note to the reader: above information found in literature which might be outdated).

## II Guidance on technical aspects

This Chapter is intended to represent a starting point for discussions in the country where land-use planning framework is under development or reviewed. The aim of this Guidance is to help responsible persons to comply with the minimum requirements for establishing the compatibility of land-use with the hazardous industry, taking into account other existing guidance on land-use, air, water and ground pollution.

The EU land-use planning guidelines describe the three principles that make an ideal land-use planning technical advice system. These principles are consistency, proportionality and transparency:

- consistency: similar outcomes are achieved when adopting a similar approach under similar circumstances;
- proportionality: intervention is proportionate to the magnitude of risks;
- transparency: make open and transparent the decision-making process and the implications of the reached decisions.

However a fourth principle might be added and which is accountability:

- accountability: identifying who is accountable when things go wrong.

To this respect the risk analysis is a fundamental step. Managing the risk to humans, the environment and property related to hazardous facilities are subject to a variety of control mechanisms specific to the different legislations. One is through land-use planning which is centred on two main themes:

- a set of minimum performance requirements that apply to any hazardous activity
- a mechanism for distinguishing between hazardous facilities deemed to be of low risk (i.e. permitted activities) and those of higher risk (i.e. those requiring a resource consent, enabling further controls to be imposed).

There are different approaches to land-use planning but all in the end aim to verify that the level of risk is appropriate and acceptable for the different land-use zones existing in the area in the vicinity of the hazardous facility. Land-use planning approaches include the following elements:

- hazard/risk assessment methods
- reference scenarios for the calculation of effects
- occurrence estimates for events of concern (e.g. frequency of “loss of containment”)
- comparison of risk to tolerability thresholds, vulnerability indicators (e.g. effect endpoints)
- classification of territorial, urban and environmental targets (i.e. transport corridors, buildings, natural elements);
- separation distances dependent on risk levels and technical measures to replace separation distances;

The risk analysis applied to a hazardous facility siting is made of five elements. In the first step are assessed the types of potential accidents that can lead to the release of energy or toxic/flammable substances. The second step estimates the location, size, rate and duration of the releases. The third step determines the probability of occurrence of the identified type of releases. The fourth step determines the consequences of each type of release in terms of specific hazard criteria or exposure of people, environment and property. And the last step compares the calculated risk with the risk acceptability criteria.

The siting of the plant is permitted when the risk posed by the hazardous facility is below the acceptability threshold risk and not permitted if the calculated risk is above the maximum allowable risk. However, in between the upper and lower acceptability threshold the risk is in a “grey area” safety improvement and additional mitigation measures may be enforced on the hazardous facility to reduce the risk to the population. This process is schematically illustrated in Figure 15.

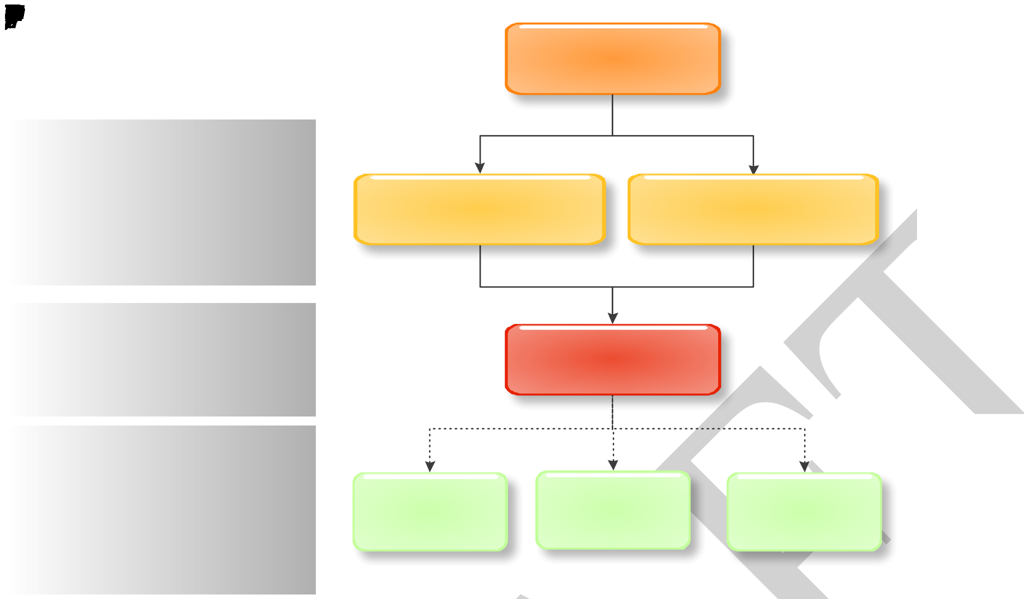

Figure 15 Examples of databases and models used in the different risk management elements (graph courtesy Lorenzo van Wijk)



Land-use planning is a risk management issue because identifying restriction of land-uses (“zoning”) or requesting technical solutions is obtained with the help of a risk analysis. Different risk quantification approaches can be applied, i.e. based on risk curves or risk map, and which leads to having different approaches for land use compatibility (e.g. consequence based or risk based). Therefore, national authorities need to choose the approach which is considered more appropriate for dealing with land-use planning within their country.

In case the country has any system in place then the consequence approach is probably a good pint to start with as it is easy to calculate without requiring sophisticated risk quantification software tools such as RISKCURVES, SAFETI, ARIPAR or ADAM. This approach includes also the selection of end-points values for the different consequences which can be for instance 4 kW/m2 for thermal radiation, 0.168 bar for blast overpressure and AEGL 2,10 minute for toxic exposure. These represent the fatalities threshold and can be used to define land-use compatibility criteria. Examples of compatibility are no light industrial buildings, warehouses or two-storey offices within 100 m of hazardous facility, no low density housing or hotels within 200 m and no school hospital or care home within 300 m. In case of the hazardous facility being a LPG storage facility then 100 m is added to each distance.

**Land use planning procedure on areas where hazardous substances are processed, manipulated and stored**

What follows can be applied to two typical situations concerning the decision to be taken on: the addition of new risk sources to an existing plant; the construction of a new hazardous installation.

The land-use planning activities around hazardous installation can be organised into the following four phases:

1. Description of the geographical area around the installation
2. Documentation about the industrial installation and related risk
3. Application of compatibility criteria according to the effects of potential accidents
4. Decision about the acceptability of the new land use

**Phase 1: Description of the geographical area around the installation**

This type of information is elaborated and periodically updated by institutional planners and should be available for use at the local municipality. It is made up by a set of thematic georeferenced maps (in digital or paper form), representing the current land zoning around the new installation, i.e. up to a distance sufficient to contain the effects of all accidents. These maps describe the land use before releasing the permission for the requested new industrial activity. They are:

- Territorial map (residential with high, medium and low index of building rights; industrial, commercial, agricultural, transports…) - from this map, the population distribution map can be derived for the purpose of societal risk quantification.
- Environmental map (quality of air, soil, surface water, and groundwater);
- Thematic maps of natural hazards, for their possibility of triggering an accident, e.g. earthquake, flooding, snowing, landslides, volcanic activity, forest fire, etc.

**Phase 2: Documentation about the industrial installation and related risk**

This type of document, i.e. the safety report, is requested by the national regulations, e.g. in EU those implementing the Seveso Directive.

With the safety report the operator must demonstrate that necessary and sufficient measures have been taken to prevent accidents from occurring and, should they occur, to limit their consequences to population, environment and property. The content of a safety report is detailed described in other national guidelines. What follows is a list of the requested information, mainly linked with the LUP problem.

Plant description:

- Description of the plant location;
- Meteorological data, i.e. wind rose and stability classes;
- Main activity and production;
- Organigram and personnel (internal, subcontractors, visitors, etc.);
- Description of the safety management system of the establishment;
- Plant perimeter with access routes and protection against intrusions;
- Plant layout with indication of where hazardous substances are stored, processed and manipulated;
- Description of the processing units, storage facilities, and wastes treatment;
- Substances data (chemical, physical and toxicological properties);
- Monitoring networks (toxic, flammable) and alarms;
- Information to the public.

Risk analysis results according to the applied procedure:

- Description of the adopted analysis procedure, models and software tools;
- Hazard identification and accident database consultation;
- Investigation on plant behaviour in case of loss of utilities and external events;
- Description of the accident scenarios to be quantified based on clear selection criteria;
- Determination of consequences of selected scenarios;
- Estimation of accident frequency with description of data sources;
- Description of the prevention and mitigation measures for each scenario;

- Determination of individual and societal risk measures;
- Description of the internal emergency plan.

**Phase 3: Evaluation of the compatibility of the new hazardous activity with the present land use**

This phase consists in applying the compatibility criteria to the land use according to the considered approach:

- Description of the land use approach (e.g. consequence based or risk based);
- Superposition of accident consequences to the territorial map to subdivide the area of impact (based on consequences or risk) into cells (cell dimension defined case by case);
- Application of the compatibility criteria to each cell;

**Phase 4: Decision about the acceptability of the new land use**

Depending on the decision about the acceptability, for each cell, of the new land use, the procedure may end or not. In case of unacceptable new land uses, the analysis must continue with Phase 2 by investigating how to reduce the accident consequences.

When the area of interest for the analysis is described by maps in digital form, the above four-steps procedure can be more easily applied using a GIS-based software tool for risk analysis, such as SAFETI, ARIPAR, RISKCURVES, just to mention a few. Indeed, the plant can be described using different georeferenced digital maps describing all plant elements with spatial character, e.g. plant boundary, plant layout, location of hazardous substances, points where accidents may occur, as well as the results of risk analysis (extension of accident consequences and/or individual risk contours). With all data in digital form phase 3 can be automatically performed by comparing, for each cell, the effects of accidents (or individual risk value) with land use criteria giving, as result, the list of all situations of incompatibility that requires further considerations.

**Transboundary effects of accidents and related land use**

When plants are located close to the boundary between two countries, reference should be made to the Industrial Accidents Convention. In this case the above procedure is still applicable, provided that the concerned countries agree on common approaches for both risk analysis and land use compatibility criteria.

Figure 16 shows the case of a hazardous facility located in country A in which accidents may have effects on the border area in country B. The situation is different when on both side of the border hazardous facilities exist as shown in Figure 17. In this case on each side of the border there are two areas that can be differentiated based on the level of impact. For instance in country A the zones in the vicinity of the hazardous facility are exposed to the effects of an accident occurring in country B and marked with “Impact B2.

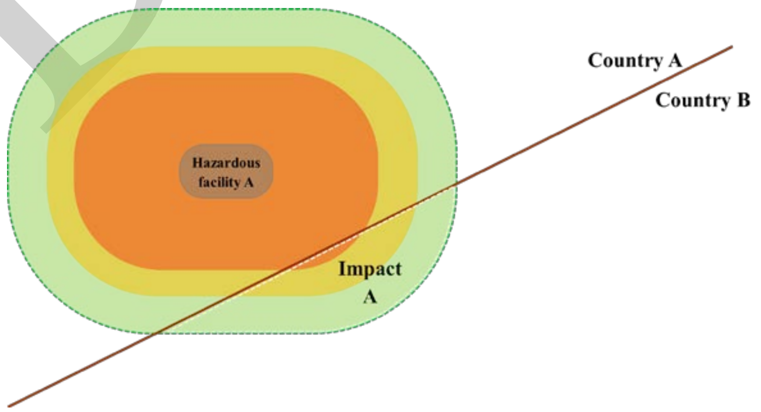


Figure 16 Illustration of transboundary effect of an accident occurred in a hazardous facility located in country A which may have effects on country B (graph courtesy Lorenzo van Wijk)

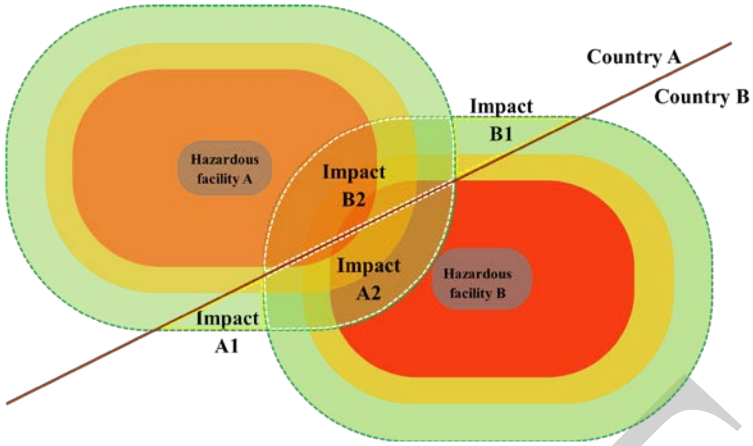


Figure 17 Illustration of transboundary effects due to the presence of hazardous facilities located each in countries and B and which may have effects on each other country (graph courtesy Lorenzo van Wijk)

In the very particular case in which both countries apply the same risk analysis approach, use the same accident consequence models, frequency estimation methods, environmental data, components reliability data as well as same compatibility criteria then, according to the Industrial Accidents Convention, they have all the instruments to reach swiftly an agreement on their land use planning problems. Unfortunately, this is not the common case. Most likely, the involved countries apply:

- different risk analysis methods and different models;
- different data;
- different land use compatibility approach and/or criteria.

These land-use situations are complex to resolve as they require a strong collaboration between the involved countries as on the above issues a full agreement needs to be achieved. This could be facilitated in case land-use planning related articles would be available within the Industrial Accidents Convention

***Different risk analysis methods and different models***

Countries A and B should find an agreement on all phases of risk analysis. To this purpose each country should have full access to all details of the safety report of the establishments in the adjacent country. Agreement of all phases of the risk analysis is deemed necessary, including the specific models and methods for accident frequency and consequence.

***Different data***

Once the agreement on methods and models has been obtained the agreement on data should not be difficult to achieve. Data on the release of the hazardous substance, e.g. source terms (type of rupture and release conditions), wind rose and stability classes, data requested by consequence models, vulnerability data, components reliability data, population distribution. Based on the data and models agreed upon, the risk analysis for both countries can be repeated with common models and data. As already mentioned, the risk model can be rapidly recalculated if suitable GIS-based tools are available.

***Different land use compatibility approach and/or criteria***

Each country has the right to apply its own compatibility criteria. The new and common risk analysis must apply land use compatibility criteria.

# B Annex Part B: Technical guidance

## B.1 Technical aspects, definitions and basic concepts of risk analysis of industrial hazardous activities in the context land-use planning

Both risk as well as land-use planning experts use specific technical and risk terminology which meaning may not always correctly be understood by non-experts leading to misunderstanding or incomprehension in conveying such information. Furthermore, the meaning of these terms may vary from country to country.

This Chapter introduces briefly the different elements in the context of risk management of hazardous industrial activities to clarify their meaning and provide a practical and realistic understanding to the reader. Such understanding can also successively improve and facilitate the communication between authorities, operators and the public on the adequateness of land use planning and control strategies to prevent and reduce the consequences of accidents on the population, human activities, environment and infrastructure surrounding major hazard sites.

It is not the intent in this Chapter to discuss these technical risk-related subjects in detail but to touch upon the salient concepts so that their use in the land-use planning can be understood. There is a vast literature on risk assessment[70,71] and its elements as well as risk communication.

### B.1.1 Main definitions and basic concepts

Hazard is defined as a physical or chemical characteristic/condition that has the potential for causing harm to people, the environment or property. A hazardous activity is an activity where hazardous substances are handled, produced or stored.

A hazardous activity is an activity where hazardous substances are handled, produced or stored. A hazardous site is where one or more hazardous activities are conducted. However, a hazard becomes the cause of an accident with dangerous consequences only when a “triggering” event occurs. For instance, in the case of chlorine, the triggering event is the loss of containment, allowing the toxic gas to spread into the atmosphere. A consequence is the result of an undesired event (an accident), such as injury to health, life, assets, or the environment. After the accident has occurred, the originating hazard may still exist or not.

Risk can be defined as the exposure to possible unwanted consequences such as economic loss or human injury. Considering an industrial activity, the risk is an indirect measure of the economic loss or injury in terms of both the accident likelihood and the magnitude of the loss or injury. In other words the risk (R) is a function of the accident probability or frequency (F) and the magnitude of the consequent damage (D). In symbolic terms: $R = F \times D$.

There would be no risk if we knew the exact time and place of an accident; also, there would be no risk without damage. It is essential in risk analysis to precisely define what is meant by damage. Indeed, an accident may cause different types of damages: to the population (fatalities, hospitalised), to the environment (ground pollution, water, air,..), and to the property (destruction of buildings, financial loss, …). Hence it is important to define the reference damage and therefore different risks can be determined for different reference damages. In risk analysis the reference damage is generally the death of people.

A given hazard is therefore associated to a certain level of risk: the higher is the former, the higher is the latter. It is therefore necessary to reduce the risk by adopting a suitable level of safeguards, i.e. technical means to remove the triggering event or to reduce the likelihood of its occurrence. For instance, crossing the ocean on board of a transatlantic would reduce the risk of sinking; the use of a double containment or a water spray reduces the

70 CCPS. Guidelines for chemical process quantitative risk analysis (2nd Edition). New York: Center for Process Safety, AIChE, Wiley Press, October 1999

71 Lees, F.P., Loss Prevention in the Process Industries, Butterworth-Heinemann; 4 edition (2012)

possibility that the chlorine may be dispersed into the atmosphere. Hence, for a given hazard, the symbolic relationship between risk (R) and safeguards (S) is the following: R = H / S.

Since the risk is a function of hazards and safeguards its reduction can be achieved by reducing the hazard (e.g. using less hazardous substances, less quantity of substances, less hazardous processes) and/or increasing the safeguards measures. The term safeguard encompasses both the technical means to prevent the accident from occurring (more reliable safety systems, shut down systems, trained and skilled operators, etc.) and, in case of accident, the means to mitigate the consequences to selected targets (e.g. water curtains, fire walls, safety distances, population evacuation).

Figure 18 describes typical risk curves in terms of accident frequency and associated consequences. Three different risk levels may correspond to three different plant designs. It is possible to pass from a generic point in one curve to a curve of lower risk by reducing the accident occurrence probability (prevention measures) and/or improving the mitigation measures.

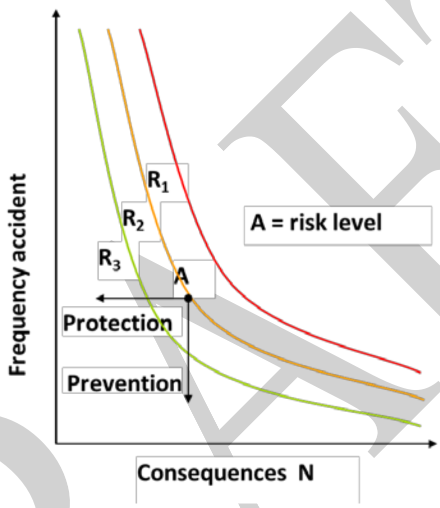


Figure 18 Risk reduction (graph courtesy Lorenzo van Wijk)

In a plant multiple accident of different severity may occur; hence the risk in a given point of the area is a proper combination of the consequences and frequency of all possible accidents. A practical and operational definition of risk is represented by a set of triplets presented in Table 24 where each triplet is made up by an accidental situation, the related frequency of occurrence and the consequences of the accident on the defined targets. Therefore the risk can be symbolically expressed as: $R = \sum_{i=1}^{n} f_i \, c_i$

Table 24 Risk definition as a set of triplets

| accident | frequency | consequence |
|---|---|---|
| $a_1$ | $f_1$ | $c_1$ |
| $a_2$ | $f_2$ | $c_2$ |
| $a_3$ | $f_3$ | $c_3$ |
| - | - | - |
| $a_n$ | $f_n$ | $c_n$ |

For many human activities, for which sufficient historical records of accidents data are available, the risk can be estimated by means of the application of statistical analysis techniques. Typical example is the occupational risk, where a comparison can also be made between the different industrial sectors.

In other cases, however, the statistical theory is useless because of the lack of significant data; this is the case e.g. of dangerous installations or of processes based on new technologies. Consequently, the decision about the risk acceptability must be based on the application of systematic and consistent predictive procedures allowing estimating the risk level and the associated uncertainties. Such a procedure is commonly referred to as Quantitative Risk Analysis (QRA), but also Probabilistic Risk Analysis (PRA) is frequently used. QRA is a procedure that allows answering the following questions:

- What can go wrong in the plant?
- Which are the consequences of malfunctions?
- How often will they occur?

Each of the above questions is dealt with by a specific kind of analysis. More precisely, hazard identification analysis deals with the first question; models for the estimation of the damage to man, the environment and property are applied to answer the second question; probabilistic techniques are used to give the answer to the third question.

In risk analysis both qualitative and quantitative approaches are available.

The qualitative approach relies on experience expressed in the form of check-lists and codes of practice. Several check-lists are available for site selection, process materials, aspect of design, commissioning ad operation. However, in some case, reliance just on check-lists cannot be considered sufficient to identify all important hazards and related causes. For instance, for new processes and new plants, a systematic analysis of possible malfunctions is an essential step towards achieving an acceptable safety level. The HAzard and Operability analysis (HAZOP) methodology is commonly applied to identify hazardous situations that arise in a plant due to components failure, human error or external events. Many other methodologies can be applied during the different phases of plant design.[72,73]

The quantitative approach is obviously more sophisticated, as it aims at producing a consistent and quantified picture of the risk induced by the operation of the plant. It is based on well established procedures in which systematic techniques for hazard identification, accident frequency and consequence estimation are applied.

Because of the uncertainties in data and models, as well as the assumptions the analysts must make to overcome the lack of information, the transparency of the whole evaluation process is an essential requirement of any risk quantification procedure.



72 BRITISH STANDARD BS IEC 61882, Hazard and operability studies (HAZOP studies) —Application guide, 2001

73 CCPS, Guidelines for Hazard Evaluation Procedures, New York, 1985

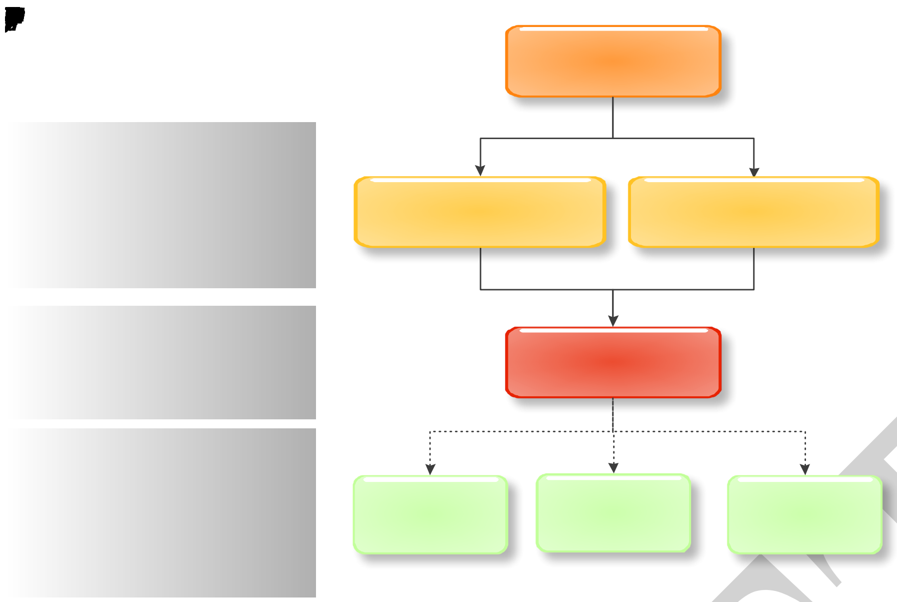

Figure 19  Main QRA phases and related data (graph courtesy Lorenzo van Wijk)



The general QRA procedure can be subdivided into four main phases, namely:

- hazard identification;
- accident frequency and consequence estimation;
- risk calculation and representation;
- risk reduction.

The first phase, i.e. hazard identification (HAZID), aims at producing a list of potentially hazardous situations (accidents) arising from the loss of containment caused by one or more “initiating events” (e.g. component failure, operator error, utility failure, deviation of plant input variables outside the normal range), hazard identification is fundamental for any risk analysis, since no protection measure can be implemented for unidentified hazards.

To be successful, this phase must be performed by a team of experts with a thorough knowledge of the plant (e.g. process engineer, mechanical engineer, instrumentation engineer, etc.), coordinated by an experienced risk analyst. The team “brainstorms” on each significant deviation of the plant behaviour from normal conditions, at the same time making suggestions to the designers on modifications needed to improve the plant performance from the safety viewpoint.

To focus (i.e. limit) the analysis to the significant problems, some screening criteria are applied, based on engineering judgement, on both the occurrence frequency and the damage caused by each identified accident sequence.  Those accidents for which the frequency, the damage or a combination of both give an insignificant contribution to the risk are neglected.  Therefore, the result of this phase is a set of “conceivable and significant accidents” to be subject to the quantification phase.  Accident data bases are also inquired to enhance the completeness of the analysis.

Since this analysis is expensive, due to the involvement of a team of plant experts, a preliminary analysis is performed by applying the so called “hazard index methods” to rapidly rank the intrinsic hazard level of the different plant units and to define, for each of them, the subsequent risk analysis phases to apply (e.g. no analysis at all, only consequence analysis, complete analysis).

The second phase is composed of two parts:

- Accident frequency;
- Accident consequences.

This first part is performed by means of a set of probabilistic methods (mainly fault trees and event trees) for modelling the different sequences of events leading to the accidents under study. These methods allow the plant to be broken down into its constituent parts up to the detail of “simple item”, i.e. of components / subsystems for which the failure probability is available or it can be statistically estimated from past experience.

The analysis of these models allows analysts to estimate the accident frequency, the different causes and the major contributors. Based on these results the designers can rationally identify the weakest point of the plant and to adopt the best cost effective design solutions to reduce the risk.

The term “consequence analysis” refers to:

- the estimate of the physical effects of accidents, and[74]
- the estimate of the damage caused to defined targets[75].

Typical accidents are fire, explosion and release of toxic substances. The models available allow analysts to determine the physical effects in terms of heat radiation from fires; blast wave intensity and fragment trajectory in the case of an explosion; and ground concentration in the case of a toxic release.

To estimate the damage, both “on-off criteria on accident effects” and the probit model (dose-damage relationship)[76][77] are frequently applied.

The results of these calculations allow the analysts to verify the adequacy of the existing protective devices and, if necessary, to suggest the implementation of other measures

In the third phase the results of the previous phase are used to estimate the risk and to represent it in the form of risk contours on the map site and F-N (Frequency-Consequence) curves.

In the fourth phase decisions can be made on further risk reduction or on its acceptability. In the former case the analysts have all the information necessary (generated during the previous phases) to identify the best cost effective plant improvements. However the decision about risk acceptability is a complex matter that cannot be purely based on risk analysis results. This phase is also very important for risk management, including land-use planning and emergency management.

Risk analysis is a complex study involving the treatment of a large amount of information by the team of experts in chemical processes, maintenance, system reliability and consequence calculation.

Uncertainties are inevitably introduced in all phases of the study. Apart from the fact that it is always more important to prevent than to quantify, an essential feature of a quantitative risk analysis is the maximum clarity in the assumption models and data used. The main sources of uncertainty are briefly listed herewith.

- Incomplete plant knowledge, which has a considerable effect on the hazard identification phase.

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[74] TNO, *Methods for the Calculation of Physical Effects*, CPR 14E, Third Edition 2005.

[75] TNO, *Methods for the determination of possible damage*, CPR 16E, First Edition 1992

[76] Finney D.J. Probit Analysis, Cambridge University Press, 1971

- Engineering judgement, needed to overcome the problem of missing data and imperfect knowledge of accident evolution, dose-effect relationships, mitigations, etc. This is an important source of uncertainty, which calls for the need of a multidisciplinary team of experts.
- Model uncertainty, i.e. inappropriate model, inaccurate model parameters, inadequate validation, model limitations which require simplifying assumptions.
- Data uncertainty, i.e. source term, reliability parameters, time to operator interventions, atmospheric data (e.g. wind rose, stability classes), vulnerability data, etc.

In spite of the many sources of uncertainty, the real value of a QRA resides in the critical identification and examination of the hazardous plant behaviours to verify the adequacy of the safety measures against possible accidents. The risk analysis is in fact an iterative process of "design improvement", leading at the end, to an acceptable level of plant safety. In other words, the QRA allows analysts to improve the awareness of the critical aspects of the plant, to check the validity of the implementation of design rules and safety criteria, and to demonstrate that the design includes adequate safeguards actions for both preventing accidents from occurring and reducing their consequences.

### B.1.2 Risk acceptability

Risk is perceived in different ways by different people, depending on several factors, i.e. involuntary exposure, lack of knowledge about the industrial activity, the degree of involvement in the risk acceptability decision, lack of control, the level of reward, diffidence on authorities, information from media, and so on. The perceived risk can also be defined as a "feeling of insecurity".

Risk acceptability is the process of deciding whether the risk posed by a certain activity can be accepted or not, i.e. if it can be perceived as acceptable by the community living around the hazardous establishment. This is complex matter whose solution requires the involvement of all interested stakeholders and the establishment of commonly recognised Risk Acceptance Criteria. The definition of acceptable levels of risk is difficult and requires considerable efforts to achieve consensus; it is more a political rather than a purely technical issue.

Like other sensitive land use questions, public information and participation are essential aspects of the process, as discussed subsequently in this document.

Acceptability depends on the trade-offs between risks, costs, and benefits and may vary from one community to another. There generally exists a level of risk that is clearly unacceptable, no matter what the level of benefits and costs. On the other hand, there also exists a minimum level of risk which is so insignificant as to not justify concern.

The high "unacceptable" level of risk together with the low "acceptable" level of risk defines the "grey area" of safety criteria, where risks may or may not be acceptable depending on the individual situations. Inside the grey area the risk is acceptable only if all reasonably practical measures have been taken to reduce it. Reasonable and "practical depend on the trade-offs between risk and costs and risk and benefits.

Decision-makers responsible for land use planning must balance the concerns both the proponents of projects and of those affected by them. The acceptable levels of risk proposed in the present guidelines are intended to serve as a basis for such choices. They apply equally to risk· from hazardous substances from all sources: fixed facilities, pipelines or transportation corridors.

As an example, the following figure shows the thresholds of the risk to which an individual, living in a given location, can be subject to as established in the UK for chemical and petrochemical installations.

In the region between acceptable ($\leq 10^{-6}$) and unacceptable risk ($\geq 10^{-4}$) the operator must adopt all reasonable practical means (safeguards) to reasonably reduce as much as possible the current risk level.

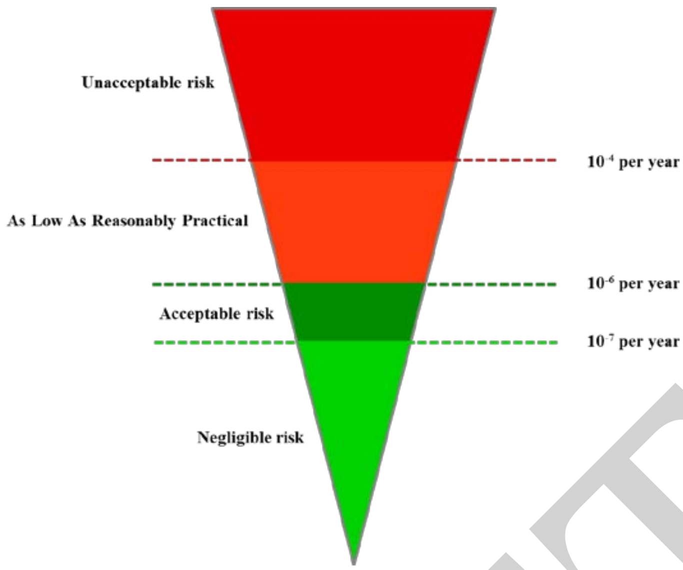


Figure 20 Example of illustration risk in UK (graph courtesy Lorenzo van Wijk adapted from HSE)



### B.1.3 Consequences and effects of industrial accidents

The use, storage, transportation and disposal of hazardous substances are associated with primary production, manufacturing and processing activities, as well as retail, business and domestic activities. There are risks associated with hazardous substances that could adversely affect the environment and human health. These hazards include explosiveness, flammability, corrosiveness, toxicity and eco-toxicity.

The estimated consequences of a release can be defined as "the chances of an exposed individual suffering a particular effect" (a fatality, an injury, etc.). Individual consequences will vary depending on the location of the receptor (the exposed individual) with respect to the emission or risk source. Factors such as the type and quantity of substance released, the concentration level at particular locations, the duration of exposure, and the type of contact (for example, inhalation, dermal contact, ingestion), determine the severity of the damage that the exposed individual suffers. Substances released into the environment can reach a receptor through a variety of transport media, such as the atmosphere, contaminated soil (dust particles), water, and ground water.

In public safety risk assessments, one must differentiate between individual and societal consequences. The individual consequences concern the chances that an individual exposed to a given hazardous event may suffer a particular effect (a fatality, an injury, etc.). The societal consequences can be estimated by adding up all the individuals suffering that given effect.

Moreover, a “consequence based” approach will characteristically show the consequence area for lethal effects and serious injuries resulting from the scenarios assessed, while a “risk based” approach will show an area within which there is a given probability of a specified level of harm resulting from the large number of possible accident scenarios

#### B.1.3.1 On human beings

The human vulnerability to the physical effects of accidents has been, and is being, an issue extensively studied.

A human being can be subject to the effects of radiation, overpressure and toxicity respectively in case of fires, explosions and release of toxic substances in the environment (mainly air and surface water). Whereas in risk analysis the effects of accidents on human beings are acute exposure, when land use planning issues are considered also the long-time effects i.e. chronical effects, should be considered.

In order to protect people from the effects of accidents, human vulnerability models have been defined. Two approaches are available: threshold values and Probit functions, all based on real or experimental data.

The threshold values approach has been adopted in many countries, for radiation, overpressure and toxicity, although there is no general agreement. A threshold expresses the minimum dose value corresponding to a certain effect. For instance, the thermal radiation of 3 $kw/m^2$ (for an exposure time of 5-20 s) is considered in Italy as the threshold for reversible effects, whereas the same value corresponds to irreversible effects in France. In case of explosion, the threshold for irreversible effects is 50mbar in France and 70mbar in Italy. Same considerations can be drawn for dose toxicity thresholds for several toxic substances.

The Probit model [78]is by those countries that adopt the risk-based approach in risk analysis and land use planning. The Probit model is a relationship between the dose absorbed and the probability of suffering a given consequence. For instance, in cases of fire, coefficients of the Probit model have been defined for first, second and third degree burns; for explosions the Probit model is available for the rupture of eardrums, for pulmonary haemorrhage, death and impact of the body with missiles. The Probit coefficients for the effects of toxic substances on humans are more uncertain than those for fire and explosions, due to the fact that data are extrapolated from laboratory data on animals.

Independently of the model applied in risk analysis, land use planning and emergency management, it is important to consider particular locations where people are more susceptible to the effects of accidents, as for instance hospitals, schools, elderly housing, recreational areas, etc., as well as other places where concentration of people can be found, e.g. parking, railways stations, churches, etc. Hence, at these locations (vulnerable centres), the risk level must be sufficiently low since the "vulnerable" population may not respond effectively in case of emergency.

#### B.1.3.2 On environmental receptors

Many others receptors are to be taken into consideration, e.g. natural protected areas, surface water, ground water, agricultural areas, cultural heritage, etc.

#### B.1.3.3 On other elements of sensitivity or interest

Possible elements are:

- Special areas of conservation defined in the Habitats Directive (92/43/EEC):
- Protected species lists "Birds Directive" 79/409/EEC;
- For water the The Water Framework Directive 2000/60/EC;
- Soil

### B.1.4 Stakeholders involved

Risk analysis for risk management and land use planning is a complex activity performed by the industry and submitted to authorities for approval with the involvement of the local population. The aim of stakeholders is to reach a consensus about the acceptability of the concerned hazardous installation. The consensus building needs a clear and transparent risk analysis procedure and a set of software tools to support the stakeholder's tasks. Updated risk situations and studies of planning alternatives need to run the risk model several time with new data and assumptions, to analyse alternative scenarios, to perform sensitivity analysis and to display results on geo-referenced maps of the area of interest. The general obligations of each stakeholder, namely the authorities, the industry and the population, are briefly listed herewith, without any reference to a specific country.

78 Eisenberg N.A., Linch N.A., Breeding N.J., Vulnerability model: A simulation system for assessing damage resulting from marine spills, GG-D-136-75, US Coast Guard, 1975

#### B.1.4.1 Authorities

In risk analysis and risk management authorities are involved at different level: national, regional and local with different tasks and responsibilities. Without specifying the level, the Competent Authority (CA) is responsible for protecting the population from the effects of accidents.

In particular, it examines the safety report submitted by the industry, for constructing a new plant or modifying an existing plant, and take decisions to either license it or not. During the decisional process the CA maintains close relations with the industry and the population.

Moreover, it draws up the External Emergency Plan, periodically revises it and, if necessary, updates it. This plan, together with the information on the industry, is also communicated to the population.

Land use planning in areas where hazardous activities are located is another important duty of the CA.

Moreover, in case of industries whose potential accidents may have transboundary effects, the CA has to supply all the necessary information to potentially affected countries to allow them to consider such accidents in their emergency plan, land use plan and information to their public.

#### B.1.4.2 Industry

The industry has the main obligation to prove that it has taken all necessary measures to prevent major accident from occurring by implementing appropriate prevention and mitigation measures as well as an adequate safety management system.

Any new hazardous activity must be described in a safety report to be submitted to the CA. The safety report shall also contain the description (resources and procedures) of the internal emergency plan to an extent sufficient for the CA to draw up the external emergency plan.

Moreover, in collaboration with the CA, the industry has to inform the population, liable to be affected by a major accident, about the hazardous activities and how to behave in case of external emergency.

#### B.1.4.3 General public

The population living around a potentially dangerous industry has the right not only to be informed about the activity which is carried out in the establishment, but also to give its opinion when a decision is to be taken on a request of a new hazardous activity that may increase the risk outside the establishment. Furthermore, as previously mentioned, the population must also be informed about the External Emergency Plan and how to behave in case of accident.

#### B.1.4.4 Non-governmental organizations

NGO have played and currently play a significant role in sustainable development at the international level. As far as the industrial risk and land use planning are concerned NGO, with their local representatives, bring the interest of the local population, in particular on environmental aspects and long term damages.

### B.1.5 Elements and criteria to support decision-making on land use and safety

In order to set a policy for land use around an installation it is firstly necessary to evaluate, as accurately as possible, the potential adverse effects from hazardous substances that need to be controlled:

- effects on human health, including risk to people and communities
- effects on property and natural resources caused by fire and explosion
- effects on the receiving environment caused by pollution, contamination and poisoning

The controls need to be implemented at the site where the activities and facilities involved with hazardous substances are to be located. This requires a careful analysis of the consequences from potential accidents.

### B.1.5.1 Consequences

Accidents begin with an incident, which usually results in the loss of containment of material from the plant. The material has hazardous properties, which might include toxic properties and energy content. Typical incidents might include the rupture or break of a pipeline, a hole in a tank or pipe, run-away reaction, fire external to the vessel, etc. Once the incident is defined, source models are selected to describe how materials are discharged from the process. The source model provides a description of the rate of discharge, the total quantity discharged (or total time of discharge), and the state of the discharge, that is liquid, vapour or a combination. Liquid and gas outflow phenomena have been thoroughly investigated theoretically. The two phase discharge occurs, for example, when pressurised vessels fail, where the liquid outflow partially flashes. These types of releases are more difficult to model than the other two, which, in any case, can be considered as limiting situations.

A dispersion model is subsequently used to describe how the material is transported downwind and dispersed to some concentration levels. For flammable releases, fire and explosion models convert the source model information on the release into energy hazard potentials such as thermal radiation and explosion overpressures. Effect models convert these incident-specific results into effects on people (injury or death) and structures.

Many models are available to calculate the effects of released material or energy leading to fires, explosions and dispersions of toxic materials. These phenomena may not be independent, e.g. a fire may produce, as combustion product, a toxic gas; a run-away reaction may produce an explosion followed by a fire, and so on.

#### B.1.5.1.1 Fire[79] [80]

The available models for fire can be classified on the basis of the properties of the substances involved, the release conditions and the time of ignition after release. The types of fire considered in risk analysis are as follows:

- Jet fire: occurs when a flammable substance escapes from a puncture in pressurised vessel or pipe and ignites immediately
- Pool/tank fire: occurs when the vapours of the flammable material, stored in a tank or spread on the grounds, due to the loss of containment, are ignited
- Flash fire: is caused by the ignition of a vapour cloud and the propagation of the flame occurs at low velocity, i.e. without exploding
- Fireball: when a pressurised vessel is overheated by an external fire an explosion occurs and the contents of the vessel rapidly vaporise forming a cloud which is ignited and burns rapidly. The duration of the fireball is very short (few tens of seconds) but the heat intensity is very high.

  The available models for fire generally determine:

  - the geometry and dimensions of the fire;
  - the heat radiation intensity at different distances;
  - the flame temperature, and
  - the heat transferred at nearby objects.

  Knowledge of the heat radiation at different points from the centre of the fire is important for:

79 CCPS, Guidelines for Vapour Cloud Explosion, Pressure Vessel Burst, BLEVE and Flash Fire Hazard, Wiley, 2nd Edition 2010, ISBN 978-0-470-25147-8

80 TNO, Methods for the Calculation of Physical Effects, CPR 14E, Third Edition 2005.

- estimating the damage to people;
- estimating the damage to structures with possible domino effects;
- identifying the type of protective clothing needed to prevent any damage to operators;
- identifying, at the design stage, the safe location of particularly critical components (e.g. tanks, vessels, control room, offices);
- to find the optimum dimensioning of the mitigation systems.

#### B.1.5.1.2 Explosion

An explosion is a rapid exothermic reaction (i.e. rapid decomposition of the substance) with a sudden release of energy: the violence of the explosion depends on the rate of energy released. An explosion can be classified as a detonation or a deflagration depending on the flame front velocity. In a deflagration the flame front velocity is relatively low, whereas in a detonation the velocity is faster than the speed of sound. The shock wave which accompanies a detonation may cause significant damages.

Explosions can also be classified as confined (occurring in a closed or semi-closed environment) or unconfined (open air).

Types of explosions of interest in risk analysis are as follows:

- Unconfined Vapour Cloud Explosion (UVCE): occurs when a cloud of flammable material is formed and ignited when its dilution in air is within the explosive range;
- Boiling Liquid Expanding Vapour Explosion (BLEVE);
- Physical Explosion: physical explosions are typically those which occur when a pressurised vessel fails catastrophically with the release of high energy (i.e. a vessel containing pressurised vapour)
- Run Away Reaction Explosion: these are chemical explosion caused by the rapid decompositions of the materials;
- Dust and Gas-Dust Mixtures Explosion: the ignition energy decreases with decreasing dimensions of the dust particles.

Models for explosions give results concerning the blast wave intensity and the trajectory of fragments (missiles) which may lead to the rupture of other parts of the plant with consequent domino effects.

These results allow analysts to estimate the probable damage caused by the explosion and to verify the adequacy of the existing protection devices.

#### B.1.5.1.3 Toxic release[81] [82]

The modelling of the dispersion of a cloud of a flammable/toxic substance firstly depends on the density of the cloud, which can be either heavier or lighter than air. The gas density changes in time due to wind speed, the stability of the air (e.g. Pasquill stability classification system) and the atmospheric turbulence which affect the entrainment of the air.

[81] CCPS, Guidelines for Use of Vapour Cloud Dispersion Models, AIChE, 2nd Edition 1996, ISBN 978-0-8169-0702-1

[82] TNO, Methods for the Calculation of Physical Effects, CPR 14E, Third Edition 2005.

Dispersion can be classified according to the duration of the release (either instantaneous or continuous) and the phase of the released material (gas/vapour, liquid, two phases). As mentioned above, the determination of the phase and the emission rate, i.e. the source term, is one of the most important factors affecting the modelling.

Lighter than air releases are generally well modelled by means of the Gaussian model, whereas the process of dispersion of heavier than air clouds is more complicated. It is generally the denser-than-air gases that are of concern in risk analysis, since the clouds present concentrations higher than lighter-than-air gases which disperse more easily.

During the first period of the release of a heavier than air gas, the dispersion is dominated by the source characteristics and the initial acceleration of the gas, followed by a rapid transition to regimes in which the dispersion is characterised by the internal buoyancy of the cloud. Thus, from a certain time on the plume should be considered as lighter than air and studied by means of a Gaussian model.

A vast literature on gas dispersion modelling is available. For toxic gases these models give the concentration of the cloud (e.g. at ground level) in time; some models determine the concentration at the central line of the plume, others also give the concentration at the borders of the plume. For flammable gases they give the zone in which the concentration is within the explosive range.

Table 25 summarises the main results that models supply and their use in risk analysis

Table 25 Use of models and their results in risk analysis

| Accident type | Model Outcome | Use of models' results |
|---|---|---|
| Fire | Geometry/Dimension of fire<br>Radiation Intensity vs. distance | Assessment of damage to people, environment, and infrastructure<br>Identification of vulnerable elements<br>Assessment of the adequacy of mitigation systems and safety distances |
| Explosion | Blast wave overpressure<br>Trajectory of fragments | Assessment of damage to people, environment, and infrastructures<br>Identification of vulnerable elements<br>Assessment of possible domino effects |
| Toxic release | Toxic concentration on ground vs. distance | Assessment of damage to people, environment<br>Assessment of the adequacy of protection means (masks, dresses) |

### B.1.5.2 Effects[83]

This section deals with the physical effects of fire, explosion and toxic release and which are a consequence of the loss of containment/release of flammable and/or toxic substances. These effects are the impact of thermal radiation, overpressure/impulse and toxic concentration on people, structures and the environment like lethality, structural damage and pollution. All of this in turn has also an impact on the business in general.

In order to determine the consequences to people and structures of major accidents, it is necessary to translate the results of the models mentioned above into the real damage caused. This requires the use of vulnerability models or damage criteria.

83 TNO, Methods for the determination of possible damage, CPR 16E, First Edition 1992

It should be noticed that the damage considered in risk analysis is of lethal type.  Many criteria (fatality dose) have been defined concerning the damage to people in case of explosions (blast wave intensity), fire (heat radiation intensity) and release (toxic concentration) of given substances. The fatality dose is defined as the product of the physical effect value and the exposure time leading to the reference damage to an exposed person.

In the case of fire, the effect depends on the level and duration of the thermal radiation, expressed in $kW/m^2$; in the case of an explosion it depends on the blast wave intensity (mbar); in the case of dispersion of a toxic substance the effect depends on the concentration (ppm or $mg/m^3$) and the time of exposure (sec), also taking into account sheltering.

#### B.1.5.2.1 Thermal radiation

The thermal radiation may cause, depending on the exposure time, relevant damages to people i.e. first, second and third degree burn up to lethality. These effects follow the pain threshold, which represents the "human alarm". Table 26 shows the time to pain threshold for varying levels of radiation, for different doses. These values are useful for defining the mitigation measures.

Fire vulnerability models are based on both experimental and real data. For instance, based on nuclear explosions, which are characterised by high radiation intensity in very short exposure times, Eisenberg plotted the 1%, 50% and 100% lethality curves[84].  In the same Figure 21 are also shown the significant injury threshold and the Mixter data related to second degree burn[85].

Table 26  Time to pain threshold for varying levels of radiation

| Radiation intensity [kW/m2] | Time to pain threshold [s] |
|---|---|
| 1.74 | 60 |
| 2.33 | 40 |
| 2.90 | 30 |
| 4.73 | 16 |
| 6.94 | 9 |
| 9.46 | 6 |
| 11.67 | 4 |
| 19.87 | 2 |

84 84 Eisenberg N.A., Linch N.A., Breeding N.J., Vulnerability model: A simulation system for assessing damage resulting from marine spills, GG-D-136-75, US Coast Guard, 1975

85 Mixter G., The empirical relation between time and intensity of applied thermal energy in production of 2+ burns in pigs, University of Rochester, report UR-316, 1954.

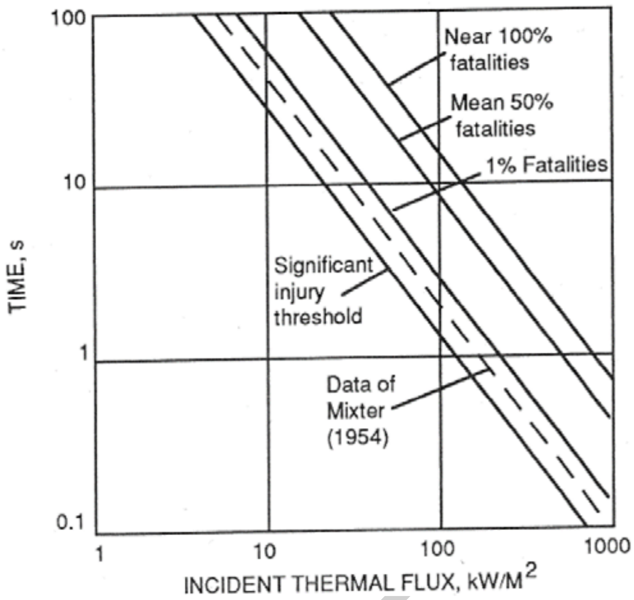


Figure 21  Damage curves for human being due to fire

A 'Probit' (probability unit) is a function that relates the dose with the probability that a receptor will suffer a certain type of reference damage.  Simply speaking, the Probit function has the following expression: P = a + b ln D, where a and b are coefficients obtained from experimental data (they are characteristic of a given damage and are available for the different degree burn and for lethality) and D is the dose.  P is the probability that the exposed person will suffer the considered damage. In case of fire D is a function of the radiation intensity and the time of exposure: $D = Q^{4/3}$ t.

In applying the Probit function it is important to accurately estimate the exposure time by considering also the escaping possibilities which depend on panic, reaction time, age, etc., and also on the type of fire; indeed in case of a fireball the radiation intensity is so high that the escaping possibilities are limited.

Criteria and Probit functions can also be applied to structural damages.  The damage to buildings subject to thermal radiation is due to the ignition of materials e.g. wood, synthetic materials, glass, steel, etc. The first two materials can lead to other fires.  Glass brakes under thermal load causing harm to people. The characteristics of the steel (structural elements, vessels, pipelines) can be modified due to thermal dose causing loss of containment with the consequent release of flammable / toxic substances.

Two threshold damage levels are generally considered: material ignition and damages that do not compromise the containment integrity level. For instance, in risk analysis $12kw/m^2$ is generally the threshold considered for plant components damage.

### B.1.5.2.2 Blast overpressure

The effects of a blast overpressure on people can be direct or indirect. Direct effects are associated with the variation of intensity and duration of the atmospheric pressure, causing the compression of lungs and eardrums. The indirect effects are related to the impact of the human body with a missile or to its translation against a rigid surface.

Table 27 contains the peak overpressure values corresponding to different damage values.  Probit function coefficients have been proposed by TNO for both direct and indirect effects, as well as for determining the probability that a person, hidden by windows glass fragments, may die.

Table 27  Physiological damage due to overpressure

| Effect | Peak overpressure [bar] |
|---|---|
| Ear drum damage | 0.35 |
| Reversible damage | 0.03 |
| Irreversible damage | 0.07 |
| Threshold for fatalities | 0.6 |

In risk analysis the structural damage due to explosions is classified into five zones:

- Total destruction, when the collapse of the structure is not less than 75%;
- Very serious damage, when about 50% of the structure collapses and the remaining part is seriously damaged;
- Serious damage, partial demolition of buildings, i.e. collapse of about 25% of external walls;
- Moderate damage, damage to parts of the building that can be restored;
- Negligible damage, such as glass rupture, roof partially damaged … i.e. parts that can be rapidly restored.

The pressure peak values associated to the above zones depend on the building characteristics. For instance, for English and American residential buildings are respectively as follows (pressure in Pascal):

- Total destruction: 70 kPa;
- Very serious damage: 35 kPa;
- Serious damage: 7-15 kPa;
- Moderate damage: 3 kPa;
- Negligible damage: 1-1.5 kPa.

Another example of peak overpressure values and related damage is the content of Table 28. Probit functions are also available in the literature for the first three damage zones and for glass ruptures.

Table 28 Damage data of explosions

| Pressure (psig) | Damage |
|---|---|
| 0.02 | Annoying noise (137 dB if of low frequency 10–15 Hz) |
| 0.03 | Occasional breaking of large glass windows already under strain |
| 0.04 | Loud noise (143 dB), sonic boom glass failure |
| 0.1 | Breakage of small windows under strain |
| 0.15 | Typical pressure for glass breakage |
| 0.3 | "Safe distance" (probability 0.95 no serious damage beyond this value); projectile limit; some damage to house ceilings; 10% window glass broken |
| 0.4 | Limited minor structural damage |
| 0.5–1.0 | Large and small windows usually shattered; occasional damage to window frames |
| 0.7 | Minor damage to house structures |
| 1.0 | Partial demolition of houses, made uninhabitable |
| 1–2 | Corrugated asbestos shattered; corrugated steel or aluminum panels, fastenings fail, followed by buckling; wood panels (standard housing) fastenings fail, panels blown in |
| 1.3 | Steel frame of clad building slightly distorted |
| 2 | Partial collapse of walls and roofs of houses |
| 2–3 | Concrete or cinder block walls, not reinforced, shattered |
| 2.3 | Lower limit of serious structural damage |
| 2.5 | 50% destruction of brickwork of houses |
| 3 | Heavy machines (3000 lb) in industrial building suffered little damage; steel frame building distorted and pulled away from foundations |
| 3–4 | Frameless, self-framing steel panel building demolished; rupture of oil storage tanks |
| 4 | Cladding of light industrial buildings ruptured |
| 5 | Wooden utility poles snapped; tall hydraulic press (40,000 lb) in building slightly damaged |
| 5–7 | Nearly complete destruction of houses |
| 7 | Loaded train wagons overturned |
| 7–8 | Brick panels, 8–12 in. thick, not reinforced, fail by shearing or flexure |
| 9 | Loaded train boxcars completely demolished |
| 10 | Probable total destruction of buildings; heavy machines tools (7000 lb) moved and badly damaged, very heavy machine tools (12,000 lb) survived |
| 300 | Limit of crater lip |

[a]Clancey (1972).

### B.1.5.2.3 Toxicity

In case of accidental release, the routes of absorption of a toxic substance by the body are:

- inhalation, process whereby irritants and toxins enter the body through the lungs during breathing;
- direct contact with skin or eyes.

Toxic substances are classified as irritant, asphyxiating, anesthetics and narcotics, systemic poisons, sensitizing, carcinogenic, mutagenic and / or teratogenic substances. Systemic poisons can be further divided into hepatotoxic agents, nephrotoxic, neurotoxic, agents acting on the blood or damage the lungs.

To assess the ultimate consequences of a toxic release it is necessary to know the effects on the affected population as a function of the absorbed dose, whose estimation presents considerable difficulties. The penetration rate of the contaminant in the body by inhalation is a function not only of its concentration in the air breathed, but also the way of breathing, the residence time within the contaminated volume; the potential toxic effects through skin absorption depend on the amount and the characteristics of the toxic substance in contact with the body and from the contact exposure time. Typically the most vulnerable people are elderly, children and people with respiratory or cardiovascular disorders.

Exposure thresholds and Probit functions are applied to estimate the human consequences of toxic releases. The exposure thresholds are the minimum values above which a certain percentage of people undergo well-defined reference damage.

The experimental data are mainly related to values LC50 (Lethal Concentration - 50% deaths), i.e. the concentration that causes death in 50% of animals exposed for a specified time. These data are then extrapolated to humans from toxicological experiments.The level LC50 is a global type of limit, which is independent of the specific mechanisms of damage caused to various organs.

Toxicological criteria that define the acceptable levels of exposure for the staff in the work environment are well known, and are not considered here. In risk analysis reference is made to IDLH (Immediately Dangerous to Life or Health), which is defined as the maximum concentration of the substance in the environment that a healthy male individual can stand for 30 minutes while maintaining the ability to escape, i.e. without suffer irreversible damage.

The ERPGs (Emergency Response Planning Guidelines for Air Contaminants) is also important. It provides three concentration levels:

- ERPG - 1: is the maximum concentration of the pollutant in the air that everyone could support up to a maximum of an hour undergoing, at most, only moderate transient disturbances.
- ERPG - 2: is the maximum concentration of the pollutant in the air that everyone could support up to a maximum of one hour without suffering irreversible damage or symptoms such as to prevent him from escaping.
- ERPG - 3: is the maximum concentration of the pollutant in the air that everyone could support up to a maximum of an hour without receiving adverse effects on health.



The Probit model for the lethality is frequently applied to assess the likelihood of death following exposure to a concentration C for duration of exposure t (dose D). When the concentration C is considered constant, the dose D can be determined simply as: D = Cn t. Hence, three coefficients, namely a, b and n are needed to determine the probability of suffering the reference damage (generally the death).

Several laboratories have proposed the three coefficients for many hazardous substances. Due to the difficulty of estimating them, it is reasonable to expect differences on the calculated fatality probability. To give an example figure lll shows the Probit functions for Ammonia proposed by six different authors. It is easy to note the difference on the vulnerability value P for any concentration ranging from 2.e+3 and 1.e+4 mg/m3.

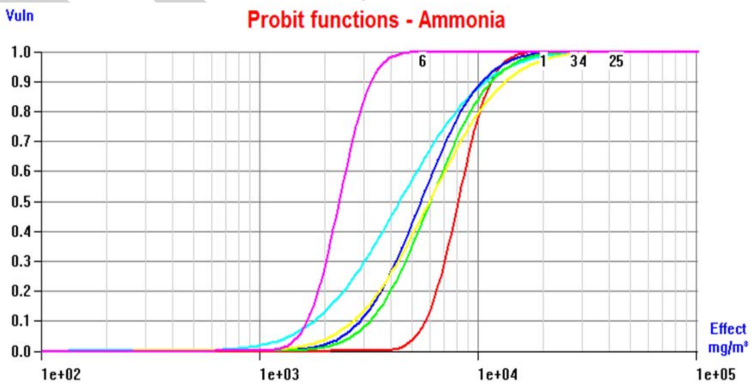


Figure 22 Some Probit curves for Ammonia (with courtesy of DG JRC MAHB)

### B.1.5.3 Harm to population

This has been addressed in B.1.5.2.

### B.1.5.4 Property damage or total or partial loss of value

The history of accidents in the chemical and petrochemical industry is full of cases where property damage, both inside and outside the establishment, was very high. Plants destruction, damages to residential areas, and damages to other infrastructures are examples of how important be the need for accident prevention policies.

### B.1.5.5 Damage to the economy (impacts on business, infrastructure, etc.)

The Longford gas plant accident[86] and subsequent loss of supply is considered to have been one of Victoria's worst disasters, especially in terms of economic impact. The Longford facility is one of the most important industrial facilities in Australia. It supplies gas to Victoria, New South Wales, South Australia, Tasmania and the Australian Capital Territory and also supplies around 20% of Australia's crude oil demand. At the time of the accident, a range of industries from power generation and transportation, to chemical manufacturing and mineral processing depended on Longford's oil and gas for their energy supplies.

Following the accident, supplies of gas ceased to all domestic, commercial and industrial consumers in metropolitan Melbourne and in several country areas. With the Longford facility supplying 98 per cent of the state's gas needs, most Victorian gas consumers were left without gas for 19 days. A restart of the gas supply was commenced on Friday, October 2nd and the final restoration of gas supply took place by 14th October 1998.

The federal government lost some $300 million in resource taxes. The Victorian Supreme Court allowed for a $32 million compensation package for businesses that suffered material damage. The joint venture partner BHP Billiton commenced a damages action against Esso for damages arising from the accident. The estimated cost of the accident to the Victorian economy was put at $1.3 billion.

### B.1.5.6 Criteria for risk assessment (and health effects)

Although it is agreed that risk is the likelihood of occurrence of unwanted consequences from an accident, the methods for addressing this risk vary among the different countries, due to different cultural and historical background and administrative frameworks. From the methodological point of view, a few countries have adopted simplified criteria based on "safety distances" between residential areas and industrial sites.

Among the countries using more structured criteria, the literature developed in the past decade agrees with the definition of two alternative methodological approaches: consequence based and risk based.

In the consequence based approach the LUP decision makers use the maps of accidents effect, whereas the risk based approach use is made of Individual risk maps and societal risks function.

#### B.1.5.6.1 Individual risk

Individual risk is the likelihood that a person who is permanently present (24 hours a day for one year) at a certain point of the area, and with no protection and no possibility of being sheltered or evacuated, might sustain a given level of harm from being exposed at all of the hazardous events. This risk figure is useful for characterising the existing risk at a given point in the vicinity of one or more hazardous facilities (independently whether a person is present or not and it is the same for a deserted area and for a very populated area). In the context of land-use planning the type of harm usually considered is fatality only and the local risk is calculated as a frequency (or probability) representing the chance of death per year.

The Individual risk is represented in the form of risk contours as it depends on the distance from the plant. A risk contour is a closed polyline connecting all points having the same risk value. The 10-x value associated to a contour delimits the region where the risk is greater than or equal to 10-x. These curves, superimposed on the map of the site, give important information for decision making on area risk control as well as on land use planning. The Individual risk is a function of the distance from the risk sources and of the meteorological data; it does not require

86 Hopkins A., Lessons learnt from Longford: The Esso gas plant explosion, CHH Australia Ltd, ISBN 1-86468-422-4, 2000.

the data on the population distribution.  Figure 23 shows the individual risk contours around a plant in which fires, explosions and releases of toxic substances may occur.

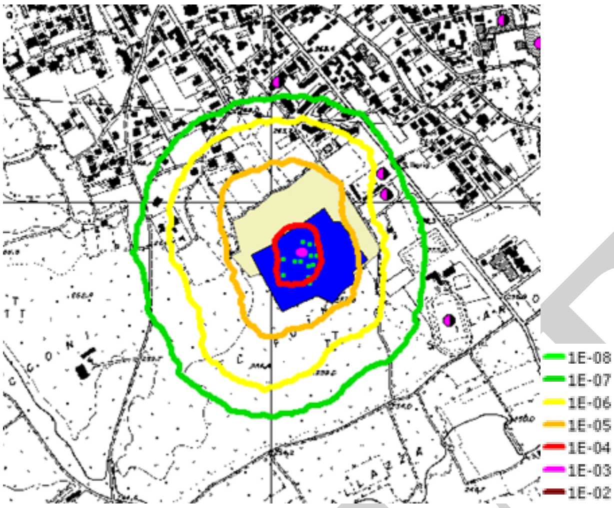


Figure 23  Illustration local risk contours around a hazardous facility where fires, explosions and releases of toxic substances may occur (with courtesy DG JRC MAHB)

### B.1.5.6.2 Individual risk for classified protected persons

The individual risk can also be calculated for classes of persons which are not permanently present and which may be partially protected. Hence the individual risk is calculated by taking into account a number of factors that affects the probability of sustaining fatal injury.  These factors reflect the group to which the person belongs (e.g. elderly, children, resident population, workers, commuters, tourists, etc.), type of place where the person is present (e.g. office, hospitals, schools and shopping centres), average exposure time (proportion of time spent in place) and possible personal protection measures (sheltering, staying indoors).  This makes for instance that a toddler and an adult person can have different individual risk under the same circumstances.  As before, this risk is represented by means of risk contours.

Some authors distinguish the two definitions above by calling “Local risk” the individual risk of an unprotected person permanently present, whereas the Individual risk is associated to classified persons.

### B.1.5.6.3 Societal risk

In order to obtain the information about the impact of an accident occurrence on the surrounding population the concept of societal risk is used.  Societal risk represents the risk that a group of people in a given community will suffer simultaneously a certain level of harm after being exposed to the outcomes of an (hazardous/major) accident.  Societal risk differs from individual risk insofar that the former latter express the total expected simultaneous loss to the community in case of a catastrophic accident whereas individual risk does not.  Differently from the individual risk, the societal risk calculation requires the knowledge of spatial distribution of the population.  A single large scale accident causing many fatalities requires more attention by the authorities compared to smaller accidents with minor fatalities.  The impact of one single accident causing hundredth deaths is perceived differently by the public from fifty separate smaller accidents events causing two fatalities each.

Societal risk can be presented either as frequency vs. fatalities (F-N curve) or individual risk vs. number of people (I-N histogram) both characterising the societal exposure to risk.  This societal risk figure is useful for ensuring that the existing risk in places where a large number of persons are present is tolerable and not excessive.  It also allows comparing e.g. the overall risk of different hazardous activities or the risk of the same type of plant located in different geographical areas.

The F-N curve links the inverse cumulative frequency F of all possible accidents capable of causing a certain level of harm to a number of people greater than or equal to N in the whole surrounding area following an accident, based on population density, places of work, and local protection (whether they are indoors or outdoors). Practices differ regarding the inclusion of the establishments workforce as well as employees at surrounding establishments, or if only the general population is included. As the number of people affected N is cumulative so the frequency F can only decrease towards the right of the graph.

The limits of risk acceptability are shown as two parallel straight lines on the same diagram, with an area between them in which risk reduction is desirable.

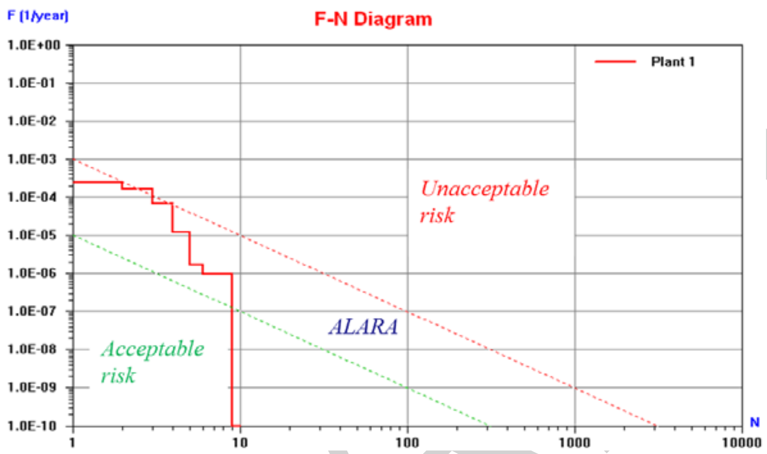


Figure 24 Illustration of a F-N curve

Another useful representation of the societal risk is by means of the I-N histogram, showing the distribution of the number N of people in the impact area exposed to an individual risk within the range I, (for example the range $10^{-6}$ - $10^{-5}$ lethal events/year).

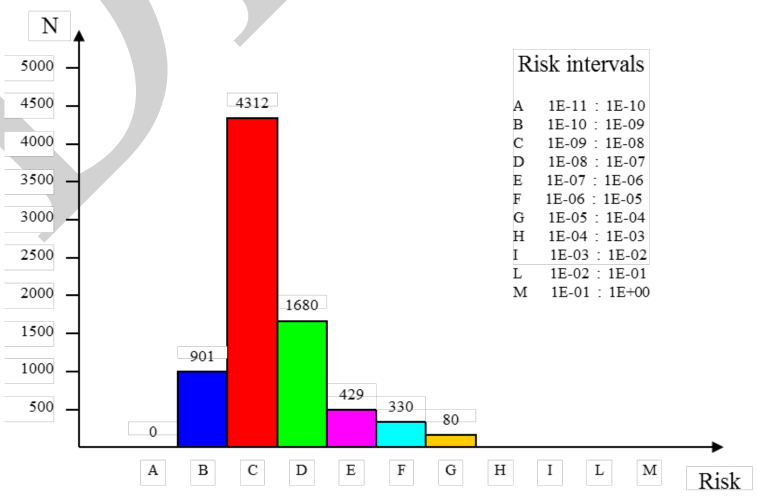


Figure 25 Illustration of an I-N histogram

#### B.1.5.6.4 Area risk assessment

Area risk analysis refers to the risk of large industrial sites hosting several production plants, storage facilities and transportation of hazardous substances which are owned by different operators. Each operator submits his own safety report. The authority has to elaborate the information from all safety report to determine the area risk for subsequent risk control, including land use planning and external emergency response.

To clarify the terms, the source area is defined as the area where risk sources are present; impact area is the geographical area affected by the occurrence of potential accidents.

From the conceptual point of view the area risk analysis is similar to the analysis of a single plant, with the addition of transport risk, since in a large industrial area this type of risk may assume a significant importance. However, the application of the risk analysis methodologies to the complex sources (plants and transportation) that insist on a territory requires the adoption of a broader set of procedures that are capable of handling the complexity of the problems due to the interconnection among the various sources of risk and their impact on the impact area.

The quantitative area risk analysis may provide useful information and benefits in the following areas:

- Emergency planning and response: the knowledge of the location of rescue services and the extent of the impact area allows the authority to identify and address possible interventions to mitigate the consequences of potential accidents;
- Land use Planning: by superimposing the risk maps to the geographical maps of the area, the interference between industrial sites, network transport and housing settlements can be identified; hence the construction of new buildings or road structures will be possible only in areas compatible with the risk level;
- Transport management: the criterion of minimizing the risk can help determine the best paths to transport hazardous substances from/to plants, or to evaluate alternative transportation means;
- The control of source area risk, i.e. the release of permits to install new plants or to modify existing plants, will be based to the a-priori evaluation of a new risk map (addition of the risk of new sources to the existing risk in the impact area).

#### B.1.5.6.5 Data used in area risk quantification

The quantification of risks requires the calculation, for all significant scenarios, from fixed plants and transport, of:

- the probability of occurrence (or frequency); and
- the extent of the damage (magnitude).

Both probability and magnitude can be combined into risk indices, the most common of which are the individual risk (contours) and societal risk (F-N curves and I-N histograms).

Often the term reference damage is associated with the death of an individual under the specified conditions; it would obviously be possible to choose other reference damages e.g. the need to seek medical attention or hospitalization, the damage to structures, or to the environment. In any case any change of the reference damage implies that part of the risk analysis procedure must be re-quantified.

The minimum set of data needed can be subdivided into those concerning the source area and the impact area, as briefly listed below.

Source area:

- industrial plants, particularly upper tiers as defined in Seveso directives;

- transportation of dangerous goods by road, rail, pipeline and channel, ensuring the supply of raw materials and shipment of products;
- facilities for loading / unloading hazardous substances in plants and ports.

Impact area:

- Map of the area with road networks, rail and pipeline, housing commercial estates, etc.;
- Map of the port with indication of the loading/unloading docks;
- Map of the location of centres of vulnerability (hospitals, elderly houses, nursing, schools, museums, supermarkets, stadiums);
- Spatial distribution of the population and its variation over time (residents, workers);
- Population concentrated in all centres of vulnerability and their variation over time;
- Weather information;
- Many effects of accident scenarios depend on atmospheric turbulence, wind speed and direction, and Pasquill stability classes;

It should be noted that both the population distribution and the risk sources generally vary in time; this requires subdividing the year into different time periods, inside which they can be approximately considered as constant values. For instance, suppose that the impact area include a touristic zone, then the population distribution changes because it increases in summer time; furthermore, beaches can be represented as vulnerable centres.

Consequently, as many risk analysis as the number of time periods are to be performed. The greater is the number of time periods the higher is the cost of the analysis, but the calculated risk maps can be more accurate.

Certainly, the most expensive phase of the area risk analysis is the characterization of the source area due to the need to examine all safety reports to extract the information on accident scenarios and the census of all transported substances. It should be stressed that the quality and quantity of information to be collected must rely on the full cooperation of managers and employees of specific risk sources.

#### B.1.5.6.6 The analysis of single risk sources

The safety reports of the establishments contain the result of accident consequences obtained by means of mathematical models for source term, pool evaporation, fires, explosions and release of toxic/flammable substances. Unfortunately, different owners use different models and/or different software tools. Hence, in order to be able to compare the risk of the different sources it is necessary that the working team re-calculate all accident consequences with the same models and same data and determine the related accident frequencies based on the same components reliability and human factors databases. This means that a preliminary phase is needed to select a set of models for frequency and consequence assessment along with the related data. It goes without saying that the working team must operate independently from the authors of the safety reports.

#### B.1.5.6.7 The re-composition of all single risk sources into the area risk

The area risk analysis necessarily requires the use of sophisticated software tools able to easily work on spatial entities. Geographical Information Systems (GIS) are applied to represent the elements of both the source map and the impact map. The impact map is subdivided into sub-areas on the bases of land use; then, each sub-area is covered by a grid whose cells dimension is inversely proportional to the population density. A dense grid is also defined for the source area.

For each scenario the corresponding risk is determined for each cell. This complex procedure calculates the risk (individual and societal) considering the meteorological data, the wind rose the human vulnerability, and the population present in the considered cell.

Finally, the total risk is determined by applying a re-combination method. In this way it is possible to calculate the risk figures for selected categories of risk sources and for selected substances. For instance, risk contours of F-N curves or I-N histograms can easily be obtained for fixed installations of a certain type, for the storage or the transport of a certain substance, etc., and for each predefined time period. It can easily be realized that such a system is very useful as a risk management tool.