Risk management in land use planning

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1. INTRODUCTION

Land use planning aims at designing the future society by deciding how land and water should be used and how towns should be developed. The potential hazards in society are continuously increasing as a consequence of the rapid technical development. These hazards could lead to accidents that affect the life quality of both the individual and the society as a whole. In order to control these potential hazards, risk management should be an integrated and natural part of the land use planning process. In the CPQRA [1] risk is defined as a measure of economic loss or human injury in terms of both the likelihood and the magnitude of the loss or injury. The IEC defines risk as a combination of the frequency, or probability, of occurrence and the consequence of a specified hazardous event [2]. Note that the concept of risk always has two elements: the frequency or probability with which a hazardous event is expected to occur and the consequences of the hazardous event.

Risk consideration in land use planning has traditionally involved the use of prescriptive rules based on distance from the hazardous activity. In Sweden, buildings are e.g. not allowed within 100 m from a dangerous goods route according to these rules. This approach generates a few problems. Distance rules do not consider the actual risk and generates an uncertainty on the achieved safety level. As no other risk reducing measure, than the distance, is considered, some important areas in the vicinity of a hazardous activity could be left unexploited.

There is on ongoing trend in the society that transforms perspective regulations into performance-based ones. The performance-based regulations focus on the aim and purpose, instead of giving detailed information to the user. In land use planning there is a need for such a performance-based risk assessment model, which could add more flexibility to the process.

2. THE RISK ASSESSMENT MODEL

A modern risk assessment model uses a probabilistic approach where the likelihood of possible accidents is estimated. This combined with assessments on the consequences involved makes it possible to calculate the risk at a certain distance from the hazard. When evaluating the risk, acceptance criteria and fundamental risk evaluation principles on proportionality, reasonableness, distribution and avoiding catastrophes should be taken into account. Terms such as ALARP (As Low As Reasonably Practicable) and ALARA (As Low As Reasonable Achievable) are frequently used when discussing risk reduction.

There are a number of requirements on a probabilistic risk assessment. The assessment should be based on reality-based frequencies, uncertainties should be treated, the evaluation must fulfill acceptance criteria as well as fundamental principles and the quality of the assessment must be assured.

2.1. Risk assessment process

The risk assessment process consists of five activities. First, all hazards are identified. Second, possible scenarios and related frequencies are estimated by the use of well-known risk analysis tools, e.g. event tree analysis or fault tree analysis. Third, the consequence for each scenario is calculated by the use of either computer models or analytical expressions. Fourth, the risk measures e.g. individual and society risk are presented and evaluated. The final, fifth activity involves the development and incorporation of risk reduction measures.

2.2. Risk measures and risk evaluation criteria

Risk can be expressed as individual risk or as societal risk. These are the two most frequently used risk measures. Individual risk measures consider the risk to an individual who may be at any point in the effect zones of incidents, while societal risk measures consider the risk to populations that are in the effect zones of incidents.

Risk can be evaluated and risk criteria established using four different principles [3]. *The principle of reasonableness* says that an activity should not involve risks that by reasonable means could be avoided. Risks that by technically and economically reasonable means could be eliminated or reduced are always taken care of, irrespective of the actual risk level. *The principle of proportionality* means that the total risk that an activity involves should not be disproportionate to its benefits. By using *the principle of distribution*, risks should be legitimately distributed in society, related to the benefits of the activity involved. Single persons should not be exposed to disproportionate risk in comparison with the advantage that the activity affords them. *The principle of avoiding catastrophes* says that it is better that risks are realized in accidents with a lower number of fatalities. When discussing risk reduction, terms such as *ALARP (*As Low As Reasonably Practicable) and *ALARA* (As Low As Reasonable Achievable) are frequently used.

The acceptable risk can be defined as limit lines in the FN diagram. Risks that are below the lower line are tolerated and they do not have to be reduced. Risks in the zone between the two lines are in the acceptable ALARP area. Risks in this zone should be reduced if it is practicable and does not involve disproportionate costs. Risks that are above the upper line are not acceptable and should be subjected to a risk reduction process. In a report commissioned by the Swedish Rescues Services Agency, A proposal for acceptable societal risk criteria to be used when putting assessment against criteria in a risk analysis is given in [3]. The proposal is given as an FN curve, where a gray zone is used to outline risks that could be accepted. The proposal is illustrated Fig. 1.

2.3. Treatment of uncertainties

Traditional risk analyses use point estimates to present the risk. There are mainly two problems associated with this approach. First, it is highly desirable for decision-makers to be aware of the full range of possible risks in order to make balanced decisions. Second, point risk estimates frequently are very conservative as a result of the accumulation of the effects of various conservative assumptions made at intermediate steps in the analysis [4]. The consideration and treatment of uncertainties in risk analysis adds considerably to the credibility of the results, which in this case is a model requirement. One approach to treat uncertainties is to employ Monte Carlo or Latin Hypercube sampling techniques.

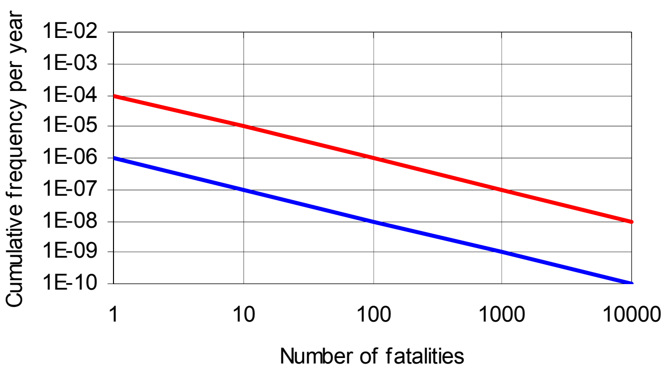

Fig. 1. Acceptable societal risk criteria.

3. CASE STUDY FROM THE ØRESUND REGION

3.1. Scope

A probabilistic risk assessment model, as described above, has been developed for land use planning in the Øresund Region. The Øresund Region encompasses Sweden's Scania and Denmark's Zealand and has Copenhagen-Malmö as its hub. Within a radius of about 100 km, there are 3.2 million people. With the construction of the fixed link and substantial investment in better communications, the region is a reality. The model has been applied to the establishment of a new urbanity "Scanstad" in Malmö. Scanstad is situated close to the fixed link to Denmark and could be seen as a gateway to the city. The urbanity includes offices, services and housing of different types.

3.2. Hazards and assessment techniques

The risk assessment is carried out in order to analyze the risk associated with the nearby traffic route for dangerous goods. Event tree technique is used to derive the scenarios, which includes three different types of releases; toxic gas, inflammable/explosive gas and inflammable liquid. Accidents considered are only those that are direct harmful to people. Events that affect property and the environment are sorted out. Possible outcomes of the selected scenarios are pool fire, jet flame, boiling liquid expanding vapor explosion (BLEVE), unconfined vapor cloud explosion (UVCE) and the release of chlorine gas, sulfur dioxide and ammoniac.

The hazard calculation models are based on effective dose, pressure build-up and radiation. The criterion is set to the LC_{50}-value. LC_{50} is defined as the dose where half of the people exposed are dying. It is the assumed that all people inside the LC_{50}-zone dies, and people outside survive [2] . Consequences are calculated with analytical expressions on release and dispersion and Monte Carlo simulations treat uncertainties in e.g. wind speed, release rates, exposure times and atmospherically conditions.

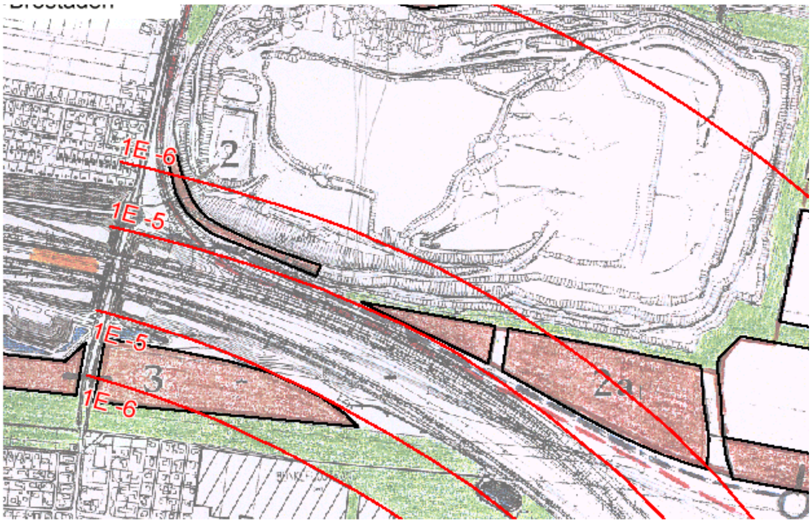

Fig. 2. Risk contours for the individual risk. The ALARP-region is between $10^{-5} – 10^{-7}$.

3.3. Results

The risk contours for the individual risk are illustrated in Fig. 2. The societal risk is illustrated in Fig. 3. The risk lies in the ALARP-region and it is therefore necessary to reduce the risk by appropriate measures. One reasonable measure to reduce the possible consequence is to install an alarm system that notifies the people when there is a release of toxic gas.

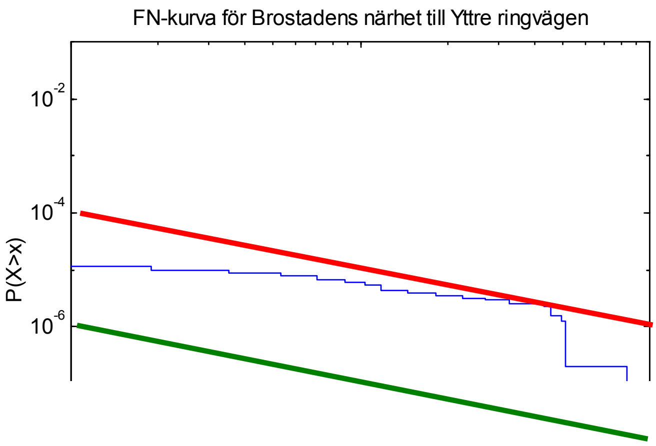

Fig. 3. FN curve for societal risk and limit lines for the ALARP-region.

3.4. Recommendations

As the risk was evaluated towards the acceptable risk criteria the following recommendations could be given.

- Risk reducing measures need to be undertaken for all establishment at a distance within 800 m from the road.
- No buildings are allowed closer than 50 m to the road. This is valid unless extreme measures are taken to reduce the impact of the hazards.
- Office buildings could be allowed on a distance at least 50 m from the road. Emergency control of the ventilation system is then an appropriate risk reducing measure.
- Residential areas must be placed further away than 200 m from the road. A public notification system is recommended.

By using this performance-based approach instead of the traditional prescriptive one a more balance and flexible use of land has been achieved.

REFERENCES

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[4] S.E. Magnusson, Uncertainty Analysis: identification, quantification and propagation, Report 7002, Dept. of Fire Safety Eng., Lund University, Lund, 1997.