CHEMICAL ENGINEERING TRANSACTIONS
VOL. 91, 2022

A publication of AIDIC
The Italian Association of Chemical Engineering
Online at www.cetjournal.it

Guest Editors: Valerio Cozzani, Bruno Fabiano, Genserik Reniers

ISBN 978-88-95608-89-1; ISSN 2283-9216

DOI: 10.3303/CET2291001

The (non)sense of the Societal Risk from the Risk Source as a Risk Tolerability Criterium with Territorial Reflection for Realizing a Safety Distance in the Land-Use Planning Processes

Mark Schaerlaekens, Kathleen Derbaix

Government of Flanders, Department of Environment & Spatial Development, Koning Albert II-laan 20 bus 8, 1000 Brussels, Belgium
Mark.schaerlaekens@vlaanderen.be

To execute the Seveso III Directive, appropriate safety distances must be maintained between Seveso establishments and some specified areas accessible to the general public. This with the objective of limiting the consequences of major accidents for human health. One benefit of maintaining a safety distance is that it is a reciprocal criterium: it works both ways. The distance between a vessel and a school is the same as the distance between the school and the vessel. As this kind of reciprocity is (luckily) rather the rule than the exception in daily life, this also applies when a risk tolerability criterium (with respect to one risk source) with territorial reflection is used: When there is no school inside a certain individual risk contour (IRC) of a dangerous facility it is implied that the school is not within the individual risk contour of the same facility. Several countries/regions use a risk tolerability threshold for land-use destinations in the realization of safety distances according to the Seveso directives, and do this for the siting of dangerous facilities and new developments in the vicinity of these facilities.
However it becomes more difficult when using a societal risk as parameter in the evaluation to limit the consequences of major accidents: The societal risk calculated for a dangerous facility, incorporates the risk of every possible major accident with its lethality and its expected frequency of appearance. Therefore, in a non-zero risk world, it is an excellent tool to evaluate whether the possible consequences of siting a dangerous facility in a particular environment is tolerable or not. However, to use the societal risk of a dangerous facility in the evaluation of a new development is less obvious: The calculated societal risk is not only dependent on the risk source and the development, but also on the entire population present in the environment of this risk source. This makes it not only practically complex to deal with, but also more arbitrary and not transparent. On top of this, one can see that although societal risk criteria for siting of dangerous facilities is differ between countries/regions in order of magnitudes, they are all (rightfully) rather stringent, as compared to individual risk acceptancy criteria that are used in facility siting and real life. The combination of more tolerable individual risk acceptance with a non-reciprocal less tolerable societal risk leaves the door open for some very counterintuitive outcome in land-use planning processes. This paper goes deeper into detail on the principles and consequences of societal risk and how they can be used beneficially

1. Introduction

In many regions in the world, a risk-based approach is used for the siting of hazardous installations (Pitblado et al., 2012). This method requires a quantitative risk assessment method to calculate the consequences of the different accident scenarios identified in relationship with their expected frequency of occurrence. The two risk parameters that are often calculated are individual risk and societal risk, which are represented respectively under the form of risk contours and societal risk curves. Both are a combination of the likelihood of an event happening, and the possible consequences - in terms of harm to people:

Paper Received: 7 February 2022; Revised: 3 April 2022; Accepted: 14 May 2022
Please cite this article as: Schaerlaekens M., Derbaix K., 2022, The (non)sense of the Societal Risk from the Risk Source as a Risk Tolerability Criterium with Territorial Reflection for Realizing a Safety Distance in the Land-use Planning Processes, Chemical Engineering Transactions, 91, 1-6 DOI:10.3303/CET2291001

Individual Risk: The risk to a person in the vicinity of a hazard. This includes the nature of the injury to the individual, the likelihood of the injury occurring, and the time period over which the injury might occur.
Societal Risk: The relationship between expected frequency and the number of people suffering from a specified level of harm in a given population from the realization of specified hazards. Practically, the societal risk can be summarized in a FN curve as depicted in Figure 1. Upper case F is used to denote the sum of the frequencies of all the individual events that could lead to N or more fatalities. Often, a limit curve with tolerable occurrence probabilities for the number of fatalities is set as a criterium. When the total risk of a hazardous installation crosses a certain limit, the risk is considered to outweigh the social and economic benefit of the installation, and the proposed location is considered unfit.

1.1 The siting of hazardous installations

For the siting of a hazardous installations, criteria can be applied for the maximum level on individual risk that can be tolerated originating from this installation. Some general principles (Macciotta and Lefsrud, 2018) apply when setting a level on the acceptable or tolerable individual risk, also from a hazardous installation: Avoidable risk should be minimized, the incremental risk associated with the hazardous installation should not be significant when compared to the risk associated with everyday life, tolerable risks are higher for natural hazards than for those engineered or controlled, and some populations tolerate higher risks than others. In most regions in Europe or the world, for the siting of hazardous installations, the individual lethal risk for a person present in the effect zone of the hazardous installations is allowed to be a non-zero risk. Either implicitly or explicitly, there is a residual risk tolerated for a person to die as a consequence of an accident in a hazardous installation.
With respect to the societal risk, although the criteria in itself are very different in different regions, the principle behind is very much alike: Events with the potential to cause a large number of fatalities should have low occurrence probabilities. This accounts for society's lower risk tolerance of large numbers of fatalities.

1.2 Safety around existing installations

Based on individual risk considerations:
Of course, it is also necessary for land-use planning (LUP) or other relevant policy to have criteria to ensure appropriate levels of safety around existing hazardous establishments. In modern society, a limit is put on the risk a person can or has to undergo, even if the risk is taken voluntary. It is generally accepted that the tolerable individual risk criteria for individuals to live/work/go to school around an existing installation is on the same level as the individual risk criterium that is decisive for the siting of a new hazardous installation. This tolerable risk level is generally several orders of magnitude lower than the risk level that most individuals choose to take for themselves for example by going hiking in the mountains or driving a car (or even participating in the Paris Dakar Rally). One could argue that all developments around existing establishments are involuntary as there is only limited land available, and one is not truly free to simply develop elsewhere. When only dealing with the risks from hazardous installations, it might seam totally logical that the individual risk criteria for the siting of establishments, and for the siting of individuals around these establishments are the same. This is also implied in the Seveso-directive when it imposes the necessity to ensure appropriate distances between hazardous establishments and defined populations. But the principle in itself should be questionable. Does the origin of the risk matter when considering whether a place is safe for living? Wouldn't it be logical to rather use the same risk criteria for living under the risk of an avalanche, flood, hurricane, forest fire, plane crash, hazardous installation and so on?

Based on societal risk considerations:
In contrast to individual risk criteria, it is inappropriate to apply societal risk criteria from one industry in another (Sponge et al., 2015), since the societal benefits are likely to be different. This was illustrated when the Dutch authorities attempted to apply their FN criteria for industrial installations to the off-site risks from Schiphol airport, and found that it greatly exceeded the criteria. This simply showed that the criteria were inapplicable, not that the airport was unacceptable. On the other hand, the societal benefits from the developments around airports and hazardous installations can be very comparable. This illustrates that LUP around existing hazardous establishments and ensuring appropriate levels of societal safety is far from evident. On the one hand society must enable to put available land to the most efficient and productive use for housing, economic development, public services and leisure in a sustainable manner, on the other hand, the external safety risk that the society takes as a whole should be reasonably balanced. During the assessment of an new hazardous installation, the total incremental risk associated with this installation, summarized in its societal risk is weighted versus its social and economic benefit (implied). Just a like, it would make sense to judge the incremental risk associated with an individual planning application versus the social economical benefits (implied or explicit) of this individual planning aspect. However, in doing so, for proposed developments near major hazards, weighing the decision on a case-by-case judgement of the incremental risk, the judgement is blind to the cumulative effects of separate

developments over time. This could lead to the possibility that an initially or currently well-located hazardous site (or chemical industrial park) may reach a societal risk that is well above the tolerable risk level.
It is worthwhile to note that paying attention to the incremental risk associated with individual planning this is not only a theoretical exercise to close a hypothetical inconsistency in risk policies. This important lesson can be learned from the historical overview of Land Use Planning in Toulouse after the 21st September 2001 disaster at the AZF plant (Dechy et al., 2005). From 1675 until World War I the plant moved in total 4 times away from the developing city center, after WWI, the urban area has settled closer and closer when the chemical plants stopped to move away from the center. This conflicting situation was perceived and discussed, but nevertheless it proved difficult to solve this situation when the Toulouse population was multiplied by five, and by ten in the Toulouse urban area, after WWI. While the Toulouse community probably didn't have any quantified risk analysis in 1675, they performed several fruitful risk-based decisions in the siting of the hazardous installations away from the city center. On the other hand they struggled from this date until very recently in maintaining an acceptable risk due to the cumulative effects of separate developments with incremental risks over time. How to deal with this logically is not a simple task.

2. Principles form the practice on how to deal with incremental risk

Once familiar with the concept of societal risk for the siting of hazardous facilities it becomes logical to take the societal risk into account for development proposals that involve a significant intensification of population in the vicinity of a hazardous facility, even if individual risk criteria are met: In response from 94 respondents to a Consultative Document (CD212), it was found that [cited from HSE, 2009]
"A large majority of respondents were in favor of taking account of societal risk in both the assessment and provision of onsite control measures and the decision-making process for land development around sites. Furthermore, for land use planning purposes, most respondents agreed that societal risk should be considered when drawing up local development plans as well as when considering individual planning applications."

2.1 Land-use planning requirement in the licensing of hazardous facilities

An example of the principally most correct approach for the siting of hazardous facilities is in use in Hong Kong, as described in the Hong Kong planning standards and guidelines (2018): In the processing application for a new Potential Hazardous Installation (PHI), a hazard assessment (HA) is required together with a Planning Study (PS). A PS examines the present and future land use and development proposals in the neighborhood of each hazardous installation and advises on the necessary planning considerations and development control within the vicinity of the hazardous installation. In the course of preparing the HA and PS, all present and future land uses and development options should be considered. Recommendations should be made on how to ensure that the existing and future developments can be protected from being exposed to unacceptable risk caused by the hazardous installation. These recommendations will be included in an Action Plan, that includes statutory re-zoning to reduce development potential with regard to population in buildings or otherwise, re-planning of open space; preventive alterations to existing public housing buildings, re-planning of estate open space, or construction of protective bunds. In this process, criteria on societal and individual risk are considered.
One can immediately see how this principally handles the challenge mentioned above: the siting of the hazardous installation, its impact on the present and future land use are weighed against the associated risk of present and future. When such a policy can be implemented successfully, it could ensure the health of those living near hazardous installations and minimize the societal impact of all hazardous installations while enabling the land to be put to the most efficient use within the strategic needs. It is also worth mentioning that this approach allows Hong Kong to maintain very similar the societal risk criteria whether the risks originates from landslides or hazardous installations.

2.2 The Bucket of Risk

According to HSE (2009), this is an approach to risk management where the outcome is simply related to a threshold value: the outcome of any risk assessment is then either that the risk is below the threshold, i.e. 'there is not too much risk' (the 'bucket' is not yet full), or else the risk is above the threshold, so 'there is too much risk' (the 'bucket' is now full).
The societal risk criterium for one establishment can be seen as the size of the bucket, and the societal risk of the installation as the liquid level in the bucket. For proposed developments near major hazards, weighing the decision on a case-by-case judgement of only the individual risk criteria, the judgement is blind to the cumulative effects of separate developments over time, and to its contribution to the total societal risk, until the risk is above the threshold. There are many practical limitations for such an approach:
First of all, it is easy to note how much empty space there still is in a bucket, while it is very difficult for all stakeholders to see how the societal risk of a hazardous installation limits the future land use and developments

in its surroundings. On top of this, a first-come-first served approach within such a framework might lead to a 'goldrush', perhaps promoting more rapid or less desirable development.
Apart from these practical challenges, there is also a conflicting logic in this approach: For the siting of a hazardous installation, the social economical benefit can outweigh the incremental risk associated with this hazardous installation: for the siting of an individual planning application in the surrounding, its social economical benefit can never outweigh its associated incremental risk, when this risk tips the societal risk of the hazardous installation over the criterium.
When such a policy can be implemented successfully, it could ensure the health of those living near hazardous installations and minimize the societal impact of all hazardous installations. Compared with approach used in Hong Kong, it fails to enable the land be put to the most efficient use within the strategic needs. Therefore extra planning processes would be required to achieve the same goal.

2.3 The Justification of incremental risk

In general, societies are prepared to accept risks from technological activities because of the benefits that they bring. In evaluating the acceptability of societal risk from an activity, its overall benefit to society should also be taken into account. By accepting that societal concerns, including concern about catastrophe risks, are better addressed through qualitative decision making rather than embedment trough strict criteria it can be accepted that the local societal risk can outgrow societal risk criterium for the siting of new hazardous establishments. The UK, the State of New South Wales in Australia and the Netherlands are all considering the societal risk for developments in the vicinity of potentially hazardous facilities (HIPAP nr 4, 2011, Saw et al., 2010). More than a decade ago, projects were initiated to tackle the contribution of incremental risk to the societal risks of hazardous installations. Both the Netherlands and the UK came with a visualization tool to put the societal risk around hazardous installations on a map. These maps show the risks from the perspective of those who are exposed to the risk, as well as the extent of the risks at the areas concerned, and can thus, give an indication whether an increase in population from a future development will further exacerbate the societal risk level or take it above a certain guide value. The maps do provide urban planners insight on which population is contributing to the societal risk, which area's do already have a SR problem, what is the extend of the problem and which area's are "safer" or "less affected" and provide possibilities for urban development or extension of industrial activities. It is stated explicitly that these maps give not rise to new criteria, they deliver also very limited insight in the evaluation of the societal risk of a hazardous installation with respect to developments in its vicinity. For the evaluation of the incremental risk, not the total local societal risk is considered the best evaluation parameter, but rather the case societal risk. In New South Wales, for all developments, and in the Netherlands for developments outside existing spatial planning have to be justified against its contribution to the societal risk. In the UK, for proposed developments near major hazards, HSE provides its advice case-by-case on the basis of individual risk (which in combination with sensitivity levels attends to 'case societal risk'). The blindness towards the cumulative effects of separate developments over time is considered and the deviation from a 'bucket of risk' approach is intentional.
The individual and incremental risk of new developments near existing hazardous installations is taken into account for projects in the vicinity of these installations. Flexibility remains to enable the land be put to the most efficient use within the strategic needs, but the social risk of a single establishment can exceed the societal risk criterium that is used in the siting of new establishments.

2.4 No explicit evaluation of a societal risk: alternatives can be manifold, like working with safety distances, and/or vulnerability classes

When no explicit calculation of the societal risk is required or done, it also possible that an approach is used that with sensitivity levels of affected populations also reflecting the number of peoples subject to an amount of risk. This is for example the case in the Italian evaluation system (Camuncoli et al. (2012)) : scenario frequencies are mapped to four probability classes and combined with the four zones in a matrix to determine acceptable land use for each zone. As the Italian land classifications take into account population density (e.g. allowing small and large hospitals, and high and low density housing to be distinguished), societal risk considerations are implicit in the system. In most cases, these kind of criteria are used reciprocal: the risk criteria with or without societal risk considerations for the siting of establishments, and for the siting of individuals around these establishments are the same. The local societal risk, and the accumulation of the societal risk are in this approach not explicitly considered, and will not be handled without complementary policy.

2.5 The total societal risk that results from the hazardous industry

Mark that although approach 2.1 and 2.2 both put a limit to the societal risk of a single establishment, they do not limit the total societal risk coming from hazardous installations. As there is no limit to the number of hazardous installations, the total societal risk is also in these two approaches not limited, but weighed against the implicit social economical value of the complete hazardous industry. Nevertheless, it can be easily accepted that in practice, the societal risk increase associated with an increase in numbers of hazardous establishments will not tend to increase to same extend as the societal risk increase associated with the possible population pressure around existing establishments.

3. The situation in Flanders

Flanders (a region in Belgium) requires an External Safety Report (ESR) with a quantification of risk. Risks are evaluated against two criteria: location specific risk and societal risk. Since 2006, there are no distinguished criteria for new and existing establishments and there is also no ALARP (As Low As Reasonably Practicably) principle in use. The criterium for the societal risk is represented in *Figure 1*, no excursion of the societal risk calculated above the red line is tolerated. Criteria for individual risk are: Maximum location specific risk on plants boundary line is 10^{-5} per year, at residential areas (isolated buildings are not counted) is 10^{-6} per year, and at vulnerable areas (schools, hospitals and elderly houses) is 10^{-7} per year. In practise the criteria are used as limit values. If establishments fail to comply with the criteria, a clear description of technical and organizational measures linked to the most important accident scenarios is required. In addition, additional safety measures will be required, their environmental permit may not be issued, or the government may prohibit operation of (parts of) the establishment. One special measure in Flanders is a so called safety information plan. This plan is a formal agreement between the major hazard establishment and other establishments in the surrounding area where they commit to exchange information about risks arising from dangerous substances. When assessing societal risk, employees and contractors at the major hazard establishment and other establishments covered by the safety information plan are not considered. People present in neighbouring establishments (not included in the safety information plan), residents, persons in traffic are taken into account (including fractional occupation). Risk calculations shall be updated every 5 years or at any important change.

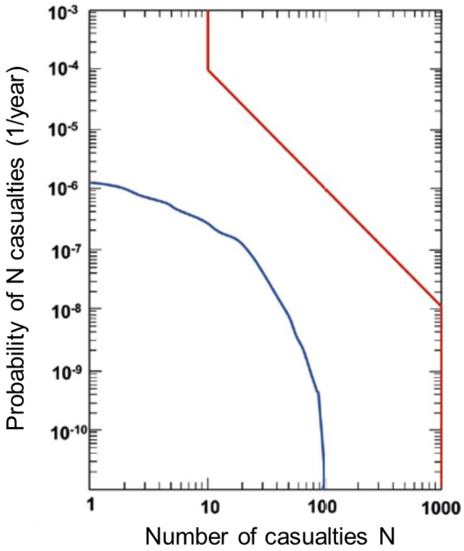

Figure 1: An example of a societal risk curve (blue), and the criterium used in Flanders (red)

Although not explicitly specified, the Flemish administration has always assumed a ‘bucket of risk’ approach with regard to the societal risk of the hazardous installations. As long as the risk of the existing installations was not reaching the risk threshold, incremental increase of risk upon densification of population around existing installations proofed difficult to stop. The absence of an ALARP region did not contribute to create awareness towards the stakeholders that the risk threshold became within reach.
Recently it became apparent that the presence of a hazardous installation limits the land use planning and individual planning applications. Any development can be the straw that brakes the camels back, or the last drop that makes the cup run over. The conflict of interest between individual planning applications and the perception that the societal risk criterium of an establishment is an arbitrary parameter to judge the incremental risk of the individual projects is too strong. Individual planning applications with a much higher incremental risk that came first can be allowed, while very similar projects with much lower incremental risk with a later application date are not tolerated anymore. At this point, it becomes very difficult to understand that the individual risk tolerable for the population subjected to the risk can be a several factors higher than the actual risk for population associated of the development that tips the societal risk of the hazardous installation over the

criterium. Also, risk reduction at the hazardous installation (or even renewed risk calculations), will have a huge impact on its calculated societal risk, and thus making the acceptability of developments in the surrounding extremely volatile and speculative. It becomes apparent that the bucket of risk approach requires an indisputable determination on the level of the societal risk, and therefore an indisputable inventory of the population in the surrounding, which is not available at the moment. Furthermore, starting the land use planning process at this point, to enable the land to be put to the most efficient use, within the strategic needs becomes extremely difficult once the societal risk almost crosses the criterium. The margin that allows a proper planning process is simply not available, although perhaps a slightly greater margin still can be created by further implementation of the safety information plan and the accompanying increasing self-reliance.
A pilot project has started recently to tackle a situation where the population pressure has become so high that the societal risk criterium is at its limit. Inevitably, this will lead to either extra limitations to the land-use as opposed to the determined strategic needs, extra risk reduction measures at the existing hazardous installations or a contribution to the societal risk of a single establishment that crosses the criterium.

4. Conclusions

Relevant general principles on risk can easily be drawn: Avoidable risk should be minimized, the incremental risk associated with the system analysed should not be significant when compared to the risk associated with everyday life, tolerable risks are higher for natural hazards than for those engineered or controlled, and some populations tolerate higher risks than others. However, making up a policy that copes coherently with these simple principles for siting hazardous installations, and developments around these installations is less straightforward. The conflict arises from the fact that on the one hand, the risk associated with the hazardous installation, is not fixed, but increases with incremental developments in the surrounding, while on the other hand the incremental risk of each development is not significant when compared to the risk associated with everyday life. This makes an initially or currently well-located site (or chemical industrial park) less suited after further development of the surrounding.
Principally, this can only be overcome by weighing the costs and benefits of the siting of hazardous installations together with the limitations they impose on the surrounding as a whole, and fixate the results of this weighing also on the surrounding. By not explicitly considering the societal risk of a hazardous installation, upon development of the surrounding by using reciprocal criteria the inherent conflict becomes less pronounced, and might be accepted. When explicitly considering the societal risk of a hazardous installation, also after development of the surrounding it becomes apparent that an accompanying planning process with the siting of the installation would have been beneficial, or at least it is best to start with this process well before the risk reach the threshold.

References

Camuncoli, G., Pilone, E., Demichela, M., 2012, Major risk installations and land use planning: Application of the local authority guidelines in Piedmont (Italy) Chemical Engineering Transactions, 26, 423-428.

Dechy, N., Descourrière, S., Salvi, O., 2006, The 21st september 2001 disaster in Toulouse : An historical overview of the Land Use Planning, 37-56, Proceedings of the 28th ESReDA Seminar, EUR 22465 Luxembourg: Office for Official Publications of the European Communities.

HSE, RR703, Societal Risk: Initial briefing to Societal Risk Technical Advisory Group, April 2009. Sudbury: HSE. [Online] < https://www.hse.gov.uk/research/rrpdf/rr703.pdf> accessed 15.01.2020.

HONG KONG PLANNING STANDARDS AND GUIDELINES, August 2018 Edition, Chapter 12, Miscellaneous: Potentially Hazardous Installations [Online] < https://www.pland.gov.hk/pland_en/tech_doc/hkpsg/full/pdf/ch12.pdf> accessed 12.01.2020

Pitblado, R., Bardy, M., Nalpanis, P., Crossthwaite, P., Molazemi, K., Bekaert, M., Raghunathan, V., 2012, International Comparison on the Application of Societal Risk Criteria. Process Safety Progress. 31. 10.1002/prs.11525.

Macciotta R. and Lefsrud L., 2018, Framework for developing risk to life evaluation criteria associated with landslides in Canada Geoenvironmental Disasters 5:10

Saw, J. L., Wardman, M. ,Holmes, A. , Reston, S., 2010, Societal risk representation for effective risk communication. Proceedings of the 13th International Symposium on Loss Prevention and Safety Promotion in the Process Industry, Vol. 1. 177-184.

Spouge J., Smith E., Olufsen O., Skjong R., Risk Acceptance Criteria and Risk Based Damage Stability. Final Report, part 1: Risk Acceptance Criteria, DNV GL AS Maritime Advisory, Høvik, Norway 2015, 0165, Rev1.