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**Evaluation method for External Safety
in Dordrecht/Zwijndrecht Railway Zone**

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Administrative Embedding of the Evaluation method for External Safety

Until recently, the emphasis in the assessment of external safety during spatial planning has been on the probability of persons to die as the result of a disaster. This has been translated into standards for individual risk and guide values for the societal risk in the “Risk Standardisation for Transport of Dangerous Substances” (*Risiconormering Vervoer Gevaarlijke Stoffen*, or RNVGS) for situations along railway lines (as in Dordrecht and Zwijndrecht). Dordrecht and Zwijndrecht were amongst the first municipalities to recognise that these standards and guidelines would not solve all problems on external safety in relation to spatial planning. Hence both municipalities took the initiative to improve this situation. This initiative gained the support of the central government in 2002 when a safety study into the Dordrecht/Zwijndrecht Railway Zone (Dutch document: “*Veiligheidsstudie Spoorzone Dordrecht/Zwijndrecht*”) was selected as a pilot in the KIEV-project. The KIEV project (*Knelpunten rond Infrastructuurgerelateerde Investeringsprojecten*) was a national project investigating the obstacles encountered in investment projects in the Netherlands related to infrastructure. There is now national interest in further expansion of this method, as illustrated a.o. in the recommendations by the council of the Ministry of Housing, Spatial Planning and the Environment (VROM) and the council for Transport, Public Works and Water Management as well as in the development of a new policy, as outlined in a letter to parliament in September 2003 about progress in external safety policy. In that letter a three-stage approach for societal risk was announced. This approach will be tested in a number of case studies to find out in which way it should be implemented in regulations.

This Evaluation method developed for and by Dordrecht and Zwijndrecht can be regarded as a first example of the three-stage approach announced in the letter to Parlement. It has been developed so all external safety aspects can be included when making and assessing plans for spatial development. The Evaluation method is primarily aimed at situations along railway lines, but can probably be made suitable for a broader application.

An important consideration underlying the Evaluation method is the fact that the municipality carries primary responsibility for making spatial development plans and that it is up to the municipality to decide which conclusions can be drawn from applying the method and how responsibility can be taken for the new situation. The method has the approval of the central government and the province of South Holland and will be applied to the assessment (including that by the central government) of spatial development plants in the railway zone in Dordrecht and Zwijndrecht. In addition, the province of South Holland views this Evaluation method as a further development of its CHAMP method.

The Evaluation method is not only intended for a final assessment of plans, but it also offers points of departure for optimising elements in earlier stages in the process, when plans can still be influenced.

Taking decisions about external safety issues requires a clear understanding of the distribution of responsibilities, both within the municipality and in relation to other authorities. The municipality holds primary responsibility for spatial development policy and policy relating to emergency response operations and will ultimately balance the various options within existing boundary conditions.

The province and the central government have the role of approving and assessing a spatial development plan. In situations near railway lines, as in Dordrecht and Zwijndrecht, the central government's role mainly concerns (national) infrastructure.

In view of the various interrelated, and sometimes conflicting, interests, it is recommended to involve all stakeholders from an early moment on and to keep a record of everyone's expectations and wishes.

External safety in municipal spatial planning along railways (like the railway zone in Dordrecht and Zwijndrecht) is largely determined by what is transported by rail and how. As this is something the municipality cannot influence, the starting point for applying the Evaluation method is the current mode of transport and changes that can be foreseen as a result of market developments.

Effects of *definite* plans and policies that will lead to an improvement in safety within a period of five years (such as the construction of the Betuweroute line¹) can be incorporated. In policy developments relating to the transport of hazardous substances by rail, the central government will make its own evaluation of the relevant guidelines, studies or policies to be followed. In the case of Dordrecht and Zwijndrecht, for example, this is the ROBEL study (into freight transport between Rotterdam and Belgium). The central government will make arrangements with other authorities on implementation and timing of these policies.

Because of this it is not possible to take such policies into account at a municipal level unless the policy-making process has advanced far enough.

This means that, if such plans were to be implemented, the associated risks will have to be made clear to local citizens and other stakeholders. Municipalities are of course free to urge the central government to endorse measures that improve safety.

Application of the Evaluation method provides insight into the external safety risks of spatial planning and the options for improvement. If risks are considerable, the municipality will have to decide if they want pursue a certain plan and if so, indicate under which conditions.

¹ New railway line that will connect Rotterdam with Germany.

The following aspects will have to be made explicit in this case:

- Which are the benefits to society of the proposed spatial development
- What are the alternative options in relation to the safety risk
- Which measures are foreseen in the plan to improve the safety situation.

The degree to which alternative locations are feasible could play an important role in this argument, but also the desire to maximise transport potential of the railway.

An early application of this Evaluation method to planning at various levels of scale (from structure plan to detailed spatial development plan) is to be recommended. If new insights occur on the basis of this Evaluation method for e.g. the entire railway zone, then these should be fed back to the level of the structure plan.

In the case of a railway zone like the one in Dordrecht and Zwijndrecht, there are several spatial development plans that deal with a safety issue of one particular area. This requires an area-oriented approach, that provides insight into the contribution of each of these plans to the total safety in the area, as has been done in this Evaluation method. With this, a municipality can balance various options; e.g. local deterioration in the safety situation (i.e. the guide value of the societal risk is further exceeded) can be compensated by improvements elsewhere, provided at least a minimal effort is put in all the criteria of the Evaluation method.

In an area like a railway zone, other risks may very well be present also, like those associated with transport via road and river, or from establishment subject to the Seveso guidelines (subject to BRZO, the Dutch implementation of the Seveso guidelines). Accumulation of these risks should be taken into account during the spatial planning process.

On behalf of the *Veiligheidsstudie Spoorzone Dordrecht/Zwijndrecht* (Safety Study into the Dordrecht/Zwijndrecht Railway Zone) steering committee



Antoin Scholten (Chairman)
Mayor of Zwijndrecht

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1. Introduction

This Evaluation method for external safety provides the content for testing external safety explicitly and transparently and shows how this can be done as a process in which risks are managed and responsibilities allocated. In the explanation and the procedural embedding of the Evaluation method, the focus in this report lies on the use of the Evaluation method when working out and testing zoning plans. This does not detract from the fact that External Safety should also be included at an earlier stage in the spatial planning procedure, for example, when drafting the spatial vision. The Evaluation method can similarly be embedded in the associated procedures.

The Evaluation method for external safety has two main elements:

- The criteria against which the external safety risks can be tested in a zoning plan. More details can be found in chapters 2 and 3.
- A list of measures and conditions that can be included when developing a zoning plan and which actor is responsible for what. More details can be found in chapter 5 and appendix 2. The list can be used when selecting measures considered relevant for further elaboration when applying the Evaluation method to a concrete situation.

The Evaluation method for External Safety should preferably be brought in at as early a stage as possible when making the plan, so that account can be taken of External Safety in good time. For that reason, appendix 1 provides assistance for embedding it in the administrative process of drawing up and approving a zoning plan.

In addition to this evaluation framework, there is also a background document called “*Veiligheidsstudie Spoorzone Dordrecht/Zwijndrecht*” [1] (Safety Study into Dordrecht/Zwijndrecht Railway Zone). It contains analyses of the current external safety situations, risk-reducing measures focussing on sources and effects and further documentary support for this Evaluation method for external safety for zoning plans in the railway zone Dordrecht/Zwijndrecht.

2. Criteria for the Evaluation method for External Safety

The external safety level in an area has to be tested against criteria. Since the test has to be transparent, these criteria have to be unambiguous. The evaluation method incorporates the criteria used in the Risk Standardisation for Transport of Dangerous Substances memorandum (*Risiconormering Vervoer gevaarlijke stoffen*, or RNVGS) [3], the individual or individual risk and the societal risk. However, these criteria are insufficient for describing the safety level at a particular location: which harmful effects occur when an accident scenario actually takes place and how these effects can be limited. The level of ability for self-rescue, i.e. how well people can get themselves to a place of safety in the event of a disaster, is an important safety criterion in this context. In addition to this, the possibility of emergency response being given in the event of a disaster and how it is managed (to what extent can the undesirable development of the disaster be prevented) play a major role. With regard to providing the administration and the general public with clear information, it is appropriate to provide an insight into the extent of the damage that can occur as the result of a disaster, should all the (possibly preventative) safety measures fail. On the basis of these considerations, the following safety criteria will be considered for testing external safety in zoning plans¹:

- individual risk
- societal risk
- self-rescue
- controllability
- consequences, expressed in terms of fatalities, injuries and/or material damage.

These five criteria are defined as follows:

The **individual risk** is the probability per year that a person is killed by an accident during the transport by rail of hazardous material if that person is permanently in a certain place and unprotected.

The **societal risk** is the cumulative probability per year that a group of a certain size is killed simultaneously by an accident.

The criterion **self-rescue** indicates the extent to which those present are capable of getting themselves to a safe place on their own. The abilities for self-rescue can be positively affected by:

- a. the provisions in the area which make escaping possible (infrastructure facilities)
- b. the physical possibilities of escape of the population in the vicinity

¹ In the assessment of the workshops about societal risk, the societal risk assessment is mentioned as an aspect of the accounting obligation when the guide value for the societal risk is exceeded. This societal risk assessment should provide an insight into the ability for self-rescue and into emergency assistance/manageability.

- c. the degree to which people are prepared for any necessity to escape or receive timely instructions for this (mental capabilities).

The criterion **controllability** focuses on the availability of the emergency services and the extent to which they are able to carry out their tasks properly and thus prevent further damage developing.

Testing this (on zoning plan level) should focus mainly on the impact per location, so that when new developments are tested it is possible to find out whether the pre-conditions and environmental conditions for the emergency services have been approved. Aspects specific to the location that are important for the deployment of emergency response services are:

- accessibility
- possibilities for setting up equipment
- availability of resources (both repressive and preventive)
- capacity of emergency services

The criterion **consequences** gives an estimate of the number of deaths, injuries and material damage that occur in a number of representative scenarios at the location being considered.

The five criteria for testing the external safety level, with the exception of the individual risk, cannot be viewed separately, since there are connections between the different criteria. This is explained briefly below:

- The individual risk represents the risk at a particular place. The presence of people plays no role in this. This means that Self-rescue and Controllability have no influence. They are not included in the determination of the individual risk (this follows on from the definition of the individual risk).
- The societal risk is determined by the probability of scenarios and the number of deaths that may occur in these scenarios. Self-rescue and the controllability/emergency response will reduce the number of casualties.
- Good facilities and measures to aid the abilities for self-rescue may lead to people being able to save themselves in time or limit the seriousness of their injuries. The lack of sufficient arithmetic models means that the effect of self-rescue cannot always be quantified (or made visible in the societal risk). The consequences (with regard to deaths and injuries) will also be reduced.
- Fast and effective assistance can prevent a disaster from escalating (e.g. cooling an LPG tanker to prevent a hot BLEVE (Boiling Liquid Expanding Vapour Explosion)). This will lower the societal risk and self-rescue will increase. If the measure is actually effective, the consequences will also be reduced.
- The criterion Consequences describes the consequences in terms of deaths, injuries and material damage. The number of deaths is also considered in the societal risk. Self-rescue, emergency assistance and controllability can reduce the consequences.

Despite the fact that there is a partial overlap and a clear relation between the five criteria, they each provide extra information about the safety situation, probability, consequences, number of deaths, injuries, material damage, the need for help with regard to the deployment of the emergency services and the possibilities of deploying the emergency services. For that reason, all five are important when assessing safety and all five should be examined in the Evaluation method. The status of the five criteria, however, is not the same. The Individual Risk is a hard and fast standard that must be met. There is a guide value set for the Societal Risk. There are no guideline values for Self-rescue, Controllability or Consequences.

To indicate the effectiveness of the various measures, it is important to consider all five criteria. If only the Individual Risk and the Societal Risk are considered, the effect of some of the measures cannot be shown, although they can have quite an impact on criteria like Controllability and Consequences. For example: fire-resistant facades and safety glass contribute to the reduction in both material damage and the number of injuries. They do not, however, have much effect on the Individual Risk and the Societal Risk. Under the terms of ALARA (As Low As Reasonably Achievable), Self-rescue, Controllability and Consequences should also be examined if there are no vulnerable objects within the Individual Risk contour of 10^{-6} a year or if the guide value of the societal risk is not exceeded.

The function of the criterion consequences is not to measure whether the safety situation is good or not good: there is no benchmark for this criterion. The function of the criterion is to provide an insight into the potential damaging effects of a few scenarios and is important to the emergency services when they are preparing for disasters. It is also important for communicating the risk.

The figure below shows the five criteria and indicates which measures in the safety chain can influence the criteria. The score in one or more criteria can be improved by adding facilities and taking measures. The measures are discussed in more detail in chapter 5.

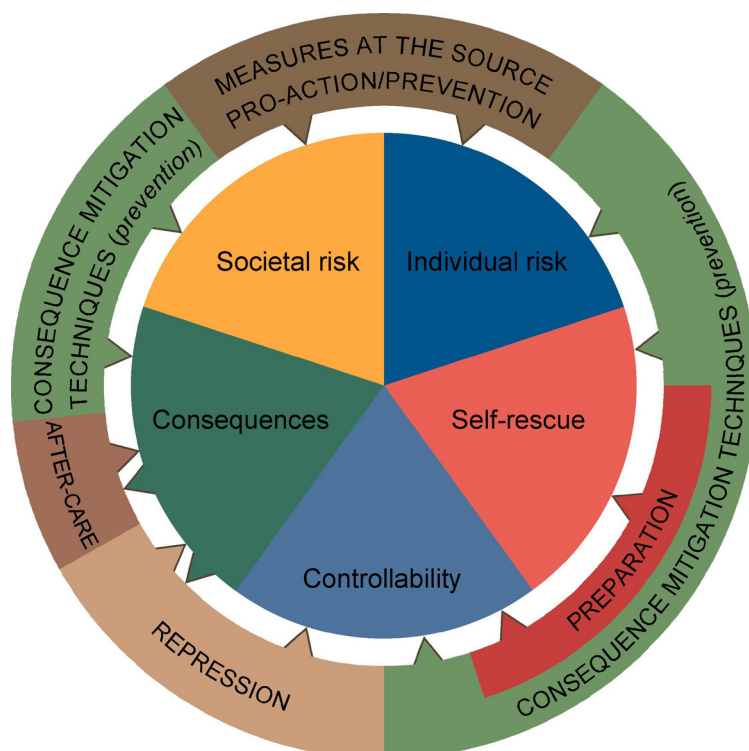


Figure 2-1 The five criteria and the effect of measures.

3. Details of the Criteria

3.1 Introduction

This chapter gives further details of the five criteria, structured as follows:

1. Definition and possibly a description
2. Method of measuring
3. Benchmark

Point 2, method of measuring, indicates how the criterion should be qualified and/or quantified. There are no standards or limiting values laid down for the criteria (apart from those for the individual risk). Benchmarks are however given for each criterion as reference material. In addition to this, the change in the safety situation can be considered by comparing the zoning plan with the current situation. When applying the Evaluation method locally, the local competent authority can choose to establish an ambition level for each of the criteria. This ambition level will not be set in this Evaluation method.

3.2 Individual risk

The individual risk is the probability per year that a person is killed by an accident during the transport by rail of hazardous substances, if this person is permanently in a certain place and unprotected.

Method of measuring

The individual risk is calculated according to recognised methods as laid down in the 'Purple book' (Guidelines for Quantitative Risk Assessment). The Manual for External Safety of Transport of Hazardous Substances (*Handreiking Externe Veiligheid Vervoer gevaarlijke stoffen*) [2] gives some rules of thumb for this. Detailed calculations, requiring special risk analysis software, are needed if a possible obstacle is suspected.

Required safety level

A precondition for the test is that no new vulnerable objects are permitted within the 10^{-6} contour. In this context, the 10^{-6} contour is a hard and fast limiting value.

When considering a new zoning plan, it is easy to check whether this condition is being met by consulting a map and the position of the 10^{-6} contour. If the norm is not being adhered to, the vulnerable objects within the 10^{-6} contour will have to be removed from the plan or risk-reducing measures will have to be taken so that the individual risk is reduced and the proposed objects no longer lie within the 10^{-6} contour.

3.3 Societal risk

The societal risk is the cumulative probability per year that a group of a particular size is simultaneously killed as the result of an accident.

Method of measuring

The societal risk is calculated according to recognised methods as laid down in the ‘Purple book’ (Guidelines for Quantitative Risk Assessment). Special risk analysis software is required for the calculation.

Benchmark

The societal risk is currently tested against the guide value. The societal risk relating to the transport risk is established per km-section and tested against a guide value per kilometre. If the value is exceeded, it will have to be supported by the CHAMP method.

In connection with the extra safety measures required in the CHAMP method if the guide value is exceeded, we suggest that, when testing, higher requirements should be set for self-rescue and controllability criteria if the societal risk is exceeded and if it is not possible to reduce the societal risk sufficiently by means of measures.

This is illustrated in the diagrams below:

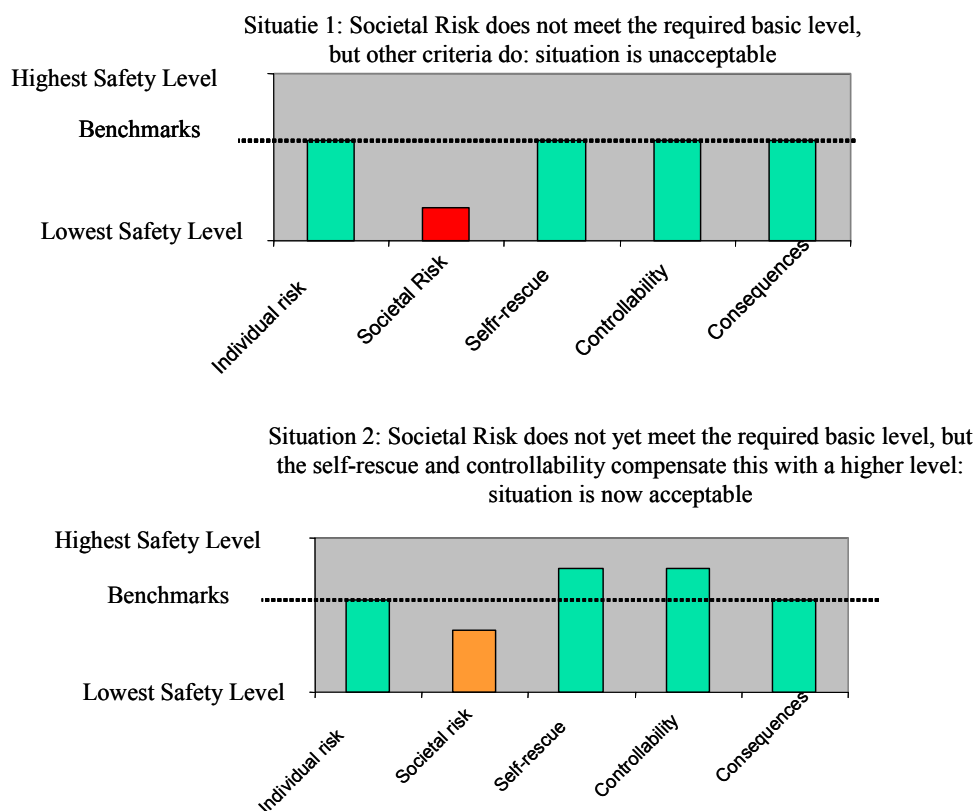


Figure 4-1 Example of exchange between criteria.

It should be noted that a sufficient safety level for the criteria Self-rescue, Controllability and consequences is also required when the societal risk is not a problem.

The current test for the societal risk is used in this Evaluation method: the societal risk is tested for each kilometre section against the guide value. If that value is exceeded, it will first be necessary to find out whether there are measures that can be taken to reduce the societal risk. If this is not possible (or the measures are not desirable in light of other considerations, for example, economic ones), a reason will have to be given showing why the development is desirable (economic, spatial, urban quality development reasons). At the same time, it will have to be shown how the safety situation will be improved as much as possible, by indicating how the other safety criteria “score” and which measures will be taken in this context.

Societal risk at urban level

Besides this, an extra insight can be gained into the societal risk issue by means of the societal risk at urban level. The societal risk at urban level is introduced in order to be able to take account of the societal risk at an early stage when developing urban programmes. Arguments for introducing the societal risk at urban level are:

- By introducing societal risk at urban level, the development of the level of safety in Dordrecht and Zwijndrecht can be guided. It makes it possible to compare different initiatives and to consider their contribution to the level of safety in the whole city.
- By introducing the societal risk at urban level, apart from the individual projects, pressure is applied for the plans to be carried out as safely as possible. (Even if the plan on the site does not result in the guide value per km being exceeded, but does mean an increase in the societal risk).
- The SR at urban level also means that the current situation (elsewhere along the railway line) is included when considering new developments.

The Urban Development departments in Dordrecht and Zwijndrecht want this to apply in the long term to all high-risk activities in the city that are accompanied by a societal risk. These activities should be indicated on a risk map and kept up to date. The details in this report are limited for the time being to the risks relating to freight transport by rail.

The societal risk at urban level is defined as follows (for Dordrecht and Zwijndrecht):

1. The societal risk at urban level will be calculated for the new situation (with a new zoning plan or urban development plan). This calculation consists of adding up the societal risks per kilometre for the kilometres inside the urban contour. For Dordrecht, this means the kilometres 1 to 5, 9 to 15. For Zwijndrecht, the entire route consists of 3 kilometre sections (for the time being 2 kilometre sections have been extrapolated; the third kilometre, beyond Kijfhoek in the direction of Rotterdam, still has to be added).

2. This new societal risk is compared with the societal risk in the current (forecast) situation¹. If the societal risk increases with respect to the current societal risk, measures can be taken to reduce the societal risk. This can be done by altering the zoning plan or other plans, by taking measures in another location or by taking measures that have an impact on the entire railway zone.

3.4 Self-rescue

Self-rescue indicates the degree to which those present are capable of getting to a safe place on their own.

Abilities for self-rescue differ for each type of accident. Self-rescue can make an extremely important contribution to reducing the number of casualties, because most casualties occur primarily within the first minutes to half an hour of the accident occurring. Examples are:

- leaving the danger area in good time so that they are at a safe distance by the time the BLEVE actually occurs
- leaving the damage area, for example a burning building, thus limiting the severity of the injury (slight burns instead of death from exposure to heat and smoke)
- escaping indoors, closing windows, doors and ventilation openings to minimise exposure to toxic gases.

The possibilities for self-rescue vary per scenario. In some scenarios there is time to escape, but in others (a cold BLEVE, for example) there is no time and no warning to escape from the danger area in time.

In addition to differences for each scenario, there are other factors that affect the degree of self-rescue. The presence of escape routes, the extent of being prepared, the number of people and their physical condition and whether or not instructions are given in good time are all important factors. The combination of these factors should ultimately be able to be measured by measuring the total evacuation time and placing requirements on this (for example, evacuation of the area within 30 minutes of the warning). Quantification of the Self-rescue abilities in the zoning plan is not possible. The methods for making good quantitative estimates are lacking. For that reason, the ability for self-rescue will be measured on a more qualitative way. A lower level: are the conditions for a good self-rescue present. In the context of testing zoning plans, matters that can be arranged within a plan will be examined in particular. In concrete terms, this means that, when adding details to the zoning plans, conditions will be placed on:

¹ This situation is always called the future situation in the safety study. It relates to the current situation plus all the zoning plans that have already been approved (but not yet put into practice).

- a. The facilities in the area that make escape possible (infrastructure facilities)
- b. The physical abilities to escape of the population present
- c. The degree to which people are prepared for a possible need to escape or can receive timely instructions to do so (mental abilities).

It must be borne in mind that this is not enough to actually ensure that casualties can be prevented by means of self-rescue. To do that, it is important that people are warned in good time and urged to escape. This requires fast detection, fast call-out of the emergency services, fast action from the emergency services and the availability of the resources needed for this. These things cannot be arranged in a zoning plan, but are important to the ultimate effect of self-rescue.

The details of the points to be tested for the zoning plan are given below:

Methods of measuring

Infrastructure facilities

Establish the following for buildings within the damage areas of the representative scenarios:

- whether the requirements (with respect to escape facilities) of the Buildings Decree have been met
- whether the building can be made airtight (or almost airtight) (the extent to which ventilation openings and ventilation systems can be closed)
- whether the escape route out of the building leads away from the railway line (the accident area) and any assembly points are not on the railway side of the building
- whether roads lead away from the railway line, preferably at right angles to the railway line.

More stringent requirements can be placed on buildings within the damage area where there could be many casualties indoors as well. The size of the damage area should be recorded in a scenario analysis. These damage distances have been laid down in the scenario analysis for the Dordrecht/Zwijndrecht Railway Zone [1] for the normative scenarios for Zwijndrecht and Dordrecht. For a Hot BLEVE, these damage distances are approximately 450 metres (total area to be evacuated) and approximately 200 metres (area within which fatalities can occur indoors as well).

Physical capabilities (of the population)

1. High ability for self-rescue: the area contains functions in which relatively few people with a low ability for self-rescue participate. Examples of this are offices, secondary schools and sports facilities.
2. Average ability for self-rescue: the area contains various functions that are also accessible to people with a reduced ability for self-rescue, like shops, museums, hotels and restaurants, and homes.
3. Low ability for self-rescue: the area contains functions pre-eminently used by people with a reduced ability for self-rescue, like hospitals, nursing homes, homes for the elderly and day-care centres.

Here too the requirements placed on the population's ability for self-rescue can be linked to the damage distances that could occur in the event of the normative scenarios.

Mental capabilities

0. No specific preparation (other than national campaigns relating to what to do when the siren sounds).
1. Basic preparation: the municipality distributes an information pack within the area (fairly regularly).
2. Targeted preparation: the area contains functions suitable for informing their users as a group about the possible necessity for self-rescue. This information provision will also be actually delivered (under the supervision of the municipality/fire service).
3. Good preparation: the area contains functions suitable for preparing the users as a group for the possible necessity for self-rescue. Besides this, regular evacuation practice will be held for the larger buildings (offices, schools, etc.).

Benchmark

There is a good ability for self-rescue if the following characteristics are met:

- Within the zone where the representative scenarios could cause casualties indoors¹, the following requirements apply:
 - Only functions with users that in general have a high ability for self-rescue are planned (offices, etc.)
 - The escape route out of the building leads away from the railway line and any assembly points are not on the railway side of the building²
 - Roads lead away from the railway line, preferably at right angles to the railway line.
- Within the zone where the representative scenarios require that this area should be evacuated, the following requirements apply:
 - No functions specially for people with a reduced ability for self-rescue are planned in this area (like hospitals, nursing homes, homes for the elderly and crèches)
- Within the zone where exposure to toxins occurs in the representative scenarios, the following requirements apply:
 - Buildings can be made airtight (or almost airtight) (ability to close off ventilation openings and ventilation systems)
- The emergency sirens can be heard indoors as well as outside.
- The inhabitants are informed every year of the risks and the possible need for self-rescue by means of a general information campaign.

The basic level also requires that the general conditions for fast self-rescue (fast detection, alerting the emergency services, alerting and informing the population) are met.

¹ This is a radius of 200 metres for a Hot BLEVE.

² The buildings must of course also meet the requirements of the Buildings Decree (with regard to escape routes).

3.5 Controllability

The controllability criterion focuses on the availability of emergency services and the extent to which they are able to carry out their tasks properly and thus prevent further escalation of the incident.

In general it can be said that, from the point of view of controllability, efforts should focus on intervening as early as possible in the development of incidents.

Two examples:

1. If there is a threat of a hot BLEVE, all efforts should be aimed at preventing the BLEVE. If the BLEVE still occurs, it will give rise to a disaster to which the efforts of the emergency services are not equal (guidance for representative disaster and operational performance).
2. When the emergency services arrive at the scene of a leakage of toxic substances, clouds will often already have escaped (and therefore their effects). The effort is then aimed mainly at preventing the further spread of the substances to prevent greater impact.

Method of measuring

Some representative accident scenarios are worked out to analyse the development of incidents. These scenarios depend on the specific circumstances in the locality and at the time of the incident. To assess the Controllability, the representative incidents have to be worked out in detail on site.

With regard to the testing of the zoning plan, the measurement of the criterion Controllability focuses on the location-specific aspects of the emergency response. Location-specific aspects that are important for the deployment of the emergency services are:

- accessibility
- possibilities for setting up equipment
- availability of resources
- capacity

These four aspects are worked out as follows:

Accessibility

- measuring the time needed from answering the call to arriving at the place of the incident (this is the driving time + any time needed to walk from the position where equipment has been set up) until deployment actually starts.

Possibilities for setting up equipment

- find out if there is enough room to set up the equipment required (for the representative scenarios) near the site of the accident.

Availability of resources

Find out if, given the representative scenarios and the location and the local circumstances (in the zoning plan):

- the standard emergency vehicles can be used
- it is possible to use a high-pressure hose (if required) to put the fire out quickly
- it is possible to use sufficient foam extinguishing agents (if this is desirable from the point of view of the scenario)
- the water facilities are sufficient to perform lengthy fire-fighting operations
- it is possible to provide assistance to those injured and transport them in a recumbent position away from the scene of the accident to the place where the equipment has been set up.

Capacity

Find out if:

- there is an increase in the required emergency response capacity compared to the required capacity already identified and whether this demand can be met. The need for assistance can be established by determining the consequences and other effects (see section 4.6). The necessary capacity can be calculated using the (Dutch) Guideline for Operational Performance.

The effect of better controllability for these four sub-criteria can only result in less damage and fewer casualties if other more general preconditions are met, such as alerting people quickly, providing good information, sufficient capacity, proper preparation by the emergency services and good coordination between the various parties involved in dealing with the incident.

Benchmark

This criterion focuses primarily on availability of resources/infrastructure for the emergency response services. The degree to which this actually leads to less damage, fewer injuries and fewer deaths varies per scenario. General requirements are set within this criterion (i.e. not per scenario, but given that different scenarios can occur) from which, depending on local circumstances, the necessary provisions and (possibly damage-limiting) measures can be derived.

The requirements that must be met to be able to say that the controllability is good are set out below.

- A. Accessibility and availability: the scene of the accident must be able to be approached from two sides and the emergency services must be able to reach it within 10 minutes (driving time and possibly walking). Deployment within 12 minutes must be possible.
- B. Possibilities for setting up equipment: these must be large enough for the emergency vehicles needed for the standard scenarios.
- C. Availability of people and resources: the preventative means and the repressive power of the emergency services (in size and time-frame) match what is needed for combating the incident and preventing it from escalating (based on the representative scenarios). The underlying principle is that people are only deployed if this can be done safely.

D. Capacity: the maximum need for assistance (necessary deployment of people and resources) will not increase due to changes in the situation.

If point A cannot be achieved with the usual people and resources, point A can also be met by deploying other resources, such as automatic extinguishing agents, in order to ensure that deployment can take place within 12 minutes.

If, when testing point C, the availability and usability of the resources turn out to be inadequate, the solution does not necessarily have to be sought in terms of extra resources, but can also be found in the form of damage-limiting measures, thus reducing the required deployment of resources.

The underlying principle is that the emergency services should meet the general capacity and quality requirements.

When considering this criterion, it should be remembered that in a number of scenarios, damage occurs within the first minutes. Good controllability does not mean that the damage and the number of casualties can be limited in all scenarios. Scenarios with many casualties and much damage remain a possibility. This is also expressed in the criterion Consequences.

3.6 Consequences

The consequences criterion provides an estimate of the number of deaths, injuries and material damage occurring in a number of representative scenarios at the location in question.

The function of the criterion is to provide an insight into the potential damaging effects of a few scenarios, which is important for the emergency services when preparing for disasters. In addition, this criterion is important for risk communication and plays a role in the managerial acceptance of the new situation. The consequences criterion, besides providing an insight into possible consequences, plays a particular role in making the impact of the changes (as a result of the zoning plan and other measures) visible. The probability of the scenario actually occurring is therefore not taken into account for this criterion. The probability aspects are incorporated in the individual risk and societal risk criteria.

Method of measuring

Models from the 'Yellow' and the 'Green' book will have to be used to calculate the size of the damage areas and the number of dead and injured. Software is available for this. Knowledge of the value of the buildings in the damage area is needed before material damage can be estimated. The expertise of the Urban Development department and project developers will have to be called upon for this. When establishing the impact, local circumstances, the time of day and the weather have a

great influence. The choice made will affect the outcome. This choice is less important when comparing two situations. The proposal is to work out a single location (as close as possible to the greatest change in housing in the zoning plan), a single moment (choose daytime where possible unless the areas under consideration are more densely populated in the evening or at night) and a type of weather (choose the most prevalent type of weather and wind-speed at the location).

The effects are shown by working out the current situation and the situation after the zoning plan has been put in place. To analyse the contribution made by extra impact-reducing measures, a third situation can show the consequences, based on these extra measures. The effect of the self-rescue and of emergency response can also be included in this list of impact-reducing measures.

Benchmark

The function of the consequences criterion is not to measure whether the safety situation is good or not good: establishing a general benchmark relating to the number of deaths or injuries or material damage is not obvious. Naturally, no deaths, injuries or damage would be the most desirable situation. In reality, however, situations in which deaths and injuries occur cannot be ruled out. The consequences will be considered in comparison with the consequences without the new development and will play a role in the managerial acceptance of this new situation.

With regard to the consequences, the ALARA principle should be applied: the consequences will be limited as much as possible by taking measures. In the sample table, both the effect of the measure (in terms of fewer deaths, injuries or less material damage) and the cost can be shown. On the basis of these data, a decision can then be taken as to whether the extra measures are desirable.

4. Safety Measures and Conditions

4.1 Introduction

The safety level of each of the five criteria can be increased by taking measures and implementing safety provisions. Chapter 2 describes the relationship between measures in the various links in the safety chain and the five test criteria. Appendix 2 contains a list of various measures, showing which of these five safety criteria are affected by these measures. This chapter shows which actors are responsible for each measure and at which stage in the planning process these measures could possibly be applied. The length of time they will take to be implemented also plays a role in this. To estimate the length of time, we have looked primarily at the technical feasibility and have come up with the following schedule: Short term: ≤ 3 years, Medium term: 3-10 years, Long term: > 10 years. The effect of the measure will be given in general terms. Specific estimates will always have to be linked to a concrete situation. The assessment in the *Veiligheidsstudie Spoorzone Dordrecht/Zwijndrecht* (Dutch document: Safety Study into the Dordrecht/Zwijndrecht Railway Line) examines this in more detail. At the end of this chapter we look in brief at the choices that can be made when compiling the package of measures.

4.2 Measures within the zoning plan (municipality)

The zoning plan provides particular opportunities for taking architectural and constructive measures, and urban development measures. The principle behind these measures is that they will lead to a limitation of the damage.

Urban development measures, such as arranging an area differently, the choice of functions, and less dense housing close to the railway line can have a positive effect on both the societal risk and on self-rescue and can also contribute to better accessibility (and therefore better controllability for the emergency services). These urban development measures are the responsibility of the municipality and can be arranged in the short term, within the zoning plan, but may place limitations on the zoning plan.

The effectiveness of constructive and architectural measures differs for each accident scenario. Measures can be taken for fire scenarios (such as fire-proof walls, introducing a sunken construction for the railway, fire-proof facades and safety glass) so that the damage in the event of these scenarios is substantially reduced. These have a positive effect on the consequences and controllability criteria in particular.

Measures taken close to the railway line, such as fire-proof screens, earth embankments, sunken construction or roofing in, are also very effective for the individual risk, which is pushed back as far as the wall, embankment or roof.

The effect of architectural and constructive measures on the societal risk is limited because the scenarios “Hot BLEVE” and “Cold BLEVE” dominate the societal risk. Architectural measures are ineffective against these scenarios.

Architectural and constructive measures can in general be taken in the short term.

Extra provisions can also be made within the zoning plan in the interests of self-rescue, emergency assistance and the consequences. The layout of the area and good accessibility have already been mentioned. Other possible measures are:

- availability of fire extinguishing water or special extinguishing facilities (in the context of controllability)
- extra requirements for buildings, such as safety glass (in the context of a lower consequences) and ventilation that can be closed (in the context of self-rescue and the consequences).

4.3 Supplementary policy (municipality)

Whether or not self-rescue and controllability in the form of fewer deaths and injuries are successful not only depends on the facilities available in the area of the accident, but also on how well prepared the emergency services and the general public are. In a sense, there is a chain of measures that will only be effective if all the measures work. For example: fast detection of the accident will have little effect if the warning procedure is too complicated and takes a long time. For that reason, to achieve a better self-rescue and/or better controllability we need to look at packages of measures to actually contribute to reduced damage and fewer casualties.

The number of casualties can be reduced significantly in some scenarios by timely escape or evacuation. This is true particularly for the “Hot BLEVE” scenario. The package of measures “Timely evacuation in the event of a hot BLEVE” requires the following combination of measures: very fast detection and warning, clear indication of the location, clear indication of the substances involved, alerting the public quickly, evacuation experience, escape facilities (in buildings and the vicinity). If this works well and an area can be evacuated (for the most part) within approximately half an hour after the accident occurred, the number of deaths and injuries can be significantly reduced, with a very favourable effect on controllability, the consequences, the SR and, of course, self-rescue. When extrapolating to the GR, the chance of the evacuation not (or not entirely) being successful should be taken into account, which will reduce the net effect.

The package of measures “Timely cooling the tank in the event of a hot BLEVE” requires the following combination of measures: very fast detection and warning, clear indication of the location, clear indication of the substances involved, good access to the railway line, sufficient water, sufficient capacity, sufficient preparation for early extinguishing. If this chain of measures works, a hot BLEVE can be prevented. It thus reduces the probability of a hot BLEVE somewhat and reduces the Societal Risk. There will still be the danger of a hot BLEVE, however, should the measures not work properly. Otherwise, similar consequences can occur in the event of a cold BLEVE. These measures have no effect on this.

Both timely evacuation and timely cooling can in principle (and preferably) be used. Both packages of measures involve a long chain of measures, each of which has to work individually. Although the individual measures can be achieved in the short term, a lot has to be done before such packages of measures actually take effect and have a good chance of success.

4.4 Measures to be taken by other actors (State, transporters, railway authority)

Source measures are particularly effective, but the responsibility for taking these measures lies with parties outside the scope of the municipality (the central government, the railway authority and transporters). Whether these measures can be achieved depends on developments at these parties.

By taking source measures, the probability of an accident can be reduced. Source measures have a particular impact on the individual risk and the societal risk. Far-reaching, proactive source measures, such as the construction of a dedicated freight line outside urban centres, remove the whole problem and thus have a positive effect on all five criteria. The central government is responsible for such measures. Such measures will only be able to be achieved in the long term.

In addition to source measures in the context of rerouting and reducing the number of transports, much benefit can be gained by improving the railway line and making transport safer (lower speeds in combination with new generation Automatic Train Control, no switches, better inspection of the wagons, etc.). These measures are the responsibility of ProRail and (with regard to technical feasibility) can be achieved in the medium term.

The effectiveness of most source measures is independent of other measures. Naturally a number of measures in this category can be combined, for reasons of efficiency, and thus greater safety benefits are gained at a lower cost. Which combinations are the most obvious depends on the local situation. This could, for example, apply to measures aimed at improving the railway infrastructure. These could all be

taken at the same time during a large-scale renovation (such as reducing the number of switches and level-crossings and introducing better security).

4.5 Choice of measures

Establishing which packages of measures and preconditions are required for a zoning plan involves individual tailoring. A selection of measures from the list can be made for each plan. What this selection will look like depends on the suitability of the measures for the zoning plan and on the resources available. Initially source measures are preferred. As has already been pointed out, in most cases these cannot be implemented in the short term and therefore other measures will have to be taken in order to improve safety in the short term. When weighing up and choosing the package of measures, both the cost and the time needed to achieve it will play an important role.

5. References

- [1] *Veiligheidsstudie Spoorzone Dordrecht/Zwijndrecht*, (Dutch document: Safety Study into the Railway Zone Dordrecht/Zwijndrecht) TNO report R2004/104, March 2004.
- [2] *Handreiking Externe Veiligheid Vervoer gevaarlijke stoffen* (Dutch document: Manual for External Safety when Transporting Hazardous Substances), The Hague, 1998 *Risiconormering Vervoer van gevaarlijke stoffen* (Dutch document: Risk Standardisation for Transport of Dangerous Substances)

6. Authentication

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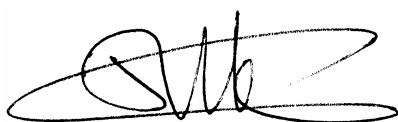
Names and establishments to which part of the research was put out to contract:

TNO-STB

Date upon which, or period in which, the research took place:

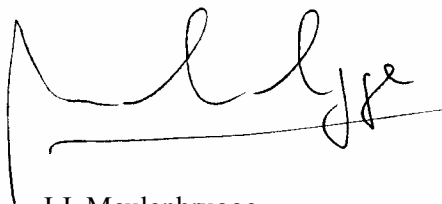
March 2003 – March 2004

Signature:



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Appendix 1 Procedural embedding of the Evaluation method for external safety

1.1 Introduction and definition

Drawing up a zoning plan is the job of the municipality and the statutory procedure is laid down in the Spatial Planning Act. The Evaluation method for external safety fits in with this: no new procedure is necessary.

It is important that account is taken of external safety at a very early stage in the development of a zoning plan. A step-by-step plan has been drawn up for applying the Evaluation method. At its heart is the design of the zoning plan, based on a programme of requirements in which external safety guidelines play a significant part (see next section)¹. This step-by-step plan focuses on the zoning plans. This focus arises from the phrasing of the project's aim: "To find concrete answers to the question of which projects within the railway zone can go ahead under which safety and other conditions in Dordrecht and Zwijndrecht." This does not detract from the fact that external safety should be included at an even earlier stage in the spatial planning procedures, for example, when drawing up the spatial vision. A comparable Evaluation method should be embedded in the procedures associated with this. In fact, the earlier external safety is brought into consideration, the more obstacles can be prevented and the more room there will be for possible solutions.

The municipality is dependent on other actors like infrastructure managers and the central government for the implementation of external safety measures. Moreover, some of these measures (e.g. reducing the transportation of hazardous substances, routing, etc.) cannot be directly translated to the zoning plan. On the other hand, such matters as the maximum density of buildings within a particular zone or the location of vulnerable and less vulnerable objects can be laid down in the zoning plan. Chapter 4 indicates which measures can be laid down in the zoning plan and which need to be organised in ways other than via the zoning plan. This might involve a private contract or a voluntary agreement. These aspects fall outside the scope of this project and have therefore not been included in the Evaluation method.

The Evaluation method is not a manual setting out how the set of instruments for the zoning plan can give substance to external safety themes. For that reason, attention will not be paid to the possibilities or impossibilities of:

- The description in outline
- An explanation of the plan
- A map of the plan
- Instructions for the plan.

¹ It is also advisable to declare the Evaluation method applicable to what is known as the anticipation procedure (art. 19). This will prevent the approval procedures in art. 19 based on prevailing zoning plans in which no or insufficient attention has been paid to external safety from leading to an administrative impasse.

These aspects are outside the scope of the project. It is incidentally advisable to write such a manual in the way the province of South Holland has done for the section on water in zoning plans (“Bestemmingsplannen blauw gekleurd” (Dutch document: Zoning plans coloured blue), 2001).

When drawing up zoning plans, a whole range of aspects and interests (including environmental aspects) have to be surveyed and complex considerations are required. However, this Evaluation method only deals with a further specification of the preconditions from the point of view of external safety. This is discussed in more detail in the step-by-step plan below.

1.2 Step-by-step plan

Deciding on which package of measures and preconditions are needed for a zoning plan is and remains a question of individual tailoring. A selection will have to be made for each plan. The final selection depends on:

- the ambition levels chosen for the criteria (see chapter 3)
- measures to be taken by (see chapter 4):
 - the municipality
 - other actors, but especially transporters and infrastructure managers
- the ultimate suitability of measures for the zoning plan.

Aligning external safety and spatial policy properly is a necessity and can only be achieved if intensive consultations and, where possible, cooperation take place between the municipality, the central government, managers and the province. Consultations based on article 10 of the Spatial Planning Decree can be used for this. It is recommended to get the right parties around the table at an early stage. The Evaluation method for external safety suggests the following steps:

Step 1 involves defining the **frame of reference**. After all, having a good understanding of the safety situation is essential. The underlying principles for the infrastructure and its use are established. The external safety situation in the area of the zoning plan is qualified and quantified by means of the five criteria in the Evaluation method. This analysis should take account of previously approved zoning plans and the established forecasts for freight transport. More information on this can be found in the background document Safety Study into the Railway Zone Dordrecht/Zwijndrecht (Dutch document: *Veiligheidsstudie Spoorzone Dordrecht/Zwijndrecht*).

This step is very important as it is used at a later stage to find out what impact a new zoning plan has on the present or future external safety situation and to identify the possibilities and limitations of the area of the plan in relation to external safety. These will be worked out in more detail in step 2. Step 1 defines the starting situation: the impact of the current situation (existing buildings, current transport

figures and forecasts, current agreements in the spatial vision) establishes the limitations or scope for external safety and development opportunities in outline. In step 2 it is possible to examine whether opportunities can be created or agreements made about changes in the starting situation.

It is up to the municipality to take the initiative for step 1 and approach the central government parties to establish the starting points for the infrastructure and its use. This is important in order to avoid a situation in which the manager of the infrastructure lodges an objection to the zoning plan at a later stage. Besides this, the municipality takes the initiative to determine the external safety situation at the location of the zoning plan.

Step 2 involves the formulation and inclusion of **external safety guidelines** based on the five criteria in the Programme of Requirements for the zoning plan to be drawn up. The starting point for this is the frame of reference and the preconditions established in it for the railway infrastructure and its use. It is recommended to involve external safety experts when drawing up the Programme of Requirements to ensure communication and interaction with the plan designers.

Please refer to chapters 3 and 4 for the formulation of the guidelines and details of possible safety guidelines and measures. In view of the fact that various measures do not come under the responsibility of the municipality, it is also important to involve other actors when drawing up the guidelines and preconditions, such as the central government, transporters and infrastructure managers.

The analysis of the effectiveness of measures reveals on the one hand that although measures aimed at the source have an enormous impact on the external safety situation with respect to Individual Risk and Societal Risk (in the positive sense), the municipality is not authorised to implement such measures. On the other hand, it would appear that not all measures can be organised directly through the zoning plan and that a distinction ought to be made between:

- measures that are directly spatially relevant (urban development/architectural)
- supplementary measures (emergency assistance, contingency planning).

It is important to have an understanding of this. A list of these measures and their details are given in chapter 4. Consultations with the different parties will have to reveal which safety measures can be integrated into the plan and who is responsible for their implementation, as well as the time this will take. This will produce transparency: it will become clear which measures can be achieved by:

- the municipality (the various services/departments such as spatial planning, environment, traffic and transport, fire service, emergency assistance)
- the infrastructure manager
- the central government.

The zoning plan will be **designed** on the basis of these guidelines in **step 3**: an important moment in the planning process. The draft zoning plan is drawn up based on the guidelines established in step 2 and the consultations with stakeholders, indicating which safety measures will be integrated into the plan and who is responsible for their implementation, and on what term.

An **external safety test** on the draft zoning plan based on the five criteria will be performed in **step 4**. This test should reveal the changes that the zoning plan will bring about in relation to the current situation. The external safety test provides a total picture of the safety situation in the area of the zoning plan, taking account of the various safety measures included in the draft zoning plan.

This is the stage of the process when the draft plan and the external safety test can be presented to the Provincial Planning Committee (*on urban and rural planning*, PPC) with a request for it to make recommendations. A large number of relevant actors are represented in this committee, both at provincial level and at central government level. Considering that all the relevant actors have been consulted at an earlier stage (step 2), the PPC test should not produce any surprises or obstacles, assuming that the guidelines in step 2 have been followed correctly.

If the draft plan needs to be **altered** as a result of the **PPC recommendations**, this is done in **step 5**. The competent authority carries out an **administrative evaluation** of the safety level of the proposed zoning plan, any objections to the plan and the benefits the plan will bring. Any changes to the zoning plan that are still possible will be examined by adding extra safety measures and/or changing the content of the zoning plan (different arrangement, different functions, etc.).

The province decides on the **definitive plan and the approval procedure** in **step 6**. The province of South Holland uses the CHAMP method to do this: exceeding the guide value is only permitted if there are important social and economic reasons for doing so (the Motivation). In that case, extra safety measures should also be taken (Anticipation and Preparation). The H, which stands for Horizon, relates to future developments that have to be taken into account. These may be both future developments relating to transport and those relating to urban development. The elements in the CHAMP method also appear in this external safety Evaluation method. If the Evaluation method is used, the requirements of the CHAMP method will be met too.

The municipality must specify which safety considerations form the basis for the proposed zoning plan and must also justify its preference for the proposed spatial plan. To do this, the plan must be presented to the local population and to other stakeholders. The usual zoning plan procedure can be used for this:

- deposit the draft plan for inspection + for submitting views
- incorporate any views into the plan
- municipality decides on zoning plan
- approval by the Provincial Executive.

When depositing the plan for inspection, the municipality must **communicate** about external safety in relation to the zoning plan. All the advantages and disadvantages, variants and measures (short and long-term) should be put forward relating to:

- Individual risk
- Societal risk
- Self-rescue
- Controllability
- Consequences.

Step 7 involves **finalising** the results from the previous steps. External safety has played a transparent and traceable part in the zoning plan process:

- The definitive zoning plan is decided upon
- Any actors other than the municipality who are to be responsible for the external safety measures to be taken are decided upon (and if necessary, recorded in contracts/voluntary agreements). This was already discussed in step 2.
- The time span for implementing the external safety measures is decided upon (and possibly recorded in contracts/voluntary agreements).

The step-by-step plan above is summarised in the table below:

Table 5-1 Step-by-step plan for External Safety Evaluation method.

Step	Description	Stakeholders and party with ultimate responsibility
1	Frame of reference: Determining and specifying the safety situation based on the five criteria at a location without a zoning plan	Municipality Railway manager
2	Providing safety guidelines to the zone planner with respect to the safety measures to be considered	Municipality
3	Drawing up draft zoning plan including proposed safety measures + variants	Planner Municipality Railway manager State, PPC, Province
4	Safety analysis of the draft zoning plan + variants based on the five criteria, external safety test, present to PPC	Municipality PPC ¹
5	Assessment and consideration of various safety variants for the zoning plan including reasons why the safety zoning plan is acceptable	Municipality
6	Approval of zoning plan, making use of the Evaluation method (and the CHAMP method used in South Holland)	Province
7	Definitive decision on zoning plan, safety measures (principal, body responsible, time span)	Municipality Central government Province

¹ PPC: *Provinciale Planologische Commissie*, Provincial Planning Committee, advisory body for zoning plans, central government parties are represented in this committee.

Appendix 2 List of Measures

This appendix describes the effectiveness of the various measures listed in this study. The effect on each of the five criteria in the Evaluation method is described in general terms. A summary is given in the table below. This list can be used when working out the details of measures for a specific situation, after which the feasibility and effectiveness of the measures for the specific situation will have to be detailed further.

When assigning pluses and minuses, the following considerations played a part:

- Measures that have the effect of reducing the probability will only affect Individual Risk and Societal Risk.
- Measures that reduce the impact may affect Individual Risk, Societal Risk, the consequences and the controllability. The necessity for self-rescue then also becomes less. This is not incorporated into the score, however, since when considering self-rescue, the *possibilities* for self-rescue are examined. Certain measures will have the effect of reducing the impact. If these are not the effects that influence the Individual Risk or Societal Risk, no plus will be recorded under Individual Risk or Societal Risk.
- Certain measures will only make a contribution in combination with others such that, for example, they lead to a reduction in the consequences and the Societal Risk. More information on such combinations is given at the bottom of the table.

The pluses and minuses have the following meaning:

- ++ Very positive effect
- + Positive effect
- (+) Positive effect, but hardly measurable or difficult to measure
- No effect
- +/- Measure has positive effect, but elsewhere along the route it may have a negative effect
- Negative effect

The period of time within which the measures can be implemented is also given, as follows: Short: ≤ 3 years, Medium: 3-10 years, Long: > 10 years. This estimate relates to the technical feasibility, taking account of implementation times. No comments are made as to whether measures will actually be implemented. When taking the decision about whether or not to implement measures, arguments other than safety arguments will also play a part. Each situation is different in this respect.

Measure	Effect on:				Stakeholders	Implementation period	Estimate of costs ¹	Comments
	LR	GR	Self-rescue	Controllability				
Routing								
Transport						Long		
- Phase out	++	++	-	+		Government (regulations) Producers and users		
- limit by reallocation production	+	+	-	-				
Re-routing								
- reallocation	+/-	+/-	-	-		Government (regulations, construction of new routes)	Medium/long	
- new route	+	+						
Choose other mode of transport	+/-	+/-	-	-	+/-	Government (regulations), producers, transporters and users	Medium/long	
Railway infrastructure								
Fewer level crossings	+ < probability (+)	+ < probability (+)	-	(+) (better accessibility)	-	ProRail ²	Short/medium	
Better protected level crossings			-	-	-	ProRail	Short/medium	
Fewer switches	+	+	-	-	-	ProRail	Medium	
Reallocate switches								
New generation ATB	+	+	-	-	-	ProRail	Medium/long	
Hot box detection	+	+	-	-	-	ProRail	Short/medium	
Anti-derailment guide	+	+	-	-	-	ProRail	Short/medium	
Measures to limiting spillage or spreading spillage	+	(+)	-	+	+	ProRail	Short/medium	
Operation and maintenance								
Lower speeds (+new generation ATB)	+	+	-	-	+	ProRail	Short/medium	

¹ Estimating the costs is limited to a rough estimate of the architectural and constructive measures. The costs of other measures will often be borne by parties other than the municipality and are not easy to estimate since they are highly dependent on the exact details on site.

² Prorail: Dutch administrative organisation of the railways

Measure	Effect on:				Stakeholders	Implementation period	Estimate of costs	Comments
	LR	GR	Self-rescue	Controllability				
Transport only at night	-	+/-	-	-	+/-	Short/medium		Depending on use of building
Block trains	+	+	-	+	(+)	Short/medium		
Extra security (incl. faster warning)	+	+	+	+	+	Short/medium		
Protocol for different timetable	(+)	(+)	-	-	-	Short/ medium		
Regular maintenance and inspection	(+)	(+)	-	-	-	Short/medium		
Train/wagon equipment								
Thicker walls in tank wagons	+	+	-	-	-	Medium/long		
Heat-resistant covering on tank	+	+	-	+	+	Short/medium		There is more time to take controlling measures and prevent subsequent scenarios
Inherently safer transport (combination of measures, compare with present procedures of chlorine trains)	+	+	-	+	+	Short/medium		
Architectural and constructive measures								
Alongside/near the railway line								
Fire-resistant concrete wall along the track	+	(+)	-	-/--	+	Short	€1.3 10 ⁶ /km	Poor view Unattractive architecturally – poor view/overview
Spillage-limiting measure: "drain" under the track	+	(+)	-	-	-	Medium, long	€10*106/km	
Sunken construction for track	+	+	-	+/-	+	Long	€50*106/km	

Measure	Effect on:				Stakeholders	Implementation period	Estimate of costs	Comments
	LR	GR	Self-rescue	Controllability				
"Normal" roofing over railway	+	+	-	+/-	+	ProRail	Medium/long	Explosion in tunnel
Tunnel under freight track	+	+	-	+/-	+		Long	Difficult to implement in practice, explosion in tunnel
"Steel" roof over freight track	+	+	-	+	+	ProRail	Medium/long	Difficult to implement in practice, explosion in tunnel
Thick wall along railway line	+	-	-	-	-	ProRail, municipality	Short, medium	Less attractive aesthetically
Two concrete walls next to track	(+)	(+)	-	-	-	ProRail, municipality	Short/medium	Less attractive aesthetically
Earth embankment next to track in combination with concrete wall	+	+	-	-	-	ProRail, municipality	Short/medium	Less attractive aesthetically
Water mitigation pipe along railway line	+	+	-	+	+	ProRail	Medium	???
Water over tracks	+	+	-	+	+	ProRail	Medium/long	€10 ⁹ /km ???
Near/on buildings								
Fire-resistant facades on buildings	-	(+)	+	+	+	Engineering firms, Housing and building inspectorate	Short/medium	€200/m ² façade surface area
Thick wall in front of buildings	+	-	-	-	(+)	Engineering firms, Housing and building inspectorate, municipality	Integrate into design	Obstructs view
Bunkers as buildings	+	+	+	+	+	Municipality, Housing and building inspectorate	Short/medium	Not realistic in context of urban development

Measure	Effect on:				Stakeholders	Implementation period	Estimate of costs	Comments
	LR	GR	Self-rescue	Controllability				
Underground building	-	+	+	+	Municipality, Housing and building inspectorate	Integrate into design	€50*10 ⁶ /building	People's perception
Round building	-	+	-	+	Municipality, Housing and building inspectorate	Integrate into design	€50*10 ⁶ /building	Works at great distance from the railway line
Blast- and explosion-resistant glazing	+	-	-	+	Municipality, Housing and building inspectorate	Short/medium	€2*10 ³ / m ² surface area of facade	Works at great distance from the railway line
Large concrete façade elements, fewer joints + check on joints	-	(+)	(+)	(+)	Engineering firm, Housing and building inspectorate, developer	Short	€50/m ² surface area of facade	Architectural limitations
Air-tight building combined with ventilation system	-	(+)	-	+	Engineering firm, Housing and building inspectorate	Short	€10 ⁶ for each building	Lot of room taken up by installations in building
Functional and other arrangement of buildings and/or the area								
Building perpendicular to the railway line	-	(+)	+	(+)	Engineering firm, Housing and building inspectorate	Short/medium	Include during design stage	Building perpendicular to railway line
Functions with low occupation in building at the railway side (auditorium, sanitary facilities)	-	+	+	+	Engineering firm, Housing and building inspectorate	Short/medium	Include during design stage	Less attractive architecturally
Functions with low occupation in the area close to the railway line (e.g. multi-storey car parks, park)	-	+	+	+	Dordrecht/Zwijndrecht municipality	Short/medium	€10 ⁵ / km	Low returns
Functions used mainly by people well able to cope (such as offices, sports accommodation, etc.)	-	-	+	-	Dordrecht/Zwijndrecht municipality	Short/medium		

Measure	Effect on:				Stakeholders	Implementation period	Estimate of costs	Comments
	LR	GR	Self-rescue	Controllability				
Contingency planning								
Faster reporting procedure + possible new technology (automatic detection, cameras and communication)	-	-	(+)	(+)	(+)	ProRail	Short/medium	
Warning protocol with clear indication of location	-	-	-	+	(+)	ProRail, emergency services	Short	
Faster communication of substances involved	-	-	(+)	+	(+)	ProRail, transporters	Short	
Fast warning of population	-	-	+	(+)	+	Emergency services	Short	
Experience in evacuation	-	-	+	(+)	+	Emergency services, managers of buildings	Short/medium	
Escape facilities (in buildings and vicinity of railway)	-	-	+	(+)	+	Municipality, managers of buildings	Short/medium	
Gas masks	-	-	+	-	(+)	Municipality	Short	Awkward, will lead eventually to negative perception
Better access to railway line: - road along railway line, doors in noise-deflecting screens every 50-100 m	-	-	(+)	+		Municipality	Short/medium	
Sufficient water along the railway line, possibly dry extinguisher pipelines with connection points	-	-	-	+	+	Municipality	Short/medium	
More assistance capacity	-	-	-	+	+	Emergency services	Short/medium	
Early extinguishing when tank is irradiated: - by emergency services	-	(+)	-	+	(+)	Emergency services	Short/medium	Only effective if preceding actions can be done quickly
Early extinguishing: - by automatic extinguishing systems	-	+	-	+	+	ProRail, municipality	Short/medium	
Covering spillage	-	-	-	+	+	Emergency services	Short	
Sealing leak	-	-	-	+	+	Emergency services	Short	

Measure	Effect on:					Stakeholders	Implementation period	Estimate of costs	Comments
	LR	GR	Self-rescue	Controllability	Consequences				
Water curtains when toxic substances are released	-	(+)	-	+	+	Emergency services	Short		
<i>Combined package for timely evacuation:</i> Fast detection, fast warning, good access, good escape facilities, good preparation	-	+	+	+	+	Municipality, ProRail, emergency services	Short/medium		
<i>Combined package for timely cooling:</i> Fast detection, fast warning, good access, good extinguishing facilities, possibly including sprinklers, good preparation	-	+	+	+	+	Municipality, ProRail, emergency services	Short/medium		