NATO STANDARD

AASTP-4

EXPLOSIVES SAFETY RISK ANALYSIS
PART I:
GUIDELINES FOR RISK-BASED DECISIONS

Edition 1 Version 4
SEPTEMBER 2016

NORTH ATLANTIC TREATY ORGANIZATION

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PART I:
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These guidelines help to determine the level of risk of ammunition and explosives storage, handling, and other operations. They do not ensure or guarantee a risk-free situation; neither can the guidelines cater for every possible situation which could be encountered.

The guidelines given in this document are, in the opinion of the Group of Experts, among the best available at the time of publication. However, this Group cannot be held responsible for any mishap or accident resulting from the application of guidelines in this document.

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NATO LETTER OF PROMULGATION

6 September 2016

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RECORD OF RESERVATIONS

CHAPTER	RECORD OF RESERVATION BY NATIONS
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EXPLOSIVES SAFETY RISK ANALYSIS

PART I

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1 Introduction

Managing the inherent risk of handling and storing ammunition and explosives requires the development of policies, methodologies, and rules to provide safety. There exist in NATO two fundamentally different methods to accomplish this purpose: Quantity Distance (QD) methods and risk-based methods. Whereas QD methods apply a longstanding approach considering mainly the quantity of explosives and distance, risk-based methods consider a much more complete set of factors influencing risk including numerical assessments of the probability of event, effects, consequences, and personnel exposure. Thus the risk-based approach provides much deeper understanding of the risk and its causal factors to aide in decision making and in risk reduction. In situations where safety of surrounding personnel is of high visibility and importance, the use of risk-based techniques is advisable because it provides the best available understanding of risks and supports the “informed decision” principle in liability protection.

AASTP-4 is in two parts. Part I is an overview designed for use by policy makers, safety professionals, and analysts. Part II is designed for the risk analyst and contains detailed algorithms for coordinating risk assessments.

1.1 *Purpose*

AASTP-4 supports the continued growth and utilization of risk-based methods. It is designed to assist in developing and using new applications and to provide examples of current international uses. Toward these purposes, it:

- Advocates the broader application of risk-based methods,
- Provides guidance in the establishment of risk-based decision methods,
- Describes existing risk-based methods in use by the participating nations,
- Identifies common features of risk-based approaches, so that assessments done by individual nations in multinational operations may be understood and, if appropriate, used by other countries.

AASTP-4 is also intended to facilitate risk management and decision making on the safety of explosives and munitions activities especially those involving joint operations. Such as:

- To quantify the risk of situations that do not meet quantity-distance (Q-D) criteria,
- To identify potential improvements in existing risk-based methods,
- To establish means of exchanging results using different national models,
- To contribute to solutions for operational problems (e.g., field storage),
- To compare situations where QD and risk-based methods lead to different decisions,
- To assess the benefit of different risk reduction options,
- To support risk assessments needed to develop insensitive munitions.

1.2 *Scope and Intended Uses*

- AASTP-4 applies to risks associated with ammunition and explosives. The underlying principles can also be applied to the management of other hazardous situations.
- This document is intended to support governments in developing and applying risk-based decision aids and in reducing risk. It should also aid comparison of the risk-based approaches and standards used by various nations.

1.3 *Benefits of Risk-Based Methods*

- Risk-based methods provide benefits which include:
  - Analyzes situations for which other methods are inadequate or unavailable (e.g. ports, transportation, transshipments, manufacturing, maintenance)
  - A good understanding of causative risk factors,
  - A good understanding of actual risk leading to better informed risk decisions,
  - Consistency in the level of risk accepted (lacking risk-based methods, decision makers must accept risk without knowing what risk is being accepted),
  - Facilitates optimization of risk reduction (by prevention and mitigation),
  - Allows optimization of land use,
  - Demonstrates benefit of additional safety measures,
  - Tailorable to the level of complexity desired.

1.4 *Key Terminology*

Significant variation exists in the terminology used by participating nations. In order for this document to be useful, several key terms are defined as used in this document.

Risk – A combination of the likelihood and consequences. (Mathematically: risk = frequency × consequences.) The risk to a person or group of people when they are exposed to a hazard can be estimated from the likelihood of the hazardous event, and the probability that a particular level of harm to people would result.

Risk identification – Is a process that is used to find, recognize, and describe the sources of risk that could affect the achievement of objectives.

Risk analysis – A process used to understand the nature and causes of the identified risks and to estimate the level of risk.

Quantitative risk analysis – The process of generating numerical estimates of risk.

Risk evaluation – A process that is used to compare risk analysis results with risk criteria in order to determine whether or not a specified level of risk is acceptable or tolerable.

Risk assessment – The process that includes risk identification, risk analysis and risk evaluation in order to aid the decision process.

Risk acceptance – An informed decision to take a particular risk.

Risk communication and consultation – A dialog between an organization and a stakeholder, both continual and iterative. It is a two-way process that involves both sharing and receiving information about the management of risk. However, this is not joint decision making. Once communication and consultation is finished, decisions are made and directions are established by the organization, not by stakeholders.

Risk treatment – A risk modification process. It involves selecting and implementing one or more treatment options. Once a treatment has been implemented, it becomes a control or it modifies existing controls. You have many treatment options. You can avoid the risk, you can reduce the risk, you can remove the source of the risk, you can modify the consequences, you can change the probabilities, you can share the risk with others, you can simply retain the risk, or you can even increase the risk in order to pursue an opportunity.

Risk management – The overall risk-based decision making process. This includes risk assessment, risk treatment, risk acceptance, and risk communication (see Figure 1)

Explosive event – An unexpected and undesired initiation of an explosive substance or article.

Effects – The immediate physical results of the explosions in terms of physically measurable parameters such as: peak side-on pressure, number of potentially lethal fragments per square meter, or the incident thermal radiation per square meter per second.

Consequences – The undesired results that stem either directly from the event or from the physical effects of the event in terms of the probability of a specific level of harm, e.g., death or need to abort mission.

Frequency – The expected number of events over a defined duration, often expressed in scientific notation (e.g., 1×10-6 per year).

Likelihood – The probability of an event occurring. This term is similar to frequency; however, it is often used in a more general context that may not include units (i.e., a likelihood of 1 in 100).

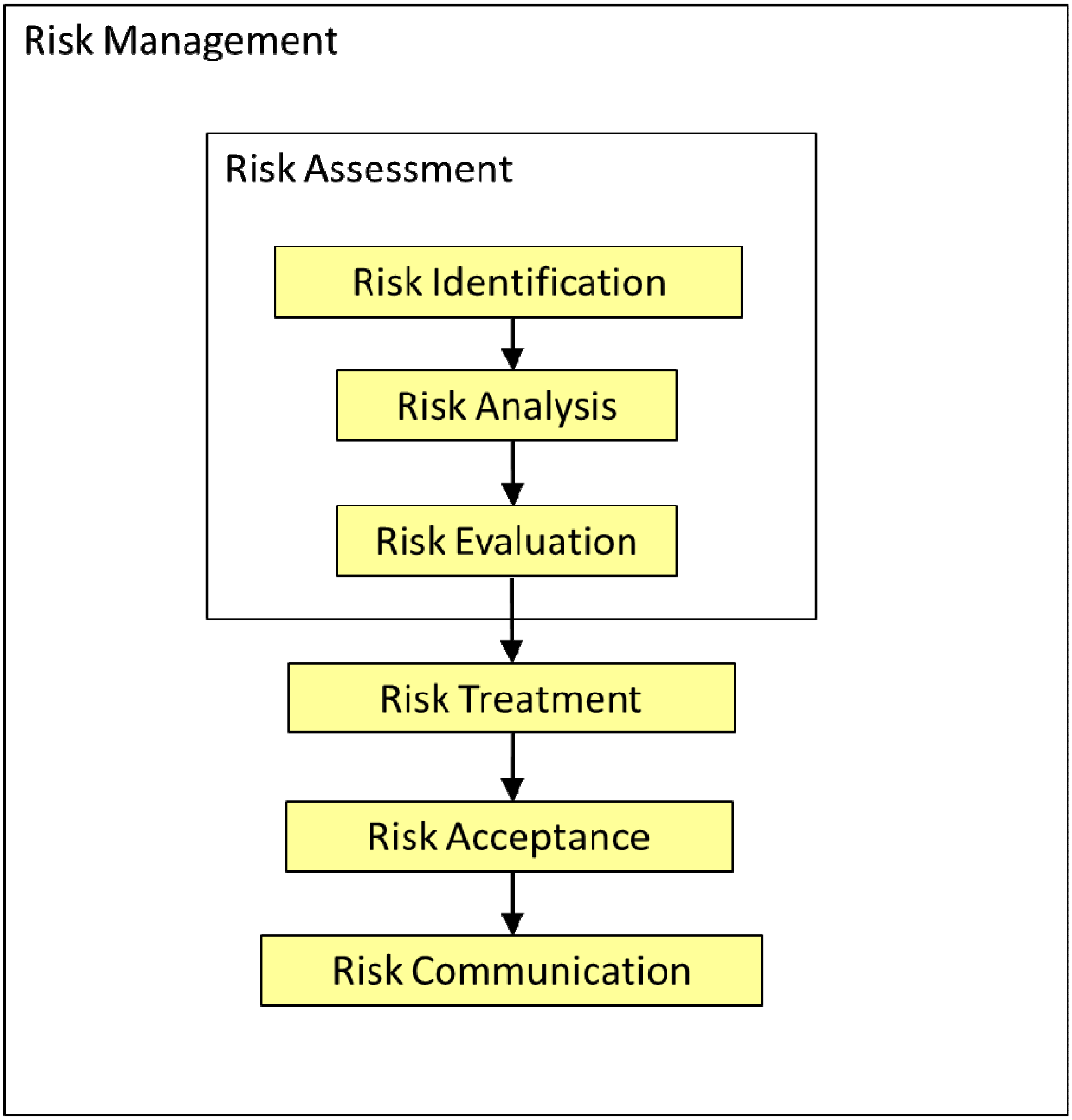


Figure 1. Elements of the Risk Management Process.

2 Risk-Based Decision

Risk-based decisions are routinely made as part of our everyday life. Some decisions involve whether or not to take a risk. Others require a choice between options, all of which involve acceptance of various risks, but also may incur different costs. Governments also make such decisions and need ways of ensuring that their approaches are coherent and consistent.

When calculating risks, it is common practice for the following parameters to be taken into account:

- Frequency or Probability
- Physical Effects
- Consequences to people or assets
- Exposure

With these parameters, different kinds of risks can be calculated such as:

- Individual Risks
- Group or Collective Risks
- Perceived Risks

Various countries may calculate risks for different groups of people or for a combination of the different groups, such as:

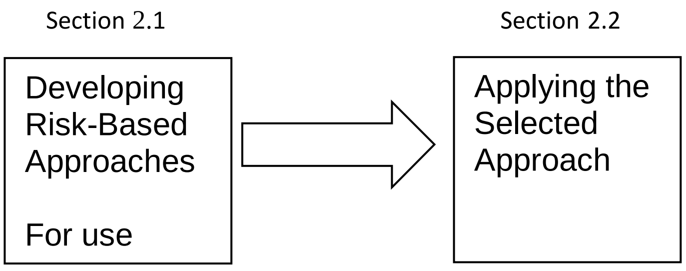
- Worker (directly involved person)
- Worker (indirect involvement)
- Public (uninvolved persons)
- Military

The calculation depends on the goals and the acceptance criteria. Good practice normally requires assessment of individual as well as collective risks.

In assessing risk, it is important to first have some consistency in the approach used, and second have consistency in the application of that approach. Therefore this chapter is divided into two major sections:

2.1 Developing Risk-Based Approaches. This section describes the systematic process for developing risk-based decision aids.

2.2 Applying Risk-Based Decision Aids. This section describes how to use the decision aids that have been developed.



2.1 *Developing Risk-Based Approaches*

To develop risk-based decision aids it is recommended that the 11-step process outlined in Figure 2 be followed. This process provides a structured risk-based method. These steps are described in Sections 2.1.1 through 2.1.11.

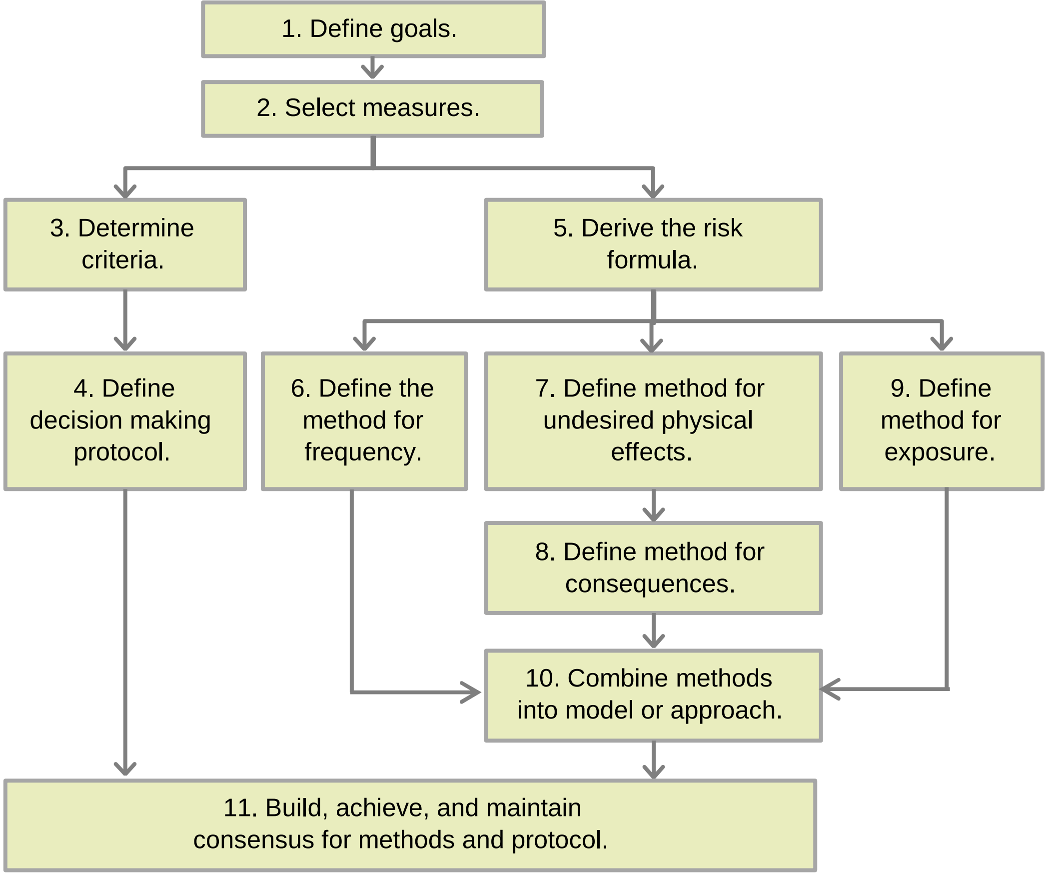


Figure 2. Developing a Risk-Based Decision Approach.

A systematic approach to developing risk-based decisions helps assure successful use.

The ordered process described above will result in a risk based decision method. In addition, the following lessons learned form a set of general rules that apply to developing these assessments.[1]

1) The model should be specifically correlated with its intended use.

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[1] Pfitzer, Tom; Hardwick, Meredith; et.al. “Status of Risk-Based Explosives Safety Criteria Team,” DDESB Seminar, New Orleans, Louisiana, July 2000.

2) A concise set of semantics should be defined and used consistently. The terminology associated with risk assessment is often the source of miscommunication.
3) Risk is best communicated using the logarithmic scale.
4) Selected methods should be easily explainable. Due to skepticism relating to risk assessments it is worth the effort to develop explanations that are easily understood. This does not mean selecting methods that are inaccurate due to their simplicity. Rather it means that the time needed to develop clear understandable explanations is well worth the effort. If it cannot be explained it may not be accepted as consensus. If it is not consensus it may not stand up in court.
5) In general, quantitative risk assessment (QRA) models used to make decisions should calculate the “expected value”. Where “worst case” information is needed, it should be clearly indicated.
6) Models should balance accuracy, simplicity and fidelity. Accuracy provides credibility, simplicity affords understanding, and fidelity is useful in making direct comparisons.
7) Uncertainty exists and can be modeled. Conservatism should not be added in the nominal estimate due to uncertainty; instead add conservatism in the uncertainty estimate.
8) When modeling uncertainty, proper handling of accumulated uncertainty should be observed. Proper aggregation protocol should be used.
9) Events with negligible likelihood still happen. Negligible does not mean never! Contingency plans for rare events are still required if they have high consequences.

2.1.1 Define Goals

The first step in a risk-based method is to clearly and concisely define its intended use. Risk-based methods are designed to assist in making decisions. Therefore, to clearly define the type of decision that will be made using the risk information should be the first step.

A goal might be to provide a consistent methodology that “assures an adequate degree of personnel safety” or “assures military capability” or “maintains public support.”

It is important to focus sharply on the goal of the method, and how it will be used. The subsequent steps are all directly related to the goal.

2.1.2 Select Measures

Many measures are currently in use for risk assessments. The measure should directly reflect the defined goal. For protection of people, for example, potential measures include fatality, injury, minor injury, etc. The selection of the measure can be a complex and subjective process involving societal values. There can be no “right” answer from nation to nation because societal values differ.

A review of the measures used internationally clearly points to the importance of protecting human life as a consistent goal in most nations. The measure of “probability of fatality" provides a useful measure for direct comparison between national models. Studies have shown that the selection of alternative measures often does little to change the resulting risk-based decision. For example, if both fatality and injury criteria were used to assess a specific undesired event, either measure applied alone would in many cases result in essentially the same decisions as both measures being applied independently. The reason for this is that the two consequences are often highly correlated from event to event. Therefore, the selection of multiple measures may add little value in terms of a higher quality decision while it may add a significant analytical burden to calculate the risks separately. During the process of selecting measures, trade-off studies can be undertaken to determine which measure best achieves the aims of the specific application.

Also, persons at risk may fall into groups or categories that require separate assessments because different protection requirements apply. For instance, the directly involved workforce may be expected to bear significantly higher risks than non-involved people.

2.1.3 Determine Criteria

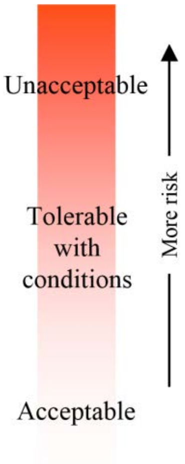
The criteria are a direct extension of the selection of the measure. The acceptance of criteria for risk is a national question. Criteria establish acceptance thresholds or regions. In the generic case there could be two or three regions on the scale of risk for any given risk measure.

Unacceptable. Risks above a certain level lead to a conclusion that the situation is "unacceptable."

Tolerable with Conditions. Sometimes risks that are tolerable under one set of circumstances are unacceptable under others. This region leads to the need to manage and reduce risks, or to change the circumstances to make the risks acceptable. Many nations apply the ALARP (as low as reasonably practicable) principle as one of the conditions.

Acceptable Risks. For any type of risk there is some level below which the risks are acceptable. This threshold varies widely from consequence to consequence and from situation to situation.

These generic regions outline a framework for selecting specific thresholds. In some cases, only the regions "acceptable" and "unacceptable" are used.



Defining acceptability – Numerous methods have been adopted to define an accepted level of risk.[2, 3, 4] These methods include:

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[2] Pfitzer, Tom; Hardwick, M., and Pfitzer, .B., "Universal Risk Scales – A Tool for Developing Risk Criteria By Consensus," DoD Explosives Safety Seminar, San Antonio, Texas, August 2004.

1) Comparison to similar risk standards
2) Comparison to actual day-to-day risks
3) Comparison to regulations and published standards
4) Cost vs. risk trade-off (willingness to pay)
5) Benefit vs. Risk trade-off. This is a correlation of risk to the usefulness of the activity.

Each of these methods may be useful in establishing an acceptability threshold. A combination of methods can provide a strong and understandable basis for criterion selection.

2.1.4 Decision Protocol

A decision protocol defines the process used to reach a decision after the analysis is completed. Government decisions are made within a national bureaucratic context and need a thorough review of the analyses leading to a decision. It is especially important for risk-based decisions to have a clearly documented audit trail which serves to standardize the decision process. This protocol would be thoroughly examined whenever an event resulted in an undesired consequence.

Such a protocol serves also to protect a legal principle which is observed in most participating nations, that of “informed decision.” It states that a government decision maker is not held liable for properly executed decisions within their span of authority if the decision was made with “due diligence” and included an assessment of risks based on the best available information at the time of the decision.

The protocol used should consider:

1. *Level of Authority*. In general, the decisions proposed herein are equivalent to QD decisions from an authoritative point of view. Therefore the same level of authority is appropriate. There may be a need to have a protocol that calls for a higher authority decision or a more in-depth analysis depending upon the scenario or the results. In addition, the level of authority making decisions should be influenced by the following considerations:
    a. Kind of activity. The kind of activity resulting in risks could vary from individual decisions resulting in individual risks, i.e. parachute jumping, to governmental decisions affecting national interest. The proper range of authority would vary widely.
    b. Level of Risk. Whether it is acceptable, tolerable, or unacceptable
    c. Type of Persons exposed. Public, workers, military, etc.

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[3] Bienz, A, and Nussbaumer, P., “Comparative Figures on Risks and Probabilities,” TM 101-45 English Edition, 11 April 1997.

[4] Bienz, Andreas, “Revision of the Risk-Based Safety Criteria for the Handling of Ammunition and Explosives in the Swiss Army and Military Administration”, Australian Explosive Ordnance Symposium (PARARI), November 2005

2. *Documentation*. The analyses supporting the decision should be clearly documented and retained to support the informed decision principle in the case of an event.

3. *Consistency*. The protocol should be capable of being applied consistently from case to case.

4. *Legal Review*. Prior to applying the protocol for the first time, a legal review may be necessary to confirm that the proper decision level is called for by the protocol, and that the process is properly authorized.

5. *Clear communication*. If risk is higher than normally would be acceptable, it will often be of interest to show risk values for a number of alternative scenarios. It is important that risk is communicated clearly, so that the decision maker can understand and place it in the proper context. Comparison data in the proper units are needed to understand relative risks. If appropriate, decision makers can be pre-briefed on the process. Training programs may need to be established.

Annex A describes existing protocols for different nations.

2.1.5 Risk Formulation

In order to evaluate and compare different risks, they must be quantified. Risk may be broken down into two distinct components:

Risk = likelihood × consequence

This concept has been applied in many variants and can be traced back to Blaise Pascal. In the mid-17th century he wrote "Fear of harm ought to be proportional to the gravity of the harm and also probability of event."[5] When expressed in mathematical form, the concept can serve as the basis or starting point for deriving a specific risk equation applicable to the situation at hand. Following is an example of the approach to defining a risk formula:

Once a measure of risk is chosen (for the left side of the equation), the terms on the right hand side can be expanded following mathematical protocol while maintaining equality. For example: The measure of risk could be the likelihood that a person will be killed during one year of exposure (Annual Individual Risk of Fatality [IR]).

Likelihood can be expanded into the chance of a hazardous event, P_e (events/yr) and consequence may be defined as the Probability that the continuously exposed person is killed if an event occurs $P_{f|e}$. From which:

$$\text{Annual Individual Risk of Fatality [IR]} = P_e \times P_{f|e}$$

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[5] Arnauld, Antoine, and Nicole, Pierre, edited and translated by Jill Vance Buroker, Logic or the Art of Thinking, Cambridge University Press, 1996. This work has been published in multiple languages and multiple editions dating back to 1662.

In addition, people can only be harmed when they are present during a hazardous process. Therefore, the risk (per year) is reduced in proportion to the fraction of the year they are actually exposed to a hazardous process/situation (a dimensionless ratio). If the probability of the person being present or exposed is denoted by E_p, then

$$[IR] = Pe \times Pf \mid e \times Ep$$

Other equations can be developed from this to meet different requirements. AASTP-4, Part II contains more discussion on the risk formulation.

2.1.6 Event Frequency

There are three approaches that are commonly used to estimate the frequency of undesired events: historical, analytical, and expert judgment.

The historical method relies on prior experience with similar situations. For example, if you want to predict the number of unplanned explosives events within a nation for the coming year, a good source of information would be how many occurred this year or the year before, etc. Data from accidents, near accidents, and tests can all be included in this general category. This type of information, if available, can provide a good basis for predicting the probability of an event.[6, 7]

The analytical method involves an attempt to define and quantify all of the potential scenarios in which an event can occur. Logic or fault tree approaches are often used depending upon the complexity of and number of scenarios leading to an event.

The expert judgment method involves the use of expert knowledge and opinion for establishing probabilities and frequencies. The Delphi method is a commonly used technique.

Each of the three methods can be used independently or in combination to obtain the best estimate of event frequency.

Frequency estimates are often the most difficult portion of a risk assessment to justify. Therefore, practitioners should be encouraged to apply the scientific method to this portion of the analyses (i.e., define what you know (history), supplement this with what you think you know (predictive analyses), and improve the frequency estimate when new data becomes available from either source).

2.1.7 Physical Effects

The science of predicting explosion effects has advanced significantly over the last 50 years. In general, a very fast and violent reaction, usually a detonation, is the basis to assess the risk of fatal accidents. The methods in use are well documented. The effects include:

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[6] US(ST)IWP/111-98 dated 15 October 1998, Pfitzer, Tom, and Hardwick, Meredith, “Risk-Based Explosives Safety Criteria Team, Phase I Final Report,” 15 September 1998.

[7] Nussbaumer, P., Bienz, A., “A Prototype Model for the Probability of an Explosion in Ammunition Storages”, DoD Explosives Safety Seminar, San Antonio, Texas, August 2004.

Blast

Blast is the basic effect from any accidental detonation event with uncased or cased explosives. The elements of blast that will be observed at the exposed site are the peak overpressure, the specific blast impulse, and the dynamic pressure (air flow). The blast pressure and the blast duration are typically related to the explosives mass and the distance by the cube-root formula.

Fragments and debris

Primary fragments from the case material will be observed if ammunition detonates. The trajectories of fragments that are launched can be calculated. Various degrees of protection from primary fragments can be achieved with structures, barricades, and earth covering.

A crater may be formed by a detonation in or on the ground and crater material thrown to the surroundings as crater ejecta. The endangerment depends on the type, amount and trajectories of the crater material. In general, sand does not present a hazard at any significant distances; however, heavier material such as chunky stones may be hazardous.

If the event happens within a structure, the structure will be broken into parts that may be thrown to the surrounding area as secondary debris.

Thermal effects

Thermal effects are generally important for hazard divisions outside of HD 1.1. For example they are significant in explosion reactions, unexplainable detonation reactions, and delayed deflagration to detonation transitions. Typically they have long duration times or variable duration times and create a significant heat flux effect. Thermal effects are dominant for HD1.3 materials such as propellants, flares, rocket engines, etc. which present a mass burning hazard.

Ground shock

Ground shock effects are usually of importance only close to explosions in underground storage areas and often decrease rapidly with distance from the detonation.

Propagation of explosion

The effects from one explosion may cause nearby ammunition and explosives to initiate. As a result simultaneous and/or delayed explosions effects may occur. At short distances, the propagation could occur via thermal radiation, blast, and/or fragments. Fragments and debris can cause a delayed explosion at much greater distances.

2.1.8 Consequence

Consequence analyses determine the outcome resulting from the physical effects of an explosion. This is done in terms of the selected measure (typically fatality, but could also be injury or loss of mission capability). Potential consequences, while not as thoroughly understood as the physical effect, are also well documented. They include fatality thresholds for:

Blast

The consequences may include direct and indirect harm to people and damage to equipment, buildings, etc.

Direct consequences for people range from eardrum rupture at low-pressure levels to lung hemorrhage causing death at higher-pressure levels. In addition to consequences from primary blast effects, people may also be harmed by being thrown down or thrown into objects.

When buildings are exposed to blast effects, the consequences range from window breakage at low-pressure levels to structural break-up, building collapse, or disintegration at higher-pressure levels. The pressures causing such destruction vary substantially with the design of the building; light, weak (“wooden”) buildings can be destroyed easily while more solid and heavy (“concrete”) buildings can withstand considerably higher loading. This structural response may cause harm to the occupants of the building.

Secondarily, the damage to buildings both source and donor will lead to dangerous fragments and debris, which pose hazards to people nearby. Glass fragments in particular can cause severe injury.

Fragments and debris

Fragments and debris from an explosion may harm personnel some distance from the original event. The consequences from a fragment impact depend on fragment size, shape, mass, velocity, and where it hits. Impacts on the head or on vital organs are more crucial than hits to the arms and legs.

Fragments hitting buildings can best be stopped by the building walls and roof. Lighter buildings will have little capacity for this. In particular, glass panes are very sensitive to fragment impact. Earth covered or massive concrete structures may give good protection.

Thermal

Consequences typically include skin burns and inhalation of hot gases and are very severe for people inside the fireball. Outside the fireball people may be exposed to thermal radiation. The consequences depend on the exposure and protection (clothing or presence inside building). The driving factor is the dose, which is a combination of radiation intensity and time of exposure. Mass fires might also cause buildings to ignite and lead to further consequences.

Ground shock

Ground shock causes lateral motion which may lead buildings to collapse and thereby harm occupants of the buildings. However, the consequences from ground shock are normally limited to the region very near the explosion.

2.1.9 Exposure

The term “exposure” takes into account the likelihood that persons will be present at an exposed site (ES) when an event occurs. This term is expressed by exposure (E) or probability that a person is present (P_p). Individual risk estimates at the same location (ES) will depend upon whether the person is present all the time, or for a predictable part of the day, or just travelling through the hazardous area. Allowance must also be made if the hazardous activity varies over time.

The exposure of groups is often estimated in terms of the average number of people exposed at the same site (ES) over a year. If more detailed exposure data are available, a more complex procedure based on the exposure at different times of the day/week/year may be used. This procedure divides a day/week/year into defined time slots (situations). Within each time slot the number of people exposed is defined and the risk for each time slot can be calculated. This procedure can be used to estimate the maximum number of people endangered, which is important for contingency planning. The procedure also helps when calculating risk aversion.

In considering exposure information, it is important to make sure that each situation is fully defined and that all possible scenarios have been identified.

2.1.10 Model

Modeling the overall risk involves a mathematical combination of different parameters. Usually this is done by use of probabilistic summations (e.g., if we want to know the risk of any fatality for a given operation we must sum the risks to all people, all potential fatality mechanisms, and all likely events which could result in fatality, for a given time period).

It is important to properly apply the statistical rules of mathematics in combining the factors leading to the overall risk. The rules of dependence and independence are important when aggregating frequency, exposure, different groups of people, physical effects, and consequences. The model should provide results that are repeatable from situation to situation and from time to time.

The mathematics used for statistical summations is well suited for computer applications. Ideally, the risk values resulting from the computer simulations should be presented in a form that can be recreated by a hand calculation to demonstrate the validity of the results.

2.1.11 Build, Achieve, and Maintain Consensus

Achieving consensus is important in the case of risk-based decisions for several reasons:

- Use of a quantitative risk-based approach is a fairly new discipline.
- The evaluations made have inherent uncertainty and are therefore subject to debate.
- Prior experience has shown that biases can creep into the frequency estimate, which undermines the validity of the process.

Consensus building and maintenance may be needed to:

- *Obtain support* of a specific organization. In some cases a particular government or private organization may be key to acceptance of the risk based methods. Obtaining input and feedback helps assure continuing support.
- *Educate* and obtain support of the general public. Significant benefit can be gained from describing the methods in public meetings. If clear logic is used to present the approach, most members of the public will accept the methods.

One lesson learned is that the use of scientific notation and a logarithmic scale helps provide an understanding of the proper scale of the risk-based assessments.

- Obtain a *legal review* of the applicability of the risk-based approach to the national laws. The laws which might be applied to the review of risk-based decisions in various countries are based on similar principles which include:
  - Reasonable risk. This principle says that if a decision is made based on an understanding of the level of risk, which was "reasonable," the decision maker is not liable.
  - Informed decision. This principle says that if a decision maker uses the best available information as the basis of a decision, the decision should not be questioned if an accident highlights information not known at the time of the decision. This principle places a burden on those gathering information to avoid hidden biases in the risk assessment.

2.2 *Applying Risk-Based Decision Aides*

After an approach to risk-based decisions has been developed as described in Section 2.1, the process can be applied to a variety of specific situations. Figure 3 provides an overview of the process of using risk-based decision support.

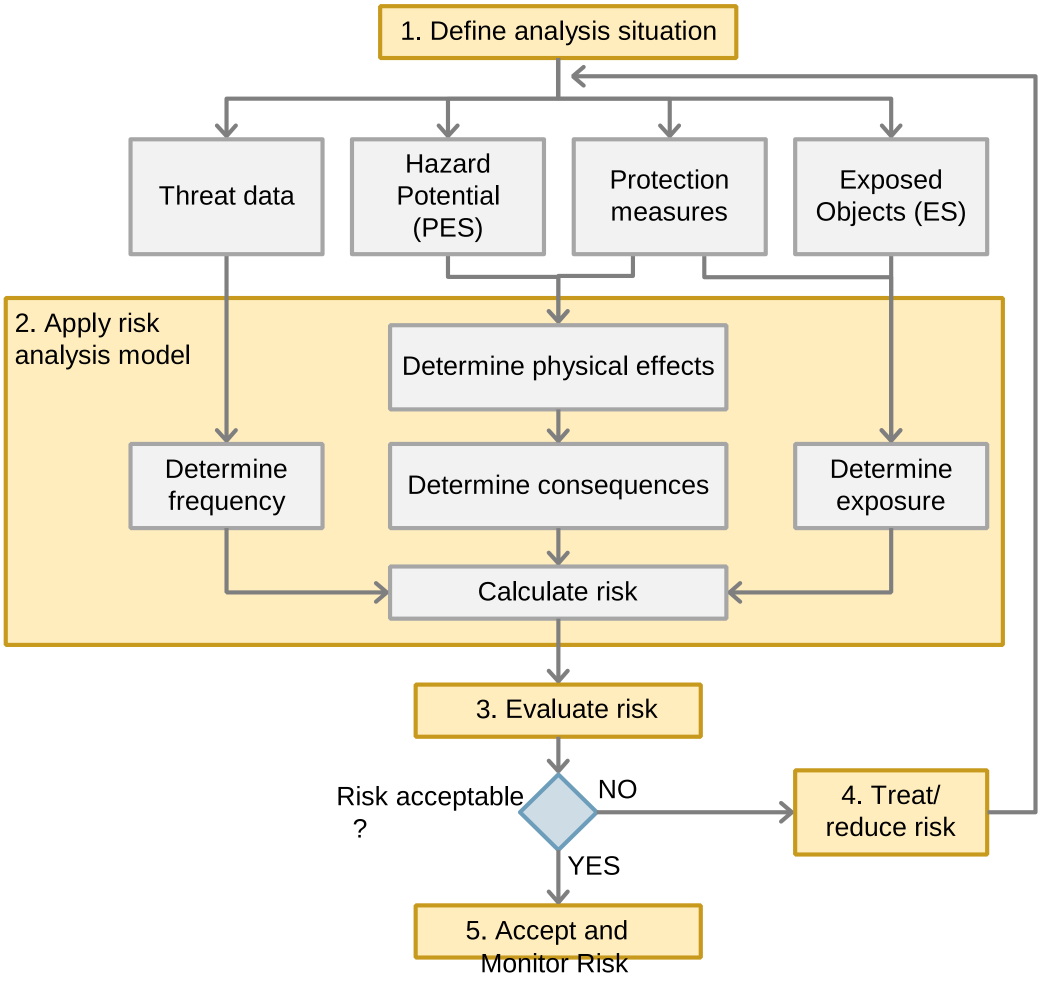

Figure 3. *Practical Application of the Risk Based Method.*

2.2.1 Define Analysis Situation

The development of scenarios is primarily a creative process for hypothesizing potential initiation event(s). It is important for the analyst to define and understand the important aspects of the situation under consideration.

Categories of needed data include:

- Threat data to describe the causes that can initiate the event
- Data to describe the hazard potential that would result from an event.
- Data to describe the protective measures at the potential explosion site (PES), exposed site (ES) and in between.
- Data to describe the amount of exposure.

Typical examples of the input data include both administrative and technical data. E.g.:

Potential Explosion Site Data:

- Building structure
- Activities
- Factors affecting event likelihood

Explosives Data:

- Type of explosives
- Hazard division
- Expected NEW
- Maximum NEW
- Compatibility group

Exposed Site Data:

- Building structure
- Roof type
- Distance from PES
- Floor area
- % Glass area
- Hours present per year
- Orientation of PES to ES
- Window size
- Number of people

2.2.2 Apply Risk Analysis Model

Once the potential initiation event or scenario is defined the risk analysis can be conducted. This is an application of the steps defined in Section 2.1 which include:

a. *Define frequency*. Using the method discussed in Section 2.1.6, the analyst can calculate the expected frequency. Care should be taken to characterize the uncertainty of this parameter and the relative conservatism included in the assessment.
b. *Physical effects*. The undesired effects are calculated using methods indicated in Section 2.1.7.
c. *Consequences*. Consequences are a direct product of the physical effects. The methods used are described in Section 2.1.8.
d. *Exposure.* Exposure is calculated using methods defined in Section 2.1.9.
e. *Calculate risk.* The values a through d combined into risk values.

AASTP4, Part II contains detailed methods that can be applied to risk assessment.

2.2.3 Evaluate Risks

The calculated risk should be compared to acceptable levels/criteria. If risk is too high steps must be taken to reduce the risks.

2.2.4 Treat/reduce risk

When the risk in a situation is too high, remedies should be taken to reduce the risk such that the probability of an event occurring, the effect in case of an event and/or the exposure of objects / persons are minimized. Specific actions may include:

- Lowering vulnerability by barricades,
- Mitigating through separation and barriers/barricades,
- Reducing NEQ,
- Removing/reducing the exposure or strengthening/hardening of exposed objects.

When the best risk reducing technique is identified then the risk assessment is repeated and the reduced risk is accepted at the appropriate level. This iterative process should take place as often as reasonably practical and necessary.

2.2.5 Accept and Monitor risk

The results of the risk analysis should be documented and presented to the decision maker. In order to make an informed decision, the decision maker should be provided with the calculated risk compared to the acceptance criteria. Optional information may include comparison of the risk to other activities, information about the uncertainty in the risk calculation, and assumptions made.

If the risks calculated are above the acceptance criteria then the options for risk reduction, their costs, and resulting benefits including quantified risk reduction should be provided.

Risk communications and information should also be made available to any affected third party either directly or through proper channels in order to ensure effective mission performance.

Once risks have been accepted they should be continuously monitored. Any changes to the conditions should be included in an updated risk analysis.

3 Existing Methods

The existing methods and models used by participating nations vary widely. Some have been in use for forty years. Following is an outline of the available programs from those countries currently using explosive safety risk analysis. It is noted that the definitions and wordings in the different countries are in some cases different. Care should be taken when comparing. Participating nations are requested to update their data as necessary.

3.1 *NATO - Operational Storage of Munitions*

NATO doctrine contained in STANAG 2617 and Allied Logistics Publication (ALP) 16 require compliance with AASTP-1 or AASTP-5, as applicable, for munitions or munitions related process associated with NATO military operations.

When those requirements cannot be met, ALP 16 dictates / defines the use of an Explosives Safety and Munitions Risk Management (ESMRM) approach that integrates risk assessment with the goal of identifying adverse consequences associated with munitions operations, risk reduction alternatives, and risk decision requirements for key decision makers.

In addition, ALP 16 outlines a risk assessment process which includes the risk analysis methodology contained in AASTP-5 (further described below). That methodology represents a combination of quantitative calculations, where the data and tools are available, and a qualitative assessment of that information taking into account other factors such as probability of event associated with the operational environment. Other risk analyses methodologies, as further amplified in AASTP-1, Part IV, Chapter 2, available to nations include:

(a) Qualitative risk assessments as detailed in nationally approved assessment methods,

(b) Quantitative risk assessments using AASTP-4, Part II models and data, or

(c) A combination of both qualitative and quantitative risk assessment methods and tools, based on available information, models, and data as implemented in nationally-approved software programs.

AASTP-5, Part II, defines - as a main part - the Field Distances (FDs) to be kept between PES (Potential Explosion Site) and PES (preventing prompt propagation of explosions) and between PES and ES (Exposed Site) (ensuring an appropriate safety level for exposed personnel and public). In cases where these FDs cannot be applied, e.g. due to lack of available area or tactical mission requirements, a consequence and/or risk analysis has to be conducted before making a decision to deviate from the FDs.

On behalf of the NATO AC/326 (CNAD Ammunition Safety Group), CHE and NLD developed a consequence and risk analysis procedure to be incorporated in AASTP-5, Part II.[8,9] Calculations with this method give a commander a clear quantitative answer about the real existing hazard to exposed people and assets for a given situation, and therefore, enable him to take informed decisions. The developed procedure allows taking into account protective measures like barricades and overhead protection, and distinguishes between different types of structures relevant to Out of Area (OoA) operations.

This method, in general following the procedure described in Chapter 2, consists of the following main steps:

1) Define situation and collect relevant data of possible PESs and exposed ESs like:

- Type of PES, barricaded/un-barricaded

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[8] Van der Voort, M.M., Kummer, P., Van Dongen, Ph., A consequence analysis method for out of Area Field Storage, Presented at the 34th DoD Explosives Safety Seminar 2010, Portland, Oregon. This reference is also published as (NLD)IWP 2010-01 - AC326(SG6).

[9] (SWI/NE)IWP 083-11(A), dated 30 August 2011, Kummer, P., Nussbaumer, P., van der Voort, M.M., “Chapter and Annex on Consequence and Risk Analysis for AASTP-5, Part II, NATO Guidelines for the Storage, Maintenance and Transport of Ammunition on deployed Missions or Operations”

  - NEQ stored in PES
  - distance between PES and ES
  - type of ES and number of exposed persons in it

2) Calculate consequences based on data above for a given PES - ES relationship
3) Aggregate consequences from all ESs (= Risk in case of event)
4) Calculate or estimate frequency/probability of event
5) Calculate total risk (per year) in terms of:
   - number of personnel killed / injured
   - material damage / loss of assets / (loss of mission)

Technical models are available to calculate the consequences from explosions in field storage sites for personnel staying in a wide range of typical structures used on deployed missions. For the frequency/probability of an event, however, only limited quantitative values exist, such as the documented frequencies in AASTP-4 Part 2 for peacetime like field storage situations. For war-time like situations, currently only qualitative values can be given as shown in AASTP-4 Part 2.

The calculation of the consequences for single or multiple ESs (step 2 and 3 above) can be performed either with the EXCEL based "AASTP-5 Consequence Analysis Tool" software, or by hand, using the tables and forms given in AASTP-4 Part 2. AASTP-5 contains a description of typical structures used on deployed missions (field storage structures).

3.2 *Australia (2015)*

Work on risk assessment for explosives storage activities started following initial training from AEA Technology. Since 1996, the process has undergone refinement and now is an integral part of the Australian Defence Force (ADF) EO facility licensing process. Nevertheless, QD principles remain the basis for ensuring the safety of explosives storage and transportation operations, while Explosives Risk Management (ERM) techniques are used to underpin those standards, demonstrate compliance with risk based legislation, and to deal with exceptional circumstances. Thus ERM complements QD principles and is not viewed as an alternative.

Within the ADF, ERM techniques are used to:

a. assist in the licensing of small quantity facilities (SQF) holding less than 50 kg net explosives quantity (NEQ);

b. support applications for public and departmental risk waivers; and

c. support specific studies in relation to EO storage, handling and transport requirements.

There are two dimensions of risk (individual and societal) that are widely publicized and are considered separately in the risk evaluation process. Individual risk (IR) is that risk related to the personal safety of a defined individual, whereas societal risk (SR) deals with the frequency of incidents with specific numbers of fatalities, e.g. the frequency of an incident that is likely to kill ten people.

There is also a third dimension of risk that Australia takes into consideration- potential risk (PR). PR is similar to IR, but is concerned with the personal safety of any individual at any time at a particular exposed site. In this respect, PR is used to establish a risk zone or contour irrespective of people being there or not and defines the worst-case situation for any single individual.

Criteria formulation assigned to PR is similar to that published in Risk Criteria for Land Use Safety Planning, Hazardous Industry Planning Advisory Paper No 4, Department of Planning, Sydney, 1990. Essentially, risk acceptance levels defined in the Hazardous Industry Planning Advisory Paper No 4 are taken as the lower limits (below which the risk is considered negligible). A margin of one order of magnitude is used to define the upper risk limit (intolerable region). The four levels of involuntary risk criteria are provided to account for differences in structure vulnerability and population types/exposure and align with QD facility grouping categories. Notwithstanding, the QD grouping basis for exposed site (ES) determination are only used as a guide to distinguish between ES categories as necessary.

Involuntary PR criteria.

Involuntary risk is that risk to which people not involved and remote from the hazardous activity, are exposed. The following are the risk criteria for such personnel:

a. The levels of risk for large hospitals and schools, major terminals and large facilities of special construction or importance are defined as:

(1) Upper level of 5×10^{-6} per year.

(2) Lower level of 5×10^{-7} per year.

Explanation: These risk levels are appropriate for facilities especially vulnerable to hazards and where people are less able to take any necessary evasive action, relative to the average residential population. Facilities classified as Group V should be afforded this level of risk.

b. The levels of risk for residential developments and places of continuous occupancy, such as hotels and tourist resorts are defined as:

(1) Upper level of 1×10^{-5} per year.

(2) Lower level of 1×10^{-6} per year.

Explanation: The 1×10^{-6} level of risk is generally adopted as the standard limit of acceptability for residential area exposure (permanent occupancy). This criterion assumes that residents will be at their place of residence and exposed to the risk 24 hours a day and continuously throughout the year. In actuality this is not the case and is therefore conservative. Residential facilities classified as Group IV should be afforded this level of risk.

c. The levels of risk for large sporting complexes, shopping centers and entertainment centers are defined as:

(1) Upper level of 5×10^{-5} per year.

(2) Lower level of 5×10^{-6} per year.

Explanation: Commercial developments, including offices, retail centers, warehouses with showrooms, restaurants and entertainment centers. The average individual occupancy of these areas is on an intermittent basis and the majority of people present are generally mobile. As such, a higher level of risk (relative to the permanent housing occupancy exposure) may be tolerated. Non-residential facilities classified as Group IV should be afforded this level of risk.

d. The levels of risk for public parks, recreational areas and active open space areas are defined as:

(1) Upper level of 1×10^{-4} per year.

(2) Lower level of 1×10^{-5} per year.

Explanation: These risk levels are only applicable to areas where people assemble only temporarily and do not have structures that are likely to contribute to fatalities. Facilities classified as Group III should be afforded this level of risk.

Voluntary PR criteria.

Voluntary risk is that risk which people knowingly accept as part of their employment at or within the confines of a hazardous installation or site. The following are the risk criteria for such personnel:

a. The levels of risk for personnel employed or in support of hazardous operations are defined as:

(1) Upper level of 5×10^{-4} per year.

(2) Lower level of 5×10^{-5} per year.

Explanation: These levels are based on the assumption that people are aware of the risk associated with the area of employment and are essential to the hazardous operations being carried out. Facilities classified as Group II (process building) should be afforded this level of risk.

Application of General Principles to Individual Risk

By comparison, individual risk (IR) assessments are more complex and sophisticated than PR assessments, in that the analysis requires detailed population surveys to determine the actual number of people exposed to the hazard and their exposure periods. For these reasons, it is inappropriate to specify hard and fast criteria (as in the case for PR) to scenarios that will ultimately depend on actual population distribution, society (and local community's) perception of the risk, political constraints, and National interest. Thus judgment on risk is to be made on the merit of each case rather than on specifically set numerical values. Nevertheless, the criteria applicable to PR are to be used as threshold limits when assessing IR.

Application of General Principles to Societal Risk

Societal risk (SR) is used as a measure for determining the disaster potential of an accident, particularly in relation to multiple casualties. In this respect SR presents real conceptual difficulties in determining universally relevant levels for tolerable and negligible risk. The population at risk and, more particularly, public's perception will have significant influences on which levels of risk are considered to be acceptable. Concentrated risks (e.g. industrial/military explosions or multiple vehicle accidents) are regarded as worse than diffuse risks like those from general road accidents or an equal number of deaths scattered around as a result of smaller scale industrial accidents. These difficulties in defining risk levels applicable to SR are outlined in many documents. For these reasons, judgement on SR is made on a case-by-case basis.

SR is expressed as the total number of fatalities expected in an accident in relation to the frequency of such an accident occurring and represented in the form of a Frequency vs. No of Fatalities (F–N) curve. The F–N curve is constructed by taking each identified hazard or accident scenario in turn and estimating the resulting, probable number of deaths. For guidance purpose, the UK HSE F–N curve is used as a threshold benchmark for SR assessments with a further order of magnitude (safety factor) to be added to frequency scale.

Software Support

Australian ERM agencies have access to several software applications, these include AUSRISK (developed by AEA Technology) and eRISKAT (locally developed for the Australian Ordnance Council), to conduct quantitative assessments. Australia will add US DDESB sponsored software code SAFER to this list when available.

3.3 *Canada (2015)*

Overview

An Ammunition and Explosives (A&E) safety regulatory authority for the Department of National Defence (DND)/Canadian Armed Forces (CAF) was established in 2006 – the Directorate of Ammunition and Explosives Regulation (DAER). One of DAER's prime mandates was to establish a risk-based approach to A&E safety management and regulation. The principles were that it was to be a systematic approach for risk assessment that would include authorization and monitoring by the appropriate departmental authority.

The development of the risk management process was accomplished by using the process detailed in AASTP-4 and based upon existing Canadian risk-based processes and in accordance with departmental and government guidance and direction. The aim was to reduce the risk of an undesired explosive event, thereby preserving personnel, equipment and infrastructure. The process is one that addresses required deviations from established minimum safety criteria by: identifying the risk; analyzing it in terms of probability and consequence; mitigating the dangerous activities; having the proper authority accept and approve the risk; and, ensuring that the risk is properly monitored.

The risk management process was designed such that it can be applied to a wide variety of A&E activities, so as to address the complete life cycle from acquisition through in-service use and, ultimately, disposal. It is based upon minimum acceptable levels of safety (i.e. for storage, Quantity Distance guidelines) but provides a risk assessment process that is applied when those levels of safety cannot be met for whatever reason. The process utilizes both qualitative and quantitative methodology. The approval and acceptance of risk is specifically assigned to appropriate authorities within the chain of command.

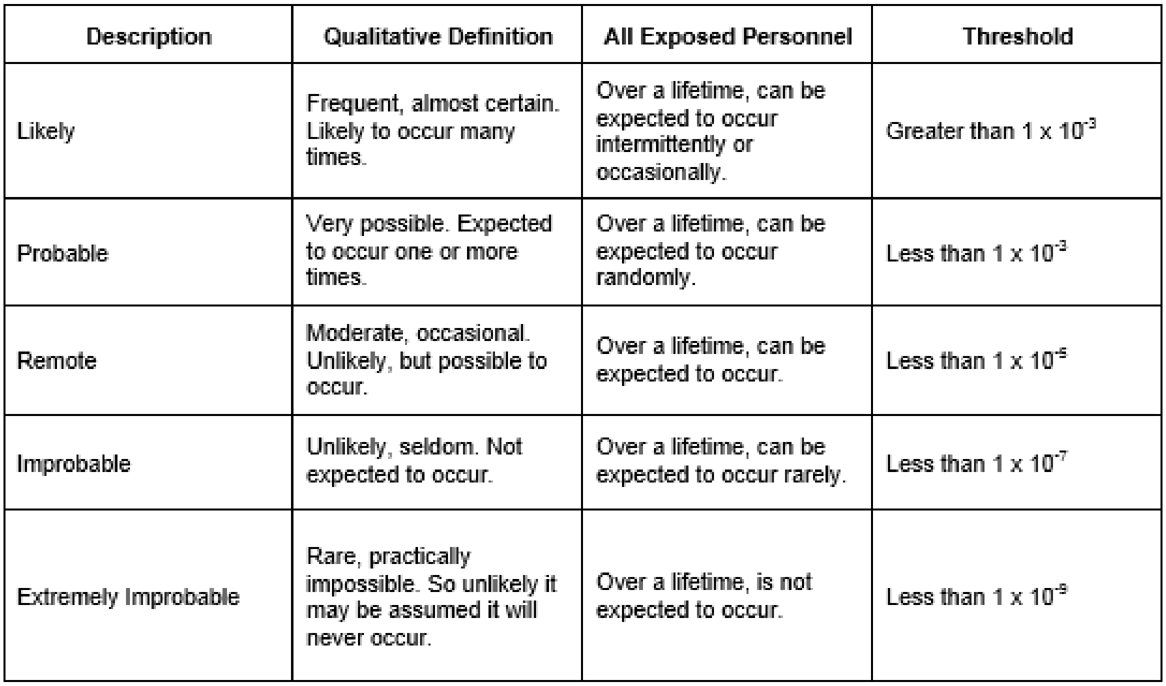
The risk management process includes five steps:

1. The identification of the hazard, assessed against an established standard.
2. The process of analysing the risk, by considering the consequences and probability. An important aspect is consideration of the exposure of persons.
3. Determining what mitigating actions can be taken to lessen the risk. The principle of As Low As Reasonably Achievable (ALARA) is followed.
4. Determining the appropriate level within the chain of command for accepting and approving the risk.
5. Ensuring that the approved risk is monitored for any changes.

The formalized study of the risk is referred to as an Ammunition and Explosives Risk Assessment Safety Case (AERASC) which documents the examination of the risk activity. The AERASC is prepared by an Ammunition Technical Authority with advice from appropriate stakeholders, including operational staff who will verify operational requirements that make the activity or situation one that is not routinely acceptable. The AERASC is submitted through the chain of command to the appropriate authority for approval which is based upon the level of risk that has been identified.

The AERASC is currently subject to review by a Technical Review Board which is chaired by DAER staff. This is in order to ensure that all technical aspects have been considered during the AERASC's preparation.

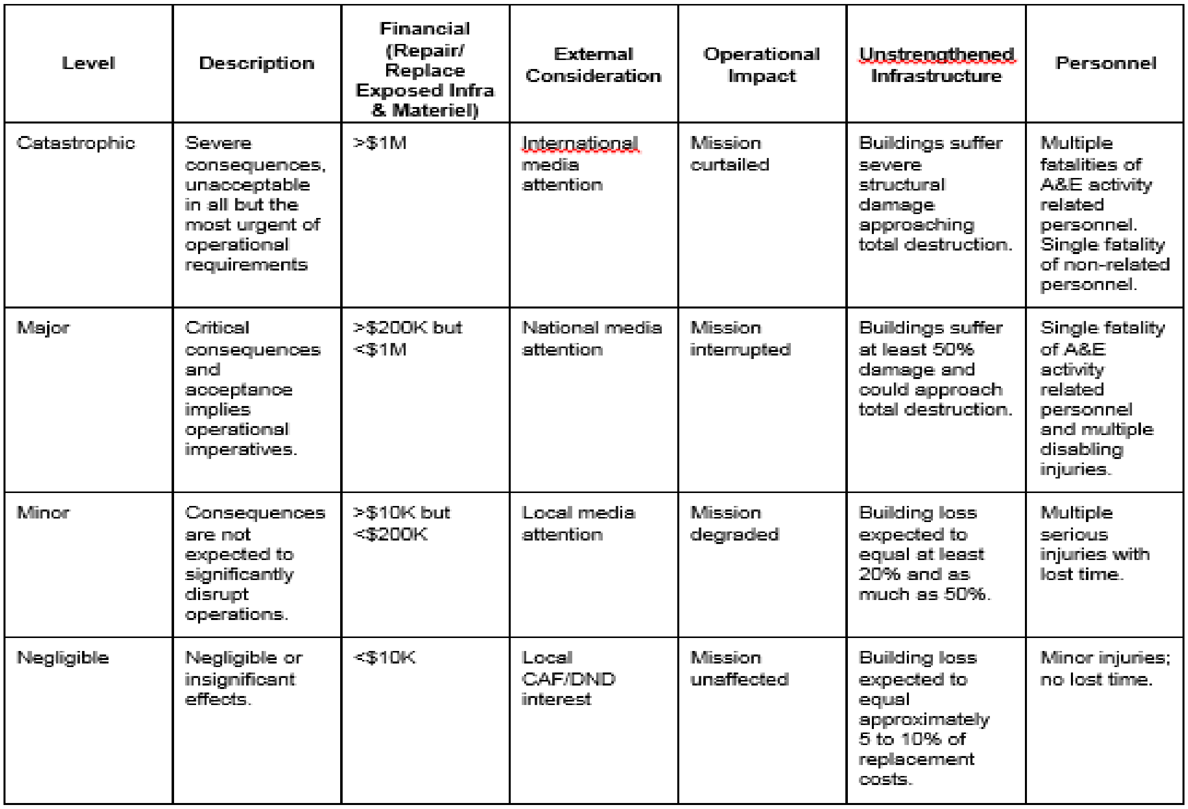
Probability
The levels of probability used are shown in the following table, with a numerical threshold value where quantitative tools are used.



Description	Qualitative Definition	All Exposed Personnel	Threshold
Likely	Frequent, almost certain. Likely to occur many times.	Over a lifetime, can be expected to occur intermittently or occasionally.	Greater than 1 x 10^{-3}
Probable	Very possible. Expected to occur one or more times.	Over a lifetime, can be expected to occur randomly.	Less than 1 x 10^{-3}
Remote	Moderate, occasional. Unlikely, but possible to occur.	Over a lifetime, can be expected to occur.	Less than 1 x 10^{-5}
Improbable	Unlikely, seldom. Not expected to occur.	Over a lifetime, can be expected to occur rarely.	Less than 1 x 10^{-7}
Extremely Improbable	Rare, practically impossible. So unlikely it may be assumed it will never occur.	Over a lifetime, is not expected to occur.	Less than 1 x 10^{-9}

Consequence

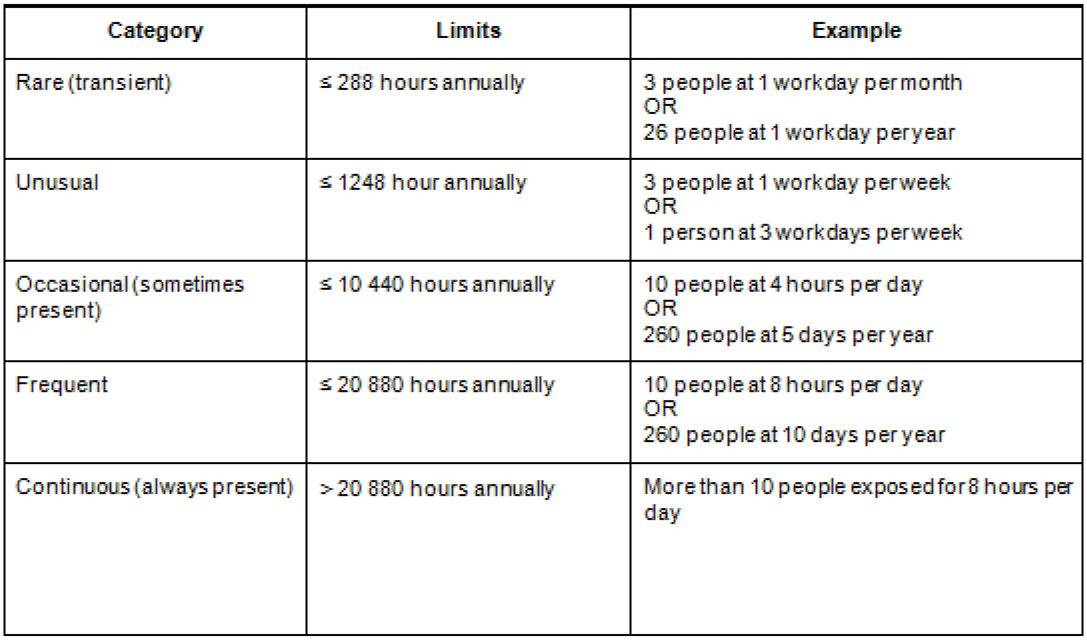
The major criteria for risk assessment for determining the level of consequence is that of the death of one person. Other consequence information is also provided in the table as a guideline.



Level	Description	Financial (Repair/ Replace Exposed Infra & Materiel)	External Consideration	Operational Impact	Unstrengthened Infrastructure	Personnel
Catastrophic	Severe consequences, unacceptable in all but the most urgent of operational requirements	>$1M	International media attention	Mission curtailed	Buildings suffer severe structural damage approaching total destruction.	Multiple fatalities of A&E activity related personnel. Single fatality of non-related personnel.
Major	Critical consequences and acceptance implies operational imperatives.	>$200K but <$1M	National media attention	Mission interrupted	Buildings suffer at least 50% damage and could approach total destruction.	Single fatality of A&E activity related personnel and multiple disabling injuries.
Minor	Consequences are not expected to significantly disrupt operations.	>$10K but <$200K	Local media attention	Mission degraded	Building loss expected to equal at least 20% and as much as 50%.	Multiple serious injuries with lost time.
Negligible	Negligible or insignificant effects.	<$10K	Local CAF/DND interest	Mission unaffected	Building loss expected to equal approximately 5 to 10% of replacement costs.	Minor injuries; no lost time.

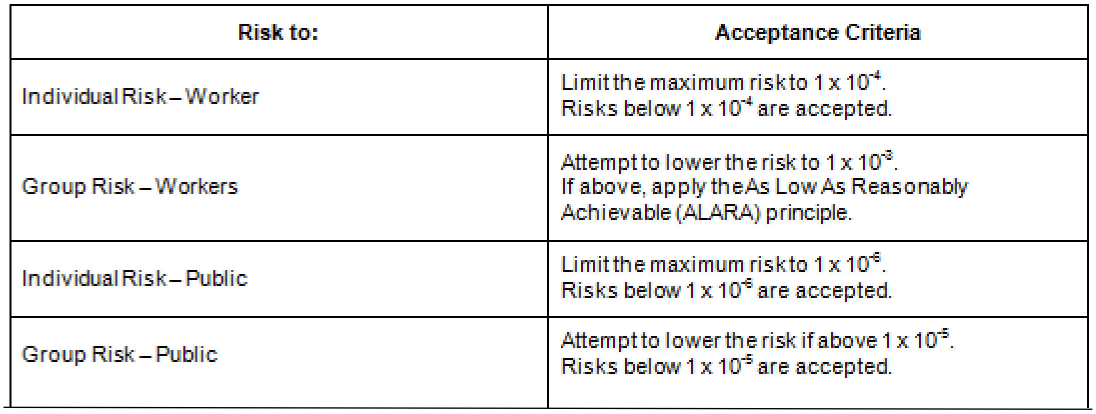
Exposure

The critical aspect of the consequence (injury or death to people) is affected by the degree to which those persons are exposed to the hazard. This is calculated based upon the likelihood of those persons being present when an undesired event occurs (i.e. personnel are always present, sometimes present or just passing through).The table provides guidelines for identifying the various categories of exposure.



Category	**Limits**	**Example**
Rare (transient)	≤ 288 hours annually	3 people at 1 workday per month OR 26 people at 1 workday per year
Unusual	≤ 1248 hour annually	3 people at 1 workday per week OR 1 person at 3 workdays per week
Occasional (sometimes present)	≤ 10 440 hours annually	10 people at 4 hours per day OR 260 people at 5 days per year
Frequent	≤ 20 880 hours annually	10 people at 8 hours per day OR 260 people at 10 days per year
Continuous (always present)	> 20 880 hours annually	More than 10 people exposed for 8 hours per day

Accepted hazard levels for DND/CAF personnel who regularly work with A&E are set differently from those persons who do not, or for the general public. For situations where quantitative probabilities can be established the table shows categories of risk acceptance levels.



Risk to:	**Acceptance Criteria**
Individual Risk – Worker	Limit the maximum risk to 1 x 10^{-4}. Risks below 1 x 10^{-4} are accepted.
Group Risk – Workers	Attempt to lower the risk to 1 x 10^{-3}. If above, apply the As Low As Reasonably Achievable (ALARA) principle.
Individual Risk – Public	Limit the maximum risk to 1 x 10^{-6}. Risks below 1 x 10^{-6} are accepted.
Group Risk – Public	Attempt to lower the risk if above 1 x 10^{-5}. Risks below 1 x 10^{-5} are accepted.

Software Support
AASTP-5 includes a risk assessment process for Field Distances which can be utilized in support of Canadian risk assessment content of C-09-005-005/TS-000 Ammunition and Explosives Safety Manual Volume 5 Deployed Operations.

Safety Assessment for Explosives Risk (SAFER©) is utilized by DAER for A&E storage siting for its capability to perform a quantitative assessment of risk levels. (Developed by the Risk Based Explosives Safety Criteria Team, sponsored by the US Department of Defense Explosives Safety Board (DDESB).)

The US-developed tool, FAST-Site, has been adapted for Canadian use whereby Ammunition Technical Authorities can utilize it to assist them in their analysis of A&E risk in terms of consequence for an event. Additional administration detail/information and some comparative information on US QD versus Canadian/NATO QD was added.

3.4 *France (2008)*

Since 1979, all manufacturers of explosive substances and munitions have been applying rules based on a qualitative or semi-quantitative risk analysis. These rules involve also the ministry of defense and in particular its munitions magazines, its proving grounds and its maintenance workshops. At the origin, these principles addressed the protection of the work people; they simply address environmental issues.

3.4.1 Before any new activity or change of the activity, the plant's manager has to analyze the risks caused by this new activity and:

- identify the possibilities of an accident and assess its consequences,
- take measures in order to avoid this accident and decrease its consequences.

In order to do that, for each PES considered and for each accident scenario, one has to:
3.4.1.1 Assess the frequency of an accident. Five orders of magnitude have been chosen:

- P1 (less than 10^{-4} accident per year). Example: munitions storage.
- P2 (more than 10^{-4}, less than 10^{-3} accident per year). Example: munitions handling.
- P3 (more than 10^{-3}, less than 10^{-2} accident per year). Example: electrical control of munitions.
- P4 (more than 10^{-2}, less than 10^{-1} accident per year). Example: machining of high explosive, EOD.
- P5 (more than 10^{-1} accident per year). Example: machining of munitions.

This assessment can be made on the basis of historical data, either with expertise or with an analytical approach (fault trees…).

3.4.1.2 Assess the hazard zones due to the accident. Five hazard zones are considered:

- Z1: injuries are lethal in more than 50% of the cases; very important damage.
- Z2: important injuries, potentially lethal; important damage.

- Z3: injuries; light and average damage.
- Z4: injuries are possible; light damage.
- Z5: very small probabilities of light injuries; very light damage.

This estimate takes into account the existence of barricades, of the type and quantity of explosives involved in the MCE (maximum credible event), and of the actual structure of the buildings.

This estimate can be calculated, using empirical models or computer models fitted to each case and taking into account various effects (blast, fragments and debris, thermal effects, and if necessary ground shock).

3.4.1.3 Describe the neighborhood of the PES, taking into account the exposure in each ES. One can consider:

♦ inside the plant:
♦ ao: staff attached to the PES
♦ a1: ES that should be near the PES
♦ a2: other facility (workshop or storage) with an activity involving explosives
♦ a3: facility with an activity not involving explosives. Example: the office of the manager's secretary

♦ the roads outside the plant, according to their traffic:
♦ b1: less than 200 vehicles per day
♦ b2: between 200 and 2,000 vehicles per day
♦ b3: more than 2,000 vehicles per day

♦ the buildings outside the plant:
♦ c1: uninhabited buildings. Example: warehouse of a farm
♦ c2: isolated houses
♦ c3: houses or industrial facilities
♦ c4: meeting places for people. Examples: schools, hospitals, stadiums…

The pass criteria take into account the type of each ES and of the probable frequency of accidents.

For example, for a workshop with P2 as a frequency of accident:

♦ the staff attached to the PES is allowed to be present in the zone Z1 (i.e. where lethal injuries are likely);
♦ a workshop with independent activities such as handling explosives (a2) is allowed to be in the zone Z3;
♦ the secretary's office (a3) is allowed to be in the zone Z4;
♦ the low traffic road (b1) is allowed to be in the zone Z3;

♦ the heavy traffic road (b3) is allowed to be in the zone Z5;

♦ the school and the hospital (c4) should be outside the hazard zones.

The higher the probability of an accident, the farther the ES should be situated from the PES.

3.4.2 Each risk analysis is checked by the inspectorate for propellants and explosive of the ministry of defense, for the benefit of the ministries of labor and environment.

The decree 79-846 mentions the approval authorities for:

♦ the risk analyses,

♦ the waivers and the corresponding compensatory measures.

3.4.3 This process functions smoothly and is fully satisfactory. In France, all the facilities involving explosives (e.g. the workshop and the magazines of a small manufacturer of shotshell cartridges, the French Guyana space center in Kourou where the Ariane rockets are mounted, the Army magazines), have been analyzed according to this procedure (with the exception of quarries and mines, for which there are particular rules).

3.5 *Germany (2015)*

The problem is *not* what is possible. That's not the problem. The problem is what is probable, what is happening (Richard P. Feynman, 'The Meaning of it All', 1963, published 1998).

The German Ministry of Defense (MOD) established a Group of Experts in May 1999 to study the feasibility of a risk-based explosives safety approach considering ammunition storage conditions typical of the German Armed Forces. The concept of the 'Explosive Safety Quantitative Risk Assessment ESQRA-GE' was accepted within the Group of Experts by June 2000. Currently Version 3.1 of ESQRA-GE is used.

The ESQRA-GE concentrates on ammunition storage scenarios. The goal was a tool for the responsible person in the MOD to assess non-standard ammunition storage scenarios consistently. Typical non-standard scenarios are: The storage in field camps of reaction forces out-of-area, civilian utilization of military airfields, in-transit ammunition storage as well as problems with ammunition in ports and in barrack areas. Consistency means that the event frequency, the event consequences and the criteria are determined consistently with what is expected to happen.

The ESQRA-GE was based on engineering judgment and expert assessment. It is a technique that simulates the event frequency Fe and the event consequences Ce for a given scenario. The resulting risk $R = Fe \times Ce$ as a product of two factors does not distinguish:

- between a number of high frequency events combined with low consequence and
- a single low event frequency event combined with high consequence.

Completely different scenarios can result in the same risk.

The ESQRA-GE distinguishes between hazard, consequence, and risk analysis. A flow chart was developed that shows the organization of the ESQRA-GE in seven analysis steps:

- Scenario Analysis
- Hazard or Effects Analysis
- Exposure Analysis
- Event Consequence Analysis
- Event Frequency Analysis
- Risk Analysis
- Risk Assessment

In the sense of a consistent quantitative risk assessment the parameters of the ESQRAGE were characterized by the following dimensions:

- Event frequency is measured in events/person-year
- Event consequence is measured in fatalities/event
- Any risk, societal or individual, is measured in fatalities/person-year

Risk was normalized to the German population on an annual basis.

The risk assessment is based on accidental fatality. There is a difference between risk of fatality and risk of accidental fatality. For example at contingency or combat operations (significant national need) the individual risk of fatality increases. An extra investigation is needed to find out if the risk of accidental fatality from ammunition storage also increases.

Looking for a *'yardstick'* to quantitatively measure the *'risk of accidental fatality'* both factors of risk were considered. Different types of accidental events were considered. By checking the accident database the tendency was observed that accidents with increasing number of fatalities occur with decreasing event frequency. For example transportation accidents (train, air, ship):

- The cumulated event frequency of accidents with 1 or more fatalities is Rt = 5 * E-5.
- The cumulated event frequency of accidents with 10 or more fatalities is Rt = 5 * E-6.
- The cumulated event frequency of accidents with 100 or more fatalities is Rt = 5 * E-7.

As a result the risk, as a product of frequency and consequence, has a constant value Rt = 5 * E-5. The risk does not increase with increasing number of fatalities/event. Few data from accidents at ammunition storage are available. Nevertheless it is assumed that the same tendency exists.

Both factors of risk, the 'event frequency' [events/person-year] as well as the 'event consequence' [fatalities/event], are comparable in different (but similar) populations (e.g. Germany, Switzerland, Norway, United States etc., but not Tibet or Sambesi). It is concluded that also the risk of accidental fatality [fatalities/person-year] as a product of frequency and consequence should be comparable.

No approved risk acceptance criteria are available in the ESQRA-GE. This may depend on the goal of the German approach. The risk assessment was based on ‘what is happening’ – on the database of accidental fatality. About 40,000 individuals out of a population of 80 million are killed annually by accidents of all different types in Germany. The societal risk of accidental fatality is Rs = 5 * E-4 [fatalities/person-year]. Annually 1 out of 2000 individuals is killed in an accident. The (mean) annual risk of German individuals to be killed by accident is Ri = 5 * E-4 [fatality/year, normalized to 1 person].

Example of risk assessment: Annually 1 individual out of 10,000 workers in the chemical industries is killed by job-related accidents. The individual job-related risk of accidental fatality is Ri = 1 * E-4 or 20% of the total risk of accidental fatality.

The ESQRA-GE helps the responsible person in the MOD to prove that the risk (of accidental fatality) of individuals that are involved in a non-standard ammunition storage scenario does not exceed the job-related risk (of accidental fatality) of workers in the chemical industries. Of course, comparison with other types of risk of accidental fatality can be done.

3.6 *The Netherlands (2015)*

Introduction

On behalf of the Netherlands MoD, the TNO Prins Maurits Laboratory started the development of the Quantitative Risk Analysis software code RISKANAL in the early eighties. In 1998, the latest definitions of Individual Risk and Societal Risk according to the Netherlands Ministry of Housing, Spatial Planning and the Environment were implemented in the model. Also, the probit functions for calculating the personal consequences due to the various explosion effects were updated. Since then, the models’ name has been changed into Risk-NL. The last update of Risk-NL was released in 2009 and has led to the current version of Risk-NL Version 5.0.

Sub-models

A variety of explosion effects and consequence models have been implemented. The latest update comprised new models for direction dependent debris throw and window failure. The calculations of the consequences of the explosion effects for persons in various conditions are performed by so-called probit functions. Most of these probit functions are described in the Dutch “Green book.”

Risk definitions

Knowing the possible explosion scenarios, their initiation frequencies, explosion effects and consequences for humans, the risks can be calculated. To do so, the definitions of individual risk and societal risk are essential for the resulting figures. In the Netherlands a distinction is made between Individual Risk and Societal Risk.

Individual Risk

This is the probability per year that an unprotected individual standing at a certain location for 24 hrs a day, all year long, will be killed by an unwanted event with dangerous goods. It is noted that the exposure is continuous in this situation. The IR is graphically depicted by iso-risk contours around the storage site with PESs, which are lines that join all points of equal values of individual risk.

Individual risk acceptance criteria

The acceptance criteria set by the Netherlands Government are as follows:

- For existing situations: 10^{-5} /year
- For new situations: 10^{-6} /year

Definition of Societal Risk

The term societal risk is applied by the Dutch government and is comparable to group risk. The societal risk is the probability per year that a group of a certain size will be killed due to an accident with dangerous goods. For each explosion scenario, i.e., for each magazine or PES, the initiation frequency and the total number of expected fatalities is calculated. The societal risk is graphically depicted in an F/N-curve, which is a graph showing the cumulative frequency of the accident scenarios and the subsequent number of victims.

Societal risk acceptance criterion

The acceptance criterion for the societal risk is that the probability of an accident with 10 fatalities should occur less than once per 100,000 years. An aversion factor is included to account for the unwillingness of the society to accept events with large numbers of fatalities.
Note that the aversion factor is included in the criterion and not in the societal risk itself. The acceptance criterion is:

$$F \times N^2 = 1 \times 10^{-3}$$

in which: F = cumulative initiation frequency (per year);
N = number of persons killed (-).

E.g. an accident with 100 fatalities should occur less than once per 10,000,000 years.

3.7 *Norway (2015)*

Norway started the preparations for performing explosives safety quantitative risk analysis (ESQRA) in the late eighties. In 1985 the acceptance criteria for risk against third party personnel was approved by the Department of Defense (DoD). In 1987 the first risk analysis resulting in an explosive storage approval was issued.

Approval of ammunition storage is done on the basis of risk assessment. When building new storage, analysis is done, to ensure fulfillment of both QD and ESQRA.

A civilian provision establishing criteria for the first party and second party risk was issued December 1999.

The method and software used in the analysis is based on a Swiss developed program. The Norwegian adaptation is known as AMMORISK. In 2000, cooperation was started with Sweden, to update the models used, and revise the software resulting in a new program, named AMRISK. AMRISK Version 2.02 is now in use.

Collective risk is defined as rp = expected event frequency × number of fatalities.

The fatality number is multiplied or enlarged with aversion factors, which are calculated for each situation where a constant number of fatalities could be expected. The average rp is then summed up according to the duration of each situation.

The aversion factor $\varphi = 2^{Fn/5}$
where the Fn equals the number of fatalities in each situation.

The use of aversion factors is found to be more practical than using a FN-curve, but otherwise complies with such curves.

Table 3.7.1: Norwegian Acceptance Criteria

Risk to:*	**Individual risk criteria**	**Group risk criteria**
1st party worker (Annual Pf)	Risks below 4×10^{-5} are acceptable	The total risk for 1st, 2nd, and 3rd party is acceptable below 3×10^{-4}.
2nd party worker (Annual Pf)	Risks below 3×10^{-6} are acceptable	The total risk for 2nd and 3rd party is acceptable below 2×10^{-4}.
3rd party (Annual Pf)	Risks below 2×10^{-7} are acceptable	The total risk for 3rd party is acceptable below 1×10^{-4}.

*Definitions:
1st Party = direct participation
2nd Party = indirect participation
3rd Party = uninvolved

The ALARP principle is not used. Waivers for 3rd party risk have not been given for some years, because of a restrictive practice. The authority of granting a waiver is on the Department of Defense level. Waivers for 1st and 2nd party risk could be granted by the chief of Defense.

3.8 *Sweden (2015)*

In Sweden, Explosives Safety Risk Analysis is authorized for use for storages for cases where QD criteria are not met. Development is ongoing for other applications. The method and software used in the analysis are based on a Swiss program as developed in Norway known as AMMORISK.

In the year 2000 cooperation with Norway has started to update and improve the models used, and revise the software resulting in a new program, named AMRISK.

Collective risk is the sum of the individual risks.

The fatality number is enlarged with an aversion factor, which is calculated for each situation where a number of fatalities greater than one could be expected.

This aversion factor $\varphi = 2^{Fn/5}$, for $Fn < 20$, where Fn equals the number of fatalities in each situation. For $Fn \geq 20$ the aversion factor $\varphi = 16$.

Table 3.8.1: Swedish Acceptance Criteria

Risk to:	**Individual risk criteria**	**Collective risk criteria**
Any 3rd person (Annual Pf)	Risks below 1.0×10^{-6} are acceptable	Collective risk below 1.0×10^{-4} are acceptable

3rd person = not directly or indirectly involved

3.9 *Switzerland (2015)*

Switzerland has 40+ years of experience with the successful application of a quantitative risk based safety concept in the field of ammunition storage and handling.

Today, the safe capacity of most of the ammunition storages is based on a site-specific risk analysis, and also for maintenance operations risk analyses are performed. For transportation of ammunition similar risk based procedures are applied today on a regular basis. Also, for siting of new facilities, the risk-based approach is the only approved method as well as for all the other activities.

The method applied is well documented. Corresponding regulations, safety manuals and safety criteria issued by the Staff of the Chief of the Swiss Armed Forces exist. The daily risk analysis work is supported by a software tool called RIMANA which complies with the existing regulations.

The probabilistic risk based concept, as introduced in Switzerland, has the following main features:

- clear distinction between the (factual, objective) risk analysis part and the (subjective) risk appraisal part
- quantification of the hazard taking into account installation, operation and site-specific conditions

- detailed assessment of exposure data within time-slots (situations)
- differentiation between the collective (societal/group) and individual risk
- differentiation between the risk bearers (directly involved staff / third party persons) - aversion function (allowing to assess potentially catastrophic events)
- quantitative risk criteria allowing to maximize the safety for the money spent

Table 3.9.1: Principles and Definitions of the Swiss Safety Concept

Qualitative criterion for safety	- General: Harm to human beings - Considered as representative in particular: lethal effects
Extent of safety	Both - the exposed individual and - the collective of all exposed persons
Definition of risk	$r_{ie} = p_e \; \lambda_{ie} \; t_{ie}$ $R_e = p_e \; C_e = \Sigma (\lambda_{ie} \; t_{ie}) \; p_e$ where r_{ie} = lethal risk of person i due to event e R_e = lethal collective risk of all exposed persons i due to event e C_e = consequences (no. of victims) due to event e in case of occurrence p_e = probability of event e λ_{ie} = lethality of person i due to event e in case of occurrence t_{ie} = time person i being exposed to the hazardous effects of event e
Aversion; perceived collective risk	Introduced with respect to the general reaction of the public to low-frequency but major-damage accidents and the specific psychological, political and social aspects of handling of ammunition and explosives by the "military": $R_{pe} = \varphi (C_e) \; R_e$ (simplified) where R_{pe} = lethal perceived collective risk of all exposed persons i due to event e $\varphi (C_e)$ = aversion factor as a function of the consequences (expected no. of victims) due to event e in case of occurrence R_e = lethal collective risk (statistically expected value) of all exposed persons i due to event e
Risk groups	The safety criteria distinguish between different groups of risk bearers according to their relationship to the hazardous activity (mainly directness of the perceived benefit of the activity and ability to know, influence and avoid the risk), such as third persons, indirectly and directly involved persons and troops

Table 3.9.2: Swiss Acceptance Criteria

Type	Method	Risk Group	Numbers
Individual risk	Upper limiting values 0)	not involved third persons 1) indirectly involved persons 2) directly involved persons 3)	3 10^{-6}/year 1.5 10^{-5}/year 3 10^{-5}/year
		troop members around installations with a+e 4) troops handling a+e	3 10^{-6}/year 1 10^{-5}/year
Perceived collective risk	Willingness-to-pay & marginal cost criterion	not involved third persons indirectly involved persons directly involved persons	30 mill CHF/saved life 12 mill CHF/saved life 6 mill CHF/saved life
		troop members around installations with a+e troops handling a+e	30 mill CHF/saved life 15 mill CHF/saved life
Aversion	Consequence weighing function	All	$\varphi(C) = 2^{C/5}$ $(C \leq 22.4)$ $\varphi(C) = C$ $(C > 22.4)$

0) max. risk per year. However, for short risk exposure, criteria per day, week, and month exist and have to be applied additionally.
1) typically residents, railway passengers, car drivers etc.
2) such as e.g. administrative personnel in an ammunition factory
3) personnel working directly with ammunition and explosives such as e.g. operators of explosives filling installations, explosives transport vehicle drivers etc.
4) ammunition and explosives

Note: 1 CHF ≈ 0.9 € resp. 1.0 US$ (2015)

3.10 *United Kingdom (2015)*

Work on risk assessment for explosives storage activities started following a study by RMCS Shrivenham in 1968, and took place in parallel with efforts in Switzerland and Norway. These were considerable help, but the United Kingdom (UK) needed to comply with national civil regulations, and wished to take account of segregated storage regimes.

Development work was contracted to AEA Technology who collated detailed information on explosives storage and handling activities in order to produce HAZOP and Fault Tree data for generic activities.

A much-simplified approach was also developed to produce a risk ranking procedure and subsequently MOD adapted this to provide the major contributions to risks from many donor (potential explosion site, PES) threats to a chosen receptor (exposed site, ES).

Since 1989, the process has been automated and applied to all major MOD explosives storage areas and shows that individual risks at inhabited building distances comply with civil regulations but do vary considerably depending upon local conditions.

Procedures have been developed to estimate risks to different groups of people (Societal risks) in terms of F-N curve analogous to the procedure used in the nuclear field. Estimates can also be made of the number of fatalities predicted from the largest accident. Managers are required to take account of societal concerns when making risk based decisions. However, there is little quantitative guidance available in this area at present.

In agreement with the UK civil regulator, The Health and Safety Executive (HSE), MOD does not incorporate an aversion factor into its risk estimates. It is thought better to produce level figures and to show any aversion effect explicitly later.

The UK regulations define intolerable risks (levels above which work must cease until the risk is lowered) and broadly acceptable risks (below which further reduction of risk is unlikely to be beneficial). The risks between these levels are defined as tolerable, and in this region risks must be reduced to a level that is as low as reasonably practicable (ALARP). In effect, this requires that a risk reduction measure must be implemented unless the cost of doing so is grossly disproportionate. MOD uses the same criteria as recommended in HSE's guidance.

Table 3.10.1: UK Risk Acceptance Criteria

Individual Risk to:	**UK Civil Guidance - Broadly acceptable below:**	**UK Civil Guidance – Intolerable above:**
Workforce	1×10^{-6} per year	1×10^{-3} per year
Non involved	1×10^{-6} per year	1×10^{-4} per year

Civil requirements for the Control of Major Accident Hazards have been translated into an equivalent set of Major Accident Control Regulations for MOD. Under these regulations, MOD agree and exercise contingency plans involving the civil populations where appropriate. Information from the risk assessments on explosives sites support this activity.

For the risk assessment results, the HSE advice is usually interpreted as a requirement for a conservative but not overly pessimistic risk estimate or a cautious best estimate of risk.

Ideally a confidence level should be assigned to the expectation that the risk was not an underestimate. To do this, however, it is necessary to carefully define the risk assessment and the declared uncertainties. Uncertainty analysis is part of the MOD risk assessment tool development, but it may only be a useful estimate of the uncertainty associated with particular models and parameters rather than the overall risk estimate.

The HSE also note a useful caveat about making decisions based on the results of a quantitative risk assessment (QRA):

“The process of undertaking a QRA can lead to a better understanding of the important features contributing to risk and weaknesses in the systems as well as allowing a numerical estimate of the residual risk to be derived. The quality of the modelling and the data will affect the robustness of the numerical estimate, and the uncertainties in it must always be borne in mind when using the estimate in risk management decisions. The use of numerical estimates of risk by themselves can, for several reasons including those above, be misleading and lead to decisions which do not meet adequate levels of safety. In general, qualitative learning and numerical risk estimates from QRA should be combined with other information from engineering and operational analyses in making an overall decision.”

An important corollary is that the models should be consistent with each other, both in terms of the level of cautiousness used in estimating the risks and the methodologies used. This will increase confidence that operational decisions that are made on the basis of a risk assessment will reduce actual risks rather than just the modelled risks.

UK MOD Explosives Risk Management Protocol

The Defence Safety Authority (DSA) is responsible for the regulation of defence health, safety and environmental protection within the UK MOD.

The Defence Ordnance, Munitions and Explosives Safety Regulator (DOSR) is part of the DSA and is an independent regulator within Defence who holds a personal letter of delegation from the Director General of the DSA which defines his authority and responsibilities. This directs the DOSR to regulate Ordnance, Munitions and Explosives (OME) safety across Defence activities in accordance with the Secretary of State’s policy statement and to maintain a regulatory regime.

The strategic objectives of the DSA are to ensure and assure that Defence Capability safety Risks to Life are both Tolerable and ALARP. Within UK, Defence complies with all safety and environmental legislation; overseas, Defence applies UK arrangements where practicable whilst responding to host nation requirements. Where UK legislation does not apply to Defence, where practicable, arrangements are maintained that are at least as good as legislation would require. DOSR achieves this with support from Subject Matter Experts from the Defence Ordnance Safety Group.

Quantitative Risk Assessment Tool Development

MOD has used RISKWING for quantitative risk assessments for many years, however recently a new eXplosion Risk Assessment tool (XRA) has been developed which follows a modular framework to allow easier update and expansion. The current version in use is XRA v1.8.

XRA outputs the individual and societal risks, which it calculates via the combination of the frequency of explosion initiation with the conditional probability of fatality at an exposed site (ES) and the relevant target population data for that ES.

The frequency of explosion initiation for a potential explosion site (PES) is made up of a number of factors, including external hazards and inter-magazine communication.

External hazards may be calculated by XRA using standard algorithms. XRA will calculate initiation frequencies from:

a. Aircraft crashes from the following sources:
    i. Airways
    ii. Airfields
    iii. Helipads
    iv. Background crash rates
b. Lightning strikes
c. Other external hazards

Communication between above-ground PES may be calculated by XRA, with the communication frequency based on the QD formulations in MOD Explosives Regulations, JSP482.

The risks to the target population are calculated by considering a number of effects that could lead to fatal consequences. Currently, the following effects are considered:

a. Fragment effects
b. Blast effects
c. Debris effects
d. Thermal effects

XRA utilises consequence models to calculate the individual risk of fatality at each ES from each of the above effects, where appropriate (some PES will not produce all the above consequences). Different models are employed, depending on the type of Hazard Division and the position of the PES, and the position of the population (indoors or outdoors).

The individual probability of fatality for an individual at the ES is defined as the risk of fatal consequences at the ES, conditional on an explosion occurring each year.

The annual individual risk presented by the PES to a resident, worker or transient at the site is calculated by combining this conditional fatality probability with the estimated annual frequency of an explosion occurring at the PES and the characteristics of the individual at the ES (i.e. the fraction of time spent there, and the time spent indoors and outdoors).

The total annual risk presented to an individual at the ES is calculated by adding up all risks from each defined PES.

Societal risks are calculated by combining the individual fatality probabilities at each ES from each PES with the number of residents, workers and transients at each ES in a number of scenarios. The risks are calculated for three scenarios:

a. only fatalities for ES on the explosive site
b. only fatalities for ES off the explosive site
c. fatalities over the whole exposure grid

Societal risk is expressed in terms of:

a. The maximum number of fatalities that might occur over the whole exposure grid from each PES, and the frequency per year with which this might occur.
b. The frequency of exceeding different fatality numbers for the ES under consideration (these numbers can be changed). This is available for individual PES and the combination of all PES.

3.11 *United States (2015)*

1. The following documents provide current DoD explosives safety risk management policy, requirements and guidance:

   (a) Department of Defense Instruction (DODI) 6055.16: “Explosives Safety Management Program”.

   (b) Chairman, Joint Chiefs of Staff Instruction (CJCSI) 4360.01A, “Explosives Safety and Munitions Risk Management for Joint Operations Planning, Training, and Execution”.

   (c) DoD 6055.09-M, “DoD Ammunition and Explosives Safety Standard”. This document provides minimum DoD requirements, to include required QD.

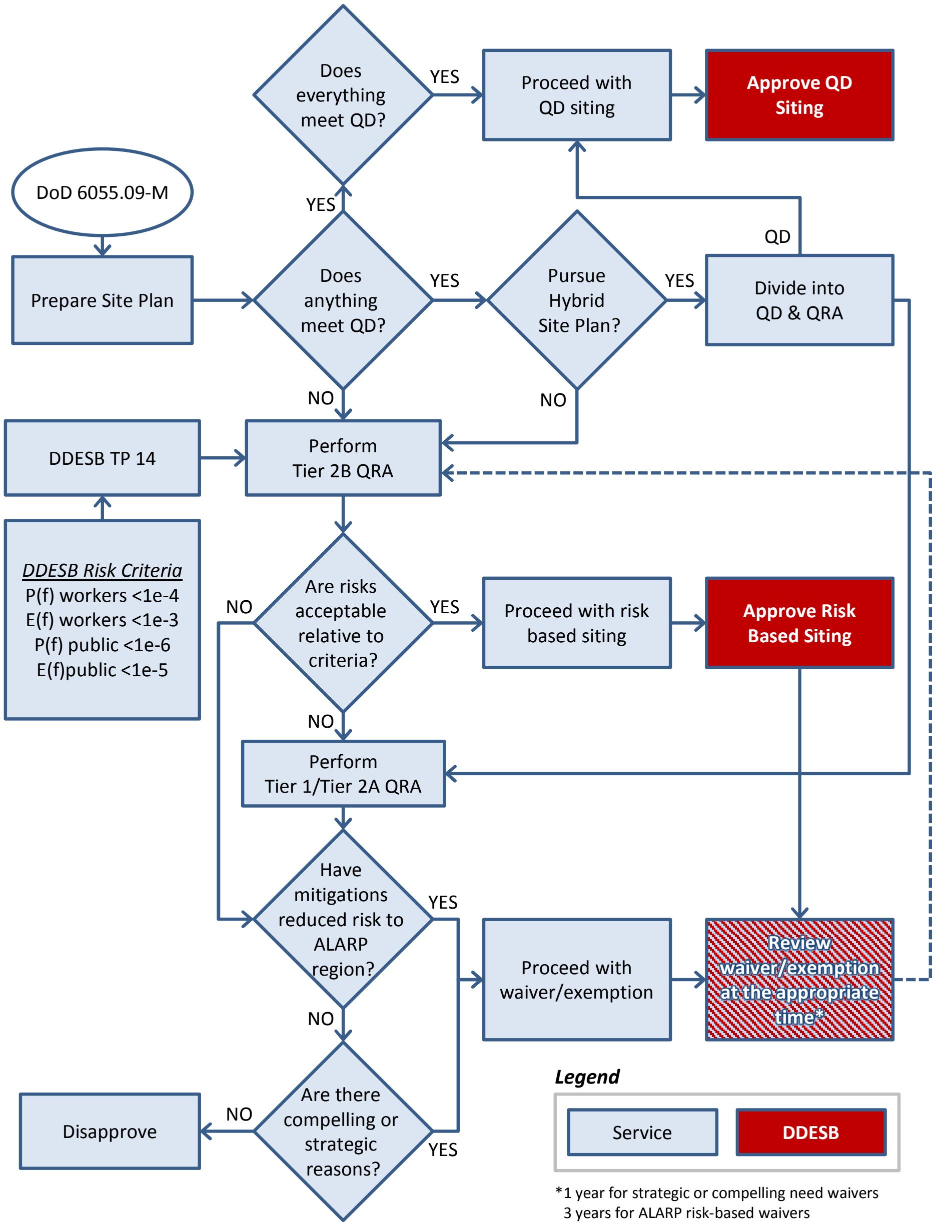
   (d) Department of Defense (DoD) Explosives Safety Board (DDESB) TP 23, “Assessing Explosive Safety Risks, Deviations, and Consequences”. This TP provides guidance with regards to the DoD’s Explosive Safety Risk Management (ESRM) program. It describes the program outlined in DoDI 6055.16, “Explosives Safety Management Program” and presents a course of action and a tool to standardize the explosives safety deviation and risk decision processes.

2. Service-level risk acceptance requirements are further amplified in the various Service manuals (e.g., Air Force Manual 91-201, “Explosive Safety Standards” and Air Force Instruction 90-901, “Operational Risk Management”).

3. DoD Explosives Safety Siting Requirements.

a. DoD policy dictates that compliance with explosives safety criteria given in DoD 6055.09-M shall be the primary approach towards risk management of explosives risk where ever DoD munitions are located or planned. Those criteria represent DoD’s regulatory acceptance of risk based on minimum requirements. When those requirements cannot be met, or aspects of a project cannot meet explosives safety requirements for strategic or compelling operational reasons, then a deviation to explosives safety criteria is required, leading to the need to conduct a Quantitative Risk Assessment (QRA) and acceptance of that risk by the proper Service Component authority.

b. Figure 4 below illustrates the sequence of actions required for the Services to obtain a site plan approval from the DDESB. The figure also gives guidance on risk acceptance decisions made by the Services.



*1 year for strategic or compelling need waivers
3 years for ALARP risk-based waivers
5 years for all other site plans

Figure 4. US DoD Notional Risk Management Diagram

4. Quantitative Risk Assessment

a. The DDESB has been applying QRA tools and principles for explosives safety siting in conjunction with existing QD criteria since 2007, based on feasibility studies initiated in August 1997 by the Risk-Based Explosives Safety Criteria Team (RBESCT). The RBESCT subsequently developed the QRA methodology described in DDESB Technical Paper 14; the risk based siting tool called “Safety Assessment for Explosives

Risk (SAFER)", as described in DDESB Technical Paper (TP) 19; the risk acceptance criteria shown below in Table 3.10.1; and the implementation logic given in Figure 3. A QRA developed using the methodology implemented in SAFER and meeting the criteria of Table 3.10.1 is considered to meet the regulatory requirements of DoD 6055.09-M with respect to personnel protection.

b. Together, the application of QD, or QRA, or a combination of the QD and QRA, form the foundation for DoD's risk management approach used to site explosives locations. When both QD siting and QRA siting methodologies are employed in a site plan, the term 'hybrid' is used to define the site plan type, as further described in the next paragraph.

5. Hybrid Site Plan

a. A hybrid site plan is used to site facilities/operations that do not completely conform to DoD Manual deterministic QD or risk-based criteria. DoD Components are responsible for accepting risk, utilizing their own deviation review / approval processes, for all nonconforming aspects of the hybrid site plan, and any risk decision must be included in site plans submitted to DDESB for approval of the QD compliant portion.

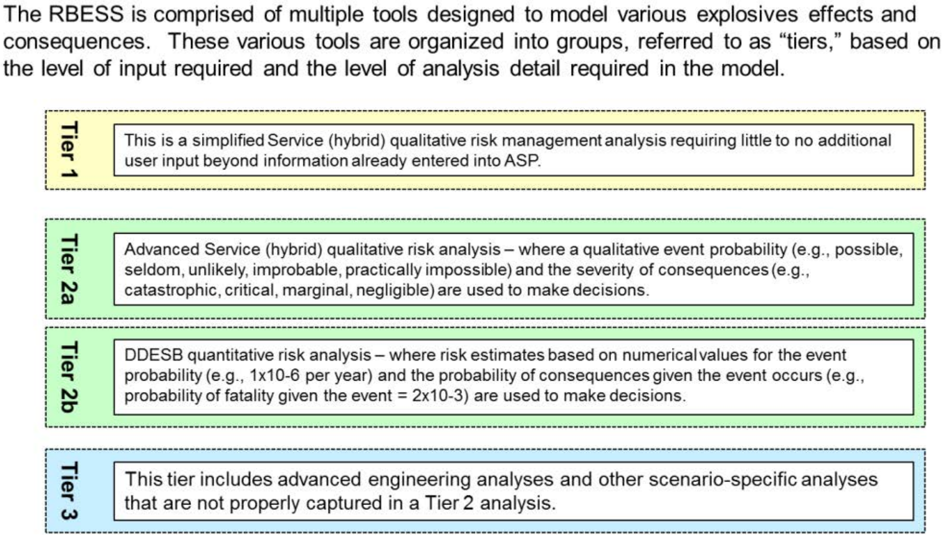
b. A Hybrid QRA assists users in completing a Deviation Approval and Risk Acceptance Document (DARAD) or other similar deviation form. Various "Tier" levels of QRA can be conducted depending on the level of data available and the degree of fidelity required. Lastly, during high risk scenarios and when the Services have compelling or strategic need, the Combatant Commands have the ability to accept the risk based on guidance found in CJCSI 4360.01A.

6. DoD Risk-Based Explosives Safety Siting and "Tiered" Approach to Risk Management

a. SAFER 3.1 is the current version of DoD's stand-alone risk-based siting software tool. In 2013 the DDESB established the requirements for integrating a Risk-Based Explosive Safety Siting (RBESS) module into the Automated Site Planning (ASP) software. RBESS is a companion module to ASP intended to build upon the existing software's strengths and features while adding new risk-based analysis capability for the user. (Note. For the purpose of this document, TP-14 refers to the most current version implemented within the ASP software. The software will provide users with the most current version just as ASP currently provides users with the most current Service-specific siting regulation manuals through the help menu.)

b. RBESS will encompass multiple tools that are designed to model various explosives effects and consequences. These various tools have been organized into groups, referred to as "Tiers" which are delineated by the level of input required and the level of analysis detail required in the model.

c. The DoD utilizes a tiered approach (see Figure 5 below) for risk-based explosives safety siting and associated risk management. Those tiers are discussed below. The rest of the US section will primarily address Tier 2b, as SAFER 3.1 is the primary software tool for conducting a Tier 2b QRA.



The RBESS is comprised of multiple tools designed to model various explosives effects and consequences. These various tools are organized into groups, referred to as "tiers," based on the level of input required and the level of analysis detail required in the model.

Tier 1	This is a simplified Service (hybrid) qualitative risk management analysis requiring little to no additional user input beyond information already entered into ASP.
Tier 2a	Advanced Service (hybrid) qualitative risk analysis – where a qualitative event probability (e.g., possible, seldom, unlikely, improbable, practically impossible) and the severity of consequences (e.g., catastrophic, critical, marginal, negligible) are used to make decisions.
Tier 2b	DDESB quantitative risk analysis – where risk estimates based on numerical values for the event probability (e.g., 1x10-6 per year) and the probability of consequences given the event occurs (e.g., probability of fatality given the event = 2x10-3) are used to make decisions.
Tier 3	This tier includes advanced engineering analyses and other scenario-specific analyses that are not properly captured in a Tier 2 analysis.

Figure 5 RBESS Tier Descriptions

Tier 1. This is a simplified Service qualitative risk management analysis requiring little to no additional user input beyond information already entered into the ASP software. A hybrid site plan is used to site facilities/operations that do not completely conform to DoD Manual deterministic QD or risk-based criteria. The DoD Component accepts the explosives risk for the nonconforming part of the site plan via the DoD Component's deviation approval process, and then forwards it to the DDESB for approval of the conforming portion. The simplified analyses are based on translating scaled distances (i.e., K-factors) into estimates of consequences through a TP-23 type analysis. A Tier 1 QRA should help a user complete a Deviation Approval and Risk Acceptance Document (DARAD) or other deviation forms. FAST-SITE and ASAP-X are software tools the planner uses to develop a Tier 1 site plan. A Tier 1 analysis may also be used to support a Combatant Commander's risk decision in accordance with CJCSI 4360.01A.

Tier 2

(a) Two types of risk analyses can be performed under Tier 2:

- Tier 2a - Advanced Service qualitative risk analysis, where a qualitative event probability (e.g., possible, seldom, unlikely, improbable, practically impossible) and the severity of consequences (e.g., catastrophic, critical, marginal, negligible) are used to make decisions.

- Tier 2b - DDESB quantitative risk analysis, where risk estimates based on numerical values for the event probability (e.g., 1x10^{-6} per year) and the probability of consequences given the event occurs (e.g., probability of fatality given the event = 2x10^{-3}) are used to make decisions.

(b) Tier 2 analyses require additional user input (e.g., number of people in Potential Explosive Site (PES) and Exposed Sites (ES), number/size/type of windows at ES, type of PES and ES construction, etc.) and produce more refined answers than a Tier 1 analysis. A Tier 2 analysis is based on engineering models that have been peer reviewed and documented by the technical community (e.g., the approved DDESB risk-based models in TP-14).

(c) A Tier 2a risk analysis should help a user complete deviation forms. A Tier 2b QRA should help a user compare the calculated risk with DDESB acceptance criteria.

Tier 3. This tier includes advanced engineering analyses and other scenario-specific analyses with increased fidelity over a Tier 2 analysis. Implementation of this level of analysis is planned for a future version of the ASP software and is not available at this time.

d. Table 3.10.1 displays the acceptable risk acceptance criteria for individuals, measured in terms of probability of fatality per year, and group risk, in terms of expected fatalities per year. The DDESB has criteria for both related people and members of the public. All criteria must be met for DDESB approval of a risk-based site plan.

Table 3.11.1: United States Risk Acceptance Criteria

Risk to:	DDESB Criteria	Service Guidance
Any 1 related (a) person (Annual Pf)	Risks below 1 x10^{-4} are acceptable	
All related (a) people (Annual Ef)	Risks below 1 x10^{-3} are acceptable	If risks are above 1 x10^{-3} apply ALARP principle (c) Accept above 1 x10^{-2} with significant national need only (c)
Any 1 unrelated (b) person (Annual Pf)	Risks below 1 x10^{-6} are acceptable	
All unrelated (b) (Annual Ef)	Risks below 1 x10^{-5} are acceptable	If risks are above 1 x10^{-5} apply ALARP principle (c) Accept above 1x10^{-3} with significant national need only (c)

Table 3.10.1 Notes:

(a) Related criteria are intended to apply to people that are associated with the explosives activity.

(b) Unrelated (or public) criteria are intended to apply to 1) Government employees working on the installation but not related to the explosives activity and 2) the general public. For Service's waivers and exemptions,

(c) ALARP is the safety principle whereby risks are lowered "as low as reasonably practicable."

7. Some of DoD’s risk-based policy milestones and RBESCT’s major software releases are shown in Figure 6.

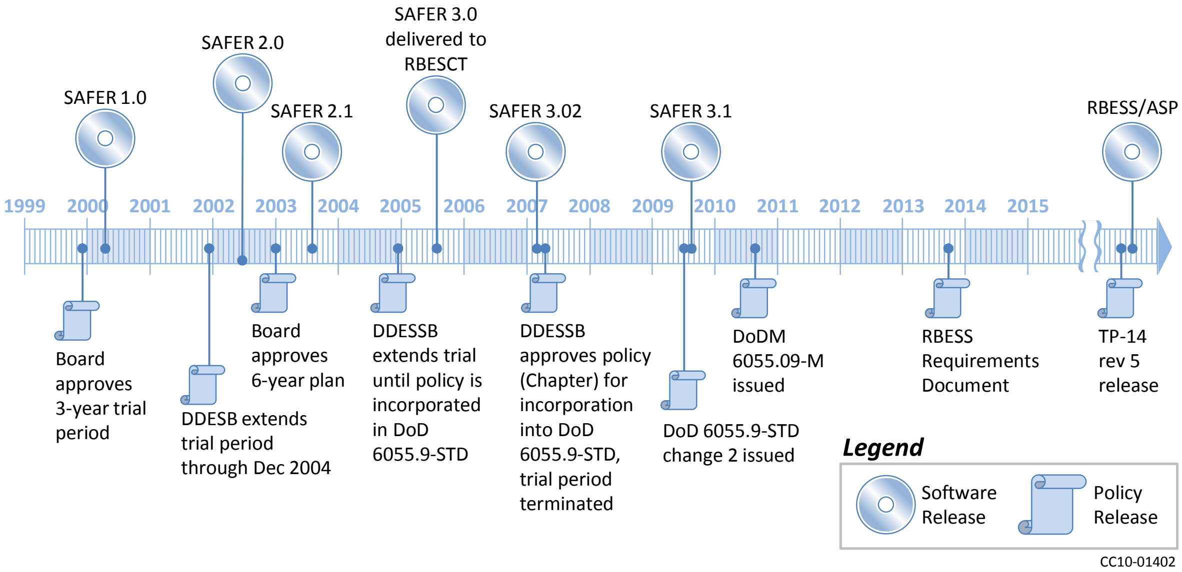


Figure 6. RBESCT Milestones

NATIONAL PROCEDURE SUMMARIES

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Country:	**Use:**
AUSTRALIA	- **Support management decisions**
(2015)	- **Licensing for QD non compliance**
	- **Licensing for Storage under 50kg Storage**

1. Goals	Determine safety risk at ES from PES Identify risk mitigation opportunities at PES and/or ES
2. Measures	*Qualitative*/ Risk is considered ALARP *Quantitative*: Predict maximum expected number of fatalities
3. Criteria	*Qualitative*: ALARP principle is applied *Quantitative*: PR broadly acceptable as 10^{-6} $(yr)^{-1}$
4. Risk Formula	*Qualitative*: Likelihood v Consequences = Risk Levels *Quantitative*: Potential Risk = Event Frequency $(yr)^{-1}$x Fatality Probability Individual Risk = Event Frequency $(yr)^{-1}$x Fatality Probability x Exposure
5. Frequency	Event frequency is determined from historical data, expert opinion and assessment of the PES to be licensed
6. Effects	AASTP-1 applied as required
7. Consequence	Upper limits used – not average / expected values. Blast/overpressure data Weapon (primary) fragmentation lethality Fire-ball radiation calculations/estimates Building debris (secondary fragment) trials data Reference to supporting studies
8. Exposure	Exposure of personnel is linked to presence of hazard at PES Transient exposure calculated as a proportion from continuous value.
9. Model	*Qualitative*: Explosives Risk Assessment (ERA) Database (management tool) *Quantitative*: AUSRISK version 4 and ERISKAT version 2. SAFER is also available. All for conducting sensitivity analyses
10. Protocol	OPSMAN 3, Section 10 provides policy, responsibilities, methodology (qualitative and quantitative), and the application of Explosives Risk Management within Defence
11. Consensus	Approved within Defence by Explosives Storage and Transport Committee as tool to support licensing
12. National POC for AC/326	Mr Tony Robson, Head Technical Regulatory and Audit Address:- CP4-3-160, Directorate of Ordnance Safety, Campbell Park Offices, Canberra, ACT 2620, AUSTRALIA Telephone +61 02 62664498 Fax +61 02 62664781 Email tony.robson@defence.gov.au
13. Supplied by	Ms Rachel Campbell, Technical Regulation & Audit Address:- CP4-3-160, Directorate of Ordnance Council, Campbell Park Offices, Canberra, ACT 2620, AUSTRALIA Telephone +61 02 62662709 Fax +61 02 62664781 Email rachel.campbell@defence.gov.au

Country: **CANADA** **(2015)**	**Use:** **Risk management for: introduction into service; handling; storage; and, disposal of Ammunition and Explosives.**

1.	Goals	To provide an overarching risk management process that can be applied to select Ammunition and Explosives activities.
2.	Measures	Low risk is considered ALARA and deemed to be “minimum accepted levels of safety”; risk assessment required where these levels are not met. Combination of qualitative and quantitative methodology.
3.	Criteria	Critical criteria are injury or death of persons. Loss or damage of materiel and infrastructure also considered.
4.	Risk Formula	Risk = probability x consequence
5.	Frequency	Event frequency is determined based upon historical data and expert opinion. Guidelines assist in determination of the level: likely, probable, remote, improbable and extremely improbable.
6.	Effects	Consideration of explosion effects (blast, fragmentation & debris, thermal, ground shock, propagation).
7.	Consequence	Guidelines assist in determination of the level: catastrophic, major, minor or negligible.
8.	Exposure	An annual probability of death of one in a million (1×10^{-6}) is determined to be an acceptable level for individual members of the public whereas 1×10^{-4} is the limit for individual workers.
9.	Model	SAFER and FAST-Site for quantitative values.
10.	Protocol	C-09-005-001/TS-000 Ammunition and Explosives Safety Manual Volume 1 Program Management and Life Cycle Safety
11.	Consensus	DAER on behalf of the Chief of Defence Staff and the Deputy Minister through *Explosives Act* exemption as developed based on international group of experts of AC/326
12.	National POC for AC/326	Gilles Belley Director Ammunition and Explosives Regulation National Defence Headquarters 101 Colonel By Drive Ottawa, Ontario, Canada K1A 0K2 Tel: +1-819-939-8425 Email: Gilles.Belley@forces.gc.ca
13.	Supplied by	Wayne Haggart Director Ammunition and Explosives Regulation 2-4 International Programs and Risk Management National Defence Headquarters 101 Colonel By Drive Ottawa, Ontario, Canada K1A 0K2 Tel: +1-819-997-7949 Email: Wayne.Haggart@forces.gc.ca

Country: **FRANCE** **(2008)**	**Use:** **Examine the risks due to each facility with explosive substances and give administrative approvals**

1. Goals	Get the administrative approvals
2. Measures	The method is not quantitative.
3. Criteria	Each ES has to be situated in a hazard zone compatible with the frequency of accident for the PES considered
4. Risk formula	The method is not quantitative. One takes account of : ♦ the frequency of an accident, ♦ the importance of the consequences of the accident, ♦ the frequentation of each ES.
5. Frequency	One uses five magnitudes of frequency from P1 (the lower one : less than 10^{-4} accident per year) to P5 (the higher one : more than 10^{-1} accident per year).
6. Effects	One uses five hazard zones from Z1 (the more hazardous: lethal injuries) to Z5 (the less hazardous: very small probabilities of light injuries).
7. Consequence	See 6.
8. Exposure	Each ES is described as a function of the people involved and the corresponding exposure (11 types).
9. Model	The method is not quantitative.
10. Protocol	Labor Decree 79-846 dated September 1979 Environnemental CODE articles L511-1 and next “Arrêté d’application” dated 20 April 2007
11. Consensus	Procedure approved and compulsory for each activity involving explosive substances and munitions in the civilian field and by the armed forces.
12. National POC for AC/326	Mr Albert Audouy STBFT 9, rue des Récollets F 78000 Versailles Tel: +33-1-39076774 Fax: +33-1-39076771 E-mail: bpsi@stbft.terre.defense.gouv.fr
13. Supplied by	Mr Régis Guégan IPE/SP 5 bis, Avenue de la porte de Sèvres F 75509 Paris Cedex 15 Tel: +33-1-45525207 Fax: +33-1-45526027 E-mail: regis.guegan@dga.defense.gouv.fr

Country: **GERMANY** **(2015)**	**Use:** **Specialists assess non-standard ammunition storage scenarios**
1. Goals	Consistent analysis tool for the responsible person in the German MOD to assess non-standard ammunition storage scenarios.
2. Measures	Expected event frequency. Expected number of accidental fatalities as consequence measure. Individual and societal risk of accidental fatality. The basis (yardstick) for risk assessment is the cumulated risk of all type of accidental fatality in Germany. Risk Factor Rc = 5 * E-4.
3. Criteria	There is no officially accepted risk criterion. A decision has to be taken on a case by case basis. For example, it could be that risk of accidental fatality for individuals involved in the scenario shall not exceed 20% of Rc. Comparable to the job-related risk in chemical industries. Ri < 1 * E−4. Societal risk of accidental fatality for all ammunition storage activities in Germany shall not exceed Rs < 1 * E-7.
4. Risk formula	*Risk factor = Event frequency * Event Consequence* R = Fe * Ce [fatalities per person –year] *Risk normalized to the German population on an annual basis.*
5. Frequency	Expected event frequency Fe [events/person-year], normalized to the German population on an annual basis. Fe-table generated by expert analysis based on ammunition accident database. Fe depends on HD, compatibility, activity and scaling.
6. Effects	Fatal effects of blast, fragments, debris, building collapse and thermal. Pfei (0 to 1), percentage of fatality for the individual ‘i’ present at the local sub-scenario ‘x’ given an event. Differentiate unprotected, semi protected, protected personnel, personnel in buildings.
7. Consequence	Expected event consequence Ce = Σ(Pfei * Ni * Epi) measured in [fatalities/event]. Sum up all involved individuals i = 1 to N.
8. Exposure	(Ni * Epi). Determine the expected exposure of all individuals to all PES, create sub-scenarios. Ni marks the individual ‘i’ involved in the local sub-scenario at location ‘x’. Epi (0 to 1) is the time exposure factor for individual ‘i’ at location ‘x’. Complex if several PESs are involved, if individuals are present at different places at different time.
9. Model	Explosive Safety Quantitative Risk Assessment (ESQRA-GE)
10. Protocol	Decision processing flow chart follows the Risk Acceptance Logic. Results of seven analysis steps are recorded. PES, ES, consequences and iso-risk marked on map and printed in table and diagram.
11. Consensus	Concept accepted within the German Group of Experts. Develop consensus from international agencies.
12. National POC for AC/326	LTC Sascha Decker Division Ammunition Safety / Range Safety in the Territorial Command of the Federal Armed Forces Kurt-Schumacher-Damm 41 D-13405 Berlin, Germany Tel: +49 30 4981 - 3475 Fax: +49 30 4981 - 3462 Email: SaschaDecker@bundeswehr.org or KdoTAAbtMunTSichhSchSichhDez1Grundlagen@bundeswehr.org

13. Supplied by	Fraunhofer-Institut fuer Kurzzeitdynamik Ernst-Mach-Institut, Am Klingelberg 1 D 79588 Efringen-Kirchen, Germany Dr Malte von Ramin Tel: +49 7628 9050 749 Fax: +49 7628 9050 77, Email: Malte.von.Ramin@emi.fraunhofer.de

Country: **Use:**
THE NETHERLANDS (2015) **To assess the risk for external safety of ammunition storage in the Netherlands and deployed locations.**

1. Goals	To assess and analyse individual and societal risk of third parties where QDs could not be applied
2. Measures	Individual risk: • Risk for individuals which are unprotected and standing at a specific location, 24hrs a day, 365 days a year. This is expressed as Iso-risk contours Societal risk: • Risk for a group of persons in a given condition (e.g. time of exposure, (un)protected, etc.).
3. Criteria	Individual risk: • Existing situations: 10^{-5} (per year) • New situation: $1x10^{-6}$ (per year) Societal Risk (F/N-curve): • $FxN^2 = 1x10^{-3}$ (N is number of expected fatalities and F is cumulative frequency)
4. Risk Formula	Individual risk at given location for PES 1 to n: • $\Sigma\ [P_e]_n \times [P_{f/e}]_n$ Societal risk: • For each explosion scenario (each PES) the total number of fatalities (absolute) in the environment and the cumulative initiation frequency are put in an F/N-curve.
5. Frequency	Average value for deep storage is $1x10^{-5}$ (per magazine per year). Other conditions: experts opinion based on results of international (NATO partner) studies
6. Effects	Various effect models related to blast, fragments, debris, and thermal effects.
7. Consequence	Dutch “Green Book”: probit-functions which assess the probability of fatality given a specific explosion effect
8. Exposure	Individual risk: • 24 hrs a day, 365 days per year Societal risk: • Actual presence of persons and their conditions is taken into account
9. Model	Risk-NL Version 5.0
10. Protocol	Described in MP40-21 (publication of the Ministry of Defence)
11. Consensus	Nationally approved methodology
12. National POC for AC/326	Head of section Military Committee on Dangerous Goods P.O. Box 90822, 2509 LV Den Haag, The Netherlands Tel +31 (0) 6 53773481 316 5091 Email JP.Kollmann@mindef.nl
13. Supplied by	TNO Defence, Security and Safety P.O. Box 45, 2280 AA Rijswijk, The Netherlands Tel +31 (0) 888 666 1288 Email martijn.vandervoort@tno.nl

Country: **NORWAY** **(2015)**	**Use:** **Siting explosives facilities and land use in adjacent areas**
1. Goals	To establish a consistent basis for siting explosives storage based on risk, which supplements the existing QD methods.
2. Measures	Six measures are used: Annual likelihood of fatality from any individual (1st, 2nd, and 3rd party) and the annual expected fatality for all persons (1st, 2nd, and 3rd party). Generation of Iso-risk contours for land use control.
3. Criteria	Criteria for approval Annual E(f) for 1st party + 2nd party + 3rd party = 3×10^{-4} Annual E(f) for 2nd party + 3rd party = 2×10^{-4} Annual E(f) for 3rd party = 1×10^{-4} Annual Maximum Individual P(f) for 1st party = 4×10^{-5} Annual Maximum Individual P(f) for 2nd party = 3×10^{-6} Annual Maximum Individual P(f) for 3rd party = 2×10^{-7}
4. Risk Formula	$E(f) = P(e) \times P(f/e) \times E(p) \times \varphi (P(f/e))$
5. Frequency	P(e) generated from curves linear to stored quantity, checked against historical data
6. Effects	Various models comparable to methods given in AASTP-1.
7. Consequence	Various consequence models related to blast, fragments, debris, and thermal effects.
8. Exposure	Separate input of maximum presence for calculation of individual risk and average presence for calculation of group risk. The presence is described in several situations in each – approximately constant number of persons are exposed.
9. Model	AMRISK
10. Protocol	Decision processing flow chart as implemented in the Norwegian Logistics Organization quality system.
11. Consensus	Approved methodology within Norway. Included in the Norwegian Law/Provisions (civilian and military). Cooperation with Sweden for consensus model.
12. National POC for AC/326	Hans Øiom Forsvarets logistikkorganisasjon - Felles Pb 24 2831 Raufoss Norway Telephone +47 6251 5745 Cell +47 9153 5521 Fax +47 6251 5725 Email hoiom@mil.no
13. Supplied by	Same as block 12.

Country: SWEDEN (2015)	**Use: Siting explosives facilities**
1. Goals	To establish a consistent basis for siting explosives storage based on risk, which supplements the existing QD methods.
2. Measures	Measures are: Annual likelihood of fatality from any 3rd party individual and the annual expected fatality for all 3rd party persons
3. Criteria	Annual E(f) for 3rd party 1 × 10^{-4} as a criterion for approval Annual Maximum Individual P(f) for 3rd party = 1 × 10^{-6}
4. Risk Formula	E(f) = P(e) × P(f/e) × E(p) x φ (P(f/e))
5. Frequency	P(e) generated from curves linear to stored quantity, checked against historical data
6. Effects	Various models comparable to methods given in Swedish Fortification Handbook within 20%.
7. Consequence	Various consequence models related to blast, fragments, debris, and thermal effects.
8. Exposure	Separate input of maximum presence for calculation of individual risk and average presence for calculation of Collective risk. The presence is described in several situations in each – approximately constant number of persons are exposed.
9. Model	AMRISK
10. Protocol	Decision according to standard procedures for ammunition storages
11. Consensus	Approved methodology within Sweden for storage. Cooperation with Norway for consensus model.
12. National POC for AC/326	Rickard Forsén, Swedish Defence Research Agency-FOI, SE 147 25 Tumba, Sweden Telephone (46) 8 5550 3941 Fax (46) 8 5550 4180 Email rickard.forsen@foi.se
13. Supplied by	Roger Berglund, Swedish Defence Research Agency-FOI, SE 147 25 Tumba, Sweden Telephone (46) 8 5550 3990 Fax (46) 8 5550 4180 Email roger.berglund@foi.se Carl Elfving, Swedish Fortifications Agency SE-631 89 Eskilstuna, Sweden Telephone (46)10 444 149, Fax (46) 16 13 37 02 Email carl.elfving@fortv.se

Country:
SWITZERLAND
(2015)

Use:
- Optimization of safety by cost effective risk reduction
- Storing, handling and transportation of ammunition and explosives within the forces and military administration
- Siting of explosives facilities

1. Goals	Ensure safety of all activities with ammunition and explosives based on a consistent risk based methodology Main tool for safe siting of new installations and licensing of storages
2. Measures	Individual risk and perceived collective risk Representative measure: lethal effects
3. Criteria	Individual risk: Upper limiting values - third persons 3 x 10^{-6}/ - indirectly involved persons 1.5 x 10^{-5}/y* - fully involved persons 3 x 10^{-5}/y* Perceived collective risk: Willingness-to-pay & marginal cost criteria - third persons 30 mill CHF/life saved* - indirectly involved persons 12 mill CHF/life saved* - fully involved person 6 mill CHF/life saved* * proposed criteria, yet effective
4. Risk Formula	Individual risk IR = $P_{(e)}$ $P_{(f/e)}$ $E_{(p)}$, $P_{(e)}$ = Frequency/Probability of event, $P_{(f/e)}$ = Lethality of person, $E_{(p)}$ = Probability of exposure Perceived collective Risk PR = A·Σ IR (simplified), A = Risk aversion factor
5. Frequency	Storage: $P_{(e)}$ = A + B x Q, (simplified) A, B depending of type and location of storage, operation, and storage-probability-group of ammunition, Q = amount of stored ammunition Fabrication: basic frequency rate system
6. Effects	Models for all basic explosion effects contained in TLM 2010/Part 2. Results are physical effects at an exposed site.
7. Consequences	Models for lethality of persons due to air-blast and debris contained in TLM 2010/Part 2.
8. Exposure	Actual exposure of persons on a time scale is taken into account. Risks are calculated based on situations wherein the number of people is assumed to be constant. This procedure shows the variation of the risk and the maximum number of fatalities to be expected over a time period
9. Model	RIMANA (fully compatible with procedure according to TLM 75/2010)
10. Protocol	Regulations: WSUME, TLM 2010/Part 2
11. Consensus	Approved methodology. Mandatory for all activities with ammunition and explosives within the forces and military administration.
12. National POC for AC/326	Jachen Cajos, Swiss DOD, IOS-OSI Head OSI, CH-3003 Bern, Switzerland Telepone +41 58 464 2092 Fax +41 58 463 3821 Email jachen.cajos@vtg.admin.ch
13. Supplied by	Peter Kummer, Bienz, Kummer, & Partner Ltd. Langaegertenstrasse 6 CH-8125 Zollikerberg, Switzerland Telephone +41 44 391 2737 Fax +41 44 391 2750

	Email bkp@bkpswiss.ch

Country: **UNITED STATES** **(2015)**	**Use: Facilitate informed decisions**: **- Siting explosives facilities** **- Reduce risks where explosives exist**
1. Goals	Support U.S. national policy to adopt risk-based methods where possible. Specifically, to establish a consistent basis for siting explosives facilities based on risk, which supplements the existing QD methods. Improve risk management at ports, out of area locations and other high risk locations.
2. Measures	Four measures are used: Annual likelihood of fatality for any individual (related or non-related) and the annual expected fatality for all persons (related or non-related)
3. Criteria	Annual E(f) for related = 1×10^{-3} Annual E(f) for public = 1×10^{-5} Annual Maximum Individual P(f) for a related person = Limit maximum risk to 1×10^{-4} Annual Maximum Individual P(f) for public = Limit maximum risk to 1×10^{-6}
4. Risk Formula	$F = \Delta t * S * \lambda(NEW, E) * P_{f\|e}(NEW, Yield, Effects) * E$ Where Δt is the fraction of time people and explosives are present S is the environmental factors λ is the probability of event $P_{f\|e}$ is the probability of fatality given an event and exposure E is the exposure of personnel to an explosive event based on the number of people present in a facility during the year and the number of hours the exposed site is occupied This method evaluates risk and the associated uncertainty
5. Frequency	P(e) table generated from historical data from the US Army, Navy, Air Force, and Marine Corps
6. Effects	Consensus methods developed by international team as documented in TP #14.
7. Consequence	Consensus methods developed by international team as documented in TP #14.
8. Exposure	Number of people, hours present at ES per year, and time fraction of when explosives and people are present is taken into account
9. Model	Safety Assessment for Explosives Risk (SAFER) v3.1, to become RBESS. TP 23, CJCSI 4360.01, and DoDI 6055.16 address the hybrid site plan model
10. Protocol	Policy as documented in DoD 6055.09-M, specifically implemented in Technical Paper #14, “Approved Methods and Algorithms for DoD Risk-Based Explosives Siting,” Technical Paper #19, “User’s Reference Manual, Safety Assessment for Explosives Risk”
11. Consensus	Developed broad consensus from U.S. and International agencies.
12. National POC for AC/326 AASTP-4	Dr. Josephine Covino DoD Explosives Safety Board (DDESB) 4800 Mark Center Drive Suite 16E12 Alexandria, VA 22350-3606Phone: +1-571-372-6685e-mail: josephine.covino.civ@mail.mil
13. Supplied by	Same as block 12.

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