A complete system for siting ammunition storages based on risk assessment

Abstract

This paper outlines the Norwegian methodology for siting ammunition storage facilities, leveraging Quantitative Risk Assessment (QRA). Norway has for 35 years, based licensing of ammunition storages on QRA.

From mostly paper-based documentation and handling, the routine has been developed into integration of several digitalized tools and databases.

Except from the license that can be printed out, the process no longer produces paper. The limiting factor now is the ability to sustain knowledge of the background and use of the system rather than the capacity to produce licenses.

The intent of the presentation is to show how this system works

Introduction

Effective storage and handling of ammunition and explosives require robust policies, methodologies, and safety rules to mitigate risks and ensure operational safety. Approving ammunition storage areas poses several challenges, including areal limitations and the complex activities within these sites. Comprehensive knowledge of the site and its buildings is required, along with ensuring safe and efficient storage practices. The siting system needs to be simple, minimizing errors, and offering flexibility. For maximum effectiveness, the system should be digital, reducing reliance on manual paperwork.

In NATO, two primary approaches are recognized for siting: Quantity Distance (QD) methods, which focus on the amount of explosive material and physical separation distances, and risk-based methods (RBM), which consider a comprehensive set of factors influencing safety, including probabilities of events, effects, consequences, and personnel exposure. Norway adopts a risk-based approach, utilizing a structured 11-step process, Figure 1, outlined in NATO guidelines (AASTP-4), providing a thorough understanding and management of potential risks.

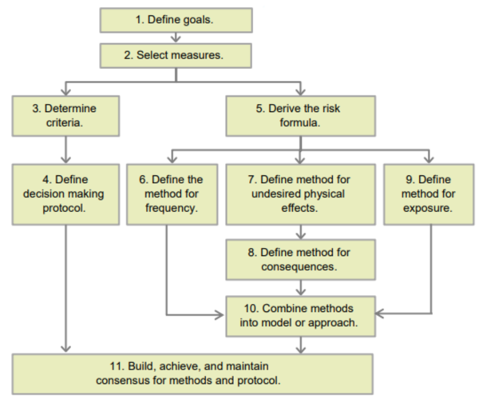

Figure 1. Risk based approach AASTP-4 part 1 [1].

The primary purpose of this paper is to present a comprehensive overview of the Norwegian approach to siting ammunition storage facilities, emphasizing the application of quantitative risk assessment (QRA). It will explore the structured processes, key systems (such as HER, AMRISK, and AMSYS), and the organizational roles involved in this critical decision-making process. The paper further investigates the integration of these elements, showcasing how they collectively contribute to a robust and reliable safety framework. Ultimately, the aim is to offer a clear understanding of how Norway balances operational needs with stringent safety requirements, providing valuable perspectives for other nations facing similar challenges.

Risk assessment Framework in Norway

This section details the initial steps of the risk assessment methodology, Figure 1, essential for establishing a clear and effective framework for managing ammunition storage risks.

Norwegian experience with RBM dates back to the late 1980s, supported by specialized risk analysis tools such as the AMMORISK and later AMRISK programs. These tools, developed through international collaboration, in the early 90-es mainly with Switzerland but also bi-lateral with UK. In the late 90-ies and early 2000 collaboration with Sweden became more pronounced, and the tool have evolved over time, with the latest version (2.5) released in 2021 and an upcoming version (3.0) under development. The risk criteria in Norway are based on probabilistic assessments, societal risk considerations, and safety distance calculations, with ongoing evaluations to reflect economic and societal changes.

Figure 2. The Norwegian Department of Defense hierarchy.

Figure 2 shows the hierarchy of the Norwegian Department of Defence. The Norwegian Defence Material Agency (NDMA) is at the same level as the Armed Forces, Estates Agency and Research Agency. The Norwegian defence is regulated by the Law for fire and explosives prevention but is exempted for most of the provisions under the Law. This means that the defence must satisfy the general safety norm but can apply their own regulations to support the required safety. The ammunition section is one of the offices in NDMA. Norwegian decision-making protocols for ammunition safety are governed by national regulations, which align with broader legal frameworks and are overseen by the Norwegian Defence Material Agency (NDMA). These protocols ensure a consistent, safety-oriented approach to risk analysis and storage approvals, integrating military requirements with civilian safety standards. Although ammunition safety is a material agency responsibility the NDMA always worked closely and coordinated with NDEA and FFI on management as well as development. This document provides an overview of the current methodologies, criteria, and decision frameworks that underpin munition safety in Norway, serving as a foundation for further developments and improvements.

Define Goal

The initial step emphasizes establishing a clear, understandable, and actionable objective. The primary goal is to make decisions based on state-of-the-art knowledge while efficiently allocating resources to achieve the necessary accuracy. This involves optimizing the analysis for quality results, reducing uncertainties, and keeping input streamlined, avoiding a significant increase in resources compared to Quantity Distance methods.

Select Measures

For Explosive Safety Quantitative Risk Assessment (ESQRA), the primary measures are Individual Risk (IR) and Group Risk (GR). IR is defined as the annual probability of lethal injury to a specified person, calculated as IR = probability of event * consequence * exposure. Group Risk limits the collective risk, considering the expected number of fatalities across all exposed objects: RE = Pe * Fn. The methodology incorporates an aversion factor (Φ) to account for increased risk in short-duration exposures. The perceived Group Risk (RP) is then calculated as $RP = Pe * \sum(Fn(n) * \varphi(n) * duration(n))$. The central values of individual risk, group risk and aversion factor has proven effective for evaluation of risk for 4 decades.

Determine Criteria

Well-defined criteria are established based on provisions approved by the Ministry of Defense. Key to these criteria is the average probability of event (5x10-5, derived from historical data), individual risk based on lethality assessments (2x10-7), and societal risk considerations. Group risk is determined by factoring in the general accident rate, GDP, the value of the storage, and the Norwegian population. Periodic updates to these acceptance criteria are necessary to reflect current social benefits and economic values.

Define Decision-Making Protocol

Norwegian decision-making protocol follows the provision for ammunition safety given by the Department of Defence, which breaks down to regulations handled with "Reglement for ammunisjonstjenesten – fellesregler". NDMA ammunition safety office is exempt from regulations subject to the law and follows directives from the ministry. It involves coordination among the Norwegian Defence Material Agency (NDMA) and other relevant bodies to ensure a consistent and safety-oriented approach. Regulations are signed by the delegated authority of the commander of the FMA/LAND division.

Systems used in Norway

Comprehensive Property Register (HER)

The Norwegian Defence Estate Agency (NDEA) updates and own the HER. The list contains all buildings, owners, building types for military areas in Norway, size and other relevant information. All buildings have a unique number related to the location area and placement in Norway. This list is uploaded in AMSYS. The updates is on a yearly basis, or when there are updates to areas.

Ammunition System (AMSYS)

AMSYS is used to manage inventory of ammunition storage and ammunition lots. It is strongly attached to Systems, Applications & Products in Data Processing (SAP) and is based on Oracle database. AMSYS is a more detailed database and draws out necessary information from SAP basic data. With input from HER on all buildings on defence sector estates It is possible to extract quantity in each storage or munition article data. Input to AMSYS is HER, SAP. With all those data points and risk assessment the output is approval and sertificate (safety and security).

AMRISK

AMRISK is a developed through joint effort between Norway and Sweden and is a software tool designed for Explosives Safety Quantitative Risk Analysis (ESQRA). It calculates risk values for individuals near military or civilian ammunition storage sites, considering the complete chain of events from potential accident to hazards to exposed persons. Developed collaboratively from the original Swiss AMMORISK (used in Norway since 1985 and Sweden since 1999). AMRISK is updated in collaboration between Norway and Sweden as a project. AMRISK evaluates the probability of an accident, subsequent free field effects (air blast, ground shock, heat, debris), interaction with objects, and the impact on humans.

The software encompasses as shown in Figure 3

- Event analysis
- Effect analysis (air blast, debris, cratering, ground shock)
- Exposure analysis
- Individual and group risk calculation

The models are implemented from STANAG 4802 – AASTP 4. The resulting risk assessment compares calculated values to established risk criteria. AMRISK is intended for use by safety professionals with expertise in ammunition storage and risk analysis, providing a comprehensive approach to managing explosives-related risks. The AMRISK is also used by the civilian sector for documenting acceptable risk as required by the provision for prevention of major accidents (Norwegian implementation of the Seweso-directive).

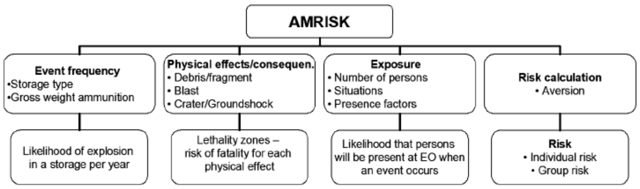

Figure 3. General description of the structure of AMRISK.

Workflow and Documentation Systems

Systems described above are linked together as shown in Figure 4, with different security levels. The only paper in the process is the approval, but also this could be sent to the end user digital. The approval needs to be put up on the wall of the belonging storage. Input to the system is secret and restricted data with unclassified outputs for community management purposes. Figure 4 outlines the “documentation system” used in Norway. Input data from the user or site inspection within the ammunition area are entered into the AMRISK system. Based on this input, an area restriction is generated and sent to the NDEA, which creates an unclassified map image and transmits it to the local municipality. Additionally, a report is produced on a secret platform, which is then transferred to the AMSYS system, also classified as secret. This report includes information such as the nearest buildings, individual risk assessments, and group risk considerations. There is also an option to adjust parameters such as quantities, compatibility groups, and other relevant factors, which can be stored for further use. The system also provides a preview of how the approval will look, allowing users to go back and make adjustments as needed. Subsequently, these data are transferred to AMSYS on a restricted platform, from where they can be retrieved and sent to the user via the agency’s document management system.

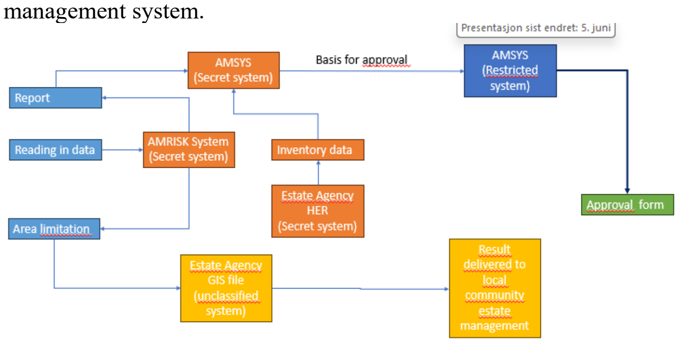

Figure 4. Documentation system.

The flowchart in figure 5 shows what triggers a risk analysis (blue). The steps are different for some of the steps. There may be a need for a whole new risk analysis, if the storage area has never been used before. If there is a change in stock requirements, periodic need for update, change in environment, change in presence or incorrect data there is also a need for a new risk analysis.

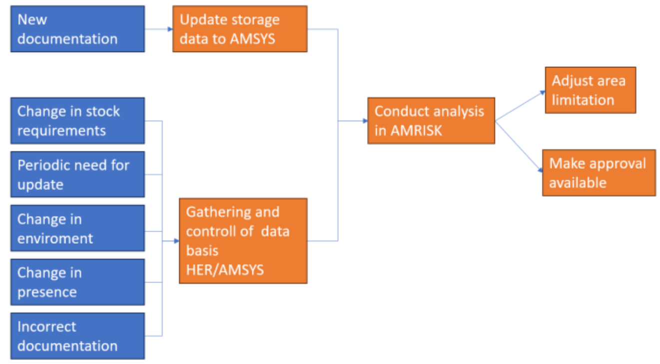

Figure 5. Workflow chart.

Siting in Norway are applicable to supply ammunition storage, department storage (kasun with small amounts will not be risk assessed. 65kg 1.2.2 and 1.3.2), shelter and parking site for plane, harbor, loading unloading space and magazine on vessel (do not use AMRISK, but evacuation plan in case of fire).

In addition to the explosive safety approval, a security certificate is also needed to store ammunition in Norway. The certificate secures Attractive Weapons and Ammunition (AVA) and is given if the site is found secure enough according to intrusion time versus response time. If the site only stores weapons this is the only document needed. For ammunition you need a certificate and approval. Without the AVA certificate there is a need to guard the site around the clock.

Risk analysis framework

The primary purpose of both methods is to facilitate informed decision-making to ensure proper management of storage facilities. There are two directions to achieve this in NATO:

- Quantitative methods – AMRISK (AASTP-4)
- Qualitative methods – QD (AASTP-1)

Quantitative methods, (AASTP-4), offer a high degree of adaptability to various scenarios and are considered cost-effective relative to the measures implemented. However, these approaches can be more skill-intensive, requiring proficient personnel to ensure correct application. Faulty or unqualified use of the method could significantly elevate risks, especially if any of the 11 critical steps are overlooked or fail. Precision and thoroughness are essential to prevent increasing the potential for errors that could compromise safety and efficiency.

In contrast, qualitative methods such as QD (AASTP-1) enable rapid decision-making through the use of clear and straightforward requirements. They are designed to be accessible, requiring less expertise to operate effectively. While offering flexibility in adapting to different situations, these methods often entail extensive requirements related to volume and distances, which can complicate implementation. Additionally, mitigation measures derived from qualitative assessments can be costly and may lack targeted effectiveness. The process frequently relies on voluminous tables that must be supported by specialized tools to manage large datasets efficiently. Overall, each approach has its strengths and limitations, and selection depends on the specific context, resources, and operational demands.

Summary/Conclusions

This report has demonstrated how Norway's approach to risk analysis and siting of ammunition storage facilities is built on a structured and comprehensive methodology, combining both qualitative and quantitative tools to ensure safety and operational efficiency. By utilizing risk assessment techniques such as AMRISK and systems like HER and AMSYS, Norway facilitates a documented, risk-based decision-making process that accounts for both uncertainty and background knowledge.

The importance of following the 11-step process and ensuring sufficient expertise is crucial for maintaining high safety standards. At the same time, the methods are adapted to the context, with Norway primarily using quantitative approaches for siting, while qualitative assessments apply for internal distance settings. This ensures a flexible yet precise approach that balances risk, costs, and resource use.

The integrated use of digital systems and clear procedures provides a foundation for consistent and transparent risk management. This supports continuous improvement and adaptation in response to new challenges and technological developments.

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Contact Information

Ann Leni H. Fladvad
Senior Engineer
Norwegian defence materiell agency
Land and joint Capasities.
Ammunition.
e-post: afladvad@mil.no
Telefon: 6251 5731 - Mobil: 920 80 512