QUANTITATIVE RISK ANALYSIS OF AMMUNITION TRANSSHIPMENT IN HARBORS

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TRANSSHIPMENT IN PRACTICE

SOURCE OF RISK

- Ammunition transshipments are a source of risk to the surrounding area and the people nearby (involved in the transshipment or third parties)
- In a harbor generally large volumes and quantities of ammunition and explosives are transshipped, so the expected effects of an explosion are significant (reaching up to several kilometres)

- The Dutch MoD tasked TNO to develop a method to quantify the risk associated with ammunition transshipments, so an informed decision can be made if the level of risk is acceptable. If not:
  - Possible risk mitigation measures
  - Different harbor to perform transshipment(s)

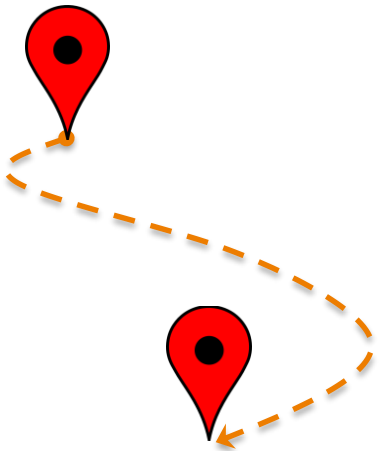
- This presentation gives an overview of the method to perform a quantitative risk analysis of ammunition transshipments in harbors

MAIN CAUSES OF ACCIDENTS

- Crane operations (hoisting of containers)
- Fire on ship or truck
- Accident with vehicles

METHOD FOR RISK ANALYSIS

- Quantitative risk analysis (QRA):
  1. Scenario's for transhipments
  2. Estimation of probability of accidental explosion
  3. Calculation of effects of accidental explosion
  4. Calculation of consequences (lethality) of accidental explosion
  5. Calculation of risks (consequences x probability)
  6. Assessment according to national norms



- QRA performed with TNO Transhipment Tool:
  - Developed especially for this purpose, risk analysis of ammunition transhipments

SCENARIO'S

- For a specific harbor a set of scenarios is defined, this set contains all transshipments that are planned to be performed in that particular harbor in a single year
- A scenario defines:
  - Total amount of explosives and ammunition to be transshipped:
    - NEQ in kg TNT
    - Hazard Division: HD 1.1 is assumed for all ammunition, except HD 1.4 articles
  - Number of transshipments of a certain NEQ per year
  - Number of ISO-containers per transshipment of a certain NEQ
  - Number of kilometers travelled by vehicles in a transshipment of a certain NEQ
  - Type of ship involved (CONRO, RORO, etc.)
  - Amount of time needed for a transshipment

PROBABILITY OF AN EXPLOSION

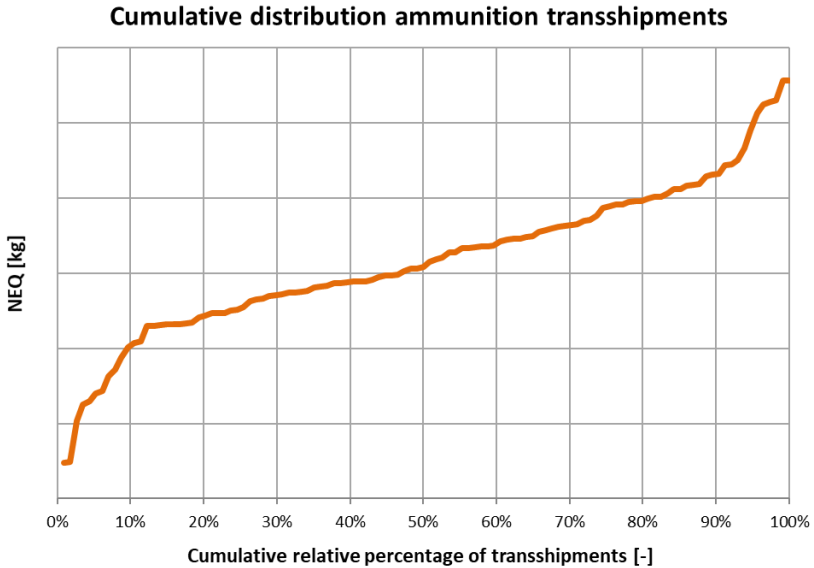
- Based on parameters for each scenario, probability of explosion is determined using:
- $P_{expl} = 2 \cdot \sum P_{event} \cdot N_{event} \cdot P_{expl,event}$
- For several types of accidents, based on historic data, frequencies and probability of explosion are estimated:

Event, unit	Event frequency / unit	Probability of explosion / event
Fire in a vehicle, km	$5.0 \cdot 10^{-9}$ / km	1.0
Accident or collision with a vehicle, km	$1.0 \cdot 10^{-7}$ / km	0.001
Fire aboard a CONRO/general cargo, # of ships	$1.0 \cdot 10^{-6}$ / ship	1.0
Fire aboard a container ship, # of ships	$2.0 \cdot 10^{-8}$ / ship	1.0
Crane accident with container, # of crane moves	$2.0 \cdot 10^{-6}$ / move	0.011

- Cumulated to get total probability of explosion for specific scenario

NEQ PER TRANSSHIPMENT

- To help establish how many transhipments with a certain NEQ need to be planned in a particular port, historic data can be used
- Cumulative (relative) distribution can provide insight



Cumulative distribution of the NEQ NL ammunition transshipments. Based on data from the Dutch Ministry of Defence from the period 2002-2015

EFFECTS OF AN EXPLOSION

- The following physical effects of an accidental explosion are calculated:
  - Peak pressure of the blast wave
  - Peak impulse of the blast wave
  - Duration of positive phase of the blast wave
  - Fragment and debris distribution
  - Heat radiation (HD 1.3)

CONSEQUENCES (LETHALITY)

- The determined explosion effects are related to a probability of lethality using Probit relations:
- $Pr = A + B \cdot \ln X$

- Probit relation either valid for people in the open field or inside a building:

In the open field	Inside buildings

• Fragments
• Debris
• Blast:
  • Lung injury
  • Collision of head
  • Collision of body
• Heat
	• Fragments
	• Debris
	• Combination of factors (model of Gilbert, Lees and Scilly*):
	  • Building collapse
	  • Window breakage
	  • Blast
	  • Etc.

* = Gilbert S.M., Lees F.P. and Scilly N.F., *A model hazard assessment of the explosion of an explosives vehicle in a built-up area*, 1994

QUANTITATIVE RISK ANALYSIS (1)

- Main focus on third party risk, two common concepts to describe this:

A. Individual risk (IR):
   - All transshipments that are planned to be performed in a particular harbor in a single year are considered
   - Does not take into account any buildings
   - Assumes permanent presence of persons in the area of interest
   - For scenarios 1 to *n* : $IR\ (r) = \sum_{i=1}^{n} P_{expl,i} \cdot P_{lethal}(NEQ_i, r) \cdot N_i$
     - $P_{expl,i}$: probability of explosion
     - P_{lethal} : probability of lethality for a certain location
     - N_i : the number of transhipments per year of scenario *i*

QUANTITATIVE RISK ANALYSIS (2)

B. Societal risk or Group risk (GR):

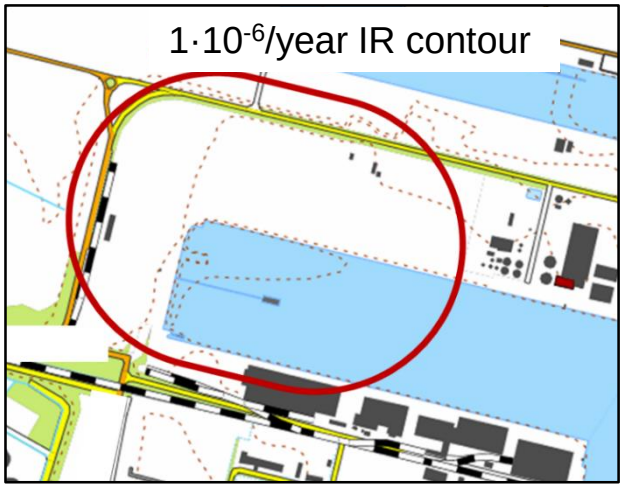
- All transshipments that are planned to be performed in a particular harbor in a single year are considered
- Accounts for actual presence of people in surrounding area and presence of buildings
  - Only within area of influence: area within ‘Inhabited Buidling Distance’ (IBD), obtained from AASTP-1, with an ISO-container as PES
  - A lot of work to gather data:
    - Amount of people present in houses, factories, offices etc.
    - Many parties involved (companies, municipalities, etc.)
- Presented in cumulative F(N) curve, expressing cumulative frequency per year that N or more fatalities can occur

ACTUAL CASE

- Case calculated for NL MoD
- Scenario’s based planned transhipments for coming years (estimate)
- Risk analysis results:
  - Individual Risk
  - Group Risk

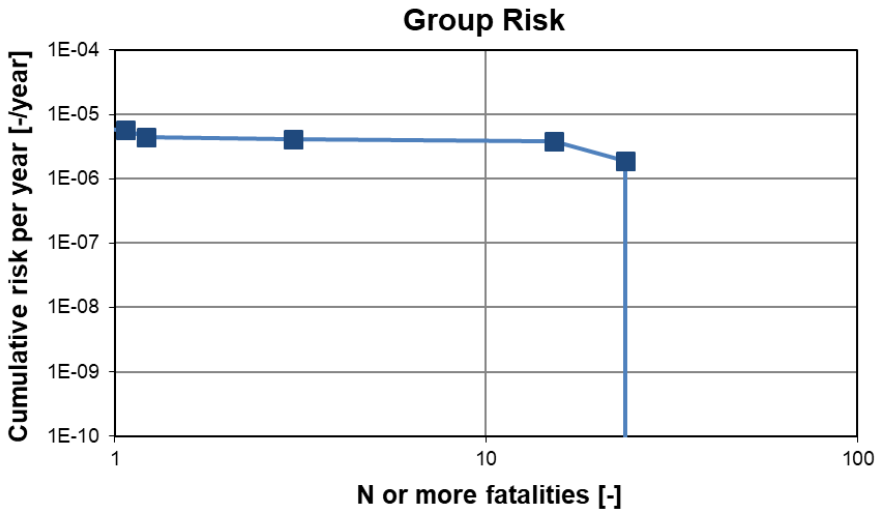
ACTUAL CASE: INDIVIDUAL RISK

- In NL $1 \cdot 10^{-6}$/year is an important limit value for IR
- Inhabited buildings inside this contour are considered an infringement
- Contributions of all scenario's cumulated
- Local and national government decide on acceptance of risk



ACTUAL CASE: GROUP RISK

- Each blue dot represents a number of identical transhipments grouped in one scenario
- Blue curve represents the cumulated contributions of all scenarios
- Local and National government decide on acceptance of risk



POSSIBLE FUTURE DEVELOPMENTS

- Improve debris and ballistic flight condition models for ISO-containers:
  - Axisymmetric debris throw by ISO-containers is very crude assumption
  - Klotz Group research can be used as basis

- Below decks placement of ammunition containers:
  - Research on influence of ship structure on explosion effects
  - Debris and fragment throw, and blast propagation affected by ship structure

- Efforts to develop better/alternative methods to determine probability of explosion:
  - Now, scarcity of data (fortunately), estimated uncertainty up to a factor of 2

THANK YOU FOR YOUR ATTENTION

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