Explosive properties in Conditions of Transport

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Content

- Why assess the transportation risk?
- What can go wrong during transportation
- Why explosives properties matter?
- Quantitative Risk Assessment
- Constraints and challenges

Why assess the transportation risk?

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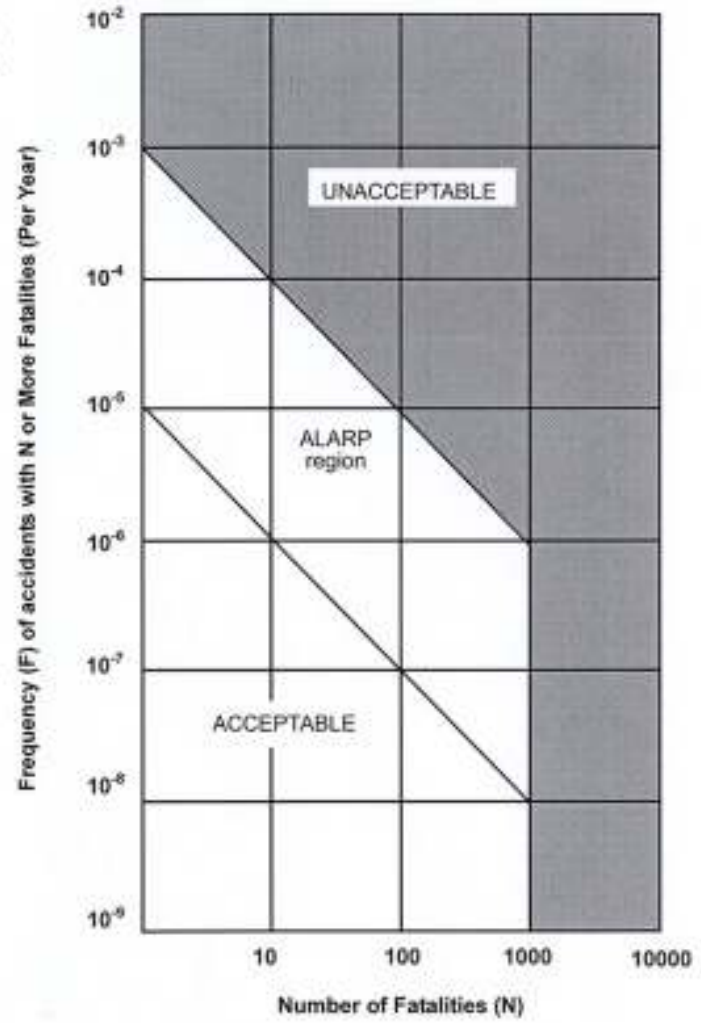
Why assess the transportation risk ?

- **Make-risk based decisions base**
  - route length
  - population density
  - traffic density
  - Proximity to sensitive sites
  - Time of delivery
  - Logistics: all the load in one t
  - Siting of explosives magazine storage, delivery points
- **Comply with local regulations**



What can go wrong during the transportation of explosives ?

Fire related accidents with ANFO and emulsion explosives

Year	Country	Type of Load	Type of Event	Cause
1959	USA	ANFO	Explosion	Vehicle Fire
1998	Canada	ANFO	Explosion	Vehicle crash/ collision
1998	Australia	ANFO	Explosion	Vehicle Fire
2004	Russia	Emulsion	Explosion	Vehicle Fire
2009	Canada	Watergel	Fire	Tyre fire
2010	Brazil	Cartridged emulsion	Fire	Brake fire
2010	Saudi Arabia	ANFO	Fire	Vehicle crash/ collision
2007	Mexico	ANFO	Explosion	Vehicle crash/ collision

Hubei Accident

Gunpowder-loaded truck explosion kills 4 in Hubei China: December 2009

Walden Accident

- August 5th, 1998
- Walden, Ontario
- 18,000 kg
- Intense fire ensued
- Detonation 30 minutes later

Walden Accident

- Severe damage to the tractor-trailer
- Fragments: 2.5 km
- 70 kg piece of axle recovered at over 1 km
- Windows cracked: 3 km

What can go wrong during transportation ? (Cont'd)

- **In general, accidents associated with transport can be grouped into:**
  - Non-crash fire
  - Crash impact
  - Crash impact resulting in fire
  - Spontaneous Explosion ('Unsafe Explosive'):

Why explosives properties matter ?

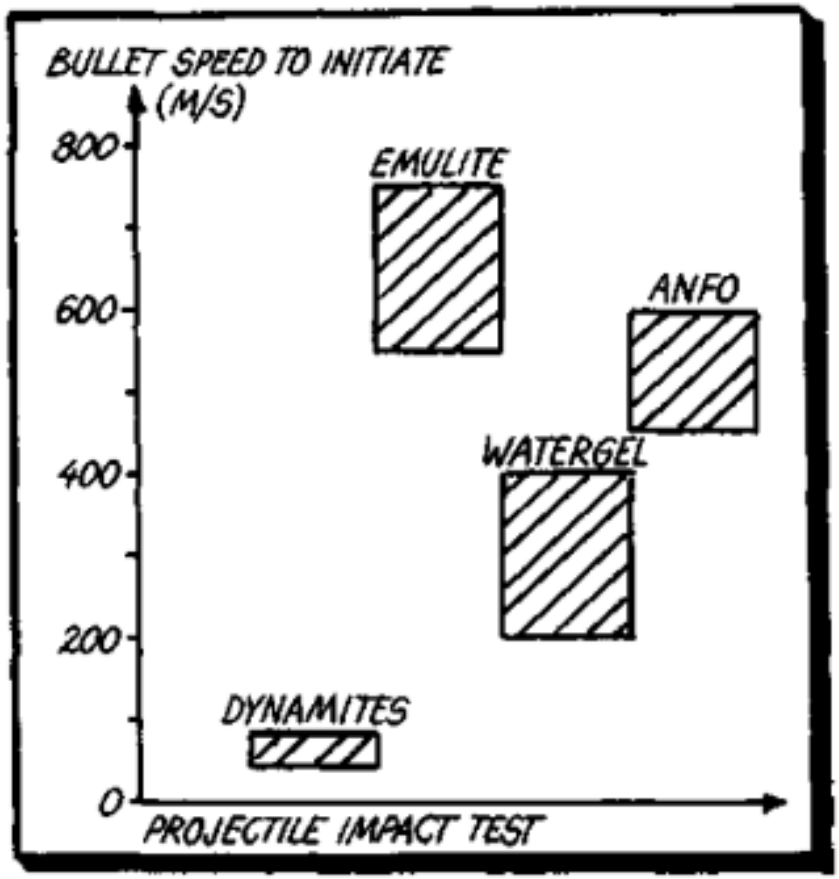
- **How to derive probabilities of cargo load initiation due to:**
  - Friction/impact
  - Heat stimulus
- **Other relevant properties to derive:**
  - Time available before accidental explosion
  - Blast impulse characteristics
  - Propagation potential
  - Level of induced vibrations
  - Fumes toxicity level

AN based Emulsion Explosives – general properties

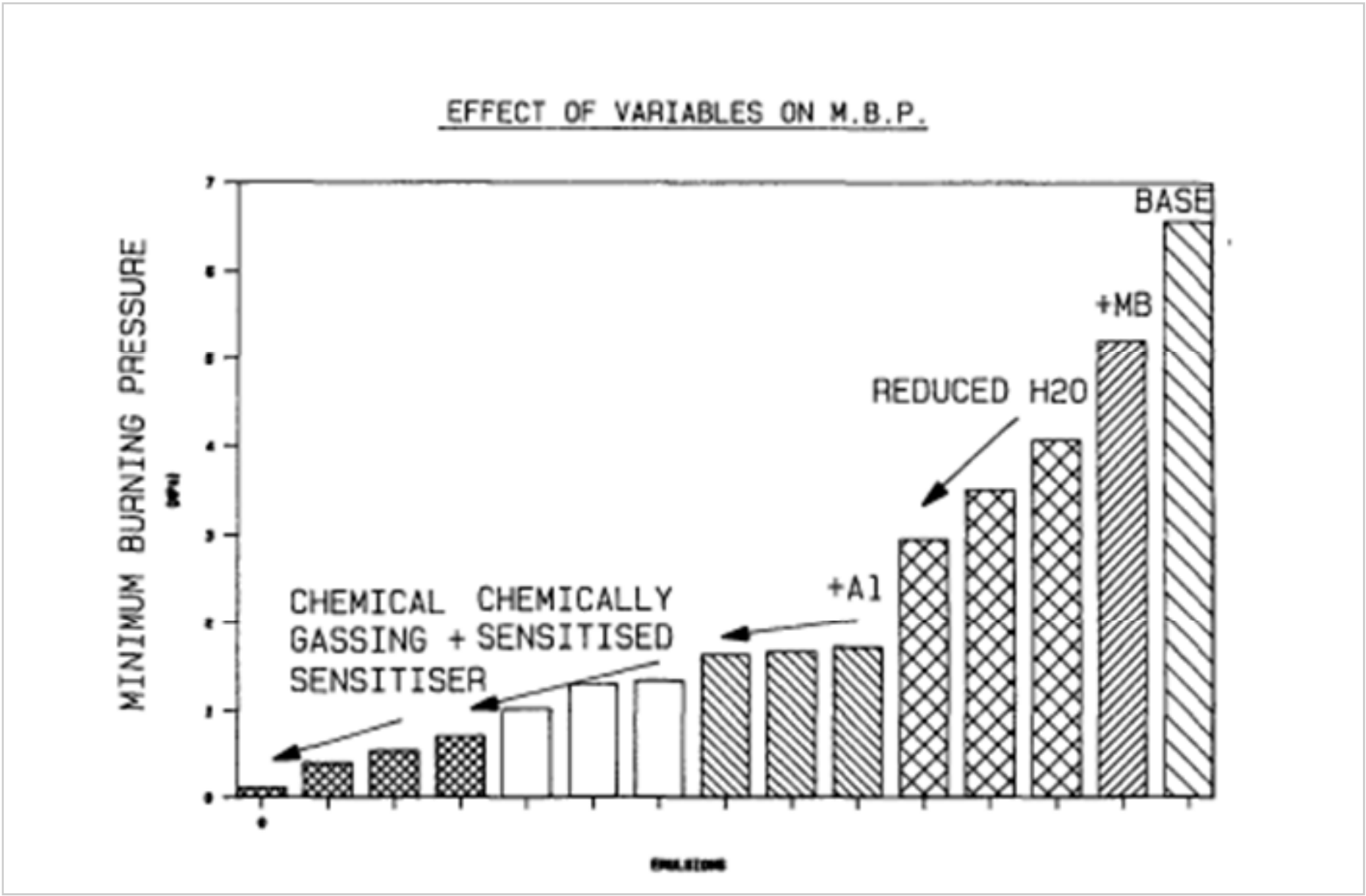
(cartridged emulsion, water 12 %w/w, no sensitiser)

- Largely insensitive to typical mechanical impact, instantaneous friction, electrostatic or photolytic stimuli
- Sensitive to (very) high velocity impact and shock
- Potentially reactive from thermal stimulus once water driven off as steam
- Non-deflagrating at ambient Temperature & Pressure conditions
- Failure diameter for detonation - unconfined ~ > 10-20 mm
- Susceptibility to contamination from energetic species, catalysts/ synergists for AN solution decomposition

Bullet Impact Tests on a range of explosives (Holmberg)

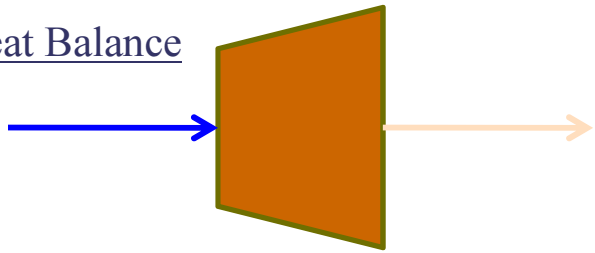


http://www.maden.org.tr/resimler/ekler/1f5738a827405b0_ek.pdf


EFFECT OF VARIABLES ON M.B.P.
MINIMUM BURNING PRESSURE
BASE
+MB
REDUCED H2O
+Al
CHEMICAL GASSING + SENSITISER
CHEMICALLY SENSITISED

Thermal Explosion (Cook-off/ Reaction Runaway) – Critical Temperature - > 140 deg C

Dynamic Heat Balance



Heat Input

Heat Output

Accumulation

Factors

Sensible and latent heats of premix powder

Loss of material (flow, evaporation)

Loss of heat (conduction, convection)

Heat from or to chemical reactions e.g. Endothermic or exothermic

Effect of scale, geometry & environment (heat transfer to environment)

Thermal Explosion/ Reaction runaway

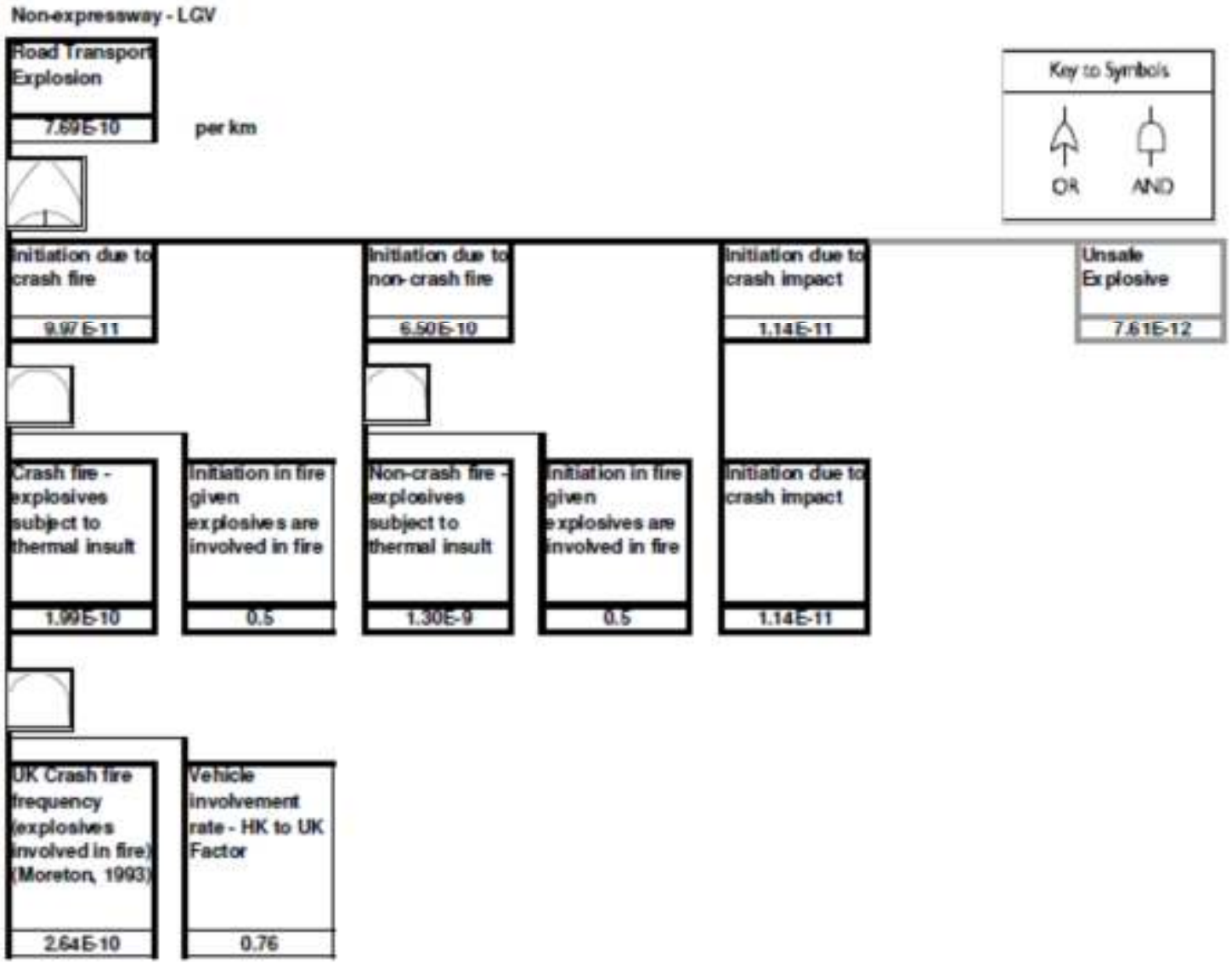
Near simultaneous exothermic reaction - small thermal gradients.

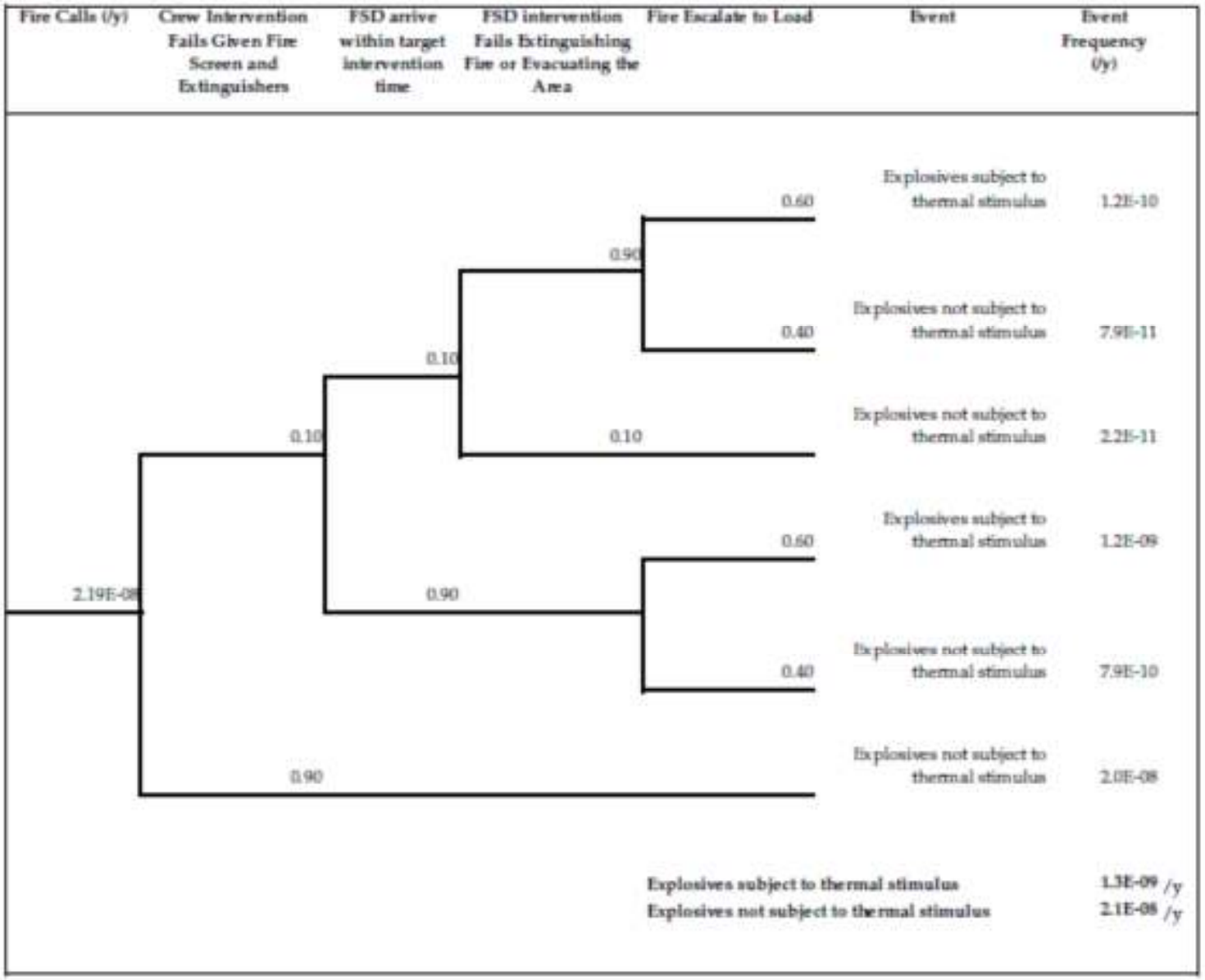
For pure AN, with endothermic & exothermic reaction pathways, onset temperatures for thermal explosion are high, ie ~ MPt.

This onset temperature can, however, be dramatically reduced by the presence of a fuel or catalyst for thermal decomposition

Quantitative Risk Assessment

- **Likelihood/ frequency assessment**
  - What is the chance of a vehicle involved in an accident?
    - Vehicle type
    - Road and traffic characteristics
  - What is the chance of explosion in case of an accident?
    - Vehicle fire
    - Light accident
    - Serious accident
    - Properties of explosives


Non-expressway - LGV
Road Transport Explosion
7.59E-10
per km
Key to Symbols
OR
AND
Initiation due to crash fire
9.97E-11
Initiation due to non-crash fire
6.50E-10
Initiation due to crash impact
1.14E-11
Unsafe Explosive
7.61E-12
Crash fire - explosives subject to thermal insult
1.99E-10
Initiation in fire given explosives are involved in fire
0.5
Non-crash fire - explosives subject to thermal insult
1.30E-9
Initiation in fire given explosives are involved in fire
0.5
Initiation due to crash impact
1.14E-11
UK Crash fire frequency (explosives involved in fire) (Moreton, 1993)
2.64E-10
Vehicle involvement rate - HK to UK Factor
0.76

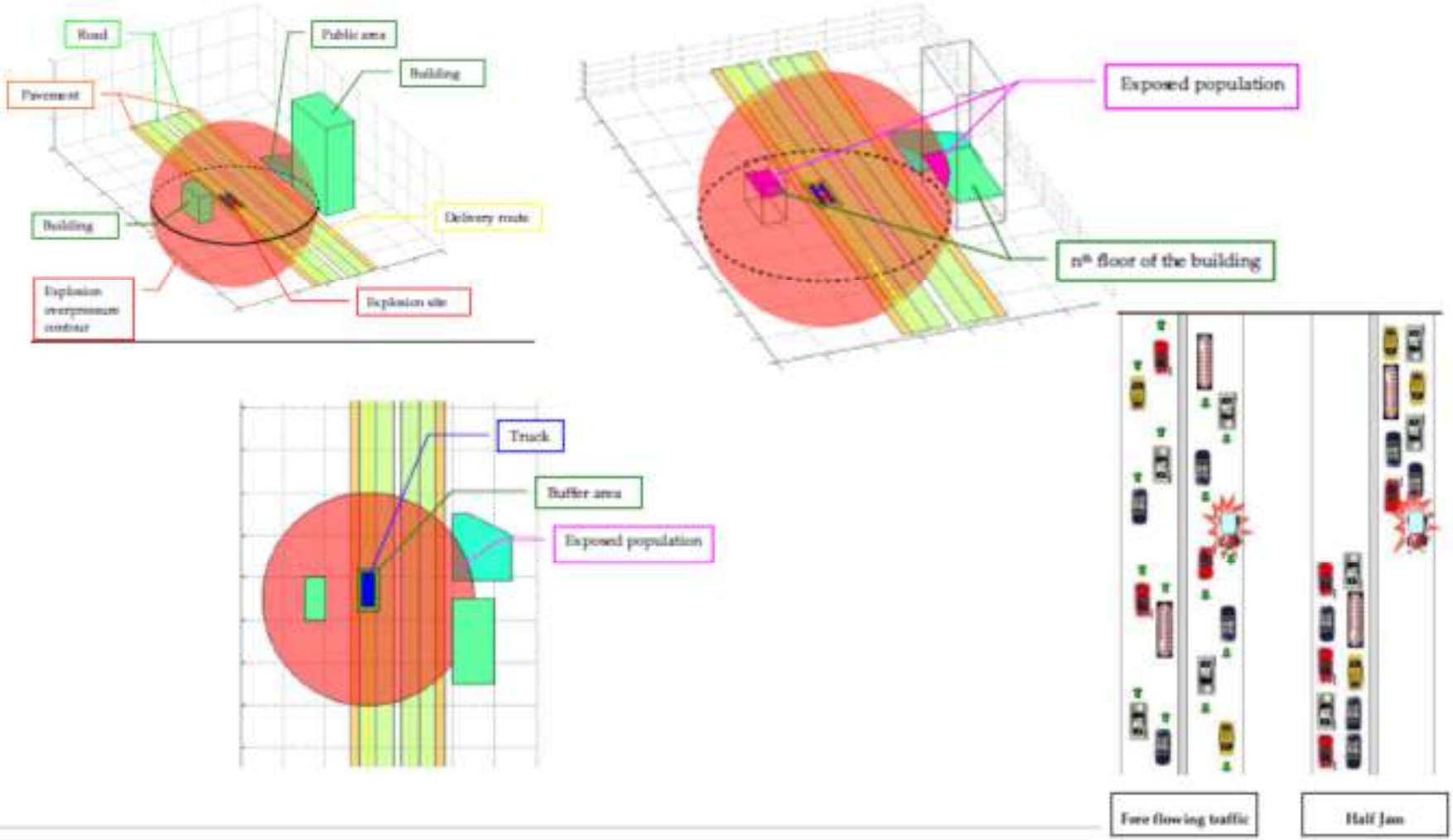

Fire Calls (/y)
Crew Intervention Fails Given Fire Screen and Extinguishers
FSD arrive within target intervention time
FSD intervention Fails Extinguishing Fire or Evacuating the Area
Fire Escalate to Load
Event
Event Frequency (/y)
2.19E-08
0.10
0.90
0.10
0.90
0.60
0.40
0.10
0.90
0.60
0.40
0.90
Explosives subject to thermal stimulus
1.2E-10
Explosives not subject to thermal stimulus
7.9E-11
Explosives not subject to thermal stimulus
2.2E-11
Explosives subject to thermal stimulus
1.2E-09
Explosives not subject to thermal stimulus
7.9E-10
Explosives not subject to thermal stimulus
2.0E-08
Explosives subject to thermal stimulus
1.3E-09 /y
Explosives not subject to thermal stimulus
2.1E-08 /y

Quantitative Risk Assessment (Cont'd)

- **Consequence of event to the explosives and the transportation environment**
  - Extent of Fire
  - Extent of Blast
  - Primary debris
  - Structural response to blast
  - Secondary debris (eg. building windows)

Quantitative Risk Assessment

- **T-QRA Consequence Model**



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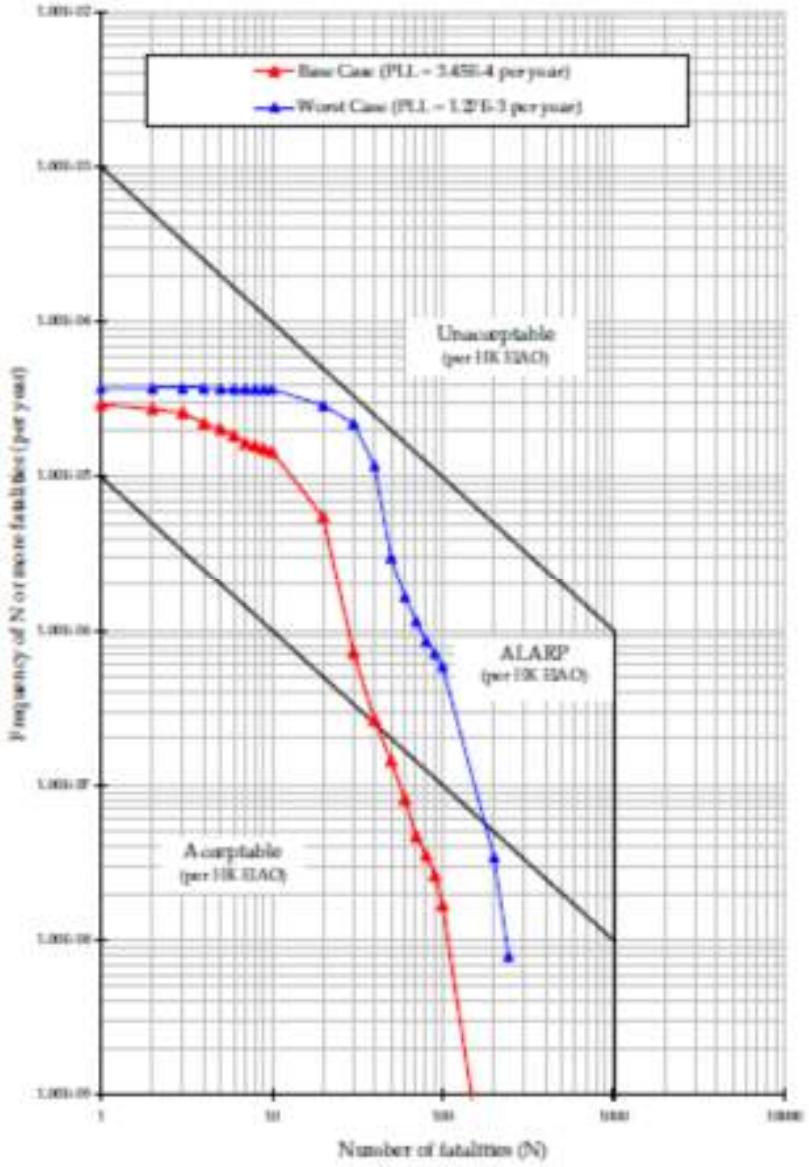
Base Case (PLL = 3.45E-4 per year)
Worst Case (PLL = 1.27E-3 per year)
Unacceptable
(per HK EIAO)
ALARP
(per HK EIAO)
Acceptable
(per HK EIAO)
Frequency of N or more fatalities (per year)
Number of fatalities (N)

Constraints and challenges

- **Limitation of available references**
- **Limitation of local transport data**
- **Limitation of data specific to the explosives of interest**

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