QRA Model for Dangerous Goods Transport through Road Tunnels

Developed under the joint OECD-PIARC ERS2 project

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- Calculations and data requirements
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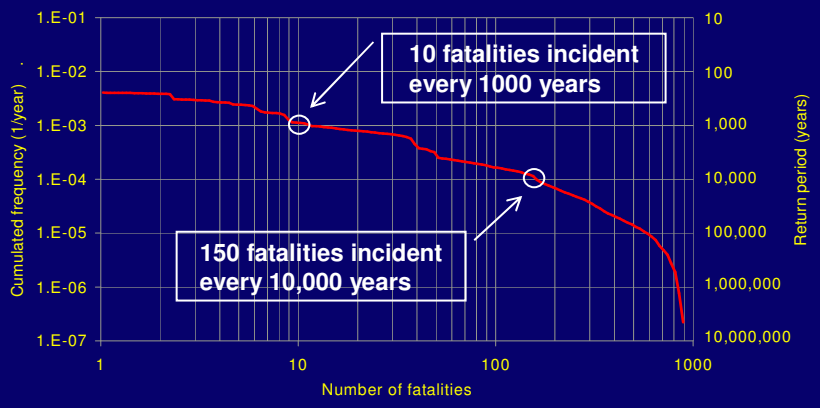
QRA Objectives

- Compare risks due to Dangerous Goods (DG) transport for alternative routes
- Compare DG risks with acceptability criteria
- Evaluate tunnel regulations for DG traffic
- Evaluate tunnel equipment options

QRA Model produces F-N curves

- Number of Casualties
- Cumulative Frequency (= 1 / Return Period)



How are F-N curves produced?

- **Assessment of all situations is impossible…**
  … simplification is necessary

- **Methodology**
  - Small number of representative DG scenarios
  - Accident frequencies
  - Physical consequences in open and within tunnel(s)
  - Physiological effects on people
  - Take account of escape and sheltering
  - Calculate risk of death or injury

Representative DG scenarios

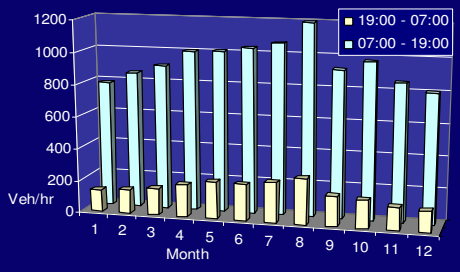
1	Empty / non-combustible load	20MW HGV fire
2	Combustible load	100MW HGV fire
3	LPG	BLEVE (cylinder)
4	Motor spirit	Pool fire
5	Motor spirit	VCE
6	Chlorine	Toxic gas release
7	LPG	BLEVE (bulk tank)
8	LPG	VCE
9	LPG	Torch fire
10	Ammonia	Toxic gas release
11	Acrolein	Toxic release (bulk tank)
12	Acrolein	Toxic release (cylinder)
13	Non-flammable liquefied gas	BLEVE

Input data - Routes and Tunnels

- **Routes**
  - defined in sections
  - constant carriageway geometry, traffic and accident rate
- **Tunnel**
  - defined in sections of constant geometry and ventilation
  - ventilation *(may need specialist help for complex tunnels)*
  - drainage
  - emergency egress (warning systems, spacing of exits)
  - structural parameters (lining, overburden, fire rating)

Input data - Traffic

- **Traffic flow**
  - defined for each route section, traffic direction and time period
  - vehicle mix (light vehicles, buses/coaches, HGVs)
  - traffic speeds
- **Dangerous Goods vehicles**
  - DG traffic flow
  - proportions of different classes of dangerous goods

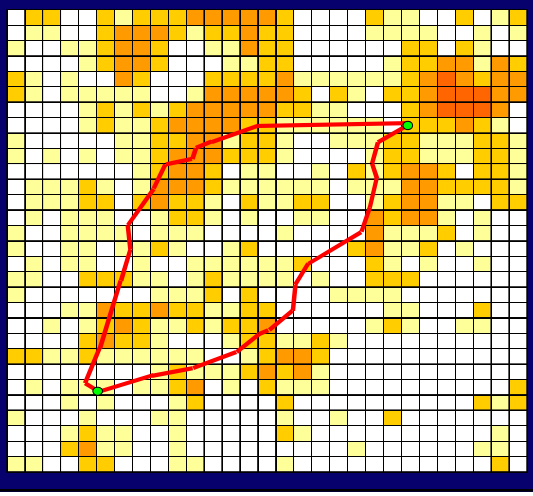


Input data - Accident Frequencies

- HGV accident rates
  - according to road type, speed limit, etc
  - default data provided from France, Canada and Norway
  - use correct national or local statistics where available
- Apply correction factor for DG vehicles
- Conditional probability of DG scenario, once a DG vehicle is involved in an accident

Input data - Population & Meteorology

- Population density
  - grid-based data
  - according to period (day/night)
- Wind data
  - frequency according to:
  - wind speed
  - direction
  - stability class



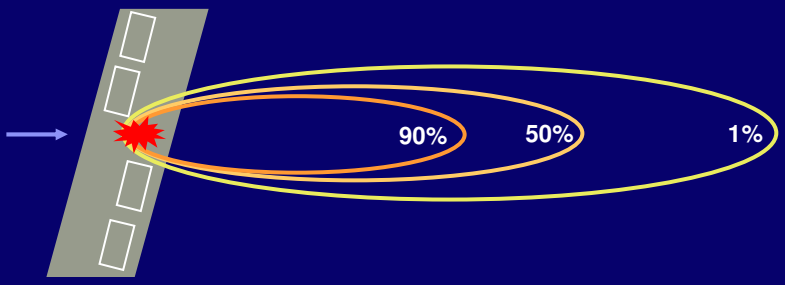
Hazard Analysis

- Fire
  - HGV or hydrocarbon pool fire, radiant heat and smoke spread
- VCE (Vapour Cloud Explosion)
  - liquid release, evaporation, gas dispersion, ignition, blast effects
- BLEVE (Boiling Liquid Expanding Vapour Explosion)
  - catastrophic failure of tank heated by fire, blast and fireball effects
- Toxic release
  - dispersion of toxic gas cloud along tunnel or in open air

Lethality Ranges

- Tunnels

- Open air



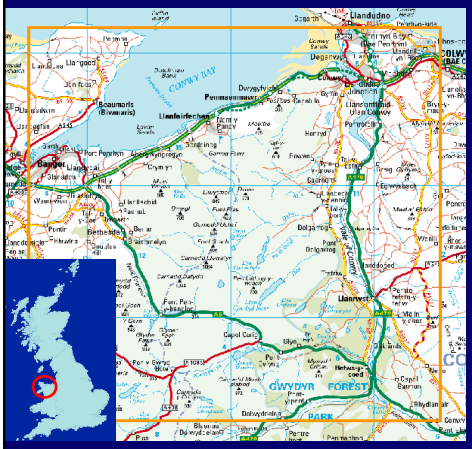
Casualty Analysis

- **Lethality ranges**
  - hazard ranges for radiant heat, toxic concentration & overpressure
  - exposure duration
  - hazardous dose
  - probit equations
  - % fatalities (and/or injuries)
- **Population**
  - road users and/or local population
  - possibility of escape and sheltering
- **Number of fatalities = %fatalities x people present**

QRA Model Software

- **Software**
  - based on Microsoft Excel with Visual Basic programming
  - data entry screens to assist the user
  - User Manual — data preparation, entry and processing
  - Reference Manual — theoretical basis and examples
- **Latest release**
  - QRAM v3.60 released 2003

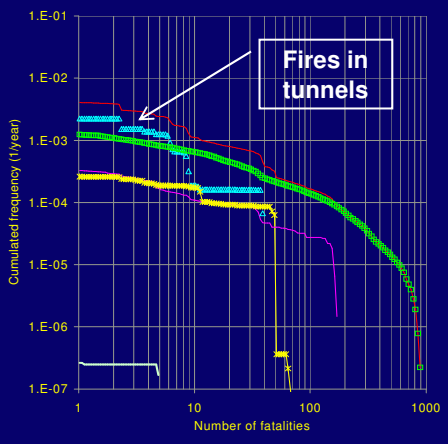
Example 1 - Compare Routes



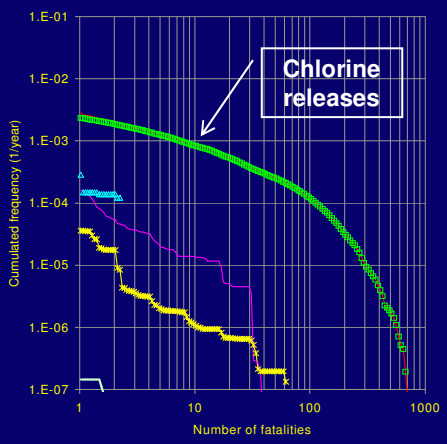
- 6 shipments of bulk chlorine East-to-West every day
- 6 shipments of bulk bromine West-to-East every day
- Dual carriageway coastal route passing through 3 tunnels
- Single carriageway through mountainous region
- Which route is safer?

Example 1 - Comparison of F-N Curves

- Route via tunnels



- Alternative open route

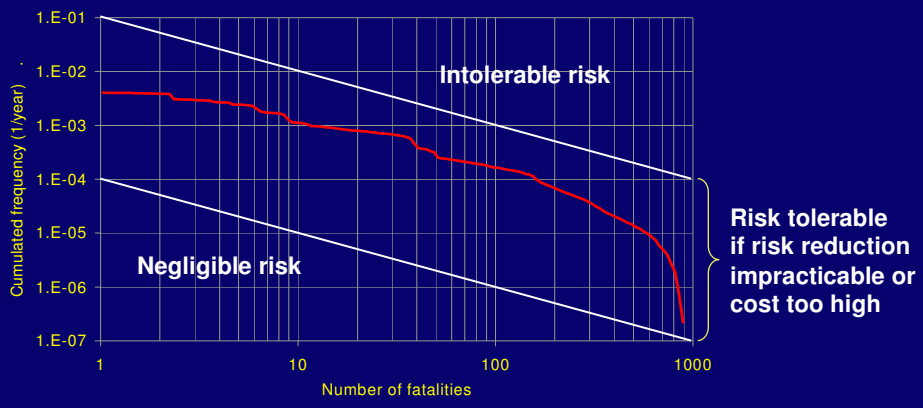


Example 1 - Route Conclusions

- Risks along alternative (open) route greater than risks along tunnel route
  - chlorine risk dominates along open route
  - HGV fire risk dominates in tunnels
  - larger number of people at risk along open route

Example 2 - Acceptability Criteria

- Compare DG risks with acceptability criteria
  - criteria are specific to country and application
  - subjective issues (risk aversion, etc)



Example 3 - Evaluate Equipment Options

- Investigate 'what if ?' scenarios
- Existing tunnel
  - 650m single bore, no emergency exits
  - no CCTV or detection systems
- Possible improvements to reduce risks during prolonged contraflow traffic operations
  - install additional escape route(s)
  - upgrade detection/surveillance
  - upgrade traffic control and communications

Example 3 - QRA Results for Options

Traffic	Tunnel ventilation	Upgrade detection & communications	Fatalities/year
Single direction	Y	-	0.09
Bi-directional	-	-	0.30
Bi-directional	-	Y	0.06
Single direction	Y	Y	0.02

Software Evaluation and Usage

- **Evaluation studies**
  - Austria, France, Netherlands, Norway
  - Spain, Sweden, Switzerland
  - Germany (trial pending)
- **Practical studies**
  - France (20 studies) *regulatory role*
  - Greece (1 study) *possible regulatory role*
  - UK (3 studies)

Dissemination and Support

- **Responsibilities**
  - contract between PIARC and OECD
  - dissemination and support led by WG5 on behalf of C5
- **Software distribution**
  - CD-ROM sold (at low price to cover costs), and/or
  - freely downloadable from PIARC website
- **Support**
  - direct arrangement between developers and users
  - training courses
  - user group meetings

Future Development

- Only very limited maintenance by PIARC
- Development by users authorised
  - encouraged to make modified models available to PIARC and other users
- Future development possible through international projects or by individual countries / bodies