Introduction to Quantitative Risk Assessment

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Speakers

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software@dnvgl.com
Agenda

What is QRA?

Drivers for QRA

why QRA?

Challenges that QRA can help address/Applications of QRA

Pros/Cons of QRA

Doing a QRA – Practical considerations, best practices, pitfalls

Conclusion
What is QRA?
What is Risk?

Commonly used definition...

The **LIKELIHOOD** and *consequence* of a specified *undesired event* occurring within a specified *period* or under specified *circumstances*

\[ R = f(L,C) \]
What is Quantitative Risk Assessment?

is a risk assessment methodology that allows for numerical estimates of the level of risk associated with a certain activity or series of activities to be estimated and then assessed.
What is Quantitative Risk Assessment?

- What Can Go Wrong?
  - Hazard Identification

- How Often?
  - Frequency Analysis

- How Big?
  - Consequence Analysis

- So What?
  - Risk Assessment

- What Do I Do?
  - Risk Mitigation
Typical QRA Outputs

- **Individual Risk**
  - Solo rock climbing (5 hr per week)
  - Heart Disease
  - Smoking (10 cigarettes per day)
  - Accident at home

- **Societal (Group) Risk**
  - “Relationship between frequency and the number of people suffering from a specified level of harm from the realisation of specific hazards”

- Riskiest Industry:
  - Traffic Accident (driving 10h per week)

- Safest Industry:
  - Struck by lightning
  - Solo rock climbing (5 hr per week)
  - Heart Disease
  - Smoking (10 cigarettes per day)
  - Accident at home

- Risk Levels:
  - 1 in 1,000
  - 1 in 10,000
  - 1 in 1,000,000
  - 1 in 10,000,000

- Risk Categories:
  - UNACCEPTABLE RISK
  - BROADLY ACCEPTABLE RISK
  - ACCEPTABLE RISK
  - LOWEST RISK
Typical QRA Outputs – Individual Risk

LSIR

Location Specific Individual Risk

IRPA

Individual Risk Per Annum

“1 in 10 000/Yr” or “10^-4/Yr”

“1 in 100 000/Yr” or “10^-5/Yr”

“1 in 1 000 000/Yr” or “10^-6/Yr”

“1 in 10 000 000/Yr” or “10^-7/Yr”

10^-8/Yr

10^-9/Yr
**Individual Risk – ALARP Principle**

**ALARP – As Low as Reasonably Practicable**

- **NEGLIGIBLE RISK**
  - **Unacceptable region**
    - The ALARP or Tolerability region
      - *(Risk is undertaken only if a benefit is desired)*
    - Broadly acceptable region
      - *(No need for detailed working to demonstrate ALARP)*

- **LOW RISK**

- **HIGH RISK**
  - Risk cannot be justified save in extraordinary circumstances
  - Tolerable only if risk reduction is impracticable or if the cost is grossly disproportionate to the improvement gained
  - Tolerable if cost of reduction would exceed the improvement
  - Necessary to maintain assurance that risk remains at this level

**Maximum Tolerable Criterion**

**Desirable Target**
### Individual Risk Criteria – Global Examples

<table>
<thead>
<tr>
<th>Country</th>
<th>2 Bands</th>
<th>3 Bands</th>
</tr>
</thead>
<tbody>
<tr>
<td>UK: Safety Cases/Reports</td>
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<tr>
<td>UK: Land Use Planning</td>
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<td>Netherlands</td>
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<td>Belgium: Flanders</td>
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<tr>
<td>Hong Kong</td>
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<tr>
<td>Brazil (3 states)</td>
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<tr>
<td>Singapore</td>
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<tr>
<td>Malaysia</td>
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<tr>
<td>Australia: Western Australia</td>
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<tr>
<td>Australia: New South Wales</td>
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<tr>
<td>Australia: Queensland</td>
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<tr>
<td>Australia: Victoria</td>
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<td></td>
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<tr>
<td>Canada</td>
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<tr>
<td>France</td>
<td></td>
<td></td>
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<tr>
<td>Switzerland</td>
<td></td>
<td></td>
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<tr>
<td>USA: Federal Agencies</td>
<td></td>
<td></td>
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<tr>
<td>USA: Santa Barbara County, CA</td>
<td></td>
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<tr>
<td>USA: New Jersey</td>
<td></td>
<td></td>
</tr>
<tr>
<td>IMO</td>
<td></td>
<td></td>
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<tr>
<td>Abu Dhabi</td>
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</tr>
</tbody>
</table>

The diagram on the right illustrates the risk categorization using three bands: **Intolerable**, **ALARP**, and **Tolerable**. The 3 bands represent the risk categories, with red for Intolerable, yellow for ALARP, and green for Tolerable.
Typical QRA Outputs – Societal (Group) Risk

FN Curves
Frequency/Number of fatalities

PLL
Potential Loss of Life
Sample Societal Risk Criteria (Upper Limit)

Frequency (/year) of N or more fatalities vs Number of fatalities, N

- UK HSE
- RdJ & RGdS
- Victoria
- Hong Kong
- São P & WA existing
- Flanders
- Santa Barbara
- Netherlands & CH
- WA new
- NSW

Number of fatalities, N

1 10 100 1000 10000

Frequency (/year) of N or more fatalities

10^-2 10^-3 10^-4 10^-5 10^-6 10^-7 10^-8 10^-9
Drivers for QRA
Drivers for QRA

NRC WASH-1400 Reactor Safety Study

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### TABLE 6-3  INDIVIDUAL RISK OF EARLY FATALITY BY VARIOUS CAUSES

(U.S. Population Average 1969)

<table>
<thead>
<tr>
<th>Accident Type</th>
<th>Total Number for 1969</th>
<th>Approximate Individual Risk Early Fatality Probability/yr (a)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motor Vehicle</td>
<td>55,791</td>
<td>$3 \times 10^{-4}$</td>
</tr>
<tr>
<td>Falls</td>
<td>17,827</td>
<td>$9 \times 10^{-5}$</td>
</tr>
<tr>
<td>Fires and Hot Substance</td>
<td>7,451</td>
<td>$4 \times 10^{-5}$</td>
</tr>
<tr>
<td>Drowning</td>
<td>6,181</td>
<td>$3 \times 10^{-5}$</td>
</tr>
<tr>
<td>Poison</td>
<td>4,516</td>
<td>$2 \times 10^{-5}$</td>
</tr>
<tr>
<td>Firearms</td>
<td>2,309</td>
<td>$1 \times 10^{-5}$</td>
</tr>
<tr>
<td>Machinery (1968)</td>
<td>2,054</td>
<td>$1 \times 10^{-5}$</td>
</tr>
<tr>
<td>Water Transport</td>
<td>1,743</td>
<td>$9 \times 10^{-6}$</td>
</tr>
<tr>
<td>Air Travel</td>
<td>1,778</td>
<td>$9 \times 10^{-6}$</td>
</tr>
<tr>
<td>Falling Objects</td>
<td>1,271</td>
<td>$6 \times 10^{-6}$</td>
</tr>
<tr>
<td>Electrocution</td>
<td>1,148</td>
<td>$6 \times 10^{-6}$</td>
</tr>
<tr>
<td>Railway</td>
<td>884</td>
<td>$4 \times 10^{-6}$</td>
</tr>
<tr>
<td>Lightning</td>
<td>160</td>
<td>$5 \times 10^{-7}$</td>
</tr>
<tr>
<td>Tornadoes</td>
<td>118 (b)</td>
<td>$4 \times 10^{-7}$</td>
</tr>
<tr>
<td>Hurricanes</td>
<td>90 (c)</td>
<td>$4 \times 10^{-7}$</td>
</tr>
<tr>
<td>All Others</td>
<td>8,695</td>
<td>$4 \times 10^{-5}$</td>
</tr>
</tbody>
</table>

**Nuclear Accidents (100 reactors)**: $8 \times 10^{-6}$

(a) Based on total U.S. population, except as noted.
(b) (1953-1971 avg.)
(c) (1901-1972 avg.)
(d) Based on a population at risk of $15 \times 10^6$. 

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Drivers for QRA

Today, QRA is a ...

01 Decision support tool

02 Core process safety methodology

03 Key to Risk Regulation
Challenges that QRA can help address? /Applications of QRA
Examples of QRA Applications

- Life Cycle Asset Risk Management
  - Design
  - Construction
  - Operations
  - Decommissioning

- Escalation Assessment

- Safety Case Development
- Equipment Design

- Land Use Planning
- Decision Support

- Cost Benefit Analysis
- Technology Option Selection
- Quantify the benefit of mitigation measures

- Operational Risk Management
- Compliance (Legal Requirement)

- Layout Optimization
  - Site
  - Equipment

- Insurance
## Example of Cost Benefit Analysis

<table>
<thead>
<tr>
<th>Base</th>
<th>Cost</th>
<th>Reduction in Risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Cost a lot</td>
<td>Little reduction in risk</td>
</tr>
<tr>
<td>2</td>
<td>Cost a little</td>
<td>Little reduction in risk</td>
</tr>
<tr>
<td>3</td>
<td>Cost is moderate</td>
<td>Moderate reduction in risk</td>
</tr>
<tr>
<td>4</td>
<td>Cost is relatively little</td>
<td>Large reduction in risk</td>
</tr>
</tbody>
</table>

### Diagram:
- **Risk** vs. **Cost**
- **Base**:
  - Cost a lot (1)
  - Cost a little (2)
  - Cost is moderate (3)
  - Cost is relatively little (4)
Pros/Cons of QRA
Pros of QRA

- Enables risk (various) to be quantified
- Offers an objective/rational approach to risk assessment
- Understanding an Engineered System
- Identify Risk Drivers
- Visual Depiction of Risk
“The key benefit of estimating risk lies in the achievement of detailed understanding of the engineered system and the implications of various siting and technical options”. (Royal Society, 1999)
Strengths of QRA – Visual Depiction of Risk

“1 in 10,000/Yr” or “10^{-4}/Yr”

“1 in 100,000/Yr” or “10^{-5}/Yr”

“1 in 1,000,000/Yr” or “10^{-6}/Yr”

“1 in 10,000,000/Yr” or “10^{-7}/Yr”

10^{-8}/Yr

10^{-9}/Yr
Strengths of QRA – Identify Risk Drivers

“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” (HSE, 1999)
Cons of QRA

**Uncertainty** in the risk estimates
- Addressed by adopting a conservative approach

**Cost/time intensive**
- Addressed by software tools such as Safeti reduce the analytical burden approach

**Susceptible to “GIGO”**
- Expertise is key

**Highly specialised activity**
- Expertise e.g. DNV GL is available
Doing a QRA – Practical considerations, best practices, pitfalls
QRA is akin to predicting the weather...

- Goal is to predict the weather based on available data, models
- Accuracy is dependent on a range of factors:

Expertise  Data

Robustness  Uncertainty

Quality
Key Considerations for QRA

- Uncertainty
- Quality Management
- Choice of Software application
- Competency of resources
Practicalities

- Do I need a QRA?
  - Is it appropriate for my site?
  - How will I use the results?
  - Regulatory requirements?

- Information needed?

- Can I do the QRA myself or do I need someone else to do it?
  - Capabilities/competencies
  - Software
  - 3rd party assurance (may be regulatory requirement)
  - Maybe mix both in-house and external

- Documentation – the QRA should be well documented (all assumptions etc.)
Software Applications for QRA

- Many solutions exist, most are in-house proprietary and Microsoft Excel® based (i.e. spreadsheet models)

- Commercial quality QRA software is available e.g. Safeti/Safeti Offshore for on/offshore QRA respectively
  - High quality, integrates codified best practice and industry standards
How to check a QRA Study/Report for quality etc.

- Independent checks - verification

- Validation versus comparable assets

- Specifically, check:
  - Main risk contributors – are they as expected and consistent with experience?
  - Consistency of:
    - Individual versus Societal risk
    - FN Curve and PLL
    - FN Curve and individual risks
The need to dig deeper: Hazards With Same PLL

<table>
<thead>
<tr>
<th>Frequency</th>
<th>No of fatalities</th>
<th>PLL</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 per 10 years</td>
<td>1</td>
<td>0.1</td>
</tr>
<tr>
<td>1 per 100 years</td>
<td>10</td>
<td>0.1</td>
</tr>
<tr>
<td>1 per 1000 years</td>
<td>100</td>
<td>0.1</td>
</tr>
<tr>
<td>1 per 10000 years</td>
<td>1000</td>
<td>0.1</td>
</tr>
</tbody>
</table>
Conclusion
Conclusions

- What is QRA?
- Why/ how is it done?
- What is it used for?
Useful resources on QRA and Risk Analysis

- HSE (1999) Reducing Risks, Protecting People
Q&A
Thank you for attending

Webinar recording, presentation slides, together with a Q&A document will be sent to all registered delegates in ~ 2 wks

Any further questions can be sent to software@dnvgl.com

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