A Strategic Approach to the Application of Occupied Building Risk Assessment

Akansha Khandelwal, P.E.
Peter Smith, PhD

EPSC Webinar | 20th March 2020
BakerRisk – Who Are We?

- Employee Owned
- Over 100 Engineers and Scientists
- Over 30-years Experience “Providing Solutions to Manage Hazards and Risks”

San Antonio, Houston, Chicago, Los Angeles, Canada, United Kingdom
Webinar Presenters

Akansha Khandelwal, PE  
Senior Engineer  
Protective Structures  
BakerRisk (Houston)

Peter Smith  
Senior Engineer  
Protective Structures  
BakerRisk (UK)
1. Introductions
BakerRisk & presenters

2. Risk Management Programmes
Objectives, drivers, scope, key considerations

3. Assessment
Brief outline of building risk assessments

4. Optioneering
Investigation & evaluation of risk mitigation options

5. Implementation
Basis-of-design, development, implementation & validation

6. Q&A
Let us fill in any knowledge gaps!
Risk Management Programmes
PRINCIPAL OBJECTIVE: Provide solutions to prevent or mitigate potential risk exposures and demonstrate risk is *As Low As Reasonably Practicable (ALARP)*

1. **Identify & Evaluate**
   - Identify hazard scenarios (release cases and other applicable hazards)
   - Evaluate the consequences and associated risk of fire, toxic, explosion and other potential hazards to onsite personnel

2. **Examine**
   - Examine the risk profile computed
   - Identify and develop potential options to mitigate risk exposure
   - Implement decision making criteria to identify balanced risk reduction strategy

3. **Implement**
   - Implement and commission selected risk mitigation measures

4. **Review**
   - Review for additional low-cost risk reduction solutions and demonstrate risk tolerability
Guidance prevalent in the UK/Europe

- COMAH & Seveso II Regulations
  - Legislation that requires hazards and risk be assessed
- Guidance for the Location and Design of Occupied Buildings...
  (CIA, 2020)
  - 4th Edition good practice standard for the siting and design of occupied buildings at chemical and major hazard sites

Guidance prevalent in the U.S.A.

- Process Safety Management of Highly Hazardous Chemicals
  (OSHA - U.S. 29CFR1910.119)
  - Legislation that requires hazards and risk be assessed
- API RP 752/753/756
  - Deal with locating onsite populations (permanent and temporary buildings as well as tents; respectively)
3 Key Ways to Reduce Site Risk

**Address the Process**
- Learn from previous incidents
- Switch to inherently safe design
- Enhance detection and isolation capabilities
- Focus on PSM of high-risk processes
- Reduce likelihood of failure

**Address the People**
- Move non-essential personnel offsite
- Move essential personnel to low risk buildings
- Enhance PPE and train for emergency response

**Address the Buildings**
- Upgrade existing buildings
- Design / build for hazard or risk profile
- Portable Buildings (Trailers, BRMs, etc.)
- FORTRESS
Factors & Constraints

1. **Multiple drivers**
   Often multiple local stakeholders with differing priorities and constraints.

2. **Forecasting**
   Must align with long-term strategic programmes and initiatives, i.e., master planning.

3. **Differing complexity**
   Decision making for the simplest to the most complex and difficult of operational cases.

4. **Emotion quotient**
   Criteria need to overcome emotionally charged challenges and decision making.

5. **Tangible vs. intangible**
   Overcome bias toward tangible benefits.

6. **Basic constraints**
   Ensure risk is adequately and effectively controlled within funding and time constraints.
Consistent Methodology
- Consistent assessment methodology needed for common baseline

Risk Tolerance Criteria
- Risk tolerance metric (individual, aggregate/societal) needed for benchmarking and prioritisation

Basis for Decision Making
- Establish hierarchy of controls, secondary priorities, constraints, etc.

Consistent Basis for Risk Management Programme
Objective Achieved…?

Before:

After:

Intolerable risk
Risk is ALARP
Negligible risk
Building Risk Assessment
Hazard Identification & Evaluation
Hazard Identification & Evaluation
Hazard Identification & Evaluation
Hazard Identification & Evaluation
Hazard Identification & Evaluation
Hazard Identification & Evaluation

- Blast Overpressure
- Toxic Dispersion
- Thermal Radiation
- Flammable Dispersion
Derivation of Risk

Consequence × Frequency = Risk

Identify Scenarios
- Fires
- Explosions
- Toxic releases

Evaluate Consequences
- Fatalities
- Equipment damage
- Economic losses

How often do the scenarios occur?
- Frequency of leaks / failure of safeguards, etc.
- Other conditional probabilities (ignition, wind conditions, etc.)

Main outcome from a Risk Assessment
- Annual probability of death
- Potential fatalities per year
- Different ways to express
  - site-wide risks
  - work group risk
  - etc.
Common Weaknesses – Limited Scenarios

Screening out low consequence scenarios:
- COMAH legislation vs. CIA guidance
- Cumulative effect on risk may be significant
- Potential underestimation of risk

Screening out high consequence scenarios:
- PHA vs. CIA guidance
- Based on low frequency perception
- Potential underestimation of risk

Neglecting site specific hazards, such as:
- Runaway reactions
- BLEVE
- BPVs
- Fire Box explosions
- Exothermic reactions → fragmentation
Common Weaknesses – Blast Damage

**Empirical (P_{so})**
- Highly expedient
- Generic construction types?
- Based on limited empirical data
- No indication of actual building response – damage prediction defined by pass/fail
- Pass/fail defined by max. tolerable pressure only – no account of dynamic response
- Not repeatable

**Empirical P-i**
- Highly expedient
- Generic and broad construction types?
- Based on limited empirical data
- Not repeatable

**SDOF**
- Expedient
- Building/ scenario specific modelling
- Complete damage/ response feedback
- Repeatable
- Varying degree of conservatism in damage prediction – tends to conservative
- Experienced practitioners only

**High fidelity**
- Time intensive
- Building/ source specific modelling
- Repeatable
- Reduced conservatism in damage prediction
- Experienced practitioners required
- Validation required
Common Weaknesses – Damage Modelling

Schematic of existing building

P-I Diagram for existing building
Common Weaknesses – Damage Modelling

Schematic of upgraded building (ext. wall post retrofit)

P-I Diagram for upgraded building
Common Weaknesses – Occupant Vulnerability

- **Fire**
  - Building resistance [*overestimate*]
  - Escape route [*overestimate*]
  - Escape time [*underestimate*]

- **Toxic**
  - Building resistance [*overestimated*]
  - Evacuation plans & available PPE [*overestimated*]
  - Exposure time [*underestimate*]

- **Blast**
  - Building resistance [*overestimated*]
  - Primary building response vs. OV [*inadequate*]
  - Secondary building response vs. OV [*underestimated*]

Commonly underestimating risk by giving unconservative/unvalidated credit
## Common Weaknesses – Results Format

<table>
<thead>
<tr>
<th>Factor</th>
<th>F-P Exceedance Curves</th>
<th>BIR &amp; BSR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blast, fire and toxic risk feedback?</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Able to interpret OV?</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Able to interpret risk drivers?</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Able to predict building response?</td>
<td>✗</td>
<td>✓</td>
</tr>
<tr>
<td>Economic design possible?</td>
<td>✗</td>
<td>✓</td>
</tr>
<tr>
<td>...</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Risk Mitigation Decision Making
Potential Mitigation Options

- Refine Model
- Mitigate Exposure
- Mitigate Release
Potential Mitigation Options

Refine Release Source Modeling
- Inventory limitations
- Pump and compressor capacities
- Emergency shutdown valves
- Operator response
- Check valves
- Detailed CFD modeling

Mitigate Release Source
- Flammable and gas detection
- Water curtains for toxic releases
- Sprinkler systems
- Dikes and runoff systems
- Enhanced maintenance procedures
- Extensive testing and inspection programs
- Detailed start-up procedures
- Thorough lockout/tagout programs
- Verification & validation programs

Mitigate Personnel Exposure
- Personnel/building relocation
- Safe Havens / SIP locations
- Building upgrades for blast resistance
- Emergency escape packs
- Supplied breathing air
- FRC requirements
- Emergency response plans
- Pressurized buildings with limited air ingress
- HVAC isolation interlocks and manual isolation
- Building thermal shielding
- Roll-up door interlocks to prevent flammable ingress
Identify Buildings for Risk Mitigation

• Risk profile
  o Risk above owner’s criteria
  o Similar risk contribution from multiple sources

• Functionality
  o Buildings can be grouped based on function for mitigation

• Location
  o “Indirect-costs” related to increased distance from personnel work area

• Potential
  o Some buildings have more potential for risk reduction based on cost efficient options than others
Explosion Risk Mitigation

**Building exceeds owner’s risk threshold**

- Strengthen building
- High fidelity modeling
- Relocate function
- New building
High Fidelity Model - Example

Full Scale PEMB TEST – Explosion Research Cooperative
Box Canyon

Finite Element Model – “Full Scale PEMB Test”
Explosion Risk Mitigation

Building exceeds owner’s risk threshold

Strengthen building  High fidelity modeling  Relocate function  New building
Explosion Risk Mitigation

- Building exceeds owner's building damage threshold
  - Strengthen building
  - High fidelity modeling
  - Relocate function
  - New building

- Is upgrade achievable and practical?
Explosion Risk Mitigation

Building exceeds owner's building damage threshold

- Strengthen building
- High fidelity modeling
- Relocate function
- New building

Is upgrade achievable and practical?
Explosion Risk Mitigation

Building exceeds owner’s building damage threshold

- Strengthen building
- High fidelity modeling
- Relocate function
- New building

Is upgrade achievable and practical?

- Preliminary designs
- Value added options
- Cost estimates

Develop designs and implement

- Milestone designs
- Coordination
- Construction
Thermal Risk Mitigation

Building exceeds owner’s risk threshold

High fidelity modeling  Retrofit Building  Shield Systems  Escape Routes
Thermal Risk Mitigation

**Building exceeds owner’s risk threshold**

- High fidelity modeling
- Retrofit Building
- Shield Systems
- Escape Routes

Using numerical techniques, estimate temperature rise inside the building

Based on the temperature rise and off gassing, determine Occupant Vulnerability (OV)

If risk is high, improve SIP conditions or design escape routes.
Thermal Risk Mitigation

Building exceeds owner’s risk threshold

High fidelity modeling  Retrofit Building  Shield Systems  Escape Routes

- Retrofit the building at openings or locations of low thermal resistance
- Exterior intumescent paint can reduce temperature rise
Thermal Risk Mitigation

Building exceeds owner’s risk threshold

High fidelity modeling | Retrofit Building | Shield Systems | Escape Routes

Shield wall can be designed to mitigate direct exposure from jet fire radiation and impingement
Thermal Risk Mitigation

Building exceeds owner’s risk threshold

High fidelity modeling  Retrofit Building  Shield Systems  Escape Routes

Escape corridors can be designed to provide occupants sheltered route to a safer location
Toxic Risk Mitigation

Building exceeds owner’s risk threshold

Detection & Isolation

Leak-tight SIP

SIP Training

Evacuation

Reliable detection
- Outdoors
- At the HVAC Inlet
- Inside

Timely and reliable isolation of ventilation system
Toxic Risk Mitigation

Building exceeds owner’s risk threshold

Detection & Isolation  Leak-tight SIP  SIP Training  Evacuation

- Testing to determine current leak tightness
- Minimize leak paths
Toxic Risk Mitigation

Building exceeds owner’s risk threshold

Detection & Isolation
Leak-tight SIP
SIP Training
Evacuation

Interior SIP
• Easier to isolate and make leak tight
• Reduces impact of later entries
Toxic Risk Mitigation

Building exceeds owner’s risk threshold

Detection & Isolation  Leak-tight SIP  SIP Training  Fallback Plan

Things to know
- Strategy for toxic risk mitigation
- SIP Actions
- When to implement fallback plan

- Strategy for toxic risk mitigation
- SIP Actions
- When to implement fallback plan
Toxic Risk Mitigation

Building exceeds owner’s risk threshold

Detection & Isolation  Leak-tight SIP  SIP Training  Fallback Plan

- Evacuation with escape masks
- SIP with Supplied Air
• Compare options based on one or more of the following factors
  o Cost
  o Interferences
  o Business Interruptions
  o Implementation time
  o Indirect-costs

Risk Reduction

Cost
Strategy Selection (Example)

Risk-Reduction Strategies vs. Approx. Cost of Mitigation

Selected Strategy:
- Building A – Option 1
- Building B – Option 3
- Building C – Option 5
- Building D – Replace
- Building E – Option 3
Etc.

Overall Plant Risk Reduction

Mitigation Cost (in $MM)

Potential INTERIM Strategies

Potential PERMANENT Strategies

Non-Cost Effective Strategies

EPSC Webinar March 20th 2020
Risk Mitigation Implementation
Risk Mitigation Implementation Time Line

Selection of Key Buildings for Hazard Mitigation

- Week(s)-Month
- Few Months
- Few months–Year
- 1-2 Years

Completion of Hazard and Risk Analyses

Path Forward/ Mitigation Strategy

Pre-Design Phase

Design Phase

INTERIM Mitigation

PERMANENT Mitigation
From Hazard Study to Design to Implementation

- **Owner**
  - Establish Basis of Design
  - General involvement

- **Risk Consultant**
  - Develop mitigation options
  - Develop design details

- **General Contractor**
  - Respond to specification
  - Solicit bids from sub-contractors

- **Sub-Contractors**
  - Design to specification
  - Relay RFIs through GC
Building Upgrade
Conceptual Design Example

• Owner selects a mitigation option

• Risk consultant develops conceptual design
  o Provide basic details of design
  o Assess windows and doors
  o Architectural details
  o Mechanical equipment
  o Provide 30% level design drawings

• Preliminary construction cost estimates
Building Upgrade
Detailed Design Example

- Developed detailed design
  - Detailing to adapt concept to specific areas of building
  - Non-typical conditions
  - General notes/specs
  - Connection details
  - Windows/doors
  - Mechanical systems
  - Architectural

- IFC drawings
• Pre-Construction Support
  o Support bid process
  o Review construction contractor bids

• Construction support
  o Review shop drawings
  o Evaluate/approve vendor submittals
  o Respond to RFIs from construction contractor
  o Adapt design to reflect as-built conditions revealed by work in progress
Contact Us

Akansha Khandelwal | Peter Smith

Houston, USA | Chester, UK

+1.281.822.3100 | +44.7739.760.113

akhandelwal@bakerrisk.com | psmith@bakerrisk.com