# National Grid Quantitative Risk Modeling

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# Agenda

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- Risk Modeling History at National Grid
- QRA risk model requirements
- QRA model choice and features
- QRA modeling strategy
- National Grid QRA  models
- Results from the models
- Follow up activities
- Lessons learned

# Risk Modeling History
# Phase 1
# Relative Risk Models

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- Kiefner Model – Original development through NYSEARCH
- Muhlbauer Model – Relativistic / Index
- Subject matter expert
  - Use all three as check and balance
- Used to prioritize IMP program inspections
- Gave some understanding of threats that drove highest ranked pipeline sections

# Risk Modeling History
# Phase 2
# Interactive Threats

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- **Kiefner Interactive threat model development through NYSEARCH – Relative Risk / Index**
  - **Update with information from records review and IMP inspections**

- **Developed common risk model with NG UK Gas Transmission -- Muhlbauer**
  - **Company wanted one model that gave visibility to all its transmission assets**

# Risk Modeling History
# Phase 3
# Process Safety

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- Company forms process safety group
- All major accident hazard groups required to perform PHA's & LOPA's
  - Initial requirement was to perform for each pipeline segment
  - Revised to highest risk ranked segment by the following :
    - Urban
    - Suburban
    - Rural

# What Did We Learn From PHA & LOPA

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- Process is subjective to participant prior experience
- Part quantitative & Part qualitative
- More applicable to fixed facilities
- Did help to further understand threats
- Clear link between threats and mitigative actions
- Tendency to get side tracked with knock on effects

# Risk Modeling History
# Phase 4
# Quantitative Risk Modeling

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- **Learned from PHA and LOPA that modeling each line segment would be difficult**
- **Action items resulting from LOPA included conducting QRA's on high risk pipelines**
- **Modeled a segment classified as Urban, Suburban, Rural for each operating company**
- **Wanted to get clear understanding of what our absolute risk was for each operating company**

# QRA Model Selection

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- UK Gas Transmission previous experience with PipeSafe modeling program
- Wanted to understand Societal and Individual Risk
- Data requirements had to be reasonable
- Robust Consequence capability
- Ability to do what if scenarios
- Could results translate into additional mitigative activities

# Quantitative Risk Modelling

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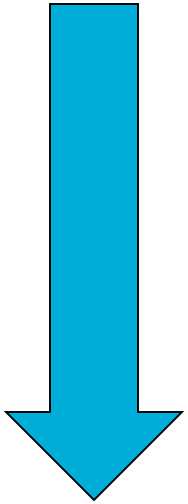
**Qualitative**



- Relative Risk Modelling
- Process Hazard Analysis (PHA)
- Layers of Protection Analysis (LOPA)
- Quantitative Risk Modelling (QRA)

**Quantitative**

# QRA Failure Mechanisms (Cause Categories)

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- **External interference or third party activity:** External interference, mostly third party activity involving interference using machinery, is generally the dominant failure mechanism both for gas and oil pipelines.
- **Corrosion:** Corrosion, in all forms, is another major cause for incidents and is increasingly prevalent in ageing pipelines.
- **Construction defect and mechanical or material failure:** Construction and material defects (caused during processing or fabrication) are often connected with welds and equipment associated with the pipeline.
- **Natural hazards:** For the majority of pipelines, there is little or no risk of failure due to the occurrence of natural hazards. However, under certain circumstances, pipelines may need to be routed through difficult terrain or hydrological conditions where the risk from such hazards is significant.

# QRA Primary Failure Mechanism

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## Primary Failure Mechanisms: Third Party Damage

## Relevant Influencing Parameters:

- Diameter; Pressure; Wall thickness; Material grade and toughness – are a measure of the resistance of the pipeline to mechanical damage.
- Location (Rural or Suburban); Depth of Cover - Influence the hit rate.
- Protective measures may be taken to reduce hit rate, including physical protection and surveillance, which can be quantified, and public awareness campaigns, which is more difficult to quantify.

# Risk Tolerance

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**Risk can be expressed either as individual risk or societal risk.**

- **Individual risk meaning the frequency of an individual at a specified location being a casualty.**
- **Societal risk is defined as the relationship between the frequency of an incident and the number of casualties which may result.**
- **Societal risk is usually expressed in the form of a graph of the cumulative frequency (F) of producing N or more casualties plotted against N (an "FN curve").**

# Risk Tolerance

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**ALARP (As Low As Reasonably Practicable).**

**Three-band approach in regulating industrial risks:**

- **At the top end of the scale there are risks that are so great that they are refused altogether.**
- **At the bottom end are situations where the risk is, or has been made, so small that no further precaution is necessary - a 'broadly acceptable' region.**
- **In between these two extremes is a region where risks are tolerable only if their level has been reduced to one which is ALARP (As Low As Reasonably Practicable)**

# Quantitative Risk Modeling Using PipeSafe

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- Input Parameters
- Failure Cause
- Failure Frequency
- Failure Mode
- Risk Calculations
- Output
- What If Scenarios
- Mitigative Measures

# Input Parameters

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- **Input Parameters**
  - **Selection of a 1 mile segment of the pipeline and its location.**
  - **Nearby population densities.**
  - **Pipeline linear attributes (i.e. diameter, wall thickness, material grade, pressure (MAOP).**
  - **Meteorological conditions (i.e. wind).**
  - **Physical properties of gas.**

# Primary  Failure cause

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- **Failure Cause**
  - **3rd party damages –Based on model prepared in the UK and modified for US.**
  - **Not modelled: Material Defects; Construction Defects; Fatigue; Ground movement; Flooding; Corrosion. Corrosion, fatigue, etc. typically do not result in ruptures so are not included in the analysis as they would typically not change the FN curve.**

# Failure Frequency

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- **Failure Frequency**
  - **Based on historical data from the UK – was originally developed for BP.**
  - **Calculation of Frequency of Failure for the US adopted from the UK using a conservative multiplier.**

# Failure Modes

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- **Failure Mode**
  - **Leak or Rupture?  Rupture.**
  - **Ignition probability is based on diameter and pressure of pipeline – based on historical data.**
  - **50% immediate ignition/50% delayed ignition.**

# Consequence Calculations

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- **Consequence Calculations**
  - **Prediction of release consequences**
  - **Calculation of release flow rate**
  - **Calculation of thermal radiation emitted by fire in an ignited release**
  - **Quantification of the effects of thermal radiation on the surrounding population**

# Model Outputs

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- **Output**
  - **Individual risk – Risk Transact**
  - **Societal Risk - F-N Diagram**

**Risk tolerance levels are established by National Grid (UK) Health and Safety Executive.**

**National Grid US specifies a broadly acceptable individual risk level of 1x10E-6 per year.**

# What If Scenerios

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- Mitigative Measures
  - Increase pipe wall thickness
  - Increase depth of pipe
  - Place warning tape
  - Install protective slab
  - Increase patrol frequency
  - Reduce MAOP
- Can changing any of these variables lower the risk

# Pipelines Modelled with Pipesafe

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- **Brooklyn Backbone:10 miles; 26”, 24” and 20” diameter; 350psi MAOP**
- **PL-C64:15 miles;12” diameter; 960psi original design pressure; 650psi current MAOP**
- **PL-E18: 27 miles; 16” and 20” diameter; 490psi MAOP**
- **PL-C16: 41 miles; 24” diameter pipe; 480 psi MAOP**
- **Tewksbury Line: 6 miles; 12”, 8”, and 6” diameter; 610 psi MAOP**
- **Milton Line: 5 miles; 20”, 16”, 14”, 10” and 30” diameter; 200psi MAOP**
- **Southern Line: 17 miles; 26” and 24” diameter; 350psi MAOP**
- **PL-E36: 9 miles; 24” diameter; 490psi MAOP**
- **PL-63: 24 miles; 12”, 24” and 36” diameter; 473psi MAOP**
- **GM-24: 31 miles; 20”, 24” and 26” diameter; 450psi/350psi MAOP**
- **GM-30: 11 miles; 26” and 30” diameter; 450psi MAOP**

# Brooklyn Backbone QRA

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- **A site-specific risk assessment of a 1 mile section was modelled in detail. The 1 mile section which was chosen runs from Leonard Street/ Maujer Street to Bedford Avenue/ Penn Street.**
- **This section was chosen as it appeared to be one of the highest risk sections with a number of high-rise buildings and schools within the potential hazard range of the pipeline.**

# Brooklyn Backbone QRA

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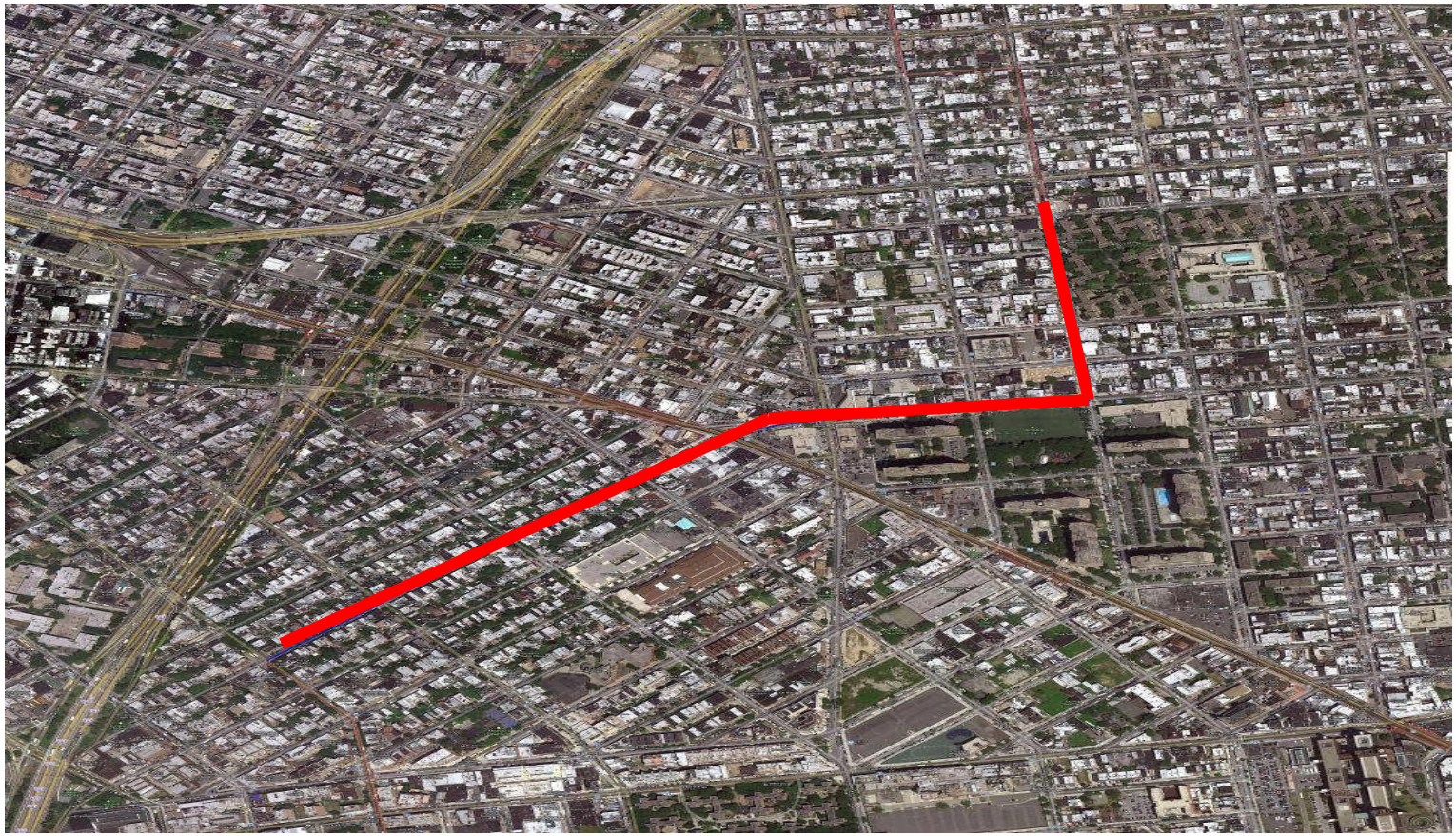

# Brooklyn Backbone QRA

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To indicate the variation in individual risk as a function of distance from the pipeline, individual risk transects have been produced at five locations along the pipeline.

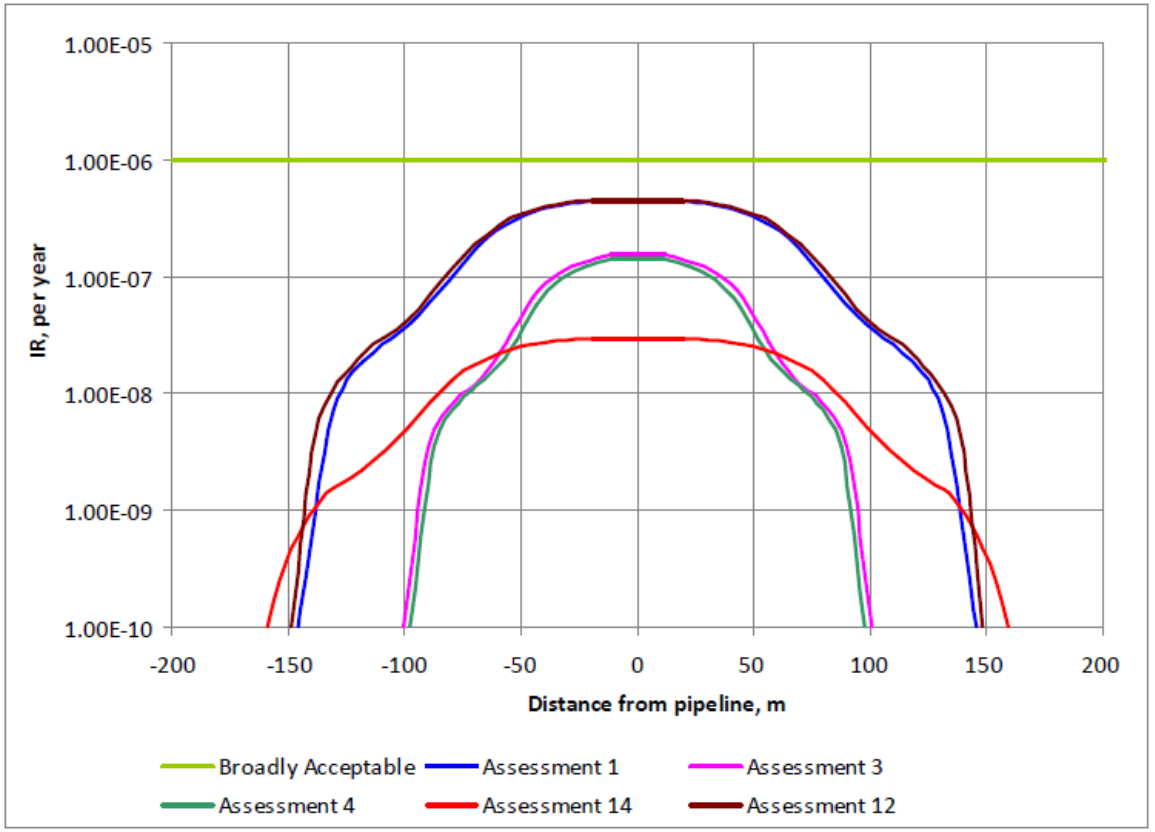


Figure 4: Individual risk transects for the Brooklyn Backbone pipeline.

# Brooklyn Backbone QRA

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The FN curves lie in the 'tolerable if ALARP' region.

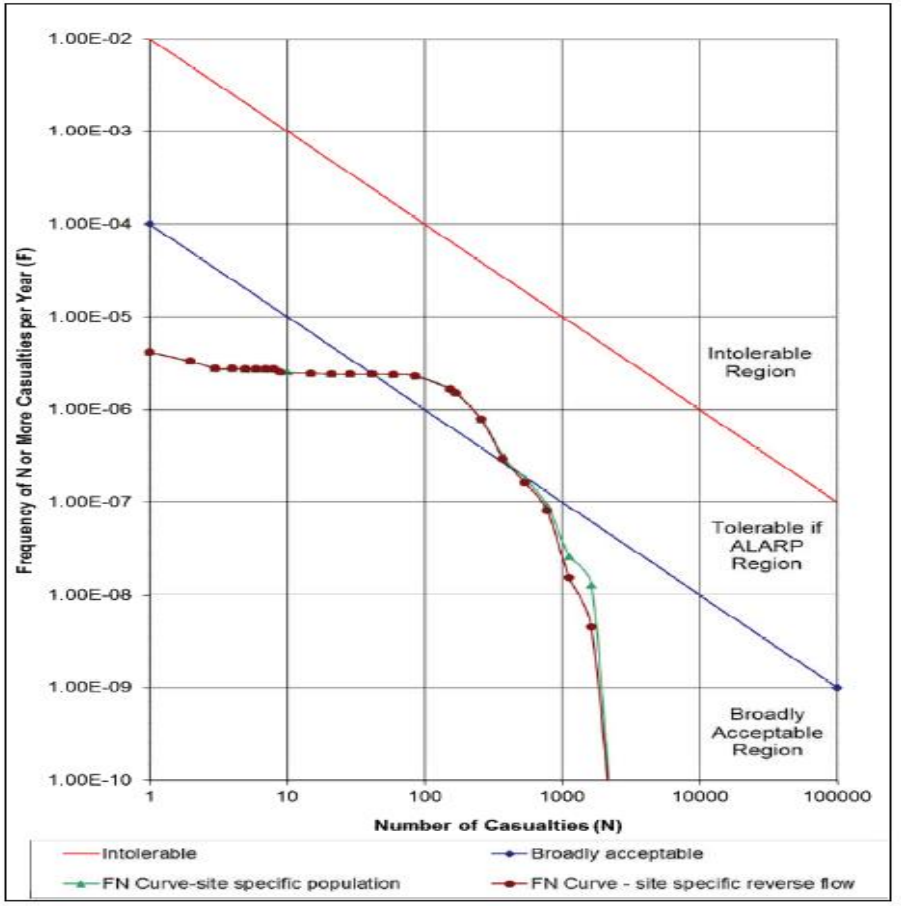


Figure 6: Societal risk results (FN curves) for the 1 mile section site-specific risk assessment

# Brooklyn Backbone QRA

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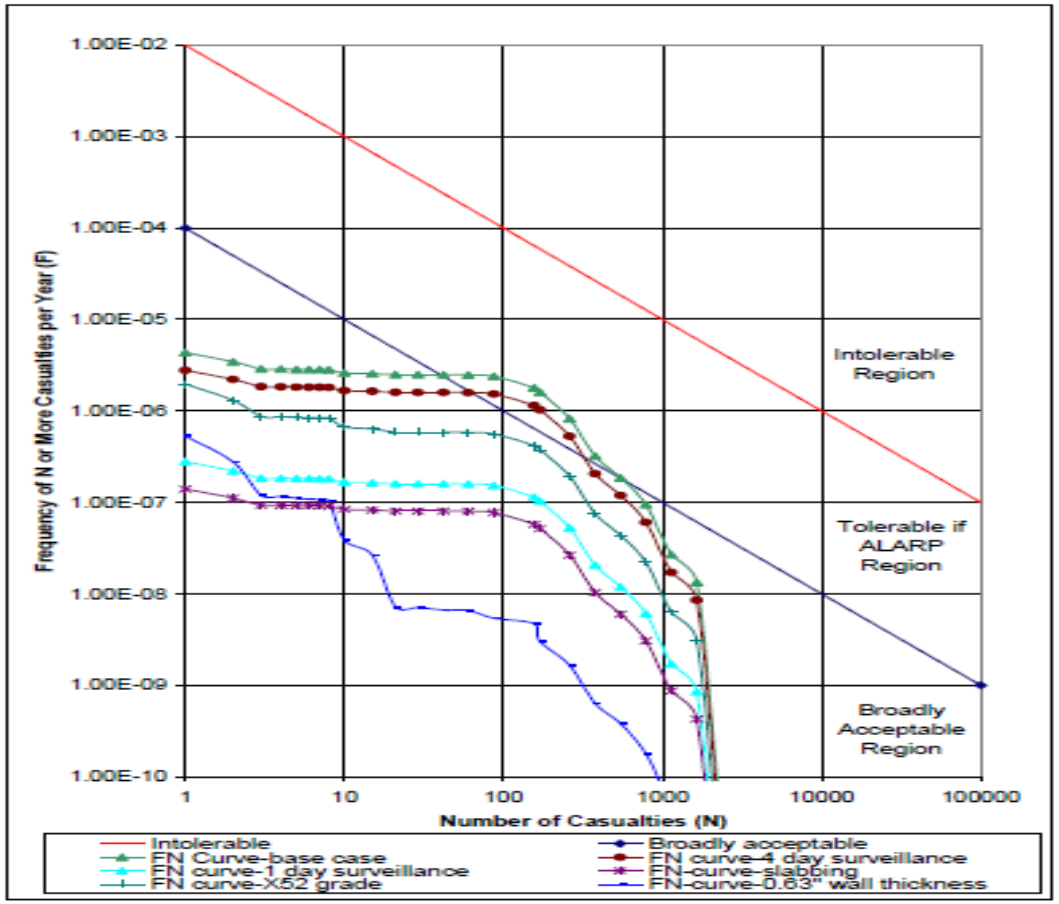
- Reducing the surveillance interval from 8 days to 4
- Reducing the surveillance interval from 8 days to 1
- Installing slabbing, barrier tapes and stripes on top of the pipeline
- Increasing the wall thickness of the pipeline from 0.375” to 0.63”
- Increasing the material grade of the pipeline from Grade B to X52.



# PL-16 QRA

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- **A site-specific risk assessment of a 1 mile section was modelled in detail. The 1 mile section that was chosen runs through the Marketplace Shopping Plaza, Cicero.**
- **This section was chosen as it appeared to be one of the highest risk sections with a number of commercial properties, restaurants and children's entertainment businesses within close proximity.**

# PL-16 QRA

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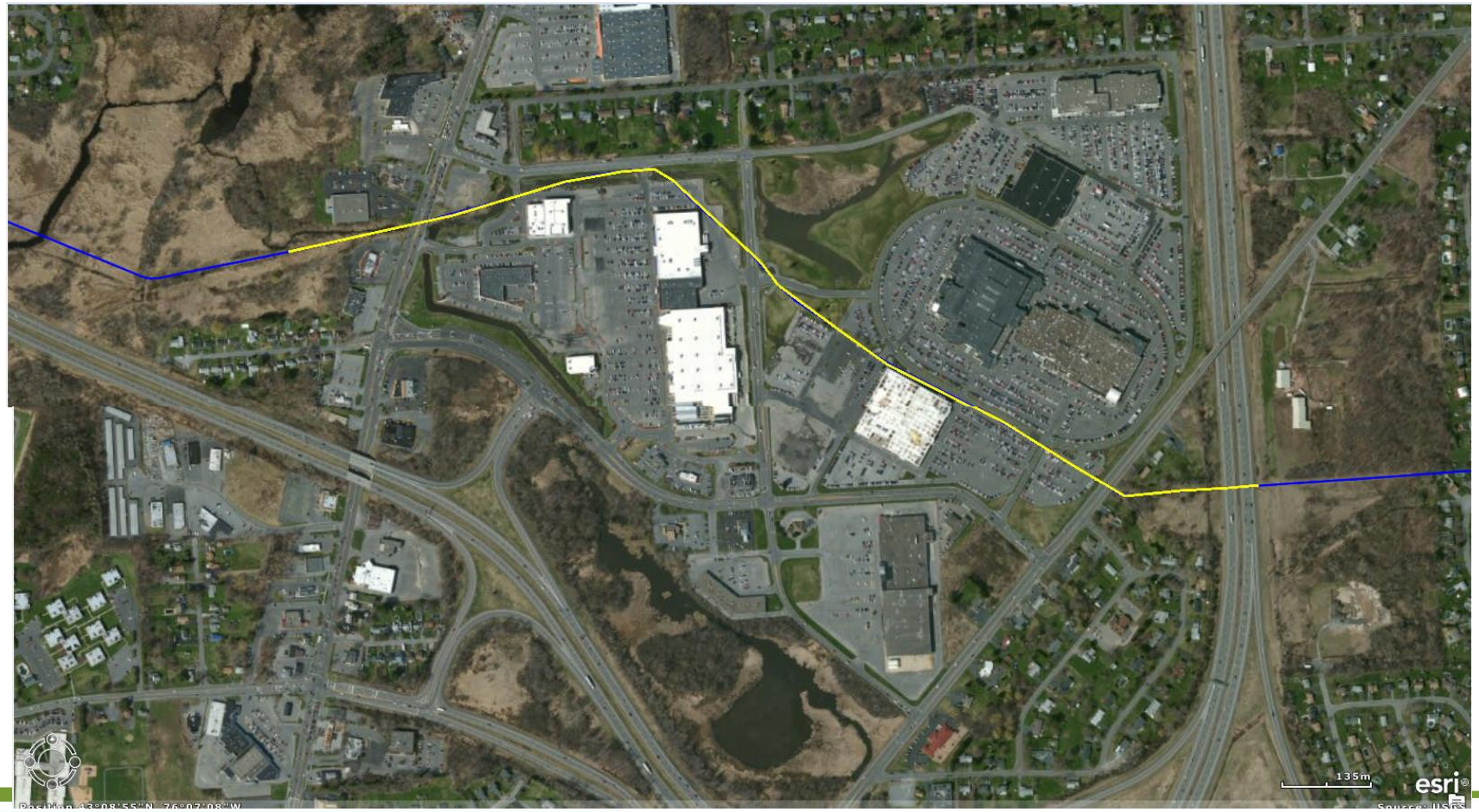

# PL-16 QRA

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The individual risk transect does not lie below the 'broadly acceptable' risk criteria for an individual of 1 x 10E-6 per year, however it does lie below the intolerable risk criteria for an individual of 1 x 10E-2 per year.

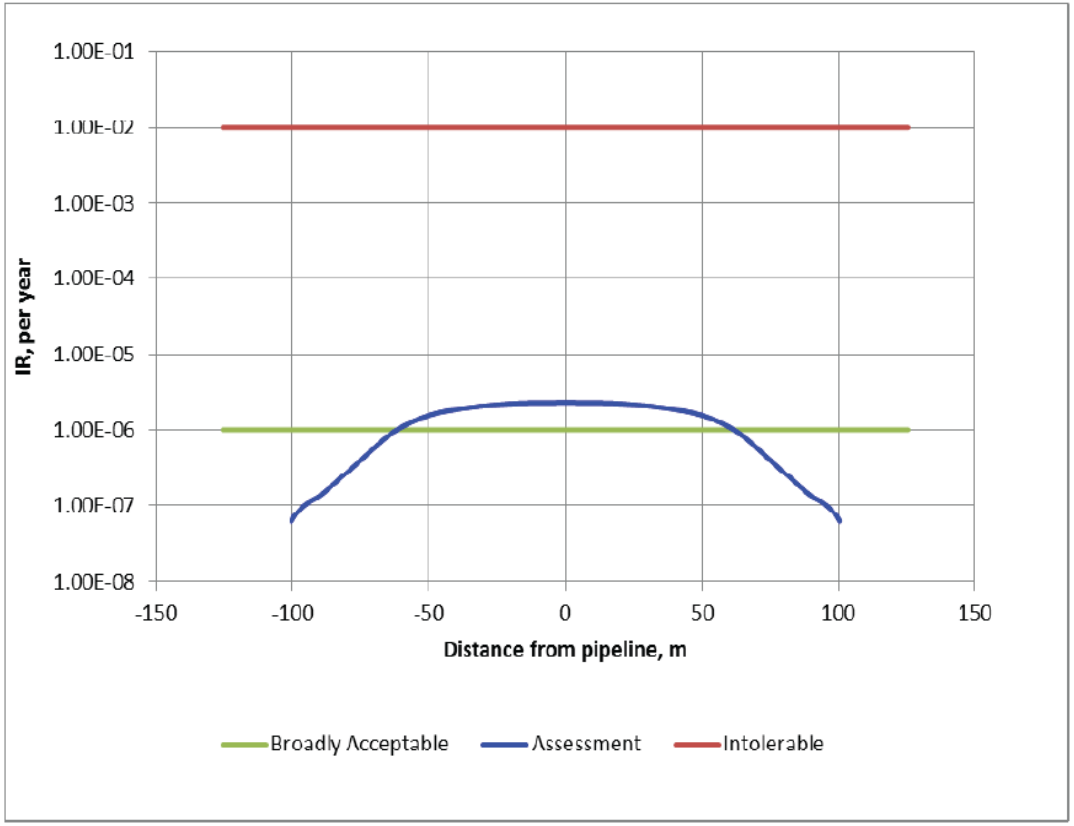


Figure 3: Individual risk transects for the PL C-16 pipeline.

# PL-16 QRA

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Part of the FN curve lies in the 'Tolerable if ALARP' region.

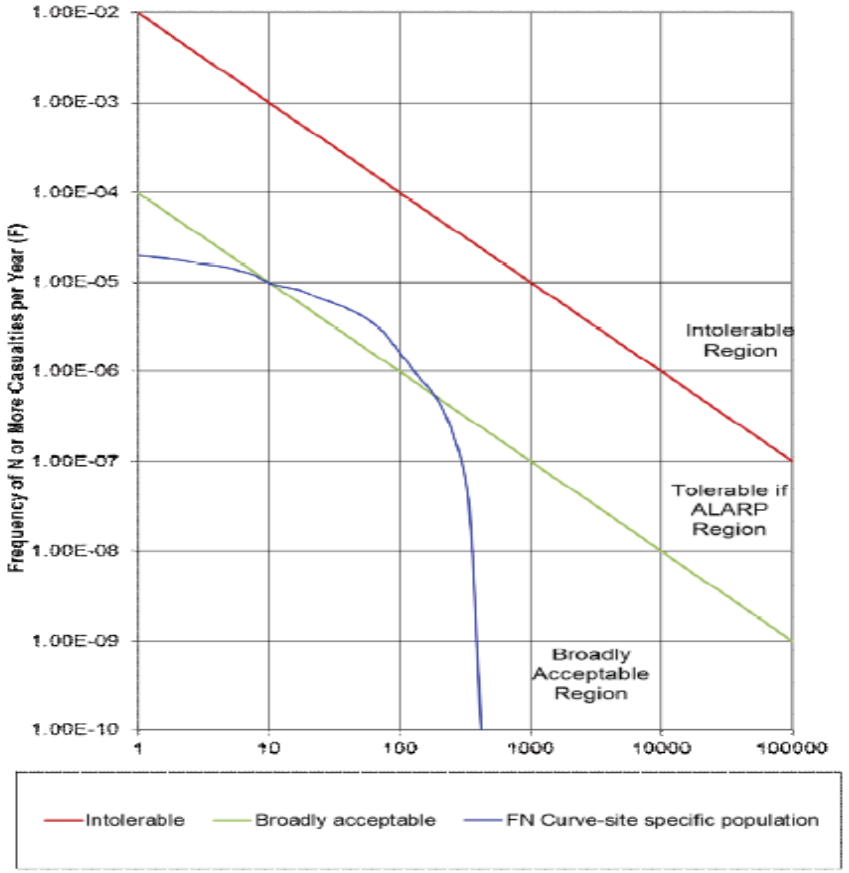


Figure 4: Societal risk results (FN curves) for the 1 mile section site-specific risk assessment

# PL-16 QRA

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Surveillance Risk Reduction Measures

Surveillance every 10,8,6,4,2,1 days plotted on F-N Diagram

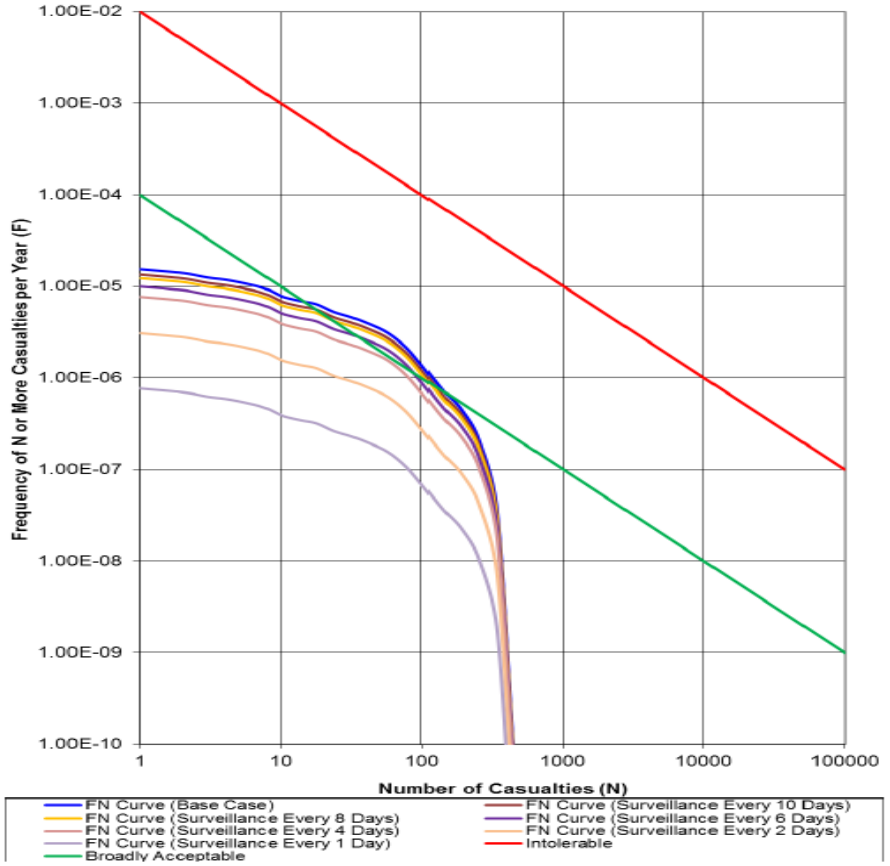


Figure 2: Comparison of the societal risk results (FN Curve) of the surveillance risk reduction measures

# PL-16 QRA

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Barrier Risk Reduction Measures

- Warning Tapes
- Concrete Slabs
- Barriers, Tapes, and Stripes

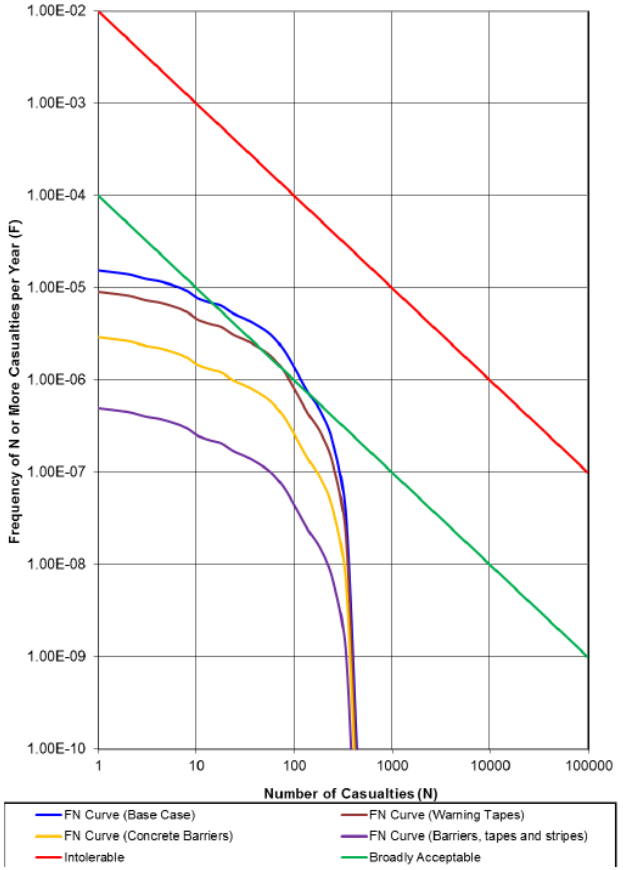


Figure 3: Comparison of the societal risk results (FN Curve) of the barrier risk reduction measures

# PL-16 QRA

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Material Grade Measures

X42; X46; X52: X56

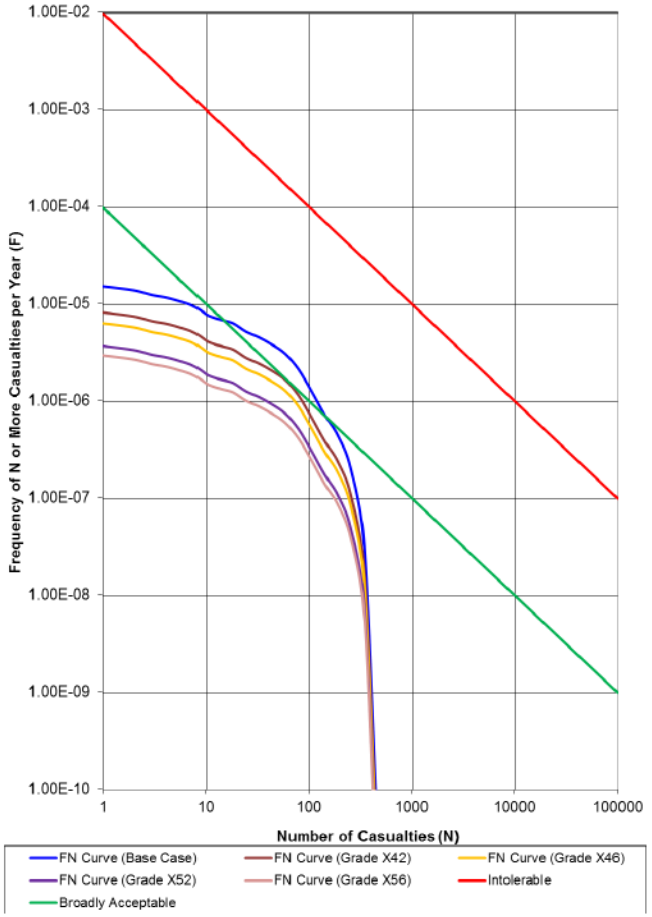


Figure 4: Comparison of the societal risk results (FN Curve) of the grade risk reduction measures

# PL-16 QRA

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Pressure Reduction Measures

432psi; 384psi; 336psi; 288psi

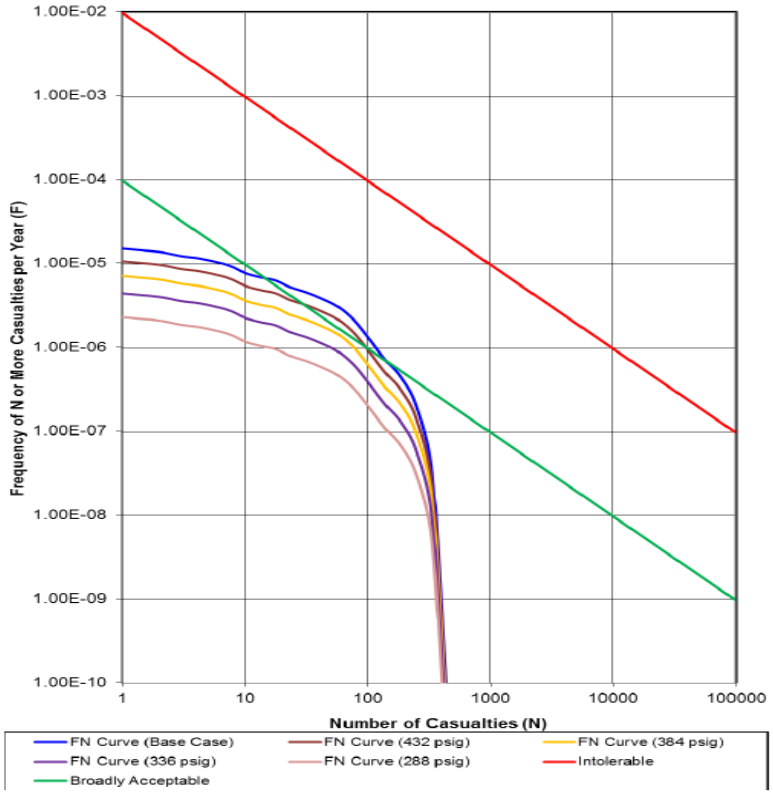


Figure 5: Comparison of the societal risk results (FN Curve) of the pressure risk reduction measures

# PL-16 QRA

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Wall Thickness Measures

.500; .560; .630; .690 inches

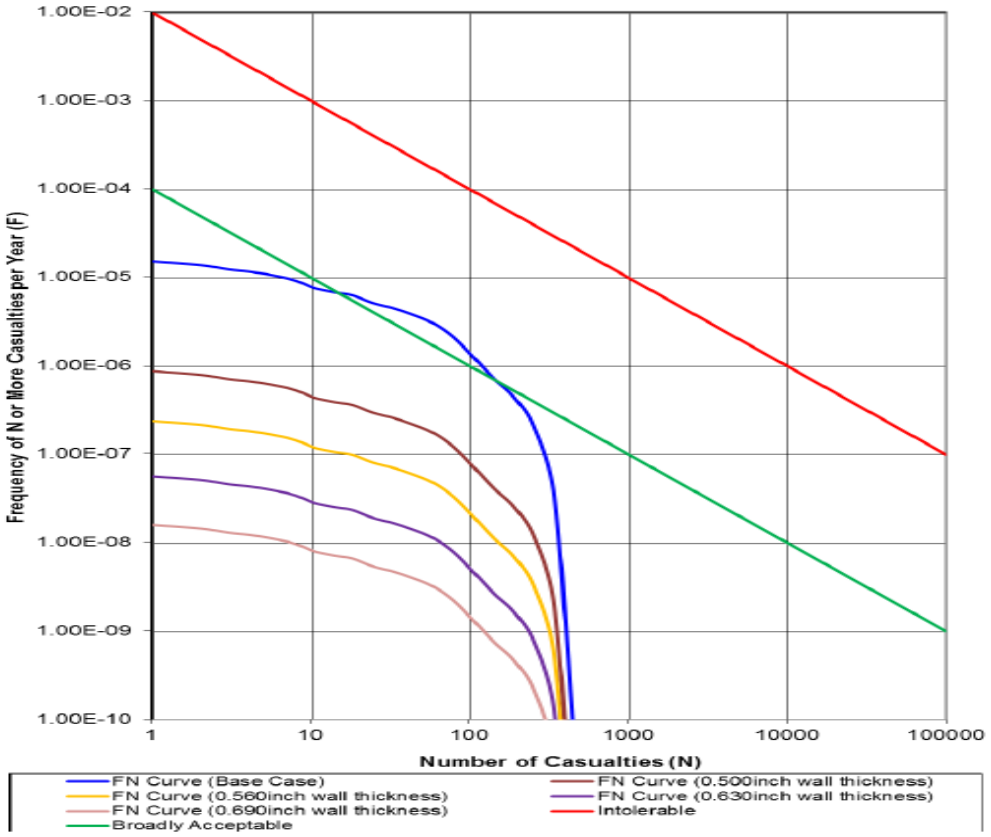


Figure 6: Comparison of the societal risk results (FN Curve) of the wall thickness risk reduction measures

# QRA's – Results – Mitigative Activity

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- **GM 24 Increase patrols to every 3 days (at least twice a week**
- **GM 30 Increase patrols to every 1 day**
- **PL16 Increase patrols to every 4 days (Twice/week)**
- **PL E18 Increase patrols to every 10 days (Once/week)**
- **Brooklyn Backbone Increase patrols to every 1 day**

# QRA's – Below Risk Threshold

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- PL-63 Pipeline's risk below NGrid's risk tolerance threshold
- PL-E36 Pipeline's risk below NGrid's risk tolerance threshold
- Milton Line Pipeline's risk below NGrid's risk tolerance threshold
- Tewksbury Line Pipeline's risk below NGrid's risk tolerance threshold
- Southern Line Pipeline's risk below NGrid's risk tolerance threshold

# Lessons Learned

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- First time we had risk in absolute terms
- Data requirements
- Generic vs location specific data
- Outside sources of data need to be verified
- One threat modeled
- Significant amount of time to pull everything together
- Are results scalable ?
- What if scenarios are useful
- Results need to translate into real actions