RISK, RISK BASED DECISION MAKING, AND RISK ANALYSIS

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CSRN Risk and BOK
Risk

- What is Risk?
- Societal Risk
- Life Loss
- Complicated Mathematics
- Risk-Based Planning and Design
- Project and Project Element Risk Analysis
Risk = Probability \times \text{Consequence}
Risk = Probability \times \text{Consequence}
Risk = Probability x Consequence
Mitigating Risk
Making Decisions Based on Risk
Making Decisions Based on Risk

Making a decision based on my cards and the chance of drawing the card I need ≠ Risk based decision making
Making Decisions Based on Risk

Making a decision based on my cards, the chance of drawing the card I need AND the potential gain/loss = Risk based decision making

http://www.wnyc.org/radio/#/ondemand/278173
Societal Risk

Societal risk is defined as *the relationship between frequency and the number of people suffering from a specified level of harm in a given population from the realization of specified hazards* [Jones, 1985]

Specific Hazards Include: chemical spills (i.e. West Virginia), plant failures (Chernobyl), train derailments (Quebec), and Natural Disasters (flooding, earthquakes, tsunamis, wildfires, etc.)
Societal Risk—The whole world

Throughout the world each year, natural disasters kill approximately 80,000 people, render millions homeless and result in economic losses of $50 billion-$60 billion, according to a World Bank and United Nations joint report. Mitigation pays back at a ratio of more than 1:5; for every dollar spent, more than $5 are saved, not including measures of human suffering (World Bank, 2008).
Effects of land use and watershed management affect how much and how quickly rainfall is transformed into river flow.

Greenhouse gas emissions can increase rates of evaporation and the quantities and intensities of rainfall as well as the percentage of precipitation that falls as rain vs. snow.
Probability: 100-year Flood

Does NOT occur 1 time every 100 years...
Means there is a 1% chance a river flow that big will occur in any year.
Consequence

Longmont, Colorado September 2013
Photo Credit: Huffington Post
Flood Damages
The Netherlands
Or is it Holland?
History of the battle with water

- 1906 Storm surge flood in Zeeland
- 1910 Sturgeon extinct
- 1916 Flood in North Holland ➔ Afsluitdijk
- 1953 Storm Surge flood in Zeeland
- 1954 Salmon extinct
Risk Based Standards

Risk = Probability x Consequence

1) Match flood protection investment with risk

2) Time flood protection investment with development and growth
Protect the property and economic investments to a level that is commensurate with the value of property and investment.

\[
S_{k+1}^{\text{mean}} = \frac{1}{D} \int_0^D S_k^+ e^{\beta t} dt = S_k^+ \frac{1}{\beta D} (e^{\beta D} - 1)
\]

met \[ D_{k+1} = t_{k+1} - t_k \quad \text{en} \quad t \in [t_k, t_{k+1}) \quad \text{en} \quad k = 1, 2, ... \]

waarin

- \( D \): lengte (standaard)interval tussen opeenvolgende investeringen
- \( S^+ \): verwachte schade onmiddellijk na investeren
- \( \beta \): groeivoet van de verwachte schade
But, these are Risk Based Standards?

The principle of economic optimization:

- $I$ – investments in safety measures
- $R$ – risk (economic damage)
- $K$ – total cost
- $X$ – optimal safety

$K = I + R$
10,000 year flood protection?

- 1 in 10,000: highly populated coastal areas
- 1/4000: less populated coastal areas
- 1/2000: tidal zones
- 1/1250: Rhine river corridors
- 1/250: Maas river corridors
- 1/? : localized intense precipitation
US flood protection?

United States Counties Protected By Levees

Legend
- City within Levees with Pop. > 300,000
- US County with Levee
- Major Rivers

“There are two kinds of levees—

Those that HAVE FAILED and those that WILL FAIL”

<table>
<thead>
<tr>
<th>Probability</th>
<th>Consequences</th>
</tr>
</thead>
<tbody>
<tr>
<td>System was not built large enough—esp with the uncertainty of climate change</td>
<td>Dense urban development behind levees</td>
</tr>
<tr>
<td>Poorly constructed levees</td>
<td>Critical infrastructure impacts</td>
</tr>
<tr>
<td>Subsidence, earthquakes, sea-level rise</td>
<td>Water Quality and Soil Contamination</td>
</tr>
</tbody>
</table>
Residual Risk

Flood Exposure Behind Levees for Various Levels of Flood Protection
(Cumulative over the life of a 30-year mortgage)

- 100-year: 26%
- 200-year: 14%
- 300-year: 9.5%
- 400-year: 7.2%
- 500-year: 5.8%
Estimated Annual Damages (USACE)

HEC-FDA
Flood Damage Reduction Analysis
HAZUS-GIS Based
Other types of Risk

Geomorphic—avulsions, debris flows, bank failures, etc...

Ecologic—threat of further degradation
Geomorphic Risk
Ecosystem Benefits

Below floodplain  Floodplain

Jeffres et al. 2008
Enclosed experiment, same age Chinook
Great for long, slow, deliberate planning

- Assess the risk in the current system
- Create regional plans to address this risk and future risk, and ecosystem rehabilitation
- Slowly implement the plans over the next 20 years…
Not so great for disaster recovery… 

BUT we are going to try to streamline the process into semi-quantitative analysis in order to come up with plans that address the risk (all types) in the system!
What risk based planning/risk based decision making is
What risk based planning/risk based decision making is

Reach 1—Flood Risk

<table>
<thead>
<tr>
<th></th>
<th>Inundated Assets</th>
<th>Asset Damage</th>
<th>Prob x Cons</th>
<th>Risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 yr</td>
<td>Natural floodplain</td>
<td>Low</td>
<td>Very High x Very Low</td>
<td>Low</td>
</tr>
<tr>
<td>10 yr</td>
<td>Bike Path</td>
<td>Low</td>
<td>High x Low</td>
<td>Low-Medium</td>
</tr>
<tr>
<td>25 yr</td>
<td>City Park</td>
<td>Medium</td>
<td>Medium x Medium</td>
<td>Medium</td>
</tr>
<tr>
<td>50 yr</td>
<td>Trailer Park</td>
<td>High</td>
<td>Low x High</td>
<td>Medium</td>
</tr>
<tr>
<td>100 yr</td>
<td>Subdivision</td>
<td>Very High</td>
<td>Low x Very High</td>
<td>Medium-High</td>
</tr>
</tbody>
</table>

**TOTAL** | **TOTAL** | **TOTAL** | **TOTAL** | **TOTAL** |

Medium
### Reach 2—Flood Risk

<table>
<thead>
<tr>
<th>Period</th>
<th>Inundated Assets</th>
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<th>Risk</th>
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<tbody>
<tr>
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<td>City Park</td>
<td>Low</td>
<td>Very High x Low</td>
<td>Low</td>
</tr>
<tr>
<td>10 yr</td>
<td>Fire Station</td>
<td>High</td>
<td>High x High</td>
<td>High</td>
</tr>
<tr>
<td>25 yr</td>
<td>High School</td>
<td>High</td>
<td>Medium x High</td>
<td>Medium-High</td>
</tr>
<tr>
<td>50 yr</td>
<td>Water Treatment Facility</td>
<td>Very High</td>
<td>Low x Very High</td>
<td>High</td>
</tr>
<tr>
<td>100 yr</td>
<td>Highway</td>
<td>Very High</td>
<td>Low x High</td>
<td>Medium-High</td>
</tr>
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**TOTAL** | **Risk** | **High**
What risk based planning/risk based decision making is

Reach 2—Flood Risk

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TOTAL: High
What risk based planning/risk based decision making is

ALL REACHES:

<table>
<thead>
<tr>
<th>Reach</th>
<th>Flood Risk</th>
<th>Geomorphological Risk</th>
<th>Ecologic Risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reach 1</td>
<td>Medium</td>
<td>Very High</td>
<td>Low</td>
</tr>
<tr>
<td>Reach 2</td>
<td>High</td>
<td>Very Low</td>
<td>Medium</td>
</tr>
<tr>
<td>Reach 3</td>
<td>Medium</td>
<td>High</td>
<td>Medium</td>
</tr>
<tr>
<td>Reach 4</td>
<td>Low</td>
<td>Low</td>
<td>Very High</td>
</tr>
</tbody>
</table>

Risk analysis helps to define the problem(s) that needs to be addressed in each reach.
What risk based planning/risk based decision making is

### Reach 2: Flood

Develop Strategies that address the high risk areas (remember to consider both PROBABILITY and CONSEQUENCE):

<table>
<thead>
<tr>
<th>Probability: elevation, or moving facilities out of flood way, opening up floodplain to reduce water surface elevations (and thus scour) along the highway…</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consequence: move electrical and mechanicals out of school basement, wet/dry flood-proofing…</td>
</tr>
</tbody>
</table>
What risk based planning/risk based decision making is

<table>
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<th>City Park</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Reach 2—Flood Risk</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Develop Strategies that address the high risk areas (remember to consider both PROBABILITY and CONSEQUENCE):

Maybe just some Bank Stabilization will address the geomorphic risk in the reach. If avulsions are a possibility, that likely won’t help.

Reach 2: Geomorphic (low)

<table>
<thead>
<tr>
<th>10 yr</th>
<th>FireStation</th>
<th>High</th>
<th>High</th>
<th>x</th>
<th>High</th>
<th>High</th>
</tr>
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TOTAL: High

Reach 2: Ecologic (Medium)

Develop Strategies that address the high risk areas (remember to consider both PROBABILITY and CONSEQUENCE):

High probability that invasive will take over=> weed management and re-veg plan. Or lack of deep pools.
What Risk-Based Planning is not:

- Delineating FEMA floodplains
- Looking only at infrastructure projects that address the probability of flooding (there are many non-structural solutions that will drastically reduce the consequences of flooding)
- Choosing designs from a book because they give the appearance of the pre-flood system
- Only assessing flood surface elevations... in Colorado floods trigger geomorphic responses and we need to look at, and address, those as well.
Recap

- Risk = Probability x Consequence
- There always will be residual risk
- Risk-based planning—the way forward
- Hand this over to Sue to talk about project and project element risk
Questions?

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http://www.wnyc.org/radio/#/ondemand/278173