What is Risk and Uncertainty?

- "Risk" and "uncertainty" are two terms basic to any decision making framework.

- Risk can be defined as imperfect knowledge where the probabilities of the possible outcomes are known, and uncertainty exists when these probabilities are not known.
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What is Risk management?

- The Risk Management process is defined as “the process of taking management action in order to respond appropriately to all identified risks to maximise the likelihood of the project meeting its objectives within its constraints, by monitoring risk exposure and adjusting project strategy to keep risk within acceptable levels”

Why is risk management important?

- The consequences of failure have many effects:
  - Costs
  - Environmental Impacts
  - Social Impacts
  - Operational Impacts
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**Why is risk management important?**

- **Decision Making**
  - Undertaking asset repair and rehabilitation decisions
  - Undertaking condition assessment decisions

- **Operational Planning**
  - Setting maintenance procedures
  - Developing emergency management plans

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**Typical Risk in Infrastructure Projects**

- **Economic Risks**: Inflation, Economic Policy stability
- **Soc.-political risks**: Social stability, regional stability, corruption, social non-acceptance
- **Regulatory & Legal Risks**: Stability of regulatory framework, enforceability of contracts, independent regulations
- **Market Risks**: Tariffs, demand, competition
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Typical Risk in Infrastructure Projects

➢ **Development & Construction Risks**: Design and Planning, construction and completion

➢ **Start-up & Operating**: Performance, environmental, suppliers

➢ **Technology**: Obsolescence

➢ **Force Majeure**: Natural disasters, war

Risk Measure

➢ Level of risk is measured using numerous indicators, for example:

➢ *Portion of an asset deemed to be critical* (expected to fail)
  – is represented by those assets that have deteriorated past the expected service life and are considered unacceptable

➢ *Impact of failure of an asset* – impacts of assessed failure are measured according to the social (health and safety of citizens), environmental (impact on the environment), and economic (cost of failure) indicators
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Risk Measure

- Level of risk is measured using numerous indicators, for example:
  - **Overall condition** – categorized by either A (very good), B (good), C (fair), D (poor) or E (very poor) or using any measure of the asset condition
  - **Severity** – reflects the overall likelihood of asset failure; the expected amount of failure and the impact of the failure on the city. An analytical combination of expected assets in critical condition and the impacts of failure of those assets help to analyze infrastructure deterioration levels at a large-scale level.

Risk Associated with Ineffective Condition Assessment

- Declining asset condition is not identified and addressed;
- Maintenance planning is not related to asset needs;
- Asset condition cannot be adequately reported;
- Deferred maintenance liability and provisions for future maintenance requirements cannot be reported in financial statements;
- Maintenance demand is not properly identified;
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Risk Associated with Ineffective Condition Assessment

- Poor quality of data leading to poor decision-making;
- Serious deficiencies can be overlooked;
- Information gathered on asset condition could be misleading; and
- Resources are not used effectively.

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Asset Criticality

- “Criticality” represents the relative importance of the asset when assessed by the impact of its failure on operations and the public
- Criticality is revealed in case of failure, when services and resources are suddenly not available anymore
- Critical infrastructure has a major importance for the society and that, if disrupted, would comprehensively affect supply chain, public safety and could lead to further dramatic consequences.
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**Asset Criticality**

- Trigger Event
  - Relevant Hazard

- Infrastructure

- Other Infrastr.

- Society

**Risk-Based Planning and Decision Making**

- Educated decision to accept exposure or to reduce vulnerabilities by either mitigating the risks or applying cost effective controls

\[
\text{Risk} = \frac{\text{Probability of Failure}}{\text{Exposure}} \times \text{Consequences of Failure}
\]

- Promotes identification and tracking of risk drivers
  - Factors impacting consequences and probability of failure
  - Economic, Operational, Social, Environmental

- Targets resources at areas where exposure is greatest
  - Focus on understanding when and where to invest
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Risk-Based Planning and Decision Making

- Supports consistent application of treatment based on Risk Exposure

<table>
<thead>
<tr>
<th>Exposure</th>
<th>Consequences</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inspection</td>
<td>H: Urgent Rehabilitate / Replace</td>
</tr>
<tr>
<td></td>
<td>M: Programmed Rehabilitate / Replace</td>
</tr>
<tr>
<td></td>
<td>L: Proactive Assessment</td>
</tr>
<tr>
<td>Maintenance</td>
<td>H: Urgent Rehabilitate / Replace</td>
</tr>
<tr>
<td></td>
<td>M: Programmed Rehabilitate / Replace</td>
</tr>
<tr>
<td></td>
<td>L: Proactive Assessment</td>
</tr>
<tr>
<td>Rehab/Replacement</td>
<td>H: Repair / Replace on Failure</td>
</tr>
<tr>
<td></td>
<td>M: Proactive Assessment</td>
</tr>
<tr>
<td></td>
<td>L: Monitor and Forecast</td>
</tr>
</tbody>
</table>

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Risk-Based Planning and Decision Making

- It is important to define which assets are critical, and focus maintenance efforts on those assets

- Critical asset which have risk of a high cost arising from failure of that asset and impacts the customers largely and immediately

- Asset criticality index: Highly critical; critical; Mid-level critical; Low-level; critical and Non-critical (following table identifies each level consequences).

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Risk-Based Planning and Decision Making

<table>
<thead>
<tr>
<th>Level</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Highly Critical</td>
<td>Extreme disruption to network causing total network operations stoppage</td>
</tr>
<tr>
<td>Critical</td>
<td>Major disruption to main network elements causing major network operations stoppage / disruption</td>
</tr>
<tr>
<td>Mid Level Critical</td>
<td>Significant disruption to major network elements causing up to 50% loss of capacity with major disruptions to operations</td>
</tr>
<tr>
<td>Low Level Critical</td>
<td>Disruption to some operations</td>
</tr>
<tr>
<td>Non-Critical</td>
<td>Little to no Disruption to operations</td>
</tr>
</tbody>
</table>

E: Extreme risk; H: High risk; M: Medium risk; L: Low risk and N: No risk

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E: Extreme risk; H: High risk; M: Medium risk; L: Low risk and N: No risk

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Risk-Based Planning and Decision Making

- Scheduling assets for maintenance depends on certain criteria identified during the condition assessment process such as:
  - The significance of the Relative Condition Level;
  - The severity of Condition Impacts;
  - Asset Criticality; and
  - The Asset Category.

Risk Hierarchy

[Diagram showing the risk hierarchy with categories and subcategories such as Environmental, Social, Economic, Short-term, Long-term, Proximity to Water bodies, Pipe Diameter, Proximity to Access roads.]
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Calculating Asset Risk Score

- **Step 1: Calculate Risk Category Index (RCI):** risk score for a given asset under a particular risk category (e.g. operational risk)

\[ RCI_i = \sum_{j=1}^{NRV_i} WRV_{i,j} \times SRV_{i,j} \]

- \( RCI_i \) = Risk Category Index for category \( i \)
- \( NRV_i \) = Number of Risk Variables in category \( i \) (for example there are 6 variables under economic risk in the above table).
- \( WRV_{i,j} \) = Weight of risk variable number \( j \) for category \( i \)
- \( SRV_{i,j} \) = Score of risk variable number \( j \) for category \( i \). Scores can range from 1 to 100 as shown in the preceding tables. Scores depend on the value of a risk variable (e.g. a 800mm pipe would score ‘50’ in the pipe size risk variable).

![Infrastructure Risk Management Diagram](image-url)
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Calculating Asset Risk Score

- **Step-2: Calculate the Asset Risk Index (ARI):** This is the total score for an individual asset taking into consideration all risk categories. It can be calculated as:

  \[ ARI = \sum_{i=1}^{NRC} RCI_i \times WRC_i \]

  - \( WRC_i \) = Weight of risk category \( i \)
  - \( NRC \): Number of Risk Categories (for example, economic, operational, social and environmental - 4 categories)
  - Based on the obtained risk score, rate the risk index (High criticality, \( ARI > 80 \); Medium criticality, \( 80 > ARI > 10 \); Low criticality, \( ARI < 10 \)
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**Calculating Asset Risk Score: Example**

- Calculate the ARI for the following two pipes given the conditions described below:
  - **Pipe A:**
    - 200mm Cast Iron
    - 1.6m deep in a residential street
    - Good soil conditions and good accessibility
  - **Pipe B:**
    - 1200mm PCCP
    - 1.6m deep in a high density downtown area
    - Good soil conditions and poor accessibility

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**Risk Responses**

- **Acceptance**: Accept the risk as is and do nothing about it. Usually possible with low risks
- **Avoidance**: Eliminate the cause of the risk. Remove item all together, stop providing service
- **Mitigation**: Accept the risk and try to reduce the consequence and/or Probability. Rehabilitate, proactive condition assessment, emergency response plan.
- **Transfer**: Place the responsibility of the risk on a third party. Insurance, Outsourcing