RISK ANALYSIS METHODS AND TOOLS FOR ENGINEERING PROJECTS: AN EXPERIENCE OF ELETROBRAS FURNAS IN BRAZIL

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Eletrobras Furnas Centrais Elétricas S.A.
Stages of a Construction Project

- Conception/Conceptualization
- Technical and Economic Feasibility
- Projects
- Bidding/Hiring
- Construction
- Use and Operation
- Maintenance
I. Corporate Risk Management Master Plan

- Integrated Risk Management
- Regulatory and institutional management
- Management of the environment
- Human Development and management technology
- Legal Management
- Enterprise Planning
- Business Development
- Technique
- Commercialization
- Operation and Maintenance
- Partnership Management
- Finance and Accounting
- Audit and Ombudsman
- Supply and Logistics
- Information Technology
- General Services
I. Corporate Risk Management Master Plan

![Probability-impact matrix diagram]

- Probability
- Impact

- Impact values: 0, 25, 50, 75, 100
- Probability values: 0, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1.0

- Matrix grid indicates risk levels with corresponding numbers for each risk factor.

- Eletrobras Furnas logo on the bottom right.
I. Corporate Risk Management Master Plan

ADVANTAGES:

✓ Created the basis for implementing the risk management culture in the company;

✓ Prioritization of Risks (Expected Value).

DISADVANTAGES:

✓ It focuses only on strategic risks and not on specific projects;

✓ It does not allow more specific risk analysis for costs and deadlines;

✓ It does not address the uncertainties inherent in a subjective process.
II. Risk Management System in Power Generation Projects

- **Objective:** Creation of software to prioritize construction risks, using the FAHP-Fuzzy Analytic Hierarchy Process methodology, which addresses the uncertainties;

- **FAHP:** Multicriteria method of decision support, addressing the inherent inaccuracies of complex decisions;

- **Case studies:** 2 Dams, 1 Eolic Complex.
II. Risk Management System in Generation Projects

Result of the FAHP application

<table>
<thead>
<tr>
<th>PRIORITY</th>
<th>SERVICE PACKAGE</th>
<th>IMPACT LEVELS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Socio-environmental</td>
<td>40.6%</td>
</tr>
<tr>
<td>2</td>
<td>Transmission civil works</td>
<td>17.5%</td>
</tr>
<tr>
<td>3</td>
<td>Complementary works</td>
<td>12.8%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>PRIORITY</th>
<th>RISK EVENTS</th>
<th>IMPACT LEVELS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Project</td>
<td>33.5%</td>
</tr>
<tr>
<td>2</td>
<td>Contracts</td>
<td>22.2%</td>
</tr>
<tr>
<td>3</td>
<td>Geotechnical</td>
<td>21.9%</td>
</tr>
</tbody>
</table>
II. Risk Management System in Generation Projects

FAHP application

ADVANTAGES:

✓ It takes into account the inherent inaccuracies of complex decisions;
  ✓ Prioritization of Risks;
  ✓ The result confirmed the expectations of the interviewees.

DISADVANTAGES:

✓ Difficulty in applying the method;
  ✓ Difficulty in in-depth interviews and content analysis;
  ✓ Subjectivity in the definition of service packets and risk events.

DIFFICULTY OF APPLICATION:

✓ Not understanding the method;
  ✓ Tiredness of the interviewee;
  ✓ Tendency to choose extreme degrees of preference.
### III. Risk Management System in Generation Projects

**Impact on the Project End´s Date**

<table>
<thead>
<tr>
<th>Duration</th>
<th>Average</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Delay</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>To Anticipate</td>
<td>1263</td>
<td>1131</td>
<td>1402</td>
</tr>
<tr>
<td>Up to 3 months</td>
<td>251</td>
<td>119</td>
<td>390</td>
</tr>
<tr>
<td>3 to 6 months</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6 to 12 months</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>More than 1 year</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Probability</strong></td>
<td>0,0%</td>
<td>100%</td>
<td>5,4%</td>
</tr>
<tr>
<td>Impact on the Project End's Date</td>
<td>74,2%</td>
<td>20,4%</td>
<td>0,0%</td>
</tr>
</tbody>
</table>
III. Risk Management System in Generation Projects

ADVANTAGES:

✓ Analysis of complex models;
✓ Assists in the decision regarding deadlines and costs;
✓ If the model is well planned, there is a good level of precision.

DISADVANTAGES:

✓ Project schedule should be well planned and defined;
✓ Beware of using best practices for network of activities;
✓ Difficulty in interviewing to define the worst and best case;
✓ It does not take into account the uncertainties regarding the definition of durations by the specialists.
IV. Risk Analysis for Dam Safety

PHASE I: Selection of Dams

Function of the Dam
Size of the Dam
Age of the Dam

PHASE II: Analysis of Risks in Individual Dams

Score Impact / Confidence Index
Risk Index
Risk Potential
Behavior Index
Risk class
Classification Matrices
Global Modified Risk Index

PHASE III: Analysis of Failure Modes of Major Problems

Methodology of Risk Analysis
LCI/FMECA
ETA/FTA
IV. Risk Analysis for Dam Safety

Risk Matrix of LCI Method

<table>
<thead>
<tr>
<th>PROBABILITY</th>
<th>IMPACT 1</th>
<th>IMPACT 2</th>
<th>IMPACT 3</th>
<th>IMPACT 4</th>
<th>IMPACT 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>HIGH</td>
<td>HIGH</td>
<td>HIGH</td>
<td>HIGH</td>
<td>HIGH</td>
</tr>
<tr>
<td>2</td>
<td>MEDIUM</td>
<td>MEDIUM</td>
<td>MEDIUM</td>
<td>MEDIUM</td>
<td>MEDIUM</td>
</tr>
<tr>
<td>3</td>
<td>LOW</td>
<td>LOW</td>
<td>LOW</td>
<td>LOW</td>
<td>LOW</td>
</tr>
</tbody>
</table>

SQ4, SQ1, 2, SQ3, 5

<table>
<thead>
<tr>
<th>IMPACT 1</th>
<th>IMPACT 2</th>
<th>IMPACT 3</th>
<th>IMPACT 4</th>
<th>IMPACT 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>HIGH</td>
<td>HIGH</td>
<td>HIGH</td>
<td>HIGH</td>
</tr>
<tr>
<td>2</td>
<td>MEDIUM</td>
<td>MEDIUM</td>
<td>MEDIUM</td>
<td>MEDIUM</td>
</tr>
<tr>
<td>3</td>
<td>LOW</td>
<td>LOW</td>
<td>LOW</td>
<td>LOW</td>
</tr>
</tbody>
</table>

BA1, 5, BA4, BA2, 3, BA1, 5

<table>
<thead>
<tr>
<th>IMPACT 1</th>
<th>IMPACT 2</th>
<th>IMPACT 3</th>
<th>IMPACT 4</th>
<th>IMPACT 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>HIGH</td>
<td>HIGH</td>
<td>HIGH</td>
<td>HIGH</td>
</tr>
<tr>
<td>2</td>
<td>MEDIUM</td>
<td>MEDIUM</td>
<td>MEDIUM</td>
<td>MEDIUM</td>
</tr>
<tr>
<td>3</td>
<td>LOW</td>
<td>LOW</td>
<td>LOW</td>
<td>LOW</td>
</tr>
</tbody>
</table>

BA1, 5, BA4, BA2, 3, BA1, 5

<table>
<thead>
<tr>
<th>IMPACT 1</th>
<th>IMPACT 2</th>
<th>IMPACT 3</th>
<th>IMPACT 4</th>
<th>IMPACT 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>HIGH</td>
<td>HIGH</td>
<td>HIGH</td>
<td>HIGH</td>
</tr>
<tr>
<td>2</td>
<td>MEDIUM</td>
<td>MEDIUM</td>
<td>MEDIUM</td>
<td>MEDIUM</td>
</tr>
<tr>
<td>3</td>
<td>LOW</td>
<td>LOW</td>
<td>LOW</td>
<td>LOW</td>
</tr>
</tbody>
</table>
## IV. Risk Analysis for Dam Safety

**FMECA (Failure Mode, Effect and Criticality Analysis)**

<table>
<thead>
<tr>
<th>FUNCTION</th>
<th>FAILURE MODE</th>
<th>CAUSE</th>
<th>EFFECT</th>
<th>P</th>
<th>I</th>
<th>ICR</th>
<th>DETECTION MODE (DM), PREVENTION (PR)</th>
<th>D</th>
<th>RPN</th>
</tr>
</thead>
<tbody>
<tr>
<td>CONCRETE DAM</td>
<td>1(1) OVERFLOW (HYDRAULIC FAULTS)</td>
<td>Exceptional water levels</td>
<td>External erosion with dam break</td>
<td>2</td>
<td>20</td>
<td>40</td>
<td>Reservoir lowering (PR)</td>
<td>2</td>
<td>80</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Level monitoring by telemetry system (DM)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1(2) SLOPE SLIP</td>
<td>Exceptional uploads</td>
<td></td>
<td>1</td>
<td>20</td>
<td>20</td>
<td>Reservoir lowering (PR)</td>
<td>3</td>
<td>60</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Inadequate material properties</td>
<td>Global instability with uncontrolled water release</td>
<td>1</td>
<td>5</td>
<td>5</td>
<td>Visual inspection and instrumentation (DM)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Geological mapping (PR)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Inadequate foundation properties</td>
<td></td>
<td>2</td>
<td>8</td>
<td>16</td>
<td>Consolidation Injection (DM), Installation of drains (PR)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Technological control (PR), Instrumentation (DM), Construction of stabilizer bats (DM), Compression (DM)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**1.C. Etoefrash Furnas**
V. RISK ANALYSIS FOR COST CONTINGENCY

SUBSTATION 1
TOTAL COST = R$ 1.667.892,00
60,57% Probability of cost of the project does not exceed R$ 1.780.621,88
EV = R$ 1.731.505,40 (1%) (EURO 509.266,00)

SUBSTATION 2
TOTAL COST = R$ 4.011.674,00
63,18% Probability of cost of the project does not exceed R$ 4.074.836,71
EV = R$ 4.059.814,09 (1%) (EURO 1.194.062,00)
CONCLUSIONS

☑ EACH OBJECTIVE HAS A RISK METHOD

☑ THERE IS NO METHOD THAT WORKS FOR EVERYTHING

☑ EACH METHOD HAS ADVANTAGES AND DISADVANTAGES

☑ THE IMPORTANT IS TO FIND THE BEST TOOL TO MEET THE SPECIFIC OBJECTIVE
THANK YOU!

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