International Atomic Energy Agency

P7: Experience in Risk Informed Decision Making

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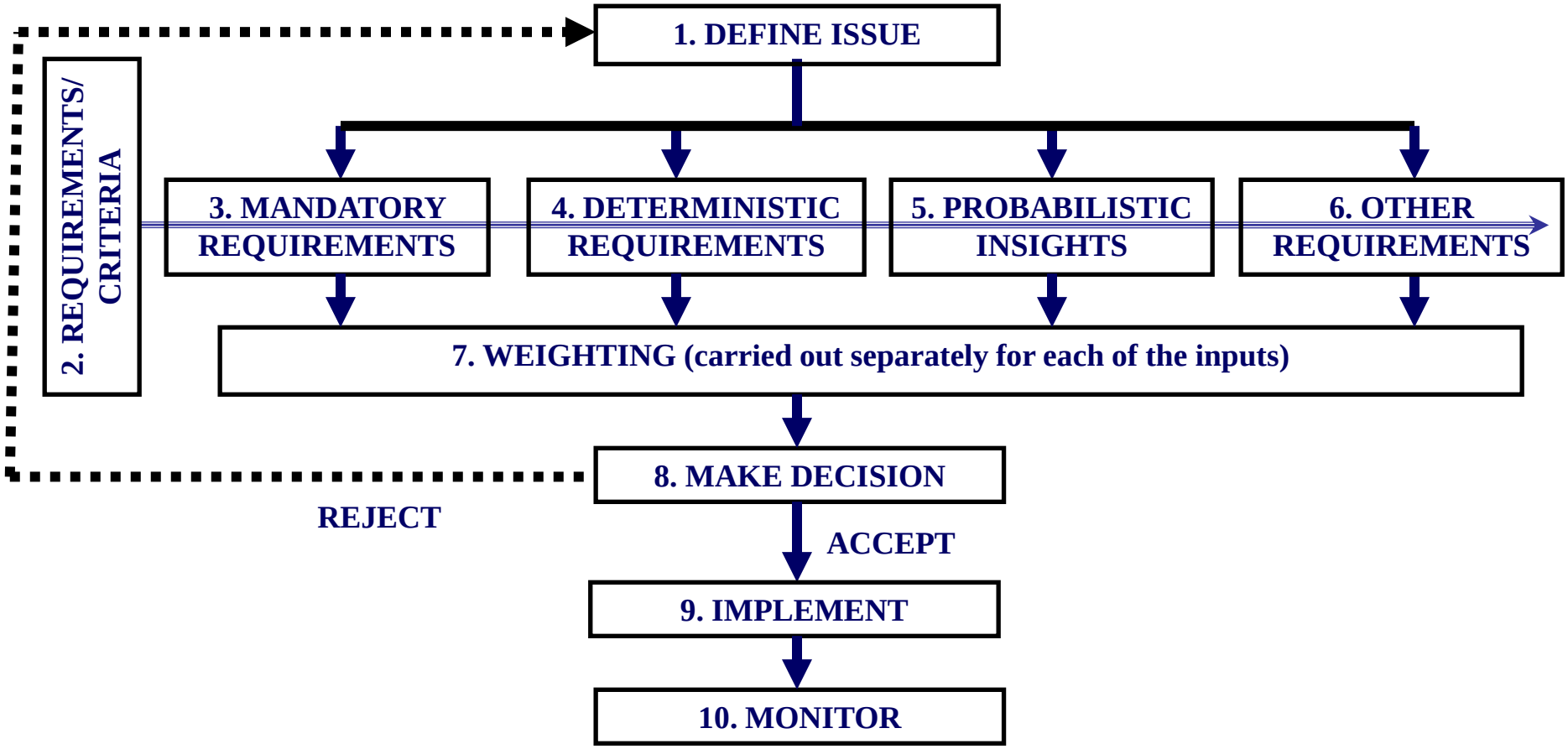
Application of Level 1 Probabilistic Safety Assessment

Bangkok, Thailand
5 – 9 September, 2022

Integrated Decision-Making Process



1. Definition of the Issue

- **The management of the NPP is considering possibly *converting to a new fuel that would allow the plant to increase the time between refuelling outages from 12 to 18 months and increase the maximum power to 104 %***
  - **The management, seeing the obvious cost benefits to this, requested a comprehensive review of the proposal be undertaken, if possible, using IRIDM since that was management policy**

- **Major restriction:**
  - **manufacturer's requirement that maintenance be performed on important safety components (SGs, Safety Valves, etc.) at yearly intervals. This maintenance requires the plant to be in a shutdown condition**

2. Determining the preliminary options

The options chosen were as follows:

- **Option 1: To allow the change under the existing conditions which require an annual shutdown for test/maintenance of certain equipment**
  - **somewhat negating the advantages of a longer duration between refuelling outages**
- **Option 2: To allow the change with modified conditions**
  - **The previous annual maintenance requirement would be modified to be consistent with refuelling intervals, every 18 months**
  - **Manufacturer immediate approval of this change would be required with formal manufacturer's documentation updated within 2 years**
- **Option 3: To postpone the change until the all the specified conditions are met (maintenance requirements and documentation revised to be consistent with refueling outages)**
  - **Formal manufacturer's documentation update is provided before implementation**
- **Option 4: To decline the change**

3. Review and screening of the options

- The options were evaluated against ***mandatory requirements*** that could possibly eliminate an option from consideration or modify the option
  - **The principle mandatory requirement was concluded to be the manufacturer's requirement that maintenance be performed on important safety components at yearly intervals.**
- ***Results of this screening process were as follows:***
- **Option 1** – Existing conditions under option 1 result in the following:
  - **Once per year, the plant would be in shutdown for yearly components tests**
  - **Fuel cycle would still be prolonged till 18 months equivalent operation**

  Note that these special conditions eliminate some of the advantages of making the change since an annual shutdown period would be required
- **Option 2** – This option violates manufacturer's requirements unless approval is obtained from the manufacturer.
- **Option 3** - This option is similar to option 2, but will be implemented only after manufacturer's documentation is changed – no violation
- **Option 4** – This option is maintained in that there is basically no change

Conclusion: All options retain in the analysis

The typical Constituent Factors (CFs) in the IRIDM process

- Standards and good practices
- Operational experience
- Deterministic considerations
- Probabilistic considerations
- Organisational considerations
- Security considerations and
- Other considerations

4. *Evaluation of the options against the relevant CFs (1/6)*

1) Affected mandatory requirements

- The mandatory requirement is the manufacturer's specification that preventive maintenance of certain equipment is performed once per year (12 months)
  - For option 2 the preventive maintenance for the Steam Generator safety valves, Pressurizer safety valves, Spray System will not be in compliance with documented mandatory manufacturer requirements if fuel cycle is changed from 12 to 18 months unless the regulator accepts informal manufacturer's approval
  - For options 1, 3 and 4 this requirement is met

Note that based on the preliminary feedback from manufactures the changes of preventive maintenance periodicity of equipment will be accepted

- Other requirements and criteria
  - No effect on other mandatory requirements and criteria were determined

2) Insights from operational experience

- There was no similar experience

4. *Evaluation of the options against the relevant CFs (2/6)*

3) Insights from deterministic analysis:

- **Defence-in-depth**
  - Compliance with the defence-in-depth concept was justified for all options under consideration
- **Safety margins**
  - A slight decrease of safety margins was observed due to higher parameters of the reactor operating at 104% rate for options 1, 2 and 3, However, the thermal hydraulic analyses confirmed that adequate safety margins were maintained.
- **Other deterministic criteria**
  - No other deterministic criteria are violated (fail-safe design, single failure criterion, redundancy, diversity, etc.)

4. *Evaluation of the options against the relevant CFs (3/6)*

4) Insights from probabilistic analysis

- **Quantitative insights**
  - **Option 1** - the PSA was not re-evaluated
    - However, it is expected that overall CDF will not increase
  - **Option 2** - the PSA showed that:
    - CDF for full power operation is increased by about 5%
    - Fuel damage frequency (FDF) for single shutdown operation practically does not change
    - Total FDF averaged over 3 years cycle period (for full power and shutdown modes) of the Unit decreased from **7.31*10-5/year** to **7.21*10-5/year** due to one less shutdown in three years period
  - **Option 3**
    - Same as Option 2 with 2 years delay
  - **Option 4**
    - no changes in risk results

4. *Evaluation of the options against the relevant CFs (4/6)*

4) Insights from probabilistic analysis (cont.):

- **Qualitative insights**
  - Qualitative results of the PSA do show that the decrease of averaged yearly FDF is explainable and makes sense (Option 2)
  - Changes to importance ranking were minimal for options 2,3, and were believed to be of no significance for option 1 and no impact for option 4.

Explanation:

  - Slight increase in CDF during power operation is compensated by decrease of FDF during shutdown (averaged over 3 years period) due to one less shutdown.

- **Probabilistic safety targets**
  - Probabilistic safety targets in terms of CDF stated in regulatory documents are met.

4. *Evaluation of the options against the relevant CFs (5/6)*

4) Insights from probabilistic analysis (cont.):

- **PSA Scope**
  - **Level-1 PSA** for internal initiators and internal hazards (fires/floods) for power operation and shutdown modes was used
  - It is accepted that change associated with Options 1, 2 and 3 will not impact the External hazards PSA results and will have negligible impact on Level-2 PSA.

Note: it is understood that source term for the options 1, 2 and 3 will be different and slightly worse than for option 4 However, the overall radiological risk and doses to the workers will be reduced in Options 2 and 3 due to reduction of the averaged shutdown duration over 3 years cycle.

- **PSA Quality**
  - Regulatory review accepted the quality and level of detail of the PSA and PSA conclusions to be sufficient for this decision making issue.

4. *Evaluation of the options against the relevant CFs (6/6)*

5) **Other factors** (e.g. equipment qualification, electricity production, maintenance costs, and radiation doses for workers)

- **Option 1**
  - Moderate increase in electricity production
  - Increase in maintenance costs due to more test/maintenance of certain components comparing to Options 2 and 3
- **Option 2**
  - Significant increase in electricity production
  - Reduction in maintenance costs due to less frequent maintenance of certain components
  - Decrease in radiation doses for workers due to less frequent maintenance and inspections
- **Options 3**
  - Same as Option 2, but benefits are delayed by 2 years
- **Option 4**
  - No changes

5. Integration of the results

- **Weighting factors approach was used**
  - The IRIDM team defined weighting factors for the above CFs based on expert judgment:
    - Weights from 0 to 10 assigned based on **importance** perceived by IRIDM team
    - **Impacts** were assigned 1 to 7 with 4 being no change, 1-3 – negative impact, 5-7 positive impact.
- **The lists of factors are shown on next slide.**

Task: Weighting factors estimation

Factor	Option 1		Option 2		Option 3		Option 4	
	Weight (W)	Impact (I)	Weight (W)	Impact (I)	Weight (W)	Impact (I)	Weight (W)	Impact (I)
Mandatory requirements								
Defence-in-depth								
Safety Margins								
Risk changes								
Electricity production								
Maintenance costs								
Radiation doses for workers								
Regulatory Approval								
Other costs								
Overall score = Sum (W*I)								

Weighting factors estimation for all options

	Option 1		Option 2		Option 3		Option 4	
Factor	Weight (W)	Impact (I)	Weight (W)	Impact (I)	Weight (W)	Impact (I)	Weight (W)	Impact (I)
Mandatory requirements	10	4	10	3	10	4	10	4
Defence-in-depth	10	4	10	4	10	4	10	4
Safety Margins	3	3	3	3	3	3	3	4
Risk changes	3	5	3	6	3	6	3	4
Electricity production	10	6	10	7	10	5	10	4
Maintenance costs	1	2	1	6	1	6	1	4
Radiation doses for workers	3	3	3	6	3	6	3	4
Regulatory Acceptance	5	10	5	2	5	10	5	4
Other costs (implementation)	1	4	1	4	1	4	1	4
Overall score = Sum (W*I)	229		205		235		184	
normalized	1,24		1,11		1,28		1	

6. Making the decision

- A multidisciplinary team was involved in IRIDM process
  - Specialists of different areas were engaged:
    - PSA specialists
    - Safety-related systems specialists
    - Specialists in TH area
    - Water chemistry specialists
    - Specialists in metal, control area I&C and electrical engineers
- The positive decision for Option 3 was made on the basis of the highest score