LESSON 7

Quantifying HRA Models

Study Guide

Topic: Quantifying HRA Models

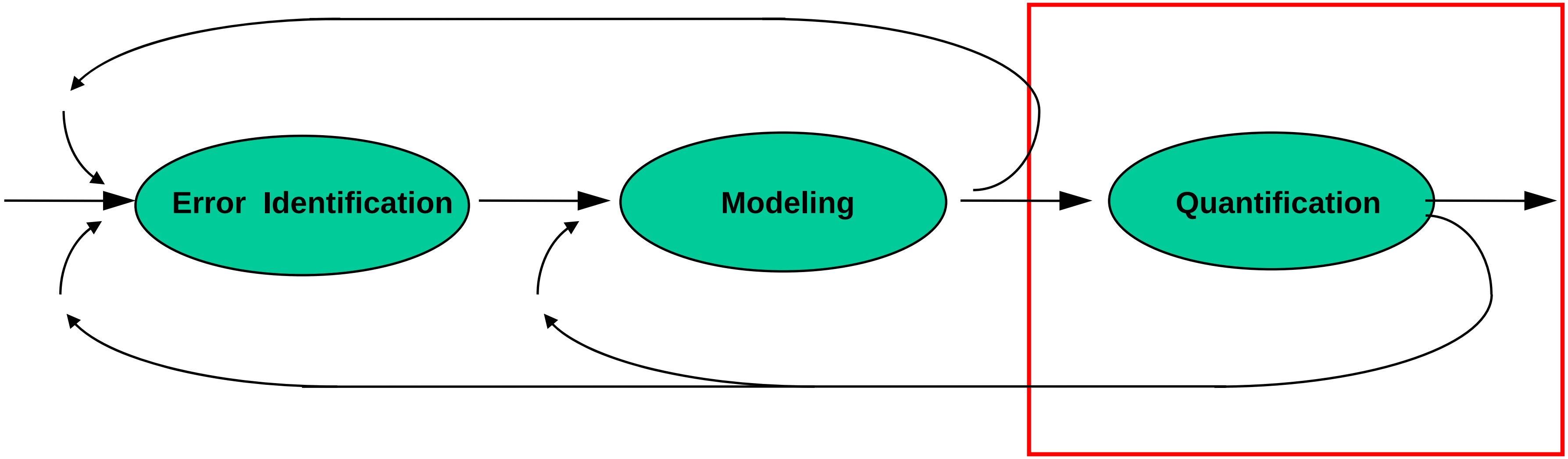
Purpose: This lesson provides students with an understanding of various methods of quantification and their application for HRA.

Objectives: At the end of the lesson, students will be able to:

- Explain what is meant by quantification
- Recall the essentials of the best known quantification methods
- Use knowledge of methods to quantify several models
- Describe the value of confidence bounds and sensitivity in quantification of models

Resources: Gertman and Blackman, Chapters 3, 5-7, 9, 11; Reason, Chapter 8

The Essential HRA Processes that are Integrated into Risk Assessments - HRA Quantification



Quantifying a Model

- ***Quantification is the process of plugging the right numbers into a model, then calculating the results***
- ***The steps involved in the calculation depend on the methodology being used***
- ***The data for the calculations may come from databanks, simulations, expert judgment, etc...***
- ***The result is typically called a Human Error Probability or HEP***
- ***Various intermediate products may be created***

Why Quantify HRA Models?

- ***Quantification is an essential part of risk assessment***

- ***Quantification promotes prioritization of prevention/remediation activities (economic or safety analysis)***
  - ***Evaluation of alternative designs***
  - ***Consideration of importance***

Two Levels of Precision

- ***Conservative (screening) level useful for determining which human errors are the most significant contributors to overall system error***
- ***Those found to be potentially significant contributors can be profitably analyzed in greater detail (which often lowers the HEP)***

Median vs. Mean

Many of the techniques produce distributions described by a Median HEP and Error Factor (EF). These can be converted to Mean HEPs for inclusion in risk assessments.

Quantification Concepts

- ***Base error rate***
- ***Recovery, PSFs, and dependency modify base error rates***
- ***Error factor (95th/50th or 50th/5th)***

95th percentile	Upper bound = median HEP multiplied by its error factor	**.001x5 = .005**
50th percentile	estimate, assumed HEP = median point	**0.001,EF 5**
5th percentile	Lower bound = median HEP divided by its error factor	**.001 / 5 = .0002**

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Sources of Uncertainty

- ***Inability to specify initial and boundary conditions precisely***
  - ***Cannot specify result with deterministic model***
  - ***Instead, use probabilistic models (e.g., tossing a coin)***
- ***Sparse data on initiating events, component failures, site conditions and human errors***
- ***Lack of understanding of phenomena***
- ***Modeling assumptions (e.g., success criteria)***
- ***Modeling limitations (e.g., inability to model errors of commission)***
- ***Incompleteness (e.g., failure to identify certain failure modes)***

HRA Quantification Approaches

- *Composite Techniques*
  - *THERP*
  - *SPAR HRA (SPAR-H)*
  - *CREAM*
  - *HEART*
- *Expert Estimation (ATHEANA, Delphi, NGT, SLIM, MERMOS)*
- *Time Reliability Techniques*
  - *TRC*
  - *HCR*
  - *ORE*

THERP (NUREG/CR-1278)

- *Developed by Swain and Guttmann at Sandia in early 1980s*
- *Based on data gathered from reactor control room, bomb-assembly, and chemical processing activities*
- *Historically most widely used method*
- *Validates as well or better than any other technique*
- *Uses HRA event tree modeling*
- *Applies data and modifications from tables (see THERP Chapter 20) for quantification*
- *Often misapplied (quantify top level without modeling and quantifying subtasks)*

BREAK

SPAR-H HRA Method (NUREG in press)

- ***Is a simplified HRA method***
- ***Developed to support NRC’s Accident Sequence Precursor (ASP) program***
- ***Is based on a Information Processing Model (IPM) of human behavior***
- ***Primarily used for to develop SPAR Risk Assessment models,simplified HRA where tasks can be combined***
- ***Explicit dependence evaluation, uncertainty approach***
- ***Provides base failure rates and performance shaping factors in worksheet format***

SPAR-H HRA PSFs

- ***Available time***
- ***Stress/Stressors***
- ***Complexity***
- ***Experience/training***
- ***Procedures***
- ***Ergonomics/HMI***
- ***Fitness for duty***
- ***Work processes***

Applying SPAR HRA (SPAR-H)

- ***Requires some judgments about the nature of human tasks***
- ***Can use all available forms of plant knowledge***
- ***Can be used at different levels of specificity***
- ***Uses the SPAR-H Human Error Worksheets***
- ***Considers dependency***
- ***Uncertainty formulation***

Worksheets available in Appendix E

A Technique for Human Event Analysis (ATHEANA; NUREG-1624)

- ***Purpose is to "develop an HRA quantification process and risk assessment modeling interface that can accommodate and represent human performance found in real NPP events"***
- ***Method focuses on errors of commission, error forcing context, unsafe acts, and recovery***
- ***Looking at more cognitive kinds of errors of commission (e.g., mistakes in judgment)***
- ***Unsafe acts - don't necessarily lead directly to an error***

Cognitive Reliability and Error Analysis Method (CREAM; Hollnagel, 1998)

- ***Provides an approach to meet the combined needs of retrospective analysis and performance prediction***
- ***Performance classification based on error modes, consequences (phenotypes), and causes (genotypes)***
- ***Uses a simple model of cognition called Contextual Control Model (CoCoM) based on the premise that:***

> ***"Cognition is not only an issue of processing input and producing reaction, but is also an issue of the continuous revision and review of goals and intentions"***

CREAM Error Identification

"Phenotypes"

Error modes & consequences:
- *Timing errors (too early, late)*
- *Distance errors (too far, short)*
- *Speed errors (too fast,slow)*
- *Direction errors*
- *Force errors (too much, little)*
- *Object (wrong action, object)*
- *Sequence errors (reversal, repetition, commission, intrusion)*
- *Duration errors (too long, short)*

"Genotypes"

Causes: Man, Technology, & Organization
- *Person-related (cognitive, temporary, permanent)*
- *Technology (equipment, procedures, temporary and permanent features of work environment)*
- *Organization (attitudes, beliefs that guide workforce actions)*

Expert Estimation Techniques - Nominal Group Technique (NGT; Delbecq, Van de Ven, & Gustafson, 1971)

- ***Form group***
- ***Review materials***
- ***Assess independently***
- ***Discuss as a group discussion***
- ***Second assessment***
- ***Consensus or aggregation***

#11 Group Exercise: The Infamous Bean Jar

- ***Break into groups. Use Nominal Group Technique (NGT) to estimate the number of beans in the jar.***

Expert Estimation Techniques - Success Likelihood Index Method (SLIM; NUREG/CR-3518)

- ***Described in detail in Gertman and Blackman pages 55-60***
- ***Uses experts to set an upper and lower bound (anchor values)***
- ***Experts determine PSFs important to tasks (also determine weights)***
- ***Experts rate condition of tasks relative to each PSF to determine Success Likelihood Index (SLI)***

SLIM Procedure

- *Identify judges competent to rate group of related tasks*
- *Use task analysis to discuss possible error mechanisms*
- *Identify the PSFs that influence the various potential error modes identified*
- *Document definitions of various PSFs*
- *Judges assess weights for each PSF (Without MAUD, use consensus to determine final weights)*
- *Judges rate each task according to each PSF*
- *Calculate the SLI*
- *Identify anchor points (using known data... e.g. from NUCLARR) or rating techniques*
- *Transform the SLI to a HEP*

Time Reliability Correlation (TRC) Techniques

- ***Human Cognitive Reliability (HCR) and Operator Reliability Experiment (ORE) are two well-know efforts***
- ***Human error rates are estimated as a function of time***
- ***More time means less probability of error***
- ***Often used to estimate the probability of diagnosis type errors***
- ***Requires accurate sequence, event, and performance time estimates***
- ***TRC estimates may be adjusted for additional influences***

#12 Second Quantification Exercise

- ***Assemble in your groups***
- ***Look at Appendix H (Irradiator Example Study)***
- ***Use the THERP Tables in your handout Appendix F to determine HEPs for the irradiator fault tree that follows***
- ***Present your results***

Other Techniques in Text

- ***Sociotechnical Assessment of Human Reliability (STAHR) (Gertman and Blackman pages 60-61)***

- ***Generic Error Modeling System (GEMs) (Gertman and Blackman pages 377-379 and Reason pages 61-68)***

- ***Confusion Matrix (Gertman and Blackman pages 45-49)***

Comparing Strengths and Weakness of Techniques

- ***Articles in readings discuss strengths and weaknesses of various techniques***
  - ***Type of tasks being modeled and quantified***
  - ***Data availability***
  - ***Time available to perform analysis***
  - ***Expertise of analyst***
- ***See also Gertman and Blackman page 72***

Lesson Summary

Key Points:

- Quantification calculates the probability of specific human errors occurring

- There are a number of methods for calculating human error probabilities

- Confidence bounds are used to show the range (upper and lower bounds)

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