A Study of Variability Effect of Performance Influencing Factors in Human Error Probability Quantification

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1.0 Introduction

1.1 Variability of HRA results (Challenge)

- Effects of PIFs in various HRA methodologies and how it affects the HEP quantification for PRA analysis.
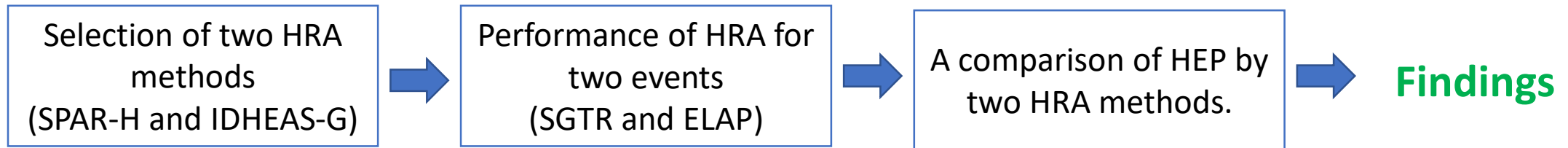
1.2 Objective of the Study

i. To **compare** the effects of PIF on HEP using **different methodologies**.

ii. To **identify** the most **efficient way to quantify** the HEP based on PIF
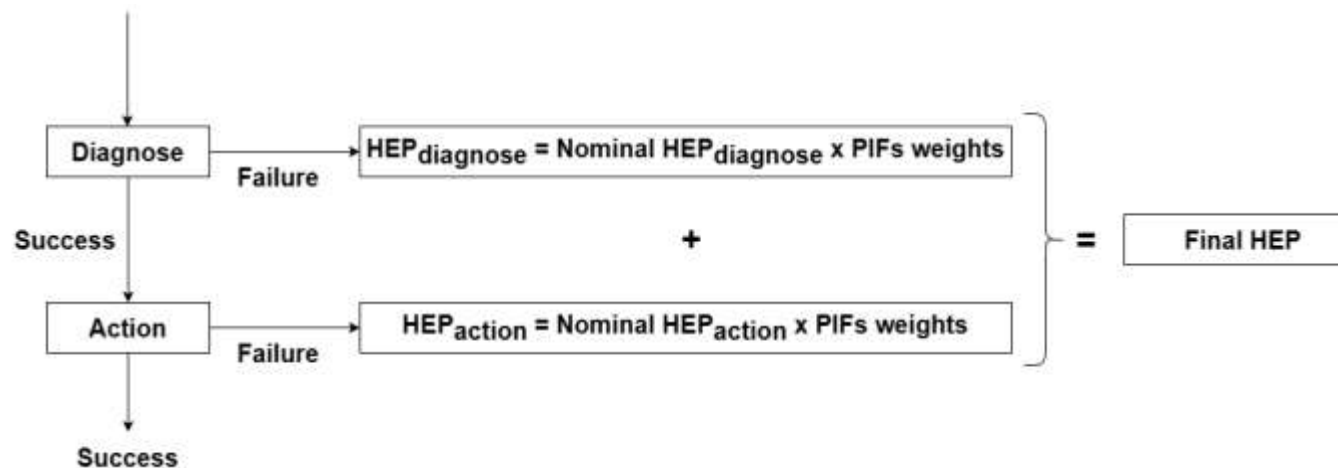
2.0 HRA Methodology

2.1 Description of the Study

Selection of two HRA methods (SPAR-H and IDHEAS-G)	→	Performance of HRA for two events (SGTR and ELAP)	→	A comparison of HEP by two HRA methods.	→	**Findings**

2.2 General HEP quantification

Diagnose → Failure → $HEP_{diagnose} = \text{Nominal } HEP_{diagnose} \times \text{PIFs weights}$

Success

+

Action → Failure → $HEP_{action} = \text{Nominal } HEP_{action} \times \text{PIFs weights}$

Success

= Final HEP

2.0 HRA Methodology

$$HEP_{SPAR-H} = P_{diagnose} + P_{action}$$

$$P_{diagnose} = HEP_{Base} \times PIFs$$
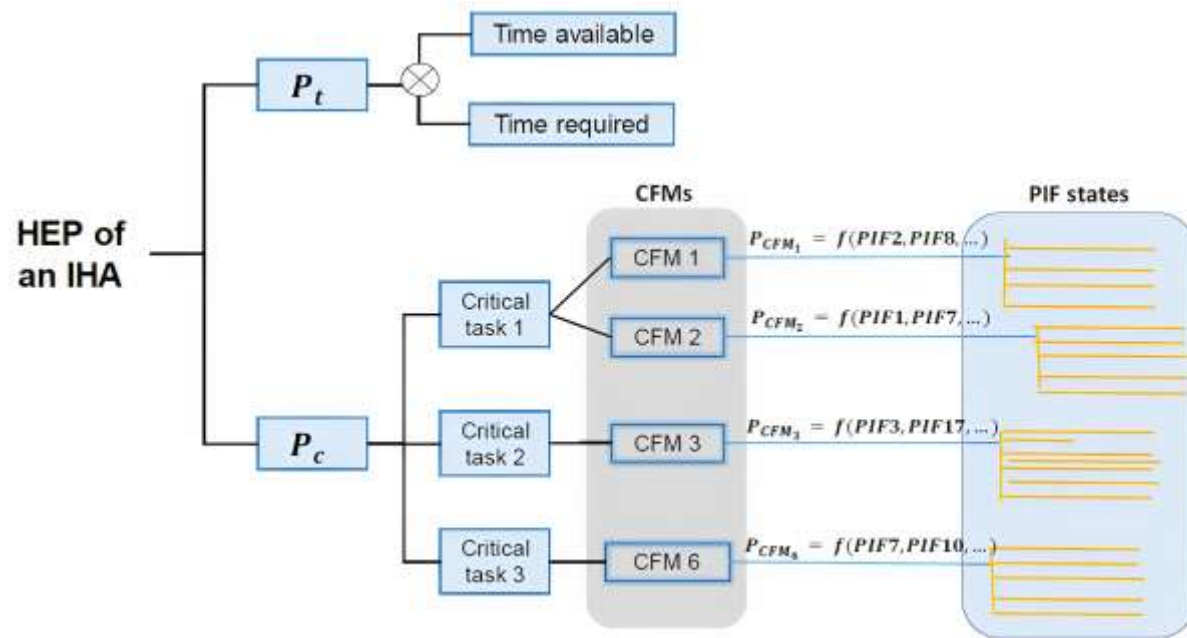
$$P_{action} = HEP_{Base} \times PIFs$$

- SPAR-H utilizes the concept of nominal HEP for diagnosis and action, which are average expected values in the absence of PIF effects (Boring,2007)

Diagnosis: $Base\ HEP = 1 \times 10^{-2}$

Action: $Base\ HEP = 1 \times 10^{-3}$

2.0 HRA Methodology

$$HEP_{IDHEAS-G} = 1 - (1 - P_c)(1 - P_t)$$

- IDHEAS-G employs the use of **base HEP** for the given **Cognitive Failure Mode (CFM)** using the following three PIFs:
  - Information availability and reliability (**INF**)
  - scenario familiarity (**SF**)
  - task complexity (**TC**)

$$P_{CFM_{Base}}(detection) = 1 \times 10^{-4}$$
$$P_{CFM_{Base}}(understanding) = 1 \times 10^{-3}$$
$$P_{CFM_{Base}}(decisionmaking) = 1 \times 10^{-3}$$
$$P_{CFM_{Base}}(action) = 1 \times 10^{-4}$$
$$P_{CFM_{Base}}(interteam) = 1 \times 10^{-3}$$

2.0 HRA Methodology

Characteristics	SPAR-H	IDHEAS-G
1. HEP	$HEP_{SPAR-H} = P_{diagnose} + P_{action}$	$HEP_{IDHEAS-G} = 1 - (1 - P_{cognitive})(1 - P_{time})$
2. PIFs	The same 8 PIFs affects $P_{diagnose}$ and P_{action}	20 PIFs affects $P_{cognitive}$ through 5 CFM: <u>detection</u>, <u>understanding</u>, <u>decision making</u>, <u>action</u> and <u>inter-team coordination</u> No PIFs affects P_{time}
3. Base HEP	Diagnosis : $Nominal\ HEP = 1 \times 10^{-2}$ Action: $Nominal\ HEP = 1 \times 10^{-3}$	$P_{CFM_{Base}}(detection) = 1 \times 10^{-4}$ $P_{CFM_{Base}}(understanding) = 1 \times 10^{-3}$ $P_{CFM_{Base}}(decisionmaking) = 1 \times 10^{-3}$ $P_{CFM_{Base}}(action) = 1 \times 10^{-4}$ $P_{CFM_{Base}}(interteam) = 1 \times 10^{-3}$

3.0 Scenario Description
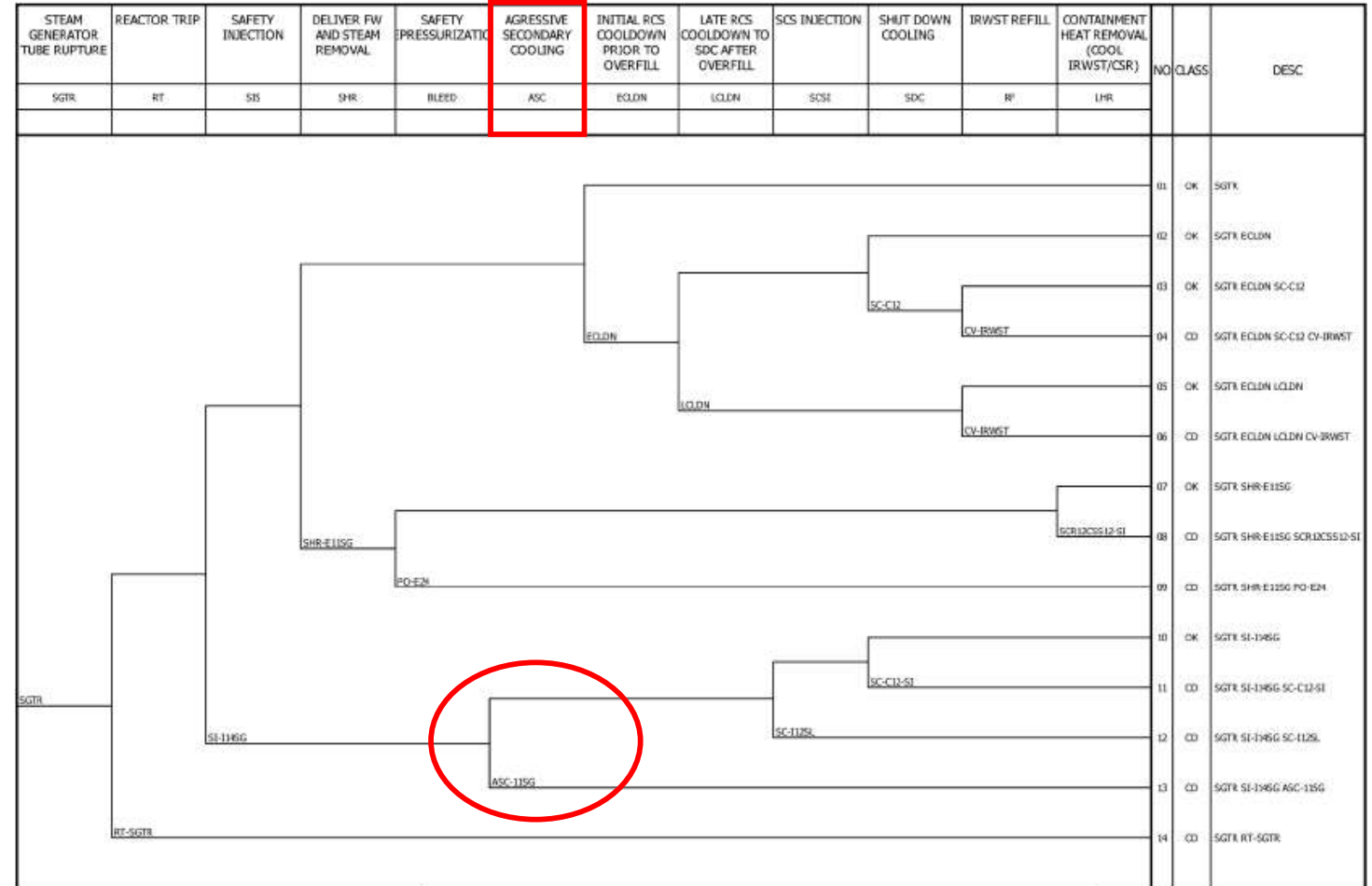
Important Human Action (IHA) considered in this scenario:

- **Aggressive secondary cooling (ASC)** to cool down the reactor coolant system (RCS) to shutdown cooling (SC) system entry temperature of 176°C with maximum cooling rate.
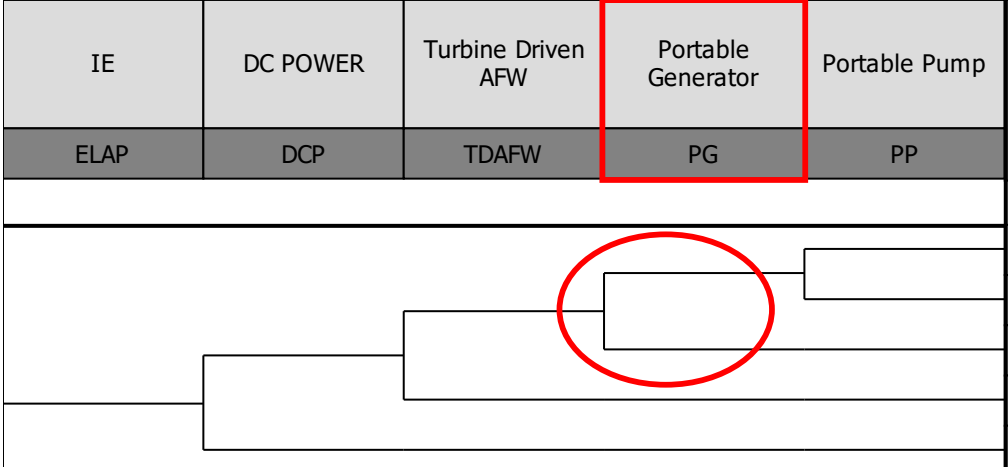
3.0 Scenario Description

The **Important Human Action (IHA)** considered in this scenario:

- **Deployment of mobile generator** initiated 3 hours after the ELAP. The **HFE** was selected as **failure to install and operate** the '1MW mobile generator'.

- **Does not involve the use of conventional EOP.**

IE	DC POWER	Turbine Driven AFW	Portable Generator	Portable Pump	Seq#	State	Frequency
ELAP	DCP	TDAFW	PG	PP			
					1	OK	
					2	CD	
					3	CD	
					4	CD	
					5	CD	

4.0 Analysis of Results

4.1 Results from scenario 1 (SGTR)

SPAR-H

Diagnose HEP: 1.00E-2

#	PIF	PIF Level	Multiplier for Diagnosis
1	**Complexity**	Moderately	2
2	**Procedures**	Diagnostic/ Symptom oriented	0.5
P$_{diagnose}$			1×10^{-2}

Action HEP: 1.00E-3

#	PIF	PIF Level	Multiplier for Action
1	**Available Time**	Available (>5x)	0.1
P$_{action}$			1×10^{-4}

$$HEP_{SPAR-H} = 1x10^{-2} \cdot (2x0.5) + 1x10^{-4} \cdot (0.1)$$
$$= \mathbf{1.01x10^{-2}}$$

4.0 Analysis of Results

IDHEAS-G

CFM	$PIF_{Attribute}$	$P_{CFM_{Base}}$	w_i	P_{CFM}
Detection	no impact	1×10^{-4}	N/A	1×10^{-4}
Understanding	no impact	1×10^{-3}	N/A	1×10^{-3}
Decisionmaking	Transfer Procedure	1×10^{-3}	1.2×10^{-2}	1.20×10^{-2}
Action	no impact	1×10^{-4}	N/A	1×10^{-4}
Total P$_c$				1.32×10^{-2}
P$_t$				~ 0.0
HEP$_{IDHEAS-G}$				1.32×10^{-2}

PIF Mapping	
SPAR-H PIFs	**IDHEAS-G PIFs**
Complexity	Task Complexity
Procedure	Transfer Procedure
Available Time	-

NOTE: The time required to deploy the action is negligible compared to the time available as such P$_t$ is 0.0.

4.0 Analysis of Results

SPAR-H

Diagnosis HEP: 1.00 E-2

#	PIF	PIF Level	Multiplier for Diagnosis
1	**Available Time**	Expansive time	0.01
	P$_{diagnose}$		1×10^{-4}

Action HEP: 1.00 E-3

#	PIF	PIF Level	Multiplier for Action
1	**Complexity**	Moderately	2
2	**Experience/Training**	Low	3
3	**Work Process**	Poor	2
	P$_{action}$		1.2×10^{-2}

$$HEP_{SPAR-H} = 1x10^{-4} \cdot (2x3x2) + 1x10^{-2} \cdot (0.01)$$
$$= 1.21x10^{-2}$$

4.0 Analysis of Results

IDHEAS-G

CFM	PIF$_{Attribute}$	$P_{CFM_{Base}}$	w_i	P_{CFM}
Decision making	SF0 - no impact	1×10^{-3}	N/A	1×10^{-3}
Action	SF3-1: Infrequently Performed Scenario TE1-7: Inadequate Training Freq. TF2: Poor Comand and control	1×10^{-4}	10 4.72 1.5	1.77×10^{-1}
Inter-team coordination	TC-C44 Cordinate activities of multiple diverse teams or organizations	1×10^{-3}	10	1×10^{-2}
TOTAL P$_{CT1}$				1.86×10^{-1}
Action	SF3-1:Infrequently Performed Scenarios TC31: Straightfoward procedure execution with many steps TE1-7: Inadequate Training Freq.	1×10^{-4}	10 10 4.72	9.44×10^{-3}
TOTAL P$_{CT2}$				9.44×10^{-3}
P$_t$				4.01×10^{-7}
HEP$_{IDHEAS-G}$				1.86×10^{-1}

PIF Mapping	
SPAR-H PIFs	**IDHEAS-G PIFs**
Available Time	-
Complexity	Task Complexity
Experience / Training	Training; Scenario Familiarity;
Work Process	Team and organizational factors

5.0 Discussion of Result

Scenario	HFE	SPAR-H (HEP)	IDHEAS (HEP)
Scenario 1	Failure of aggressive secondary cooling (ASC)	1.01×10^{-2}	1.32×10^{-2}
Scenario 2	Failure to deploy the mobile generator	1.21×10^{-2}	1.86×10^{-1}

Conclusion

- In summary, this study shows that the various HRA methods (IDHEAS and SPAR-H) are adequate in determining the HEP for internal events. However, for external events, IDHEAS provides flexible and adequate PIF to quantify the HEP while SPAR-H seems more adequate for internal events.
  - ✓ **SPAR-H** has **broad definitions of PIF** which is **unclear** compared to IDHEAS-G.
  - ✓ **IDHEAS-G** has a **wide coverage of PIFs** compared to SPAR-H methodology. It is **more specific and considers new scenarios and technology development**.
- From the results above, it is clear that HRA needs more development to enhance consistent HEP results for external events.

Thank you!