IMPROVED GUIDANCE FOR THE APPLICATION OF RECOVERY FACTORS FOR HUMAN RELIABILITY ANALYSIS (HRA) METHOD CAUSED BASED DECISION TREE (CBDT)

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The EPRI HCR/ORE (Human Cognitive Reliability/Operator Reliability Experiments) and supplementary Caused Based Decision Tree Method (CBDTM) cognitive human reliability (HRA) methods as published in EPRI TR-100259, “An Approach to the Analysis of Operator Actions in Probabilistic Risk Assessment” has been implemented in the EPRI HRA Calculator software in conjunction with THERP (Technique for Human Error Prediction). The EPRI HRA Calculator software development started in 2001, and during the last 15 years, the EPRI HRA Calculator has become the standard tool for developing human failure events (HFEs) and calculating HEPs for U.S nuclear utilities, as well as several international organizations. Based on experience and insights obtained in the application of the software, needs have been identified for additional guidance on the application of recovery factors in the CDBTM. The limited guidance on recovery factors included in EPRI TR-100259 can be interpreted differently among analysts and this can result in inconsistent HEPs among HRA analyst for similar actions. In 2014, EPRI developed preliminary guidance for when to apply each recovery factor. This guidance was developed based on HRA insights, lessons learned by performing HRA, and simulator observations of U.S crews. For each recovery factor a new recovery decision tree has been created. This paper will present the newly developed guidance for each recovery factor. It is anticipated that this new guidance will help provided consistent HEPs among HRA analyst for similar actions.

I. BACKGROUND

In 2000, EPRI the established an HRA/PRA Tools User Group. The HRA/PRA Tools User Group facilitates standardization of the HRA process through development of an EPRI HRA Calculator® and associated modeling guidance. The EPRI HRA Calculator®[1] is a software tool that quantifies and documents human error probabilities for PRAs. The software provides a standardized approach to HRA in order to achieve comparable results and assist industry in converging on common HRA methods such that different analysts obtain comparable results when considering plants that are similar in design, procedures and training. The standardized EPRI HRA methodologies embodied in the calculator are the caused based decision tree method (CBDTM)[2], Human Cognitive Reliability/Operator Reliability Experiments (HCR/ORE)[2], and elements of ASEP[3] and THERP[4].

The primary objective of HRA/PRA Tools User Group is to assist the industry in converging on common HRA methods in order to enable different analysts to obtain comparable results with similar inputs. Based on experience and insights obtained in the application of the software, needs have been identified for additional guidance on the application of recovery factors in the CDBTM. The limited guidance on recovery factors included in EPRI TR-100259[2] can be interpreted differently among analysts and this can result in inconsistent HEPs among HRA analyst for similar actions. In 2014, EPRI developed preliminary guidance for when to apply each recovery factor. This guidance was developed based on HRA insights, lessons learned by performing HRA, and simulator observations of U.S crews. For each recovery factor a new recovery decision tree has been created.

II. RECOVERY GUIDANCE OUTLINED IN EPRI-TR 100259[2]

The CDBT method models cognition as two distinct parts, errors associated with plant machine interface and errors associated with procedures. There are eight decision trees used to model cognition and for each decision tree recovery factors can be applied. The CBDT methodology provides some general guidance on which factors to apply when but the guidance is vague with no illustrative examples. Additionally, the published guidance is written in paragraph form and is not easily transferable into a set of rules which an analyst can apply consistently. Table 2 below lists each CBDTM decision tree followed by summary of the guidance for recovery based upon which crew members are available for recovery.

If a recovery factor in the table is listed as “NC” then, no credit can be taken for that recovery factor for the given failure mechanism. Additionally, the Shift Change and Emergency Response Facility (ERF) Review recovery factors can only be applied when the system time window (T_{sw}) is long enough to guarantee either the ERF is activated or a Shift Change has occurred, as defined by the shift length.

An X in Table 2 indicates that a recovery factor can be credited for the specified failure mechanism and the value is calculated as a conditional HEP given that initial failure occurred. The guidance in the methodology does not specify how to determine a level of dependence or how to calculate a conditional HEP. Within the HRA Calculator, the dependency level is determined based on time available for recovery and then the THERP conditional dependency equations are applied. The numeric values in Table 2 indicate that this value is always applied as the recovery factor for the specified failure mechanism, regardless of dependency level identified by the analyst.

TABLE 2: CBDTM Recovery Factors

Tree	Description of Decision Tree	Branch	Self-Review	Extra Crew	STA Review	Shift Change	ERF Review
Pca	Availability of information	all	NC	0.5	NC	0.5	0.5
Pcb	Failure of attention	all	X	NC	X	X	X
Pcc	Midread/miscommunicate data	all	NC	NC	X	X	X
Pcd	Information misleading	all	NC	0.5	X	X	0.1
Pce	Skip a step in procedure	a-h	X	0.5	NC	X	X
Pce		i	0.5	0.5	X	X	X
Pcf	Misinterpret Instruction	all	NC	0.5	X	X	X
Pcg	Misinterpret decision logic	all	NC	0.5	X	X	X
Pch	Deliberate violation	all	NC	X	X	NC	NC

The application of crediting recovery factors can have tremendous impact on the final HEP. The CBDT guidance states that “in order to avoid unrealistically low values of Pc, recovery credit should be taken only where the analyst can point to factors are certain to operator.” The guidance fails to identify these specific factors.

III. APPROACH TO DEVELOPING NEW RECOVERY GUIDANCE

The CBDTM recovery factors have been interpreted by analysts differently and the amount of credit applied to each failure mechanism also varies by analyst. The result is that HEPs for the similar actions at different plants can be orders of magnitude different depending on the analyst. In order to ensure consistency, amongst analysts additional guidance is needed. As part of the HRA users group, the currently operating philosophy of U.S nuclear plants was reviewed and based on 22 years of HRA experience applying CDBTM additional guidance for each CDBT recovery factor has been developed.

IV. NEW RECOVERY GUIDANCE

The new guidance is built upon the timeline developed for each individual HFE. In general, the timeline will identify when additional crew members can be credited for recovery and when additional cues will be presented to the crew. Additionally, the timeline determines how much time is available for recovery. The time available for recovery directly impacts how much credit can be given for recovery. Depending on the time available for recovery a dependency level can be selected and then a conditional HEP can be calculated using the THERP dependency rules[4]. The HRA Calculator bins time available for recovery as shown in Table 3.

TABLE 3: Time Available for Recovery and Level of Dependency

Time available for recovery	Dependency Level	Conditional Dependency Equation From THERP
0 minutes	Complete Dependency (CD)	1.0
Time ≤ 15 minutes	High Dependency (HD)	(1 + HEP) / 2
15 < Time ≤ 30 minutes	Moderate Dependency (MD)	(1+ 6 X HEP) / 7
30 < Time ≤ 60 minutes	Low Dependency (LD)	(1+19 X HEP) / 20
Time > 60 minutes	Independent	HEP

This dependency level breakdown has been used for many years in both the determining the amount of credit for recovery in CBDT as well as the EPRI dependency decision tree. The intention of the new guidance was to not change what has historically been performed but to formalize the thought process.

EPRI TR-10259[1] allows recoveries for the following crew members

- Shift Change
- Emergency Response Facility (ERF) Review/Technical Support Center (TSC)
- Shift Technical Advisor (STA) Review
- Self Review
- Extra Crew

For each crew member a new decision tree has been developed to systemically determine when and how much credit can be given to each crew member. Figures 1-5 show the new decision tree logic. The logic is based on when the specified crew member will be available for recovery and when a possible cue for recovery would occur. For example, shift change cannot be credit as a recovery factor unless the system time window (Tsw) is greater than the shift length. The last column in each decision tree represents the dependency level (DL). Once the dependency level is determined then the conditional HEP is calculated using the equations in Table 3.

IV.A. Guidance for Shift Change

Figure 1 shows the new decision logic for when credit shift change can be credited as a recovery factor. The bases for crediting shift change is that a shift change will occur after the cue occurs but before core damage and that the error made by the outgoing shift will be revealed during shift turn over. During a shift turn over, the outgoing shift is expected to brief the crew of all key parameters and the incoming shift is expected to walk down the control room panels to understand the current plant status. Finally, there must be sufficient time from when the shift turn over occurs to allow the action to be completed before core damage occurs.

There are very few, level 1, at-power, internal events operator actions for which it is possible to credit shift change. Shift change is more likely to be credited for level 2 actions or low power and shutdown actions.

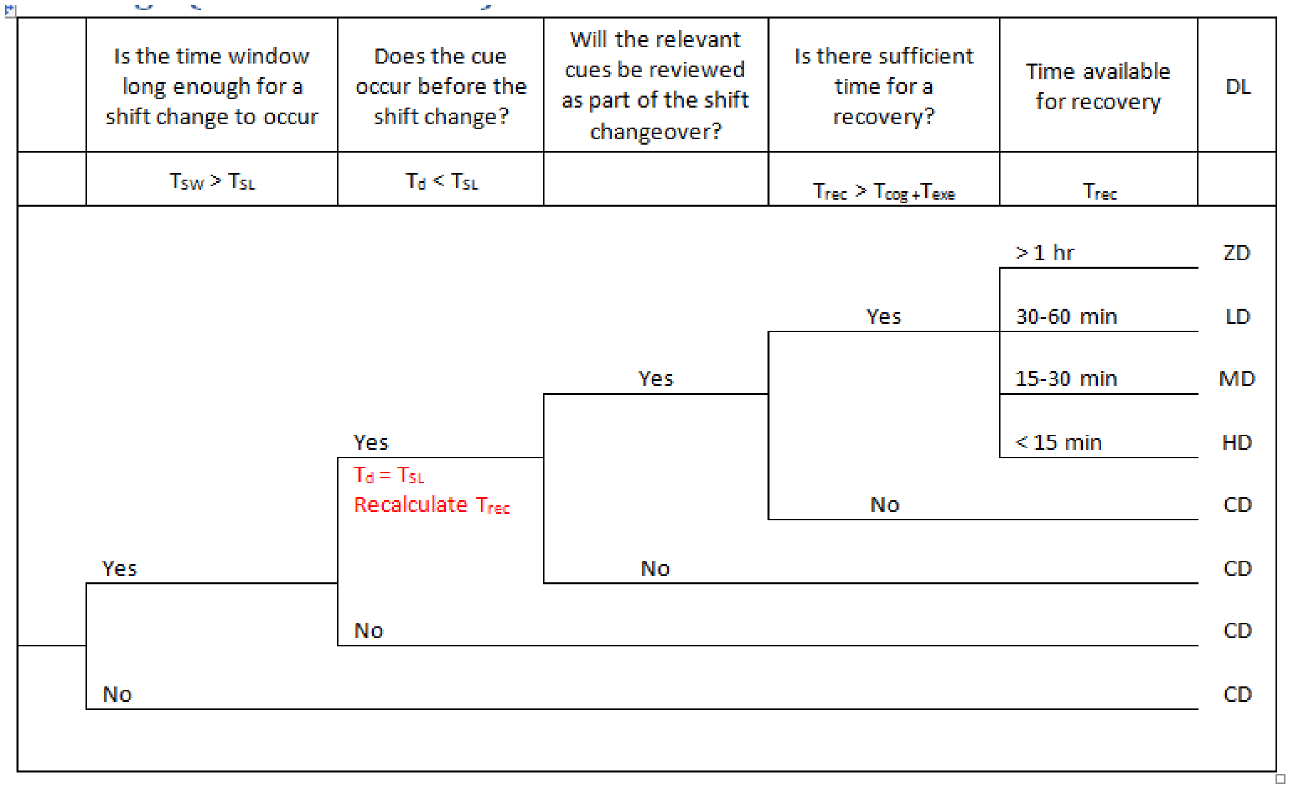

Figure 1: CDBTM Recovery Factor: Shift Change

Notes to Figure 1:

T_{sw} = System time window
T_d = Tdelay – time of the cue
T_{sl} = Length of shift
Tcog = Time for cognition
Texe = Time for execution
Trec = Time available for recovery

IV.B. Guidance for ERF / TSC

Figure 2 shows the new decision logic for when ERF/TSC can be credited as a recovery factor. The first question asked by the decision tree is if the ERF/TSC will be activated per the plants emergency plan. Not all initiating events require the ERF/TSC to be activated and if the ERF/TSC is not required to be activated then no credit can be given for recovery. Once the control room makes the decision to activate the ERF/TSC there is a plant specific period of time in which facility must be operational. (T_{ERF}) Generally, this is 60 minutes. If the system time window is less than T_{ERF} then the ERF/TSC cannot be credited.

The ERF/TSC is located away from the control room and will be monitoring the plant via computers and verbal communications with the control room. Therefore, they will not be following the procedure progression step by step and instead will be monitoring changes in key parameters. For example, the ERF/TSC will not know if the control room skips a step in the procedure but they will notice SG level dropping due to loss of secondary cooling.

If the cue for the actions occurs before the ERF/TSC is operational, then the analyst should ensure that there is sufficient time for cognition and execution after the ERF/TSC is operational in order to allow the action to be successful. In this case $T_{rec} = T_{SW} - T_{exe} - T_{cog} - T_{ERF}$.

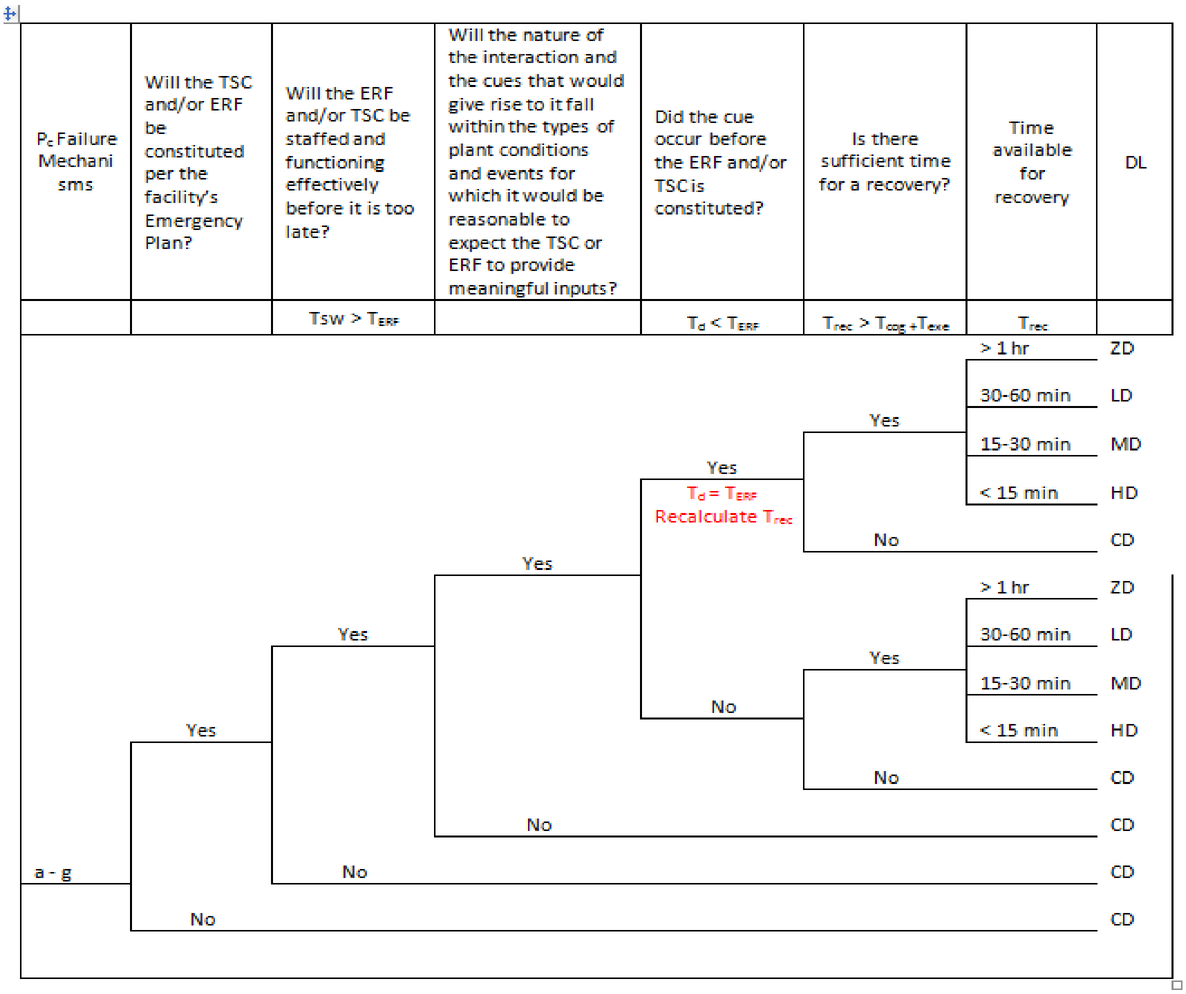

Figure 2: CDBTM Recovery Factor: ERF/TSC

Notes to Figure 2:

T_{sw} = System time window
T_{ERF} = Time at which ERF/TSC will be operational
T_d = Tdelay – time of the cue
Tcog = Time for cognition
Texe = Time for execution
Trec = Time available for recovery

IV.C. Guidance for STA review

Figure 3 shows the new decision logic for when to credit STA as a recovery factor. In U.S plants, the STA role is to provide an oversite of the control room response. In general, the STA is not required to be in control room at all times but is required to be in the control room within a specified period of time following reactor trip. (T_{STA}). The time at which he is required to be in the control following a reactor trip will be plant specific. The STA's role is not to following along step by step in the procedure instead, his role is to monitor key plant parameters. The critical safety function trees are required to be monitor continuously while other parameters (generally balance of plant) parameters can be monitored periodically. Recovery for the STA is only allowed if the STA is present in the control room and there is a recovery cue which the STA is expected to be monitoring.

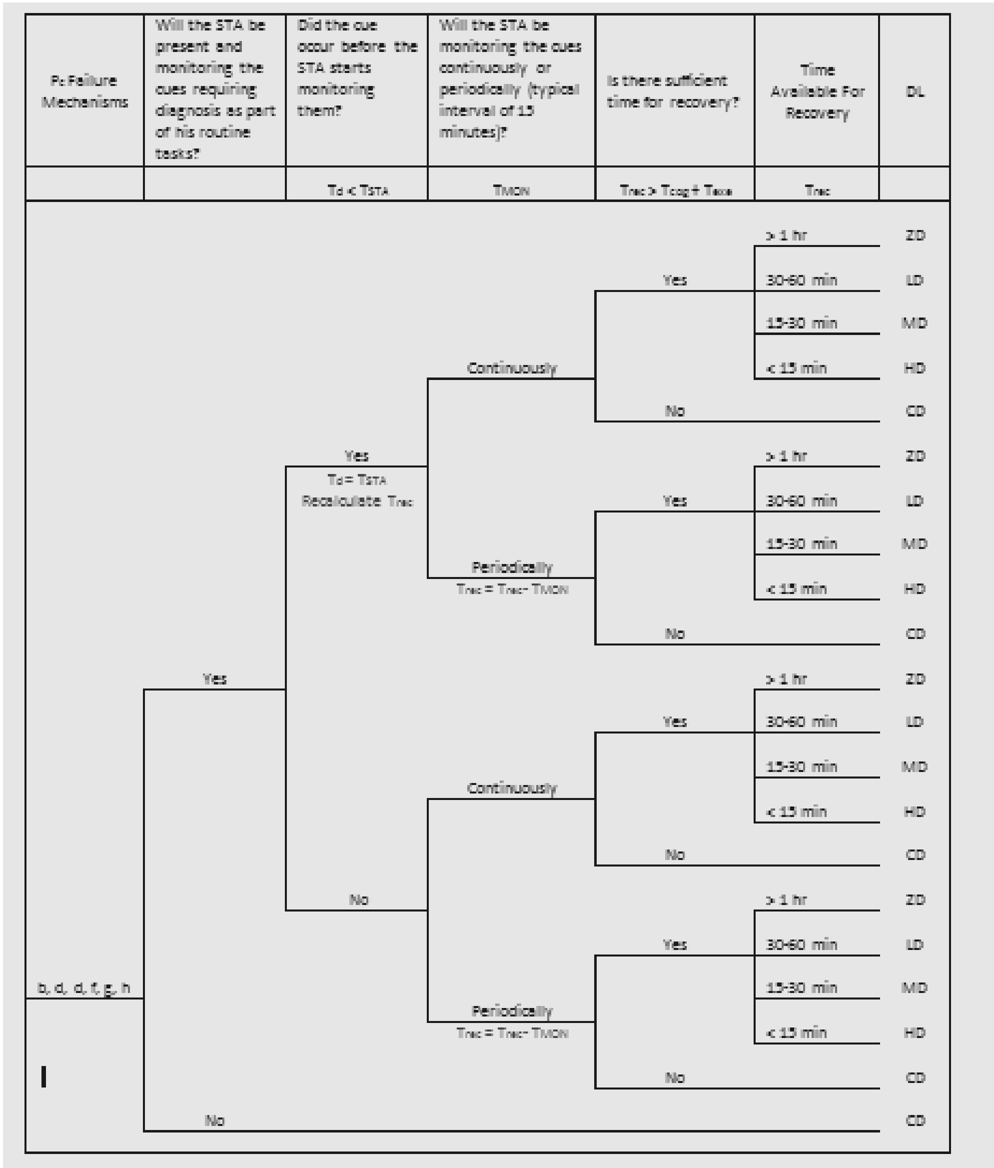

Figure 3: CDBTM Recovery Factor: STA Review

Notes to Figure 3:

T_{STA} = Time at which STA is required to be in the MCR following a reactor trip
T_d = Tdelay – time of the cue
Tmon = Length of time between periodically monitored cues
Tcog = Time for cognition
Texe = Time for execution
Trec = Time available for recovery

IV.D. Guidance for Extra Crew

Figure 4 shows the new decision logic for when extra crew can be credited as a recovery factor. All plants have a minimum crew composition. In general, the minimum crew composition is all that is credited in Probabilistic Risk Assessment (PRA) or Probabilistic Safety Assessment (PSA). For HRA, extra crew could be members on shift in addition to the minimum crew composition or for dual unit plants could be members of the crew from the unaffected unit of a shared control room.

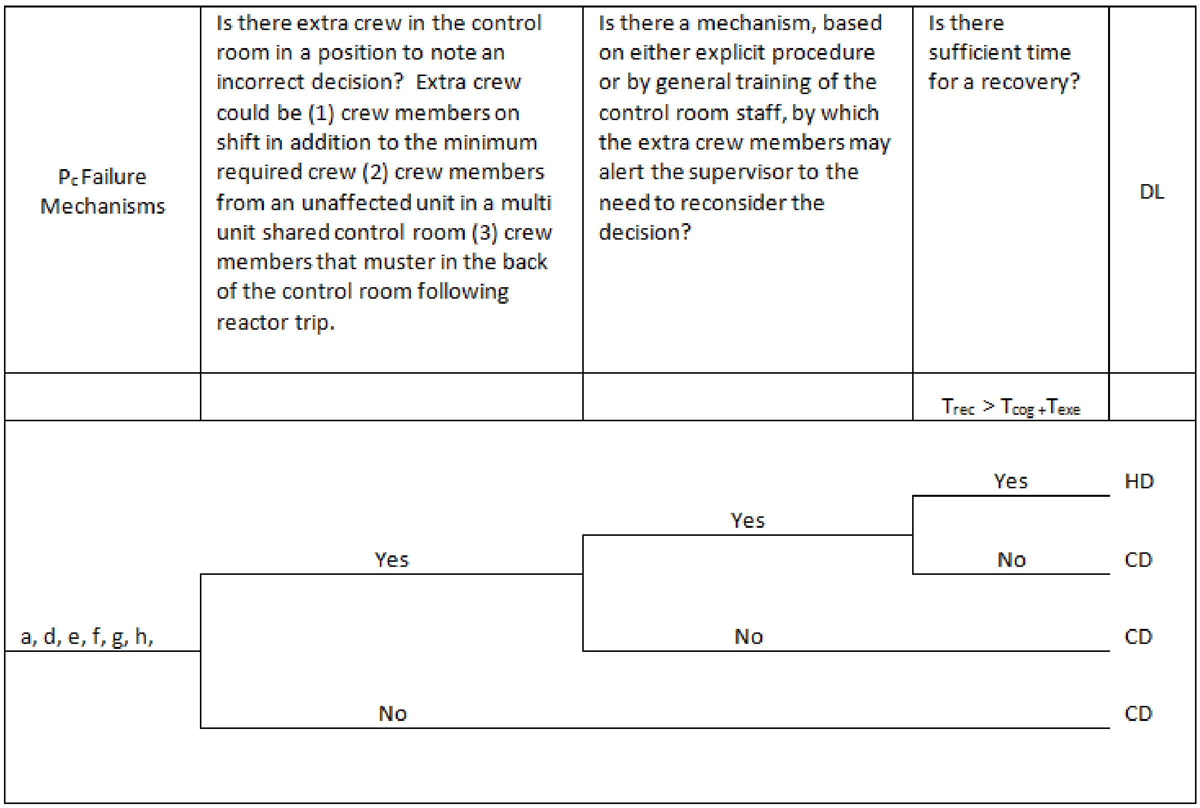

Figure 4: CDBTM Recovery Factor: Extra Crew

Notes for Figure 4:
Tcog = Time for cognition
Texe = Time for execution
Trec = Time available for recovery

IV.E. Guidance for Self Review

Figure 5 shows the new decision logic for when self review can be credited as a recovery factor. In order to credit self review there must be a second cue that would prompt the procedure reader to revisit a decision made previously. This second cue, can be an alarm or a procedure step. Many emergency operating procedures (EOPs) contain logic that if a key step is missed the crew will be forced to revisit this procedure step. In some cases, the procedures force the crew into procedurlized "do-loop" in order to ensure the correct steps are being performed. In order to credit self review the time of the second cue must be subtracted from the time available for recovery and Trec must be greater than zero. $T_{rec} = T_{sw} - T_{delay\ of\ second\ cue} - T_{cog} - T_{exe}$

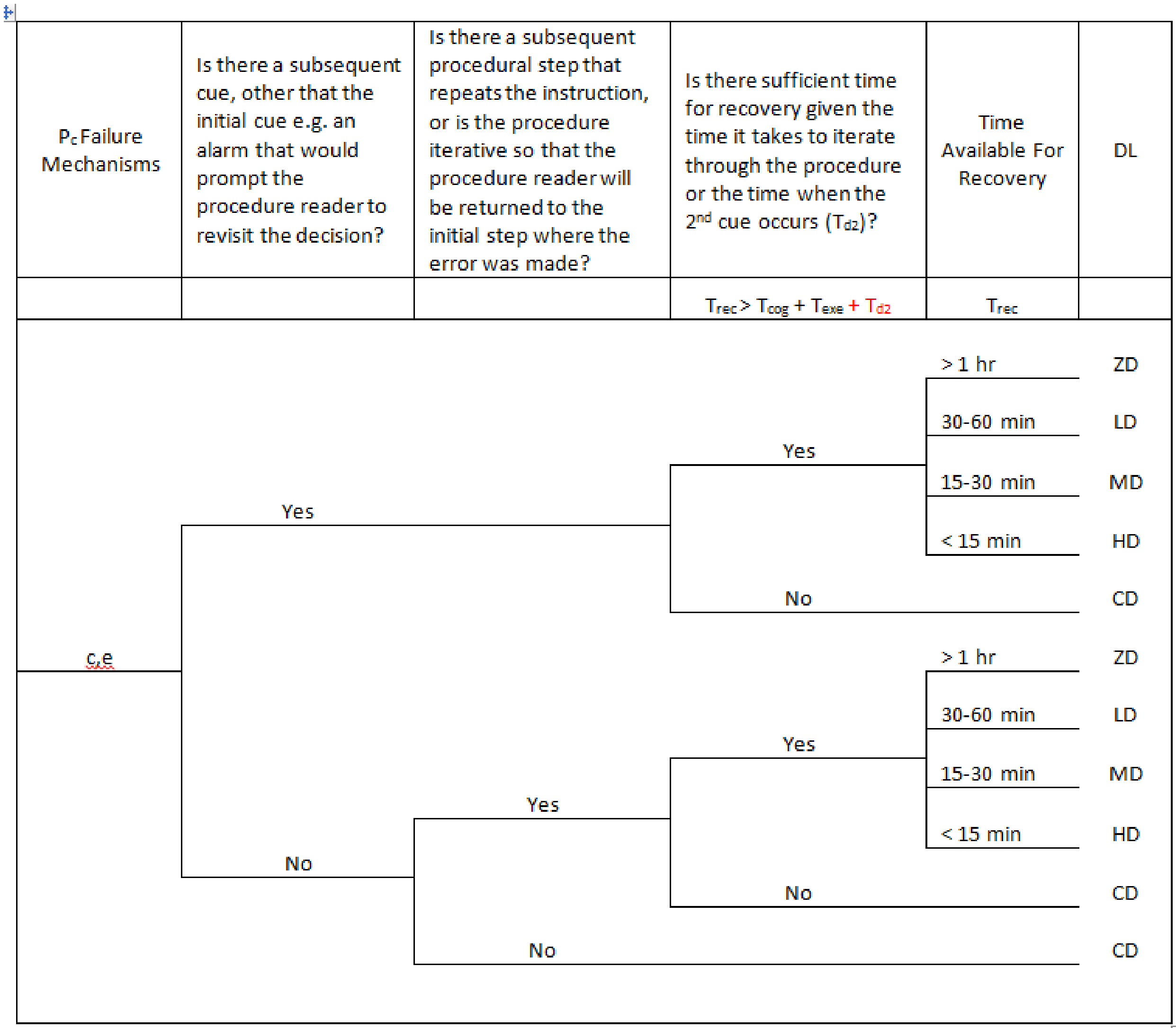

Figure 5: CDBTM Recovery Factor: Self Review

Notes for Figure 5:

T_{cog} = Time for cognition
T_{exe} = Time for execution
T_{rec} = Time available for recovery
T_{d2} = Time of the second cue credited for recovery

V. CONCLUSION

The updated guidance presented in this paper is expected to provide a consistent framework for consideration of dependency factors. This new guidance has been discussed in EPRI HRA Calculator training since 2014 and has been well received by users. It has been applied to at least two internal events HRA and one fire HRA as well. Currently this guidance is standalone and is not explicitly implemented into the EPRI HRA Calculator. As users review and apply this guidance, it is expected that this guidance will be updated or refined to ensure it is consistent with current nuclear plant operations.

VI. REFERENCES

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