Phoenix – A Model-Based Human Reliability Analysis Methodology: Qualitative Analysis Overview

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Abstract: Phoenix method is an attempt to address various issues in the field of human reliability analysis (HRA). It is built on a cognitive human response model, incorporates strong elements of current HRA good practices, leverages lessons learned from empirical studies, and takes advantage of the best features of existing and emerging HRA methods. The original framework of Phoenix was introduced in previous publications. This paper reports of the completed methodology, summarizing the steps and techniques of its qualitative analysis phase. The methodology introduces the "crew response tree" which provides a structure for capturing the context associated with human failure events (HFEs), including errors of omission and commission. It also uses a team-centered version of the Information, Decision and Action cognitive model and "macro cognitive" abstractions of crew behavior, as well as relevant findings from cognitive psychology literature and operating experience, to identify potential causes of failures and influencing factors during procedure-driven and knowledge-supported crew-plant interactions. The result is the set of identified HFEs and likely scenarios leading to each. The methodology itself is generic in the sense that it is compatible with various quantification methods, and can be applied across various environments including nuclear, oil and gas, aerospace, and aviation.

Keywords: Probabilistic Risk Assessment (PRA), Human Reliability Analysis (HRA), Human Failure Event (HFE), Performance Influencing Factor (PIF), Crew Failure Mode (CFM)

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1. INTRODUCTION

Phoenix, a model-based human reliability analysis methodology has been developed in an attempt to address the current issues in the field of HRA which include: the lack of an explicit causal model that incorporates relevant psychological and cognitive theories in its core human performance model; the inability to explicitly model interdependencies between influencing factors and their impact on human performance; and the lack of consistency, traceability and reproducibility in both the qualitative and quantitative HRA phases. These issues have led to variability in the results seen in the application of different HRA methods, and also in cases where the same method is applied by different HRA analysts.

This model-based hybrid HRA methodology was proposed in [1]. It incorporates strong elements of current HRA good practices, leverages lessons learned from empirical studies and takes advantage of the best features of existing and emerging HRA methods. The methodology itself is generic in the sense that it is compatible with various quantification methods, and can be applied across various environments and industries including nuclear, oil and gas, aerospace, aviation etc. However, this specific instance is used in nuclear power plants to support HRA in full-power internal events PRAs, low-power shut-down operations, event assessment, significance determination, as well as fire and seismic PRAs. What changes from one application domain to another are specific details of the analysis modules, techniques of the approach, and emphasis placed on aspects that are more relevant to the particular application.

The development of this methodology has been completed and this paper provides a summary of the steps and techniques of the qualitative analysis phase. It discusses the major steps and important sub-

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steps required by an HRA analyst to successfully implement this methodology. Also presented are the products of each step and the information required by the analyst in order to conduct the analysis. A separate paper in this conference [2] provides an overview of the quantitative analysis aspect of Phoenix HRA.

2. THE QUALITATIVE ANALYSIS FRAMEWORK

The broad objective of HRA qualitative analysis is to identify HFEs and characterize crew-plant scenarios that lead to those HFEs. As such, there is a tight coupling between understanding and analyzing the plant/system response and conditions (systems behavior), and understanding and analyzing the crew activities (operator behavior). Therefore, the process of HFE identification and the definition of the scenarios leading to the HFEs is, in general, inseparable from the process of modeling the plant response in a PRA.

The qualitative analysis framework uses two modeling vehicles namely [1]: (1) A process and representational method for analyzing crew-plant interactions with a focus on the identification and quantification of HFEs and possible recoveries, and (2) A human response model which relates the observable crew failures modes (CFM) to "context factors" for example, PIFs.

2.1. Layers of the Framework

This framework has three main layers namely: the CRT (top layer), the human performance model (mid layer) and the PIFs (bottom layer). The framework layers and its relationship to a typical PRA model is shown in Figure 2-1.

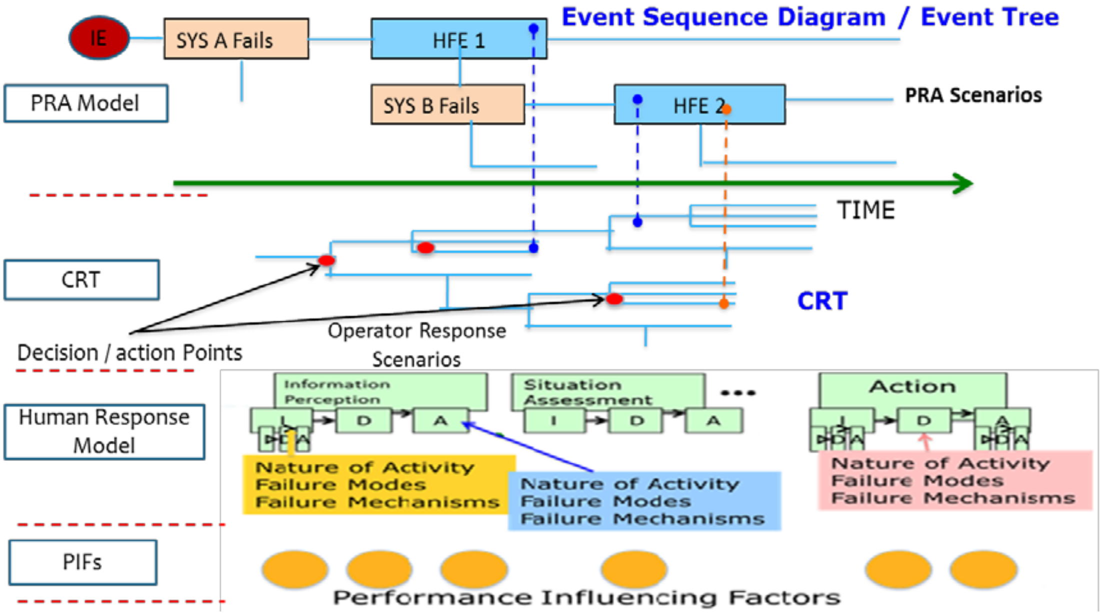


Figure 2-1: The qualitative analysis framework layers and a typical PRA model

The "crew response tree" (CRT) provides a structure for capturing the context associated with the HFE, including errors of omission and commission. A team-centered version of the Information, Decision and Action (IDA) cognitive model [3] is used to represent the human response model while the PIFs are the context factors (including plant factors) that affect human performance.

3. OVERVIEW OF THE HRA QUALITATIVE ANALYSIS PROCESS

The HRA qualitative analysis process broadly involves the identification of human failure events (HFEs) and the characterization of crew-plant scenarios that lead to the HFEs. Generally, it is assumed that the starting point for the qualitative analysis is the identification and definition of the HFEs. This process can be generically defined as a four-step process [4], [5] namely: identification and definition of the HFE and its PRA scenarios context; task analysis; identification of failure causes; and the assessment of influence of context. The above steps, captured through appropriate tools and techniques, are reflected in the following process flow diagram (Figure 3-1). The diagram recognizes two distinct possibilities as the starting point of the analysis: (1) HFEs are identified as part of an existing PRA model, or (2) HFEs are to be identified in an iterative process as part of the analysis.

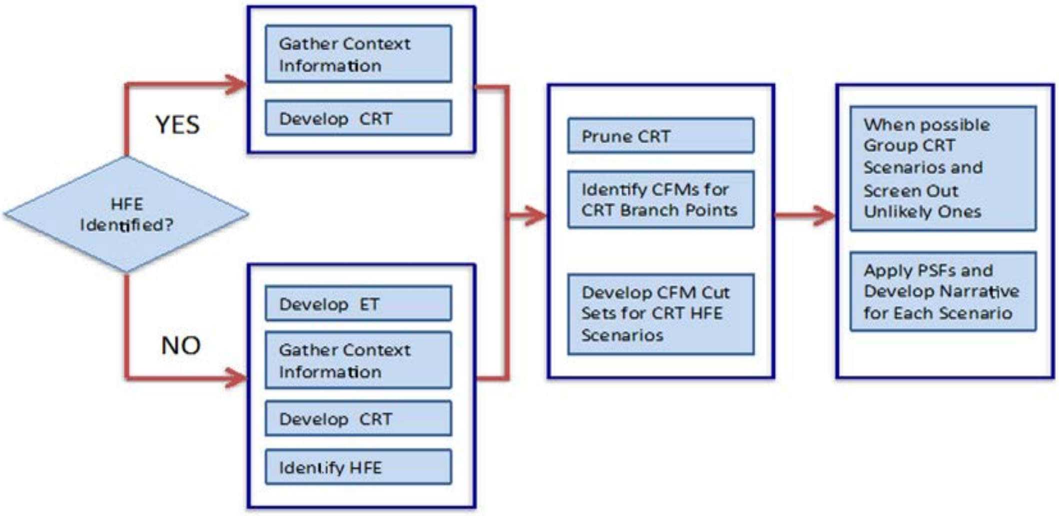


Figure 3-1: Qualitative Analysis Process Overview

4. THE QUALITATIVE ANALYSIS PROCEDURE GUIDE

The main steps, important sub-steps and the products of each step are summarized in Table 4-1 [5] and discussed in more detail in the following sections of the paper.

4.1. Step 1: PRA Scenario Development/Familiarization

In general, the objectives of steps 1 and 2 (in part) are to identify and incorporate HFEs (which, in a PRA context, are defined as functional failures, such as failure to initiate feed and bleed before core damage occurs) into a PRA. If the PRA models (event sequence diagram – ESD / event trees - ET and corresponding fault trees - FTs) exist and HFEs are identified, step 1 of the qualitative analysis primarily becomes the process of analysts gaining familiarity with the PRA scenarios leading to the HFEs and gathering the needed information to support construction of the crew response tree (CRT) and completion of other qualitative analysis steps. Otherwise, the analysis starts with the development of the PRA models and, ideally, concurrent and iterative development of CRTs. When starting with an existing HFE, the process may indeed lead to the modifications of the HFE or the addition of new ones to the PRA. The following describe the sub-steps of **Step 1**:

Step 1.A: Use standard PRA steps to Build/Review ET or ESD

This step follows standard PRA practice for PRA scenario modeling.

Step 1.B: Select PRA Scenario and Collect Context Information

The analysts need to become familiar with the PRA scenario related to the HFE(s). This includes plant visits and other activities to gather information on what, how, and why the scenario might evolve as described. The information collected would be useful during the development of the CRT(s). Additional related information will need to be collected as identified failure paths are evaluated for potential recovery branches during the CRT(s) development. The information needed include: description of the PRA scenario; expected cues (available plant information); applicable procedural guidance; required actions (manipulations) for success; and timing.

Table 4-1: Steps and Products of the Qualitative Analysis Procedure

Steps	Sub-Steps	Product
1. Develop/Identify PRA scenarios for analysis	• Use standard PRA steps to build or review ET or ESD for the IE • Select PRA scenario and gather general context information for scenario	• ESD/ET • Plant Scenario Context Factors • Major safety functions in ESD/ET
2. Develop CRT	• Perform Task Analysis (procedure review) • Construct CRT • Prune/Simplify CRT	• CRT • HFEs • Possibly modified PRA model
3. Identify Crew Failure Modes for CRT Branches	• Trace CFM Causal Models (FTs) for various CRT branches on scenarios leading to HFEs and keep portions applicable to each branch	• CFM sub-trees for CRT branches
4. Develop CRT scenarios for HFE (s) in terms of CFMs and relevant context factors and PIFs	• Link FTs of CRT scenarios to HFEs of interest and solve linked model • Identify relevant PIFs for CRT scenario using the CFM - PIF BBN model	• CRT scenario CFM “cut sets” • List of PIFs for each
5. Analyze Scenarios, Write Narrative, Trace Dependencies	• Describe scenarios as sequences of crew cognitive and physical activities and factors contributing to the success of single or multiple failures (HFEs)	• Narratives for HFE scenarios • Qualitative Insights • Input to Quantification

4.2. Step 2: Development of Crew Response Tree (CRT)

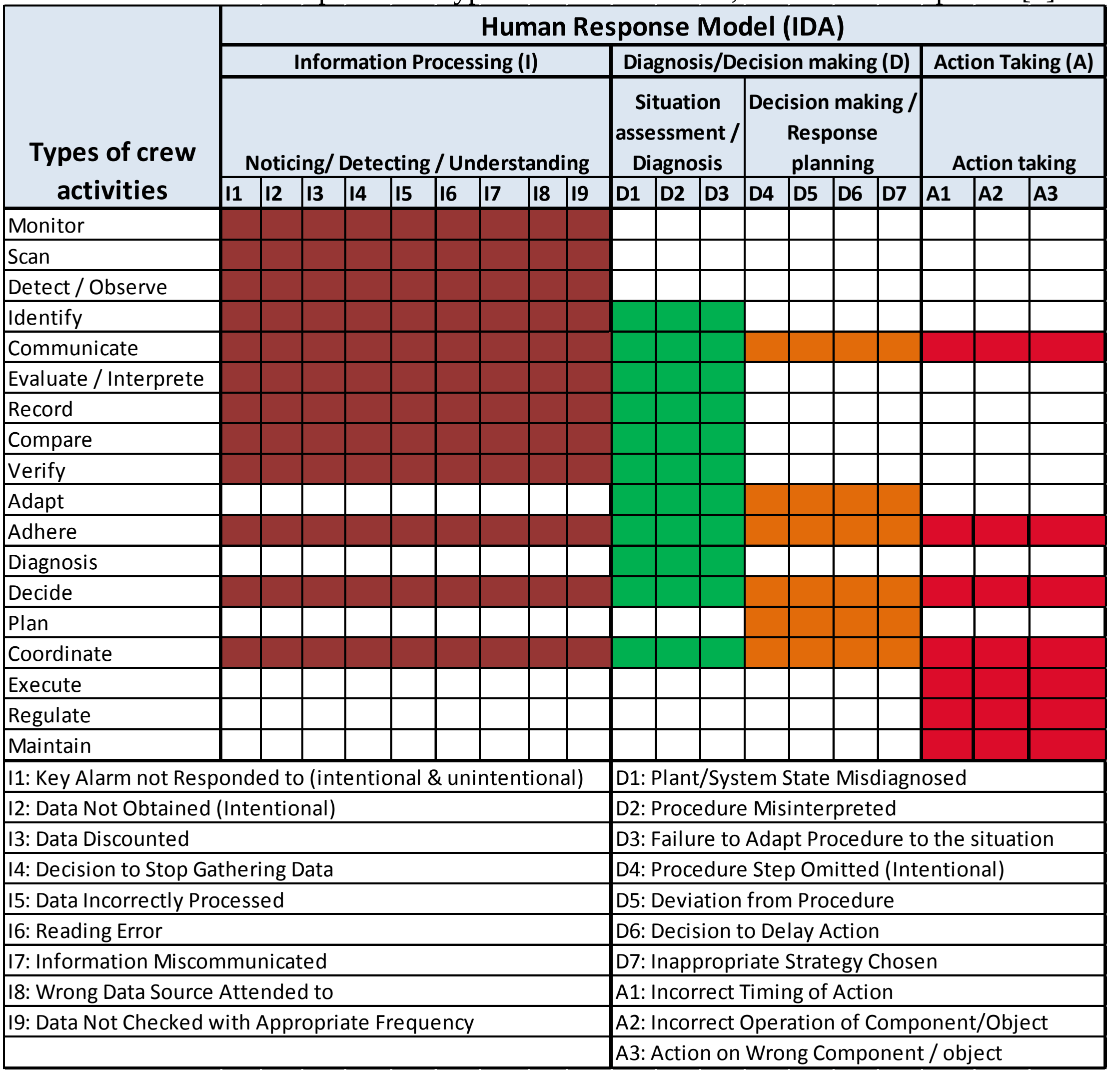
The CRT is a visual representation of the crew-plant interaction scenarios leading to HFEs as well as a structure that supports the performance and documentation of the qualitative analysis. The CRT can be devoted to find paths to predefined HFEs and possible recoveries, or used as a vehicle to also identify new HFEs. CRTs can be constructed for crew response situations that are procedure driven (PD), knowledge driven (KD), or a hybrid of both (HD) [6]. The CRT leads analysts to perform a thorough assessment of the conditions that could lead crews to take inappropriate paths**.** This will obviously lead to a more extensive qualitative analysis and a broader consideration of the conditions that could lead crews to fail, along with different ways in which they could fail. The structure facilitates systematic identification of variations in conditions that could lead the crew to take inappropriate paths. The following describe the sub-steps of **Step 2**:

Step 2.A: Perform Task Analysis and review relevant procedures

Task analysis is aimed at identifying subtasks associated with the operator actions related to the specific HFE of interest. One of the main issues in task analysis is determining where to stop task parsing, i.e. determining when to stop decomposing the task into sub-tasks in order to obtain the right level of detail required for the analysis. This is necessary to promote consistency and traceability among different analyst using this methodology and also to prevent the analysis being done at different levels of abstraction. Hence, guidelines for task analysis is provided to aid in identifying the sub-tasks (at the appropriate level of detail) associated with the crew’s actions and cognitive processes related to the specific HFE of interest.

A task can be described starting from the overall system functional goal(s) and then breaking it down to the level of individual operations. In order to successfully perform this decomposition, the analyst needs to consider the functional, cognitive and procedural requirements of the task to be analyzed. Among other features, the CRT is a tool for task decomposition of the particular safety function of interest. The functional requirements are covered in the CRT flowchart construction process by decomposing the safety function into individual crew member actions. In addition to the CRT, the human response model (IDA) is also used as a vehicle for task decomposition. Within each of the IDA elements, a nested I-D-A structure may exist. The level of decomposition of these IDA elements depends on the amount of detail needed for the task analysis and parsing of different human activities into “sub-events” or sub-tasks. In addition to the nested IDA structure, the human response model has both cognitive and physical requirements embedded in it. Connected together, both modeling tools (the CRT and associated fault trees) in conjunction with the PRA model provide the flow of task analysis. Together, they provide the analyst with the information on what to consider in the task analysis. This mixture of procedures, cognitive and physical processes, and system interface aid in the breakdown of the crew’s response to an identified safety function.

Table 4-2: Relationship between types of Crew Activities, CFMs and IDA phases [5]



Types of crew activities	Human Response Model (IDA)																		
	Information Processing (I)									Diagnosis/Decision making (D)							Action Taking (A)		
	Noticing/ Detecting / Understanding									Situation assessment / Diagnosis			Decision making / Response planning				Action taking		
	I1	I2	I3	I4	I5	I6	I7	I8	I9	D1	D2	D3	D4	D5	D6	D7	A1	A2	A3
Monitor	🟫	🟫	🟫	🟫	🟫	🟫	🟫	🟫	🟫										
Scan	🟫	🟫	🟫	🟫	🟫	🟫	🟫	🟫	🟫										
Detect / Observe	🟫	🟫	🟫	🟫	🟫	🟫	🟫	🟫	🟫										
Identify	🟫	🟫	🟫	🟫	🟫	🟫	🟫	🟫	🟫	🟩	🟩	🟩							
Communicate	🟫	🟫	🟫	🟫	🟫	🟫	🟫	🟫	🟫	🟩	🟩	🟩	🟧	🟧	🟧	🟧	🟥	🟥	🟥
Evaluate / Interprete	🟫	🟫	🟫	🟫	🟫	🟫	🟫	🟫	🟫	🟩	🟩	🟩							
Record	🟫	🟫	🟫	🟫	🟫	🟫	🟫	🟫	🟫	🟩	🟩	🟩							
Compare	🟫	🟫	🟫	🟫	🟫	🟫	🟫	🟫	🟫	🟩	🟩	🟩							
Verify	🟫	🟫	🟫	🟫	🟫	🟫	🟫	🟫	🟫	🟩	🟩	🟩							
Adapt										🟩	🟩	🟩	🟧	🟧	🟧	🟧			
Adhere	🟫	🟫	🟫	🟫	🟫	🟫	🟫	🟫	🟫	🟩	🟩	🟩	🟧	🟧	🟧	🟧	🟥	🟥	🟥
Diagnosis										🟩	🟩	🟩							
Decide	🟫	🟫	🟫	🟫	🟫	🟫	🟫	🟫	🟫	🟩	🟩	🟩	🟧	🟧	🟧	🟧	🟥	🟥	🟥
Plan													🟧	🟧	🟧	🟧			
Coordinate	🟫	🟫	🟫	🟫	🟫	🟫	🟫	🟫	🟫	🟩	🟩	🟩	🟧	🟧	🟧	🟧	🟥	🟥	🟥
Execute																	🟥	🟥	🟥
Regulate																	🟥	🟥	🟥
Maintain																	🟥	🟥	🟥

I1: Key Alarm not Responded to (intentional & unintentional)	D1: Plant/System State Misdiagnosed
I2: Data Not Obtained (Intentional)	D2: Procedure Misinterpreted
I3: Data Discounted	D3: Failure to Adapt Procedure to the situation
I4: Decision to Stop Gathering Data	D4: Procedure Step Omitted (Intentional)
I5: Data Incorrectly Processed	D5: Deviation from Procedure
I6: Reading Error	D6: Decision to Delay Action
I7: Information Miscommunicated	D7: Inappropriate Strategy Chosen
I8: Wrong Data Source Attended to	A1: Incorrect Timing of Action
I9: Data Not Checked with Appropriate Frequency	A2: Incorrect Operation of Component/Object
	A3: Action on Wrong Component / object

In the task analysis process, each task can be decomposed into different task steps and these task steps can be characterized in terms of the activities that are involved. We have provided a set of activities to serve as a guide to the entire process. These set of activities represent the types of activities generally carried out by the crew. When combined with the IDA model, each crew activity can be associated with the different IDA phases (see Table 4-2). We assume that in their interactions with the plant, the crew carries out four main functions namely: Noticing/ detecting / understanding, Situation assessment

/ Diagnosis, Decision-making / Response planning, and Action taking. These functions correspond to the different IDA phases. Each crew activity can be described in terms of any of the combinations of the four functions it requires (Table 4-2).

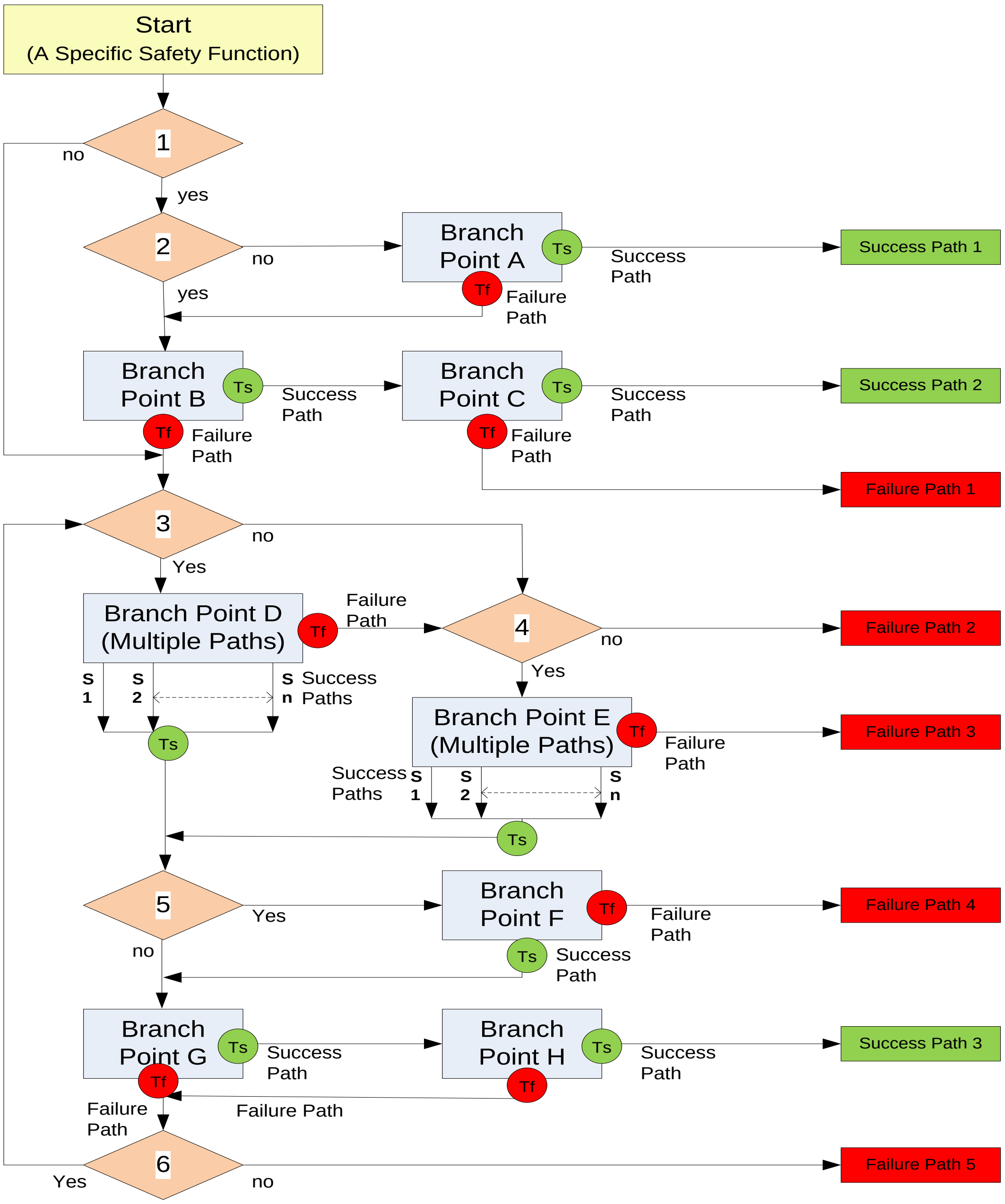


Figure 4-1: The CRT Construction Flowchart

There are no hard and fast rules on where to stop task parsing. However, we are providing some guidelines on which the analyst could base his or her decision. The level of task decomposition required for task analysis can be based on: the level of detail required in the PRA model; the resources available for modeling and conducting the analysis; the HRA requirements and purpose of the analysis; the amount and type of information available; and the success criteria for achieving the safety function. In summary, the analyst should take the follow steps to conduct task analysis: identify the HFE of interest; identify the overall task; decompose the overall task into subtasks and each subtask into other subtask depending on the level of detail required in the analysis with the aid of the aforementioned guidelines; use the types of crew activities to characterize each subtask in the lowest level of the task decomposition; and use Table 4-2 to relate the subtask characterized with the types of crew activities involved with the four main functions, IDA phases and CFMs. Therefore, each sub-task can also be traced back to the corresponding phase(s) of our human response model (IDA).

Step 2.B: Construct CRT

In order to simplify the process of constructing the CRT, a modular approach is proposed. CRTs are developed to model HFEs corresponding to a given safety function. Safety function may refer to the intended function of a specific plant system, a desired state of the plant or system in response to plant upset, or a combination of both. Sometimes, there is more than one safety function along the path to the HFE. Under the modular approach, one CRT will be developed for each identified relevant safety function. These function-based CRTs may be linked through simple merge rules, thereby producing larger and more comprehensive CRTs to cover the full range of an accident timeline and possible scenarios as reflected in the corresponding PRA ET or ESD [6].

The construction of the CRT can benefit from a flowchart to enhance consistency and completeness. The CRT Flowchart Figure 4-1 is to be viewed as the procedure aiding the analyst in the CRT development process. The questions in the flowchart guide the addition of branches to the CRT. Hence, the flowchart has pruning rules incorporated into its design. Table 4-3 provides a detailed description of the flowchart questions and we also have the description of the success and failure paths for each branch point. In order to construct the CRT, the main inputs needed by the analyst include the HFE definition, identified safety function, crew and plant context, and all procedures used to carry out the safety function. The main output is a task decomposition of the safety function in the form of an ET, which can be used to find the failure and success paths, and the branch points of interest. This would aid in the HEP quantification.

Table 4-3: CRT Flowchart Questions

No.	Question	Description and Example
1	Is the specific function designed to be initiated automatically?	Auxiliary Feed Water is an example of safety function designed to be initiated automatically. Isolation of a steam generator is an example of a safety function that is not designed to be initiated automatically.
2	Is the scenario a fast transient?	If loss of Main Feed Water occurs, the Auxiliary Feed Water will be automatically initiated shortly thereafter. Hence, Auxiliary Feed Water is a fast transient.
3.a	Is there a procedure that includes monitoring and operation of the specific safety function?	The answer to this question is either a “yes” or “no”.
3.b	Is there a specific entry point in the current procedure to a step to manually initiate the safety function?	If there is an entry point in the current procedure to a step (or a supplemental procedure) to manually initiate the safety function, the answer to this question will be “yes”.
4	Are there other procedural entry points that lead to a step to manually initiate the safety function?	The answer is “yes” if there are additional entry points in the current procedure (or another procedure to which the operator is directed to) that includes a step to manually initiate the safety function.
5	Are there any unexplored options under 3.b and 4?	If there are other options in the procedure to lead the operator to manually initiate the safety function, the answer will be “yes”.
6	Are there additional equipment and manual actions that could be used to provide the specific safety function? This question refers to recovery actions that the crew could potentially take when everything else fails.	If there are other ways to achieve the same result as the safety function, the answer to this question will be “yes”. If there are no opportunities for such recovery, the answer will be “no”.

The CRT construction flowchart (Figure 4-1) produces a skeleton CRT of the main branches in reference to the plant functions and procedural steps. The variations in scenarios due to the timing of the crew's response may also be included as branch points. Generally, the crew's response is generally considered to be either successful or not as represented in the CRT construction flowchart. In this case, timing is of no significant importance.

However, there are situations where the timing of their responses should be explicitly considered and these include: when timing has a significant impact on their next action or representation of their mental state; when there are competing events i.e. situations where one action needs to be completed before the next one; when there are events in sequence (whether short or long duration); when the current event has an impact on future events. In order to explicitly consider timing in the CRT, each success path in the flow chart can be expanded into any of the paths as indicated in Figure 4-2. Also, each failure path can be expanded into any of the paths indicated in Figure 4-3.

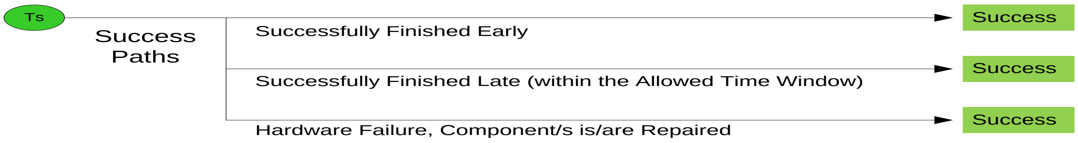


Figure 4-2: Timing in CRT Construction (Success Paths)

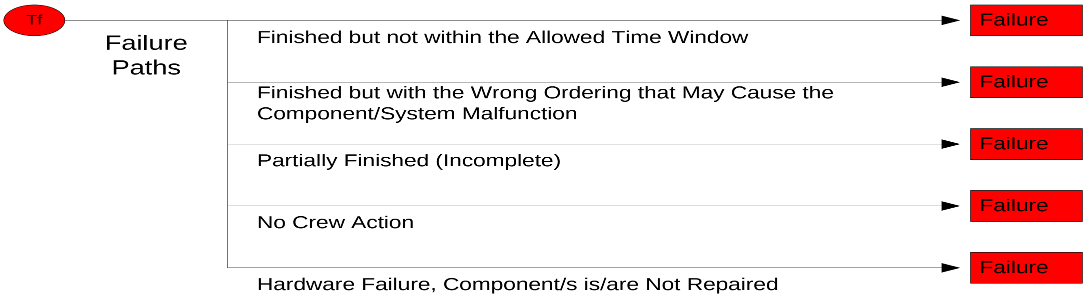


Figure 4-3: Timing in CRT Construction (Failure Paths)

Step 2.C: Prune / Simplify the CRT

In addition to deciding which branches to keep in the CRT and ultimately quantify, analysts may decide that it is reasonable to collapse some of the separate nodes or branches into a single node for quantification purposes. It may initially be reasonable to break-out the various failure paths to a detailed level. However, it may be decided later on that the cues and related decisions for some steps in the procedures create a dependency between the steps or imply that the steps should be integrated for quantification purposes. Thus, it may make sense to quantify the branches together. Also, note that new HFEs can be added to the PRA model if this becomes necessary.

4.3. Step 3: Identification of Crew Failure Modes for CRT Branches

A set of CFMs is proposed to further specify the possible forms of failure in each IDA phase. CFMs are the generic functional modes of failure of the crew in its interactions with the plant and represent the manifestation of the crew failure mechanisms and proximate causes of failure. They are selected to cover the various modes of operator response including PD, KD, or HD. In order to avoid double counting crew failure scenarios during the estimation of HEPs, the CFMs are defined as being mutually exclusive or orthogonal.

Potentially, all CFMs are relevant to each CRT branch point (and associated HFEs). However, when the analysis is conducted in the context of a scenario, and depending on the I-D-A phase, only a subset of the CFMs will apply. Therefore, a set of fault trees (FTs) were introduced [4] to aid the analysts in the selection of the relevant CFMs for each branch point within each scenario. These trees have been expanded to include the proposed set of CFMs (which form the basic events in the FTs i.e. lowest level of the FTs with red small circles underneath it) and restructured [5] to enhance clarity and consistency.

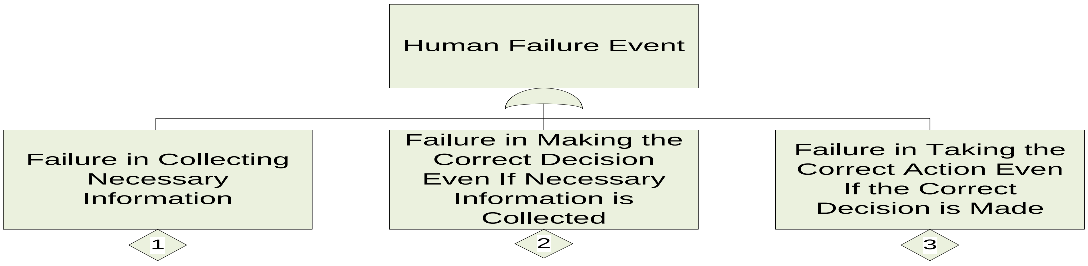


Figure 4-4: HFE logic in terms of IDA phases

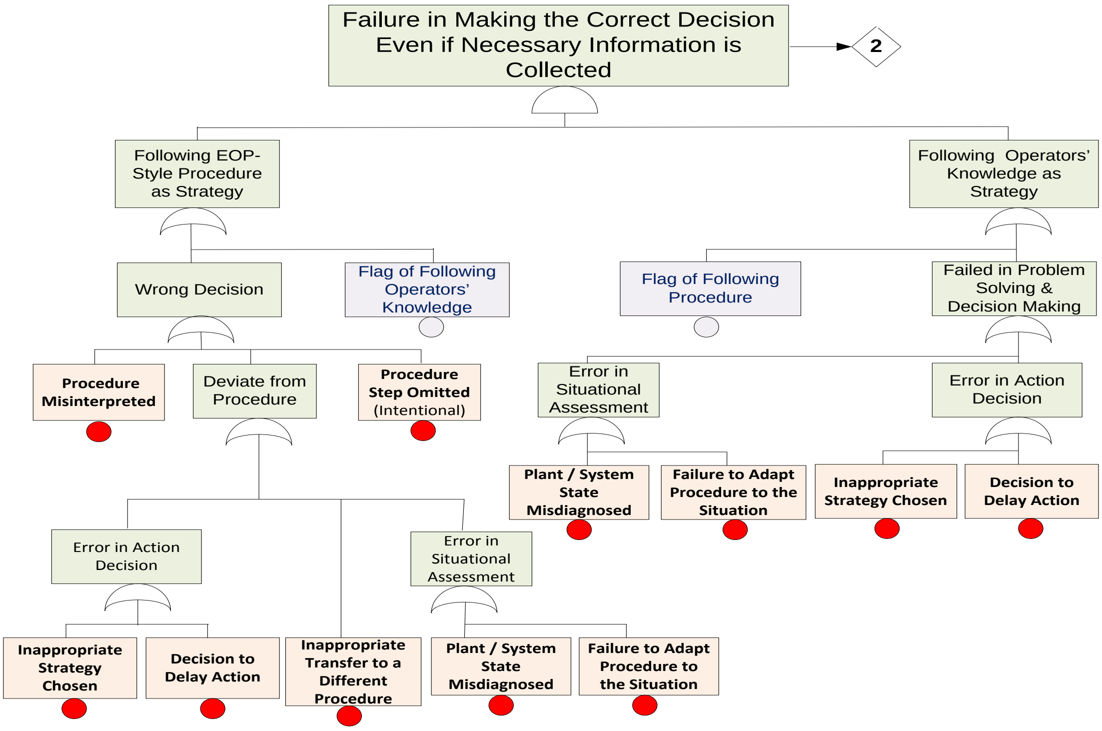


Figure 4-5: Failure in Making the Correct Decision part of the Fault Tree

The simplified cognitive model used in the FTs has three main parts as represented in Figure 4-4. Each of this part is further broken down into FTs (and example is shown in Figure 4-5). Based on the context related to the CRT branch point assessed, the analyst will trace through until eventually encountering an end point in the trees which represents the CFM associated with the branch point. The inputs needed by the analyst in order to apply the FT include: HFE definition; identified safety function; plant context; crew context; developed CRT; and identified critical paths in the CRT.

4.4. Step 4: Development of CRT Scenario for the HFE(s)

Step 4.A: Model Integration

As discussed previously, the qualitative analysis framework has three layers. The CRT represented by an ET, forms the top layer. The IDA model which is modeled using FTs forms the second layer. This approach of linking the FTs to the CRT will help identify the crew-plant interaction scenario cut-sets.

The CFMs are linked to the PIFs which form the third layer of the framework through a CFM – PIF framework. The CFM- PIF linkage is modeled using a Bayesian Belief Network (BBN) as shown in Figure 4-6. These three layers (CRT, FT & BBN) are combined together to form the integrated model illustrated in Figure 4-7. The path through this integrated model gives the details of how the entire story needs to be narrated and read. Sub-scenarios are strings which are combined to provide the detail narratives and qualitative insights into the analysis. The logic model is used to tie together all the conditionalities that appear in the story.

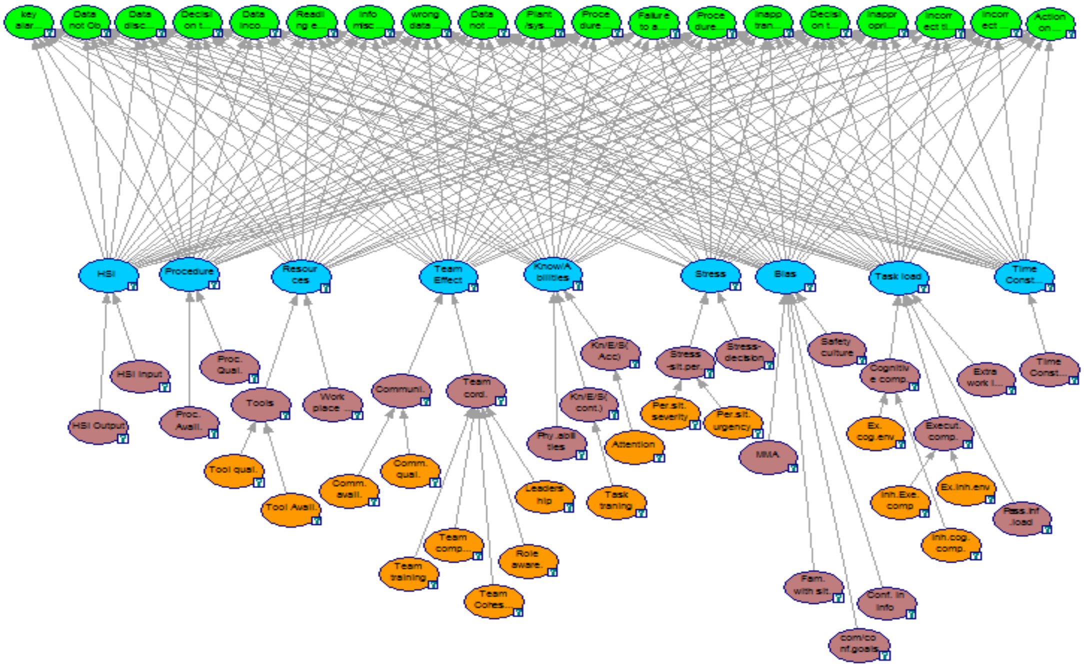
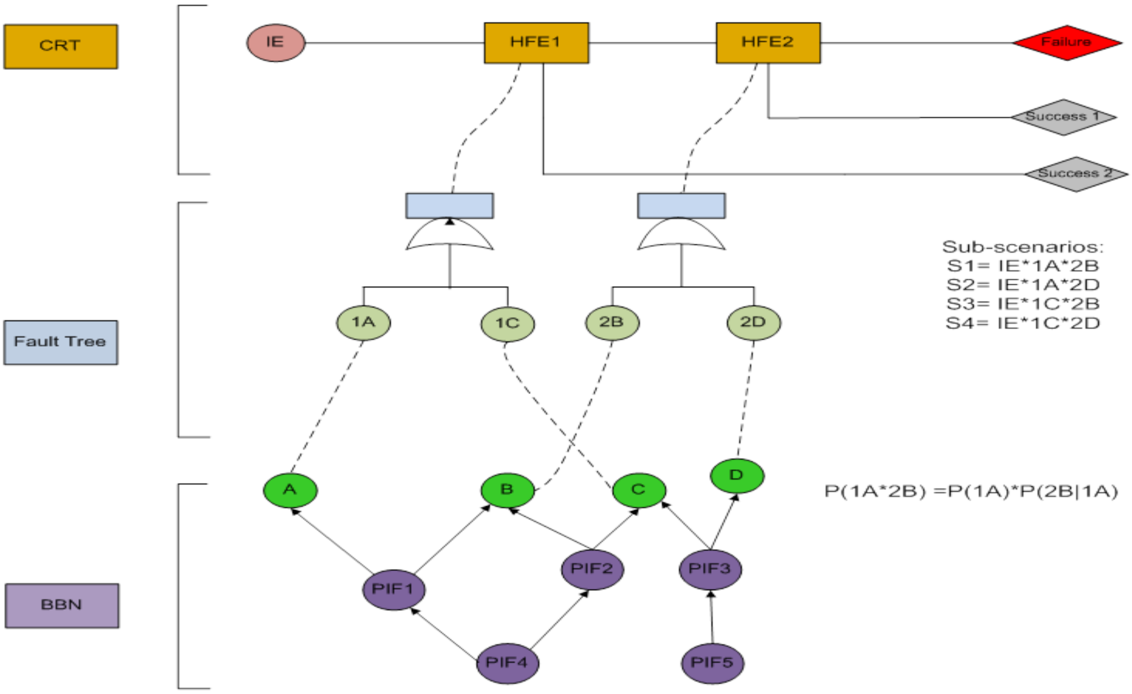


Figure 4-6: Master CFM – PIF BBN Model



Sub-scenarios:
S1= IE*1A*2B
S2= IE*1A*2D
S3= IE*1C*2B
S4= IE*1C*2D

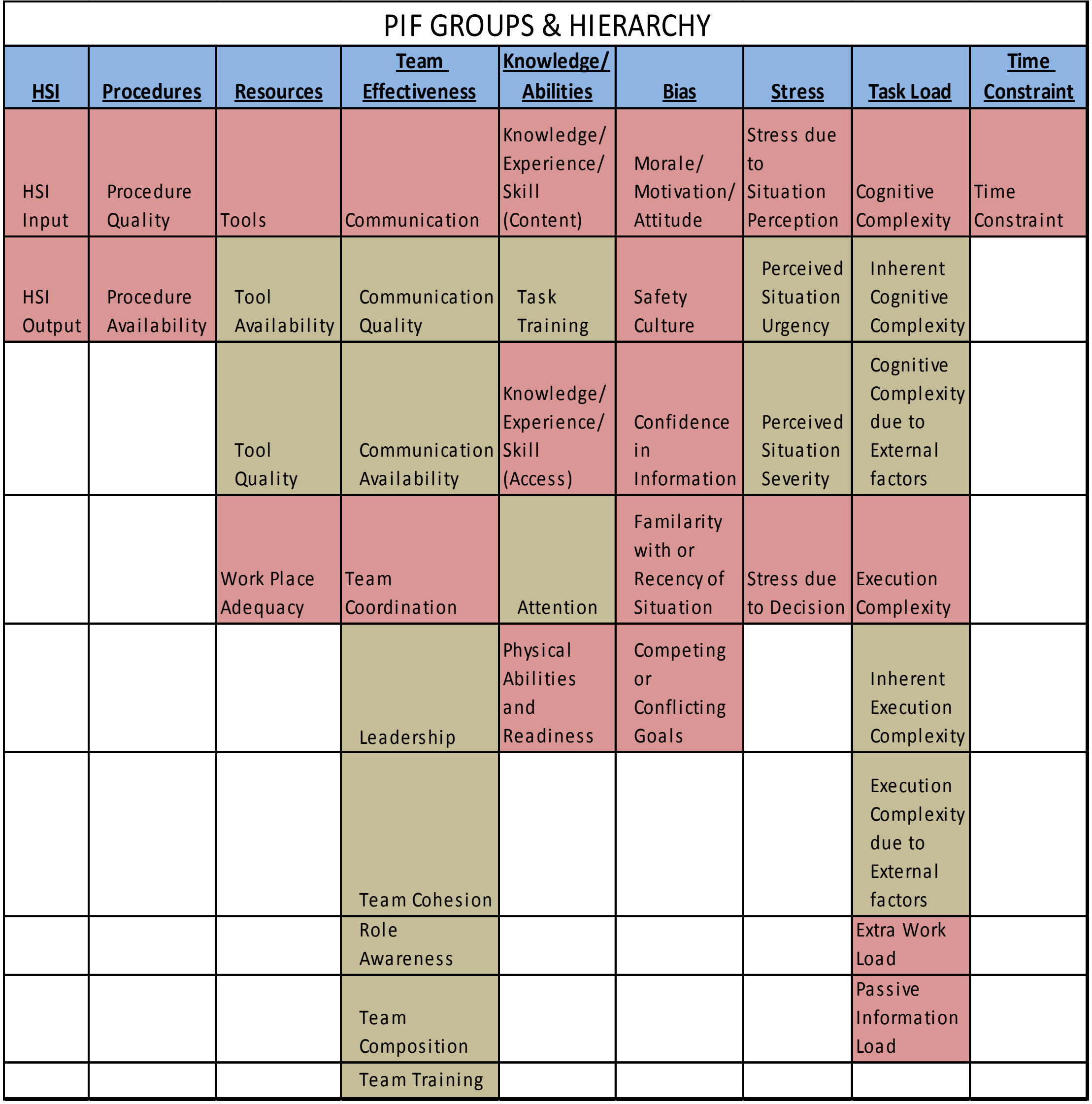
P(1A*2B) =P(1A)*P(2B|1A)

Figure 4-7: Sample diagram of the Integrated Model

Step 4.B: Identify relevant PIFs using the CFM-PIF BBN Model

The PIFs form the bottom layer of the qualitative analysis framework. We have provided a PIF set that is based on their impact on operating crew behavior. The PIFs are divided into groups and classified into levels within the groups (Table 4-5), hence forming a hierarchical structure which can be fully expanded or collapsed as needed. A set of tables which map the PIFs to CFMs has also been developed based on the results of a psychological literature review and modeling assumptions.

Table 4-4: Proposed PIF Groups and Hierarchy



PIF GROUPS & HIERARCHY

HSI	Procedures	Resources	Team Effectiveness	Knowledge/ Abilities	Bias	Stress	Task Load	Time Constraint
HSI Input	Procedure Quality	Tools	Communication	Knowledge/ Experience/ Skill (Content)	Morale/ Motivation/ Attitude	Stress due to Situation Perception	Cognitive Complexity	Time Constraint
HSI Output	Procedure Availability	Tool Availability	Communication Quality	Task Training	Safety Culture	Perceived Situation Urgency	Inherent Cognitive Complexity	
		Tool Quality	Communication Availability	Knowledge/ Experience/ Skill (Access)	Confidence in Information	Perceived Situation Severity	Cognitive Complexity due to External factors	
		Work Place Adequacy	Team Coordination	Attention	Familiarity with or Recency of Situation	Stress due to Decision	Execution Complexity	
			Leadership	Physical Abilities and Readiness	Competing or Conflicting Goals		Inherent Execution Complexity	
			Team Cohesion				Execution Complexity due to External factors	
			Role Awareness				Extra Work Load	
			Team Composition				Passive Information Load	
			Team Training					

KEY	MEANING
🟦	Level 1 PIFs
🟥	Level 2 PIFs
🟫	Level 3 PIFs

4.5. Step 5: Analysis of HFE Scenarios, Development of Narratives, and Identification of Dependencies

For each of the CRT scenarios, the “context” of an HFE to be captured by the qualitative analysis through the CRT and other layers of the methodology include: the portion of the specific PRA ET scenario(s) that lead to the HFE of interest; the corresponding time from the start of the scenario; the portion of the specific CRT scenario that leads to the HFE; and all other relevant plant and crew "factors" not shown on the ET and CRT. For each HFE, the analyst can develop a narrative version, clearly describing the causal chain and the role of various context factors leading up to the HFE.

5. CONCLUSION

In the paper, we have provided a summary of the steps and techniques of performing the qualitative analysis using Phoenix HRA methodology. This is accomplished with the aid of various modeling tools which include CRT flowcharts, CRTs, FTs, CFM-PIF tables, and BBNs. When properly applied, Phoenix methodology should produce a more extensive analysis with broader considerations for the conditions that could lead to crew failure. Also, it should produce a detailed, consistent, traceable, reproducible and properly documented HRA qualitative analysis. This would aid in addressing some of the current issue facing the field of HRA and hence, PRAs in general.

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