3 Research Design

3.1 Need for Further Study

There is need for further study on the topic of appropriate models and techniques available for analyzing barrier effectiveness. This conclusion is drawn based on the gaps in existing models as identified in the previous chapter. Reiterating these key research gaps on the basis of the preceding literature review:

i. Barrier performance parameters specific to onshore sour gas drilling is not identified

ii. Dynamic Risk assessment of MAHs which consider the failure of safety barriers for onshore sour gas drilling has not been carried out

These gaps were used to proceed the current study by leveraging these to frame the research problem.

3.2 Research Problem

Based on the reviewed literature, in the context of gas drilling (and more specifically onshore sour gas drilling operations), the missing part in the reviewed literature could be stated as follows:

"How can we proactively assess risk of MAHs considering safety barrier factors for onshore gas drilling operations?"

3.3 Research Questions

The gaps based on the literature review and the clarified research problem were then segmented into specific research questions. Segmenting allowed for clear solutions each portion of the research problem. The below research questions were identified as follows:

i. What are the parameters that are essential for barrier performance for onshore sour gas drilling?

ii. How to evaluate the major accident hazard risk to personnel and asset for an onshore gas drilling facility based on barrier performance?

3.4 Research Objectives

Each research question was further refined to a set of objectives as stated below. The study aimed to fully address each objective, and in turn, answer the two (2) research questions identified. The objectives of this study were:

Objective -1: To identify the various barrier performance parameters for onshore sour gas drilling operations.

Objective -2: To evaluate major accident hazard risk for assessing the overall personnel and asset impacts associated with onshore sour gas drilling operations

3.5 Research Methodology

In order to fully satisfy the study in a way that is methodical and comprehensive, a particular course of action was taken to pre-meditate the steps needed for the study. The current section reviews the steps through a visually mapped research design. The design shows the logical progression of steps taken to execute this study for each objective. The steps were elaborated for the study by focusing first on the steps taken for the first objective, then by reviewing the steps taken to execute the study for the second objective.

Steps for executing Objective 1 study

The purpose of Objective 1 was to identify the various barrier performance parameters for onshore drilling operations. With this goal in focus, exploratory research was conducted to understand existing barrier performance parameters in other industries to review their applicability to onshore drilling operations. This is visually explained in Figure 3.1.

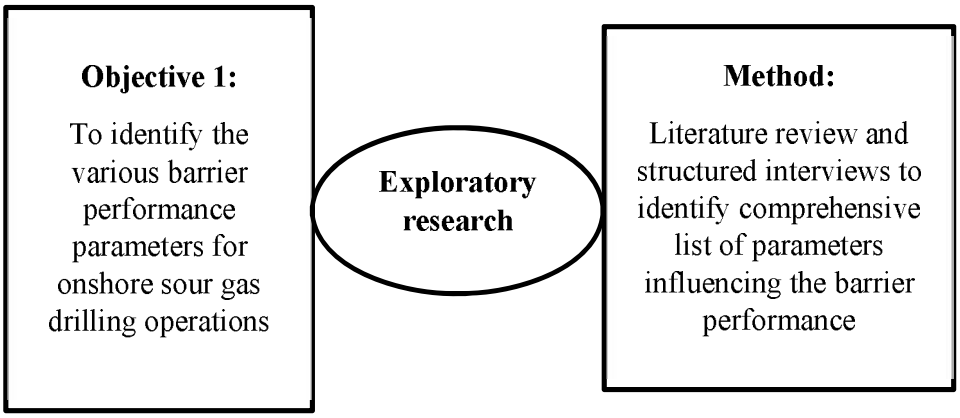

Figure 3.1: Objective 1 goal and method

There were four major steps taken to execute the method summarized above. These four steps are outlined and explained through Figure 3.2, which offers a detailed visual of steps for study execution.

i. **Identification of variables:** Literature review was coupled with structured interview (from experts) to finalize the list of variables

ii. **Designing of Questionnaire:**
   a. A questionnaire designed on a 5-point Likert scale, five (5) being strongly agree and one (1) being strongly disagree
   b. Reliability of the questionnaire which was tested after receiving responses from 30 respondents through Cronbach Alpha method. Alpha greater than 0.7 is considered highly reliable (Nunnally, 1978).

iii. **Sampling:** The questionnaire was sent to drilling experts, rig supervisors, drilling crew personnel, academicians, process safety experts, HSE advisors, HSE managers, drilling management and regulators. The researcher used a stratified random sampling method. A minimum sample size based on rule of ten (10) was considered (Nunnally, 1978).

iv. **Data Collection and analysis:** Through online media the questionnaires were sent to the respondents. In order to identify the variables that influence barrier performance, the researcher used Factor Analysis, as the parameters for the study were in large number, of which some are correlated. These data were reduced to a manageable level for achieving the objective. The respondents' data were analyzed using SPSS 16 software.

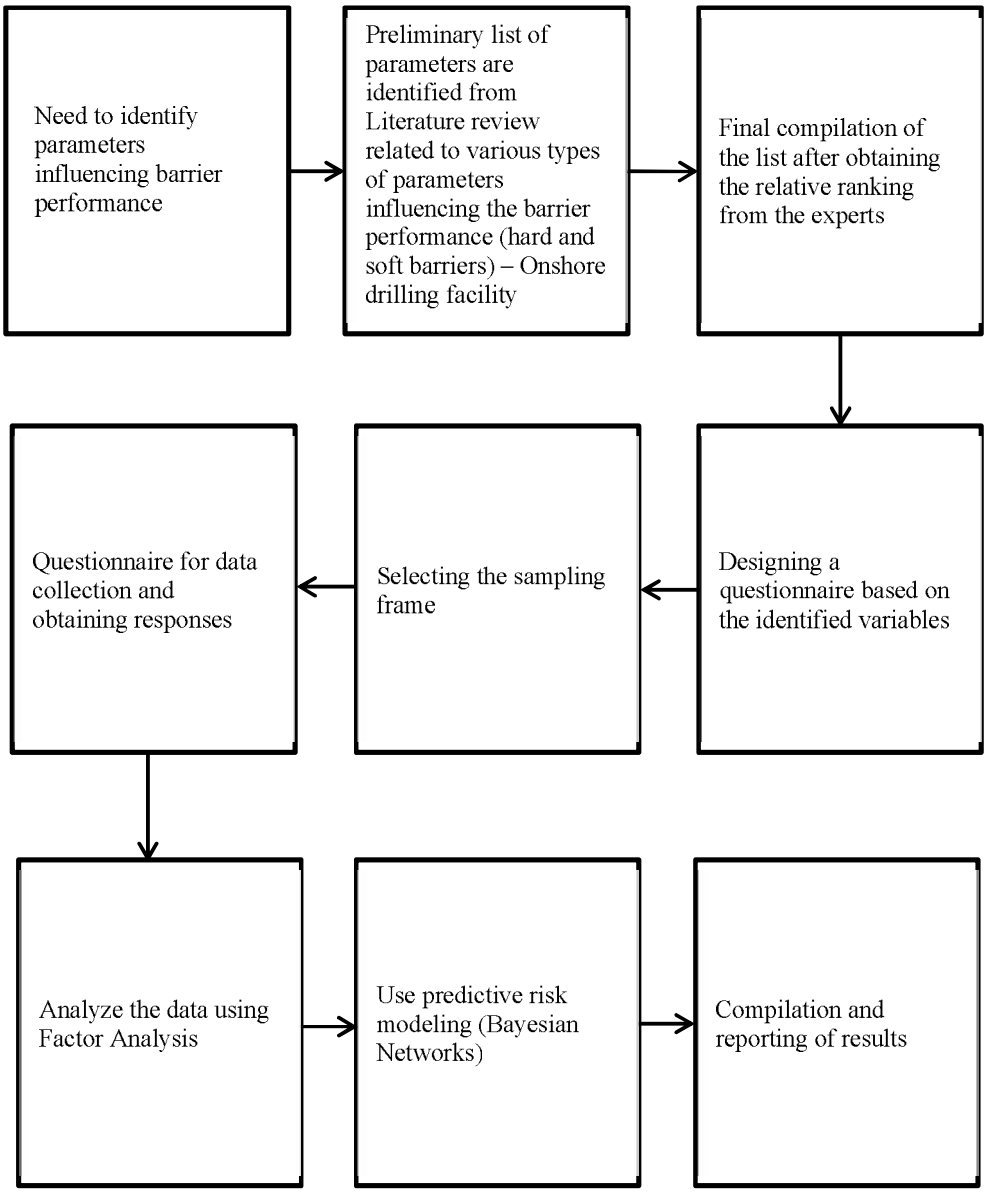

Figure 3.2: Detailed steps for study execution

Now that Objective 1 study progression is clear, Objective 2 steps for study execution are reviewed in the below section. In the same fashion, as the previous objective, the goal of the objective will be first clarified and the method for meeting that goal will be explained. Details for each step and visual depictions will aid the explanations.

Steps for executing Objective 2 study

The purpose of Objective 2 was to identify an appropriate barrier evaluation method for use in onshore drilling operations. To reach the conclusion of an appropriate solution, research was conducted to understand available models for leverage. With a narrowed focus on intent to use Bow-Ties and Bayesian Networks as a part of the hybrid solution, steps were taken to convert the existing models into a predictive risk model. This objective and method are visually represented in Figure 3.3.

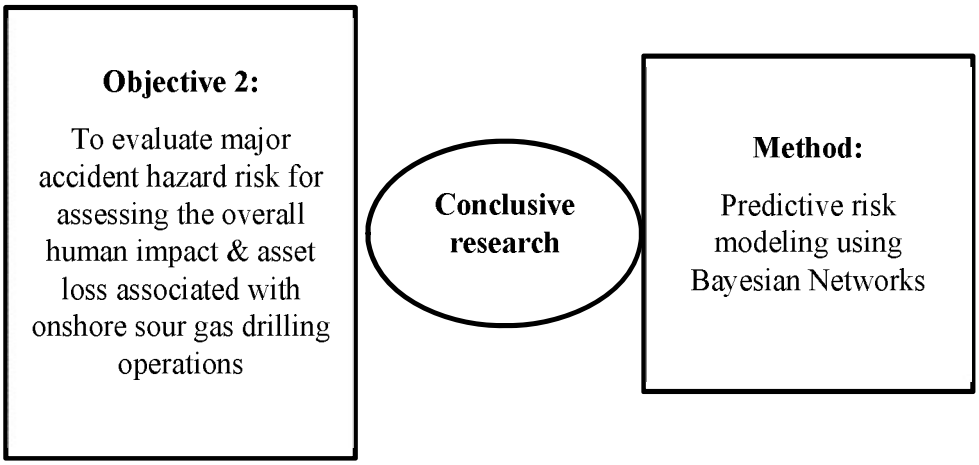

Figure 3.3: Objective 2 goal and method

There were six (6) major steps taken to create the hybrid barrier evaluation method. These steps allowed conversion of a Bow-Tie and Bayesian Network in a strategic way that minimized the gaps in either method and combined the benefits of each approach. The process for this conversion is outlined as listed below.

i. **Review of Bow-Tie:** Review current Major accident hazard Bow-Tie Model for onshore sour gas drilling operation. This data is sourced from Company Risk analysis reports. A schematic representation of a bow-tie is given in Figur

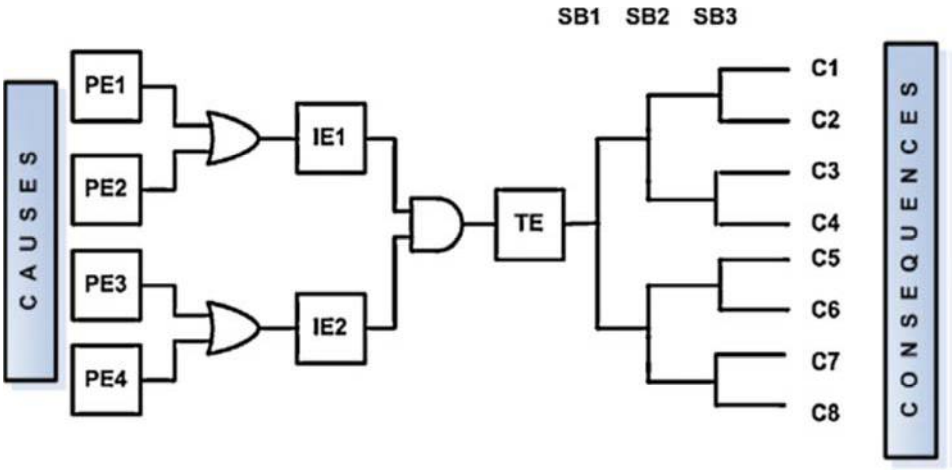

Figure 3.4: Typical Bow-Tie

Whereas:

PE- Primary Event

IE – Initiating event

TE- Top event

SB- Safety barrier

C1-8 – Consequence

ii. **Bow-Tie and Bayesian Network conversion:** Each of the Operations Bow-Tie was converted to Multiple Incident Bow-Ties for various accident pathways as depicted in Figure 3.5 evaluating personnel and asset impacts.

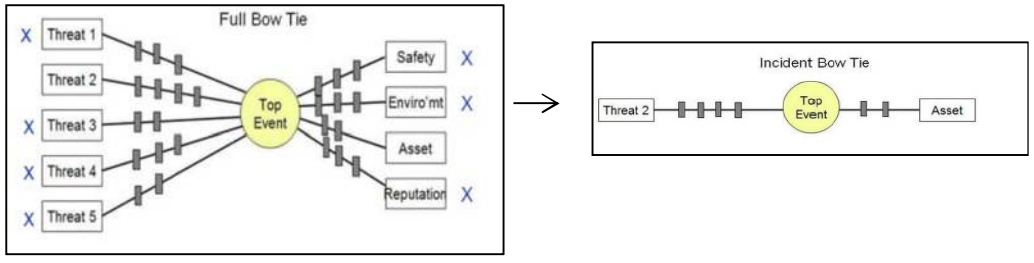

Figure 3.5: Transformation of Bow-Ties to incident Bow-Ties (Source: Pitblado & Fischer, 2010)

The Bow-Tie Model parameters were transformed into Bayesian Network (shown in Figure 3.6) parameters for various accident pathways corresponding in the Bow-Tie based on the below mapping algorithm shown in Figure 3.7 (Khakzad, N et al., 2013). The mapping was conducted by the researcher in consultation with the drilling process and safety experts. An illustrative transformation for an accidental gasoline release scenario is shown in Figure

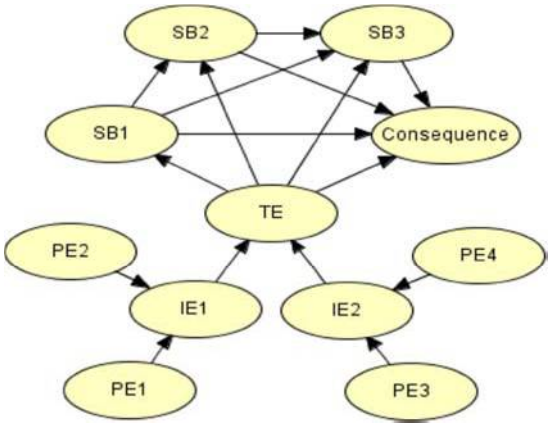

Figure 3.6: Relationship based Bayesian Network diagram

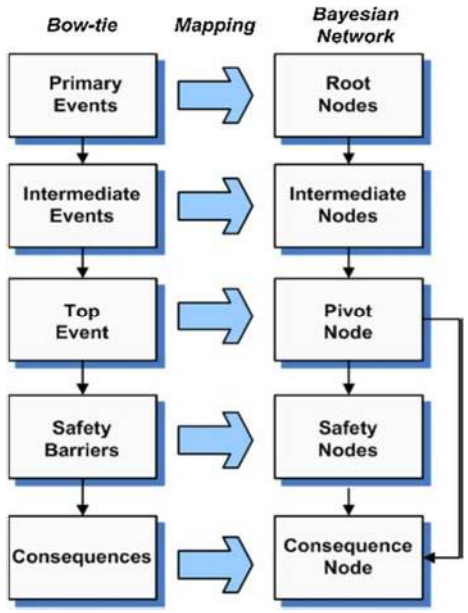

Figure 3.7: Mapping algorithm from Bow-Tie to Bayesian Network

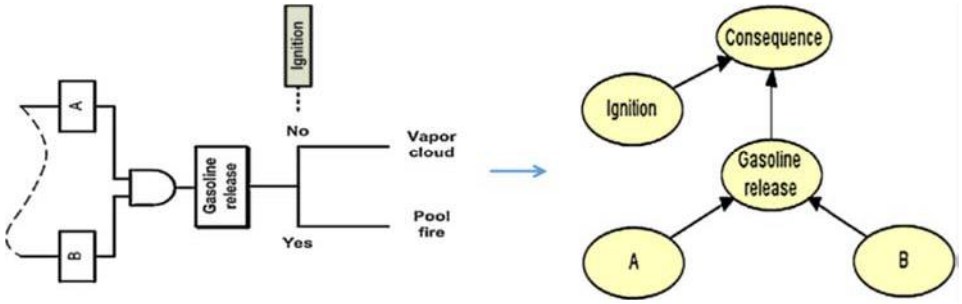

Figure 3.8: Illustrative transformation of Bow-Tie Model to relationship based Bayesian Network for an accidental gasoline release scenario

iii. **Barrier valuations using the hybrid model:** After the Bayesian Networks were transformed, the safety barrier performance of each barrier (based on the identified parameters from Objective 1) was evaluated through the workshop group and values were assigned for each safety barrier.

iv. **Safety performance calculation:** Based on the assigned safety barrier value, the incremental major accident hazard risk to personnel and asset were calculated considering the actual safety barrier performance. The Bayesian Network was modelled through AgenaRisk software.

v. **Result validation:** The risk results were validated through a workshop consisting of mixed group comprising of academicians, process safety experts, drilling operators and regulators. The approach was presented to the audiences, followed by a question and answer session for further clarification. A five-point scaling technique was used in a structured questionnaire. In the five-point scale one (1) represented the least and five (5) represented the best situation, meaning the degree of the validity of the model varied from one (1) to five (5). The parameters included conceptual framework, data, selection of the right indicators for measuring hazard, vulnerability, capacity, techniques used and interpretation made. (Source: Abbas, H, Routray, J, 2013)

This concludes the review of steps taken to execute study for Objective 2. The steps for Objective 1 and Objective 2 were carried out as described and results were gained for each objective. The following section will now explore and analyze the results of each study in depth.