# The use of CAPEMO Causal Model on the Probabilistic Risk Analysis of Human Failure on Fluid Penetrant Inspection.

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## ABSTRACT

In any industry branch, there are situations where the failure of a critical component, be it a rotating part of an aircraft engine, a pressure vessel nozzle, or a cruciform tubular welded joint in an Offshore Jacket, can have dramatic consequences. Since the visual nature of the Fluid Penetrant Inspection relies so much on the cognitive, skill, and attitudinal aspects of human performance, it is of paramount importance to study the risks of failure on such performance. Several Risk Analysis tools are applied to assist in the identification of such risks. The purpose of this paper is to use the CAPEMO Causal Model [1] to conduct a probabilistic analysis of the chances of a human error during the inspection by Penetrant Fluid.

This study analyses the FPI inspection process and identifies the challenging areas where human factors may affect inspection performance. It considers that if a critical discontinuity (in this case, a crack) is not identified during the inspection process, it is considered the pivotal event and will lead to a possible catastrophic failure with severe consequences.

The innovation in this article is the application of the CAPEMO Causal Model to perform a Human Reliability Analysis. Risk factors were combined by using the Fault Tree diagram. The model helped to define critical human factors that affect the FPI process. An online survey based on the conclusions from the fault tree diagram was submitted to specialists. The results allowed the preparation of a Bayesian Network by using specific software that allowed an assessment of the root causes that contributed more to the pivotal event. Actions to reduce the probability of a significant defect are also proposed.

This study confirms that implementing systematic barriers to mitigate the risks of human errors reduced the probability of such risk significantly. Actions taken to mitigate the risks caused by human factors connected to Environment Control, Organization Factors, Skills & Capacity and Distraction proved to be effective and reduced the probability of an Operator failure significantly. The proposed method can be used by NDT professionals, engineers, and decision-makers to identify the risk of human errors that can impact the results of the FPI inspection.

Keywords: NDT, Risk Management, BBN, Fault-Tree, Fluid Penetrant Inspection, CAPEMO, Human factors, HRA

# 1. INTRODUCTION

Inspections failures may take lives away. In the civil aviation industry, failures on the FPI inspection during a routine maintenance inspection resulted in terrible accidents, such as the Delta Flight 1288 accident in July 1998 when two passengers perished. Five got injured; the United Airlines Flight 232 accident at Sioux City, Iowa, in July 1989 was caused by a fatigue crack undetected by the FPI inspection at the company's overhaul engine facility. The accident report raised that the cause of this accident was due to human factors and limitations in the inspection procedure. One hundred twelve passengers died. Similarly, catastrophic failures like these may also happen in any other industry; for instance, the FPI inspection process is used to detect fatigue cracks on naval structures submitted to cyclic tensions or to inspect heat exchangers tube bundles, etc.

Reducing the probability of a failure in the FPI inspection process is a big priority. According to Bertovic [2], improving the performance in non-destructive testing has typically been treated by improving the equipment used and changing the method and procedures. However, limited resources have been invested in researching the human factors field. For an NDT inspection to be reliable, the whole system and its parts must be reliable (equipment, procedure, and personnel). The largest source of performance difference can be observed in the operator. It is the operators that interpret the signals provided by the equipment". Still, according to Marija Bertovic, time pressure, mental workload, and experience influence the inspection quality. Also influences from the organization of the working schedule, communication, procedures, supervision, and demonstration task [2].

The United Kingdom Health and Safety Executive defines that "Human Factors refers to environmental, organizational and job factors, and human and individual attributes which influence behavior at work in a way which can affect health and safety." Therefore, investigating how the Human factors may impact an NDE inspection, states it is paramount importance [3]. Drury also states that efficient and effective NDT inspection depends on the excellent relationship between the organization, procedures, inspection equipment, and the human operator [4].

None of the previous studies presented in section 2 addressed a method for identifying human errors related to work environment control, organizational factors, skills & capacity of the inspector, personal attitude, or distraction factors. All these factors may influence the risk of operator failure during the FPI inspection process.

This article proposes using the CAPEMO methodology developed by Pereira [1] to perform the Human Reliability Analysis on the FPI inspection process and identify the risk factors/events that lead to the operator failure. It also proposes identifying and reporting a significant defect (a crack) and defines the impact and likelihood of each event occurring. Furthermore, it suggests measures to increase human reliability in the FPI Inspection process, thereby reducing the risk of catastrophic failure caused by this significant defect occurrence.

The study responds to the following research questions:

1) Is the proposed method capable of performing a quantitative and qualitative analysis of the risks associated with human reliability in the Fluid Penetrant Inspection process?

2) What preventive actions emphasize increasing human reliability that can be implemented during the Fluid Penetrant Inspection process?

The paper is structured as follows: Section 2 covers the methodology, and the definitions of Risk assessment, the CAPEMO model, Human Reliability Analysis, Bayesian Belief Networks, section 3 discusses the results and section 4 presents the conclusion and suggestions for future studies.

## 2. DESCRIPTION

### 2.1 Methodology

The study was conducted following these steps: 1 – Research on the theoretical framework and updated literature using the keywords: NDT, Risk Management, BBN, Fault-Tree, Fluid Penetrant Inspection, CAPEMO, Human factors, HRA; 2 – Preparation of process map to define the pivotal element in the process; 3 – Preparation to define risks, causes and barriers; 4 – Conduction of survey for probability elicitation; 5. Preparation of Bayesian Belief Networks. 7 – Sensitivity analysis to define the most impactful risks. Fig. 2 shows the flowchart with these steps.

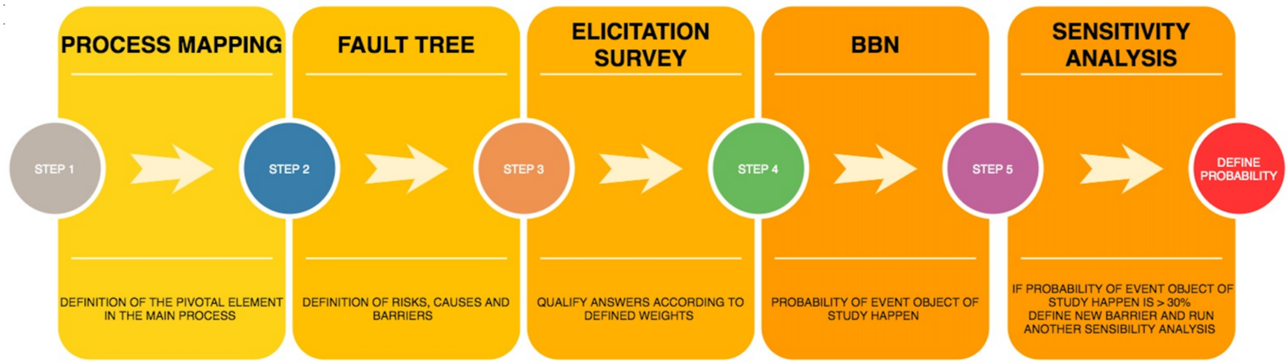


Fig. 2 – Methodology description flowchart

### 2.2 Risk Assessment

Risk Assessment is a systematic, gradational approach for appraisal of risks, establishing the probability of a risk occurring and the repercussion. It is an essential element of an effective risk management system [5]. The International Organization for Standardization defines risk as an "effect of uncertainty on objectives" [6], establishing that is the deviation from an expected objective and uncertainty to a state of lack of information related to an event, its potential consequence, or its likelihood. In simpler words, risk can be seen as "the notion of an adverse outcome or a potential negative impact that arises from some present or future event" [7].

The purpose of risk analysis is to obtain a better understanding of the risks. In risk analysis, the causes and origin of risk, their effects, and the probability that those effects can occur are considered in detail. The consequences, probability, and level of risk can be a qualitative analysis (by using importance levels such as "high," "medium", or "low"), semi-quantitative (by using numerical rates), or quantitative (by the evaluation of the risk in specific values defined during the development of the context).

During risk evaluation, the risk analysis results are compared with the risk criteria (defined during the establishment of the context) to determine the risk's significance and type. The purpose of risk evaluation is to use the knowledge gathered during the previous analyses to make decisions about future actions. Those decisions include considering whether a risk needs treatment, deciding whether they should and, if yes, which activities should be taken, and assigning priorities for treatment [2].

Martin Rousand applies three essential questions to carry out a risk analysis: What can go wrong? What is the likelihood of that happening? Moreover, what are the consequences? [8] David Hillson expands it to seven questions: a) What to achieve? (objective setting); b) Whom does it affect? (Risk Identification); c)Which ones are the biggest? (Risk prioritizing) d) What to do about it? (Plan and implement actions to mitigate Risks); e) Does it work? (Review the Risks); f) To whom to tell it about? (Report the Risks);g) What has changed? (perform a Risk update) [9]

The possibility of occurring failures on the inspections performed by Fluid Penetrant (and other NDT techniques) in general has long been part of risk management practice in organizations with high reliability and safety demand. It is typically taken into account in assessing the risk of failure of a component or the entire system. This is achieved by first assessing the risk of the component failing and deciding which FPI method should be applied. After the FPI has been performed, the inspection result is input into the risk assessment. Future inspections are planned based on this result and the general likelihood that the component will contain defects and eventually fail. In this process, the necessary methods and the frequency of their application are taken into account. This process is known as risk-based management. [2]

The IEC/ISO 31010:2018 standard on risk assessment techniques suggests that the following factors can influence selecting the appropriate risk assessment technique: 1. The method's applicability to the desired steps in the risk assessment process (some methods are applicable to identify, analyze, and evaluate the risks and support risk treatment, whereas some methods are only applicable to some steps). 2.The availability of resources (e.g. skills, experience, capacity, and capability of the team; time and budget restraints). 3.The nature and the degree of uncertainty associated with the risk (the availability of a sufficient amount of information needed to assess the risks). 4.The complexity of the problem and the methods required to analyze it (consideration of single risks versus dependencies between risks). Therefore, the CAPEMO model can also be an effective tool to perform the Human Reliability Analysis since all requirements are met in full. The same standard suggests several techniques, describing them concerning applicability for different stages of the risk assessment process (identification, analysis, evaluation), and their attributes (necessary resources, the degree of uncertainty, complexity, and the availability of a quantitative output). The consideration of the applicability of different techniques for this investigation resulted in a handful of suitable techniques. They include Hazard and operability studies (HAZOP), Structured "What-if" Technique (SWIFT), Fault-tree analysis, Failure Modes and Effects Analysis (FMEA), as well as different types of Human Reliability Analysis (HRA). [2]

### 2.3 CAPEMO Model

The CAPEMO model performs simulations on a structured approach by combining different methodologies such as Bayesian Networks and Fault tree and provides as output the probability of a significant consequential event happening. The first step is to establish the basic process mapping and define the pivotal element leading to the significant consequential event. Next, a fault tree is drawn to represent the problem mapping graphically. The third step consists of defining the probabilities for each event of the Fault Tree to be used to model a correspondent Bayesian Belief Network that will help identify the interdependence between the various events in the model. Once the BBN is complete and the probabilities are defined, the CAPEMO model will provide the final probability of the significant consequential event.

### 2.4 HRA – Human Reliability Analysis

As a general rule, human beings are responsible for performing all phases on the majority of the technical systems, from concept through management, fabrication, operation, and maintenance since system upgrade, to decommissioning and disposal. Humans tend to make mistakes, and it is often said that "to err is human." As humans, we are generally more complex than technical systems, and it is difficult to predict the types of errors that we may commit. [8]

According to the Health & Safety Laboratory, Human Reliability Assessment (HRA) involves the use of qualitative and quantitative methods to verify the human contribution to risk [10]. Human reliability is also defined as the probability of a person conducting a specific task with satisfactory performance. HRA implies a systematic prediction of potential human errors, and once such errors are identified, actions can be taken to eliminate or reduce their occurrence and maximize safety and performance [11].

The Health and Safety Executive states that "human factors refer to environmental, organizational and job factors, and human and individual characteristics, which influence behavior at work in a way which can affect health and safety" [12].

The 2nd American-European Workshop on Non-Destructive Inspection Reliability [13], offered a more specific, NDT oriented definition – "Human factors are the mental and physical make of the individual; the individual's training and experience; and the conditions under which the individual must operate which influence on the ability of the NDE system to achieve its intended purpose."

The Human Reliability Analysis has a vital role in all inspection systems, from simple visual inspections to technically advanced ones. The types of human actions required in performing a typical Non-destructive Inspection are defining inspection strategy, selecting inspection techniques, preparing equipment and procedures, acquiring, analyzing, and recording data, and reporting inspections. Inadequate performance on any of those tasks can result in missed of falsely reported defects [14].

The approach to human factors in NDT has not undergone a similar development as its original discipline. The focus is still mainly on the inspector and the prevention of human errors. In NDT literature, the "human factor"—referring to the inspector—has been frequently identified as the primary source of error or variability in the results, even though the influences of the working conditions and the inspection procedure are generally acknowledged. This can be observed in the definition of human factors in NDT as the mental and physical conditions of the individual, the individual's training and practice, and the situations under which the individual must operate that impact the ability of the NDE system to achieve its intended purpose [15].

By concentrating on the individual origins of error, according to Reason [16], the act is wrongfully isolated from its context and, therefore, essential features can be overlooked. First, it is often the best people that make the mistakes, and second, the same combination of circumstances can provoke the same errors, regardless of the people involved. In addition, people in high-reliability organizations are generally motivated to do a good job - what they do generally makes sense to them at the time [17]. Therefore, this view is being replaced by the modern systems approach focusing on the underlying conditions that create possibilities for failure. Human error is a symptom of problems hidden more profound in the system. Efforts are thus invested into the conditions under which people work and ways to prevent the failures [7, 16, 17, 18]. This is achieved by implementing defenses. Hence, when adverse events do occur, the question should not be who failed but rather how and why the defenses failed.

Typical methods for preventing errors include designing the system to be simple and easy to use, training, adequate warnings that can anticipate a system state that will likely lead to error, and restricting the operator's exposure to opportunities for error [19]. The attempts to minimize the occurrence of errors are either proactive or reactive. The proactive approach is based on improving the human-system interface. This is most commonly achieved by creating decision aids, improving the training or the procedures, automating features of the system interface, etc. The reactive approach focuses on eliminating the reoccurrence of already occurred errors. The common term used for these error prevention or minimization techniques is defenses or barriers.

### 2.5 HRA – BBN - Bayesian Belief Networks

Bayesian Networks (BNs), also called Bayesian Belief Networks (BBN), have become an increasingly popular part of the risk and reliability analysis framework due to their ability to incorporate qualitative and quantitative information from different sources [20]. It models interdependency and provides a causal structure that allows a deeper insight into risk drivers and specific interventions that reduce risk. The Bayesian structure of CAPEMO consists of nodes drawn as ellipses and connecting arcs represented as arrows. The nodes contain variables with probability information about risks that affect humans, software, and calibration failure. The directional arcs represent causal influence relationships between nodes. The starter nodes are the parents and have their probability estimated by experts, while nodes further down the structure are the children. A child can be the source for a connected follow-on child, also called sink node. BBN structure in CAPEMO has one child at the end as a target node and different parents. The majority of the parent nodes contain expert opinions, hence personal information. The discrete nets used in CAPEMO calculate the conditional probability of the random variables corresponding to linked nodes, each variable represents states of a process component. Software for BBN is freely available and used at different levels of detail depending on the problem at hand. BBN models are ideal for CAPEMO because of the ability to combine simple modules into something that can match the complexities of the jet engine manufacturing process. The BBN modeling designs a relationship framework based on expert opinion. It then populates it with probabilities obtained from historical data about engine manufacturing failure and expert elicitation. In the elicitation process, the probability data to populate the BBN tree structure is guaranteed to be sufficiently accurate because experts are appropriately selected. Elicitation of probabilities is based on accessible knowledge of failure and omission rates. The values of probabilities are obtained from experts according to probability elicitation procedures. Conditional probability tables represent the interdependencies between events. There has been an increasing trend in the literature and application of Bayesian networks in the reliability, safety, and maintenance fields. Factors considered to have a significant influence on human error are considered. The use of BBN allows the modeling of the interdependencies between events and makes the model consistent. The values of probability are obtained from experts according to specific procedures of probability elicitation. Conditional probability tables represent the interdependencies between events. Fig. below shows an example of BBN represented by parent nodes O and T causing event M. The probability that event M is true is calculated by the formula shown in (Fig. 1).

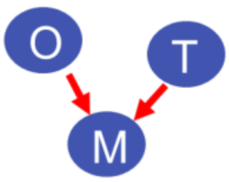


**Fig.1** – Formula for the probability that event M is true

## 3. DISCUSSION

For this study, data on FPI inspection were obtained from an in-depth literature review and from a survey conducted with certified personnel. The application of the methodology generated data and the results described herein:

### 3.1 Step 1 – FPI Process Mapping

The Pivotal element to consider in this study is the possibility of missing a significant flaw during the NDE inspection. Within the different types of discontinuities described on various standards, books, articles. As a significant flaw, the crack is credited as the most critical defect since it may lead to a catastrophic event that, depending on the application, causes loss of lives, assets, and money.

Several NDT reliability studies exist that use the Probability of Detection (PoD) curve to express the detection process's reliability as a function of a variable of interest, usually crack size, as a single parameter. Moreover, according to Drury, NDT techniques are designed mainly for a single fault type (generally cracks); much of the variance in PoD can be explained by just crack length so that the PoD is an accurate reliability measure. It also gives the planning and life management processes with just the data needed, as the structure is primarily a function of crack length [4]. Several other references confirm that crack is a defect that raises the most significant concerns in the industry in general.

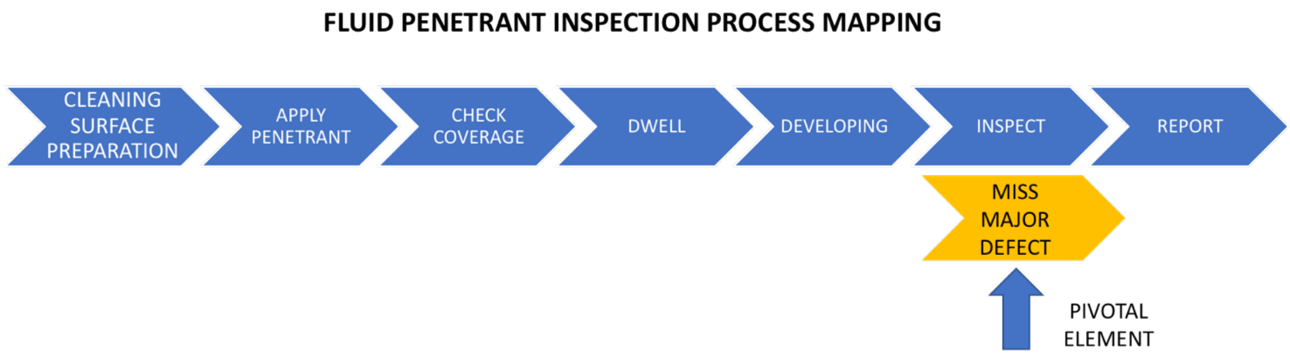


Fig. 3 – Fluid Penetrant Inspection Process – Pivotal Element identification

### 3.2 Step 2 – Fault Tree

This study is concerned with five human factors that may cause an operator failure: environment control (ergonomics, time constraints, light intensity), organizational factors (production planning, production targets, quality, and maintenance system), skills and capacity, attitude, and distraction. Also, four barriers were considered for the error prevention or minimization, process audit focused on HRA, certification of inspectors, training of the inspectors focused on preventing most common human errors, and implementation of the Measure System Analysis.

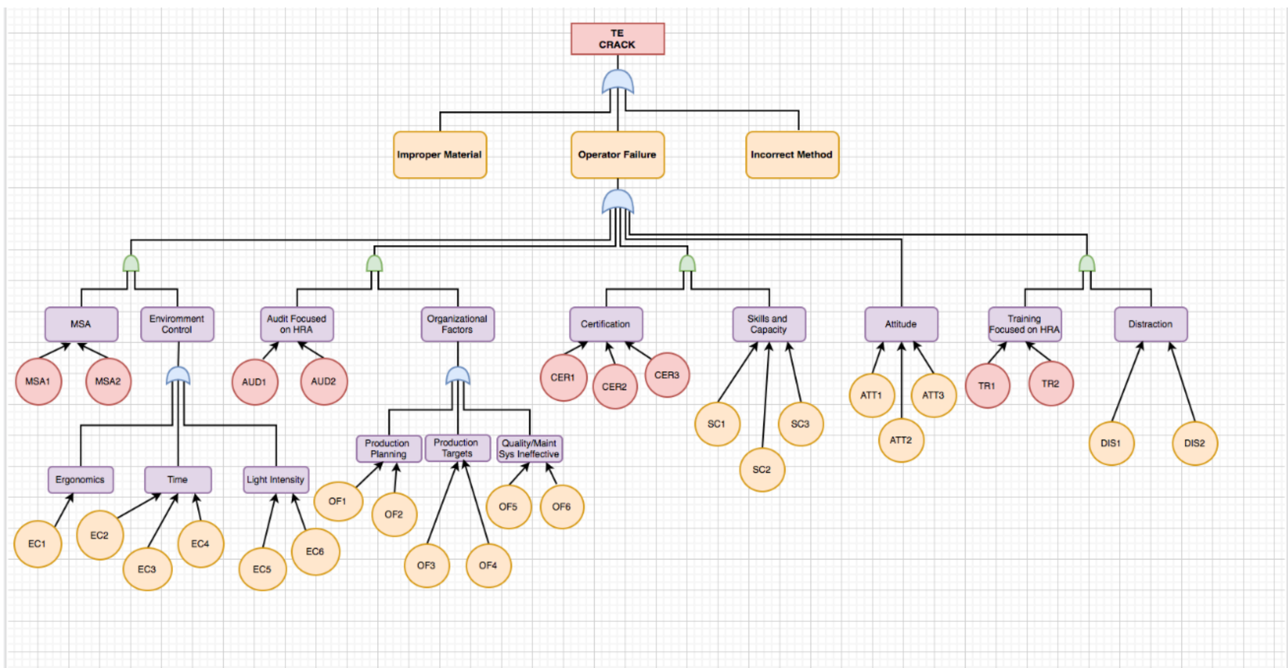


Fig.4 – Fault Tree – Human factors that may cause an Operator Failure

### 3.3 Step 3 - Elicitation Survey

An elicitation survey was prepared using the Google tool "Forms" and submitted to several professional specialists, both certified and non-certified in FPI. Twenty-nine questions correspond to the 29 possible causes identified on the Fault Tree (Fig. 4). Each question gave the expert the possibility of marking from zero to ten, meaning zero is the less likely to happen and ten the most likely to happen. The responses were tabulated and weighted as 50% for the expert not certified in FPI (for the certified experts, 100% weight was given independently of the certification level). The questions of the elicitation survey are listed in Fig. 5.

| GATE | Type | Categories | Risks Identification | Risk Factors |
|---|---|---|---|---|
| OR | EC Enviroment Control | Ergonomics | EC1 | Design of Worstation not appropriate for the type of part that will be inspected leading to difficulty to perform the inspection. |
| | | Time | EC2 | Management may put pressure to approve hardware (by complaining that there are too many rejections for instance) leading to high stress level to the inspection personnel |
| | | | EC3 | Delay on Inspection Schedule putting pressure to speed up the inspection queue. |
| | | | EC4 | Operator/Inspector in a rush to finish the workday may conduct inspection quickly. |
| | | Light Intensity | EC5 | UV Lamp intensity not being checked periodically may affect defect identification |
| | | | EC6 | White Light intensity inside inspection booth not being checked periodically may affect defect identification. |
| AND | MSA Measurement System Analysis | | MSA1 | The repeatability, reproducibility, bias, stability, resolution, and linearity of the Inspection process system not being monitored may lead to high variation in results. |
| | | | MSA2 | The Measurement System Analysis is not effective may lead to variation in results. |
| OR | OF Organizational Factors | Production Planning | OF1 | Production planning defining targets above production capacity putting pressure on the Inspection Process System. |
| | | | OF2 | Accumulated delays on the Project execution /Production line may haste the Inspection Process System leading to lack of accuracy on the results |
| | | Production Targets | OF3 | Organization's economic situation growing bad may lead to savings on the wrong sectors and affect the Inspection Process System |
| | | | OF4 | Motivational programs and productivity incentive schemes may cause anxiety and haste on the Inspectors |
| | | Quality/ Maintenance System ineffective | OF5 | Lack of supervision on the Inspecton Process System leaving the Inspectors/Operators "loose" may lead to lack of productivity |
| | | | OF6 | If the organization safety culture is not strong enough, the inspectors may not realize the importance of defect identification. |
| AND | AUD Audit Focused on HRA | | AUD1 | Lead Auditor not prepared to assess the Inspection Process System from the Human Reliability Assessment perspective |
| | | | AUD2 | Audit Check List does not include Human Reliability Assessment items. |
| OR | SC Skills & Capacity | | SC1 | Inexperienced Inspectors/Operators without proper mentoring may have difficulties to perform the inspection. |
| | | | SC2 | Not identified visual accuity decay may lead to lack of capacity of identifying smal deffects |
| | | | SC3 | Lack of proper training (On the Job Training) may jeopardize the inspection results |
| AND | CER Certification | | CER1 | During the Certification Process an inadequate general exam may not identify gaps on the Inspector's/Operator's conceptual knowledge of the process. |
| | | | CER2 | During the Certification Process an inadequate practical exam may not identify gaps on the Inspector's/Operator's practical knowledge of the process |
| | | | CER3 | During the Certification Process an inadequate specific exam may not identify gaps on the Inspector's/Operator's variables knowledge of the process |
| OR | ATT Attitude | | ATT1 | Negative mental attitude of the Inspector/Operator may lead to higher rejection rates |
| | | | ATT2 | Personal problems may affect the judgement capacity of Inspectors/Operators leading to wrong inspection result |
| | | | ATT3 | Lack of horizontal and vertical communication skills may lead to misunderstandings and conflicts |
| OR | DIS Distraction | | DIS1 | High noise levels may disturb the Inspectors/Operators |
| | | | DIS2 | Inspectors/Operatos fatigue may influence the inspection results |
| AND | TR Training Focused on HRA | | TR1 | Training instructor not prepared to teach taking into account the Human Reliability Assessment perspective. |
| | | | TR2 | Training Material not appropriate for Human Reliability Assessment focus |

Fig. 5 – List of questions made on the elicitation survey

### 3.4 Step 4 – BBN

A BBN was prepared with the results from the elicitation survey by populating onto the AGENA RISK® software with the probabilities defined in each question as shown in Fig.6

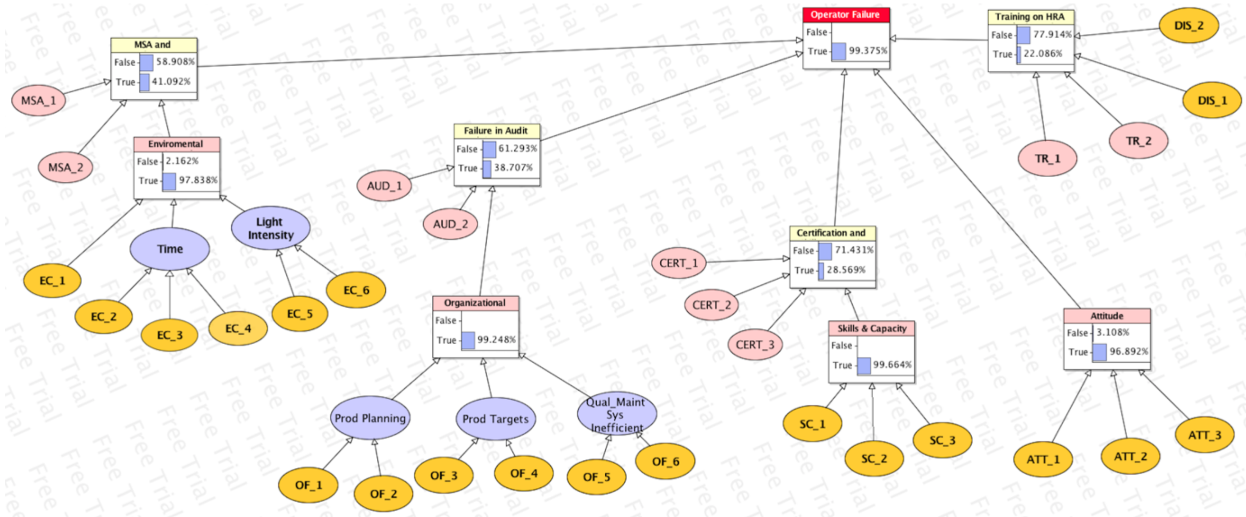


Fig 6 – BBN with the results from the elicitation survey

### 3.5 Step 5: Sensitivity Analysis

A sensitivity analysis is conducted in order to define the node/cause that has the most significant influence on the Top Event, in this case, the operator failure that leads to the non-identification and consequential non-reporting of a significant defect (crack) on the piece object of inspection. The item identified as the most significant contributor to the Top Event was Attitude witch relates to three items:

ATT1 - Negative mental attitude of the inspector/operator leads to higher rejection rates.

ATT2 - Operator/inspector's problems negatively influence the interpretation of the test results.

ATT3 - Lack of horizontal and vertical communication skills leads to misunderstanding and conflicts.

After defining the new barrier, the model should be rerun until the probability of the Top Event occurs lows below 30%

The proposed method demonstrated that implementing systematic barriers to mitigate the risks of human errors reduced the probability of such risk happening. Actions taken to mitigate the risks caused by human factors connected to Environment Control, Organization Factors, Skills & Capacity, and Distraction proved to reduce the probability of an operator failure significantly. Several barriers contributed to reducing the risk of an Operator Failure, such as: 1 - A training program that focuses on the Human Factors to sensitize inspectors, supervisors, and managers and create the perception of the importance and impact of time constraints, management pressure, personal problems. 2 - The establishment of an audit checklists that includes verification if the human factors that impact the inspection performance have been taken into consideration. 3 - A Measurement System Analysis to verify the repeatability, reproducibility, bias, stability, resolution, and linearity of the inspection process to indicate possible systemic process failures that may influence the interpretation of the test results.

These results are consistent with previous studies. Drury asserted that the dominant variance factors on the NDT procedure application are more linked to materials, procedure, and human factors [4]. Marija Bertovic stated that the organization of the working schedule, communication, procedures, supervision, time pressure, mental workload, and experience influence the quality of the inspection performance [2]. This study confirmed those conclusions.

Nonetheless, the sensitivity analysis identified that errors linked to Attitude factors lead to the high probability of an Operator Failure. Therefore, a new barrier should be established to help mitigate the following risks: 1 - An error occurring due to a negative mental attitude of the inspector/operator; 2 - Operator/inspector's problems negatively influences the interpretation of the test results; 3 - Lack of horizontal and vertical communication skills leads to misunderstanding and conflicts.

This work did not investigate the influence of human errors related to improper fluid penetrant inspection materials and supplies and incorrect inspection procedures and is limited to human factors that may lead to operator failure during the FPI process.

## 5. CONCLUSION

The paper presents how the CAPEMO causal model for probabilistic risk assessment can be applied in the Fluid penetrant Inspection process. A situational operation consists of a combination of Bayesian Belief Network and Fault Tree for human reliability analysis. Independent and structured data obtained from the expert elicitation process raised the probabilities for the different causes of failure in the inspection process.

The proposed model proved to be an essential tool for risk assessment processes strongly influenced by human factors. The CAPEMO model can be applied in quantitative analysis of the risks of a human error by using experts' opinions to map the process and draw a network of probabilities allowing a sensitivity analysis that gives the probability of occurring errors that leads to the undesired Top Event.

The CAPEMO model has combined findings from the BBN analysis on the human factors in Fluid Penetrant Inspection to produce recommendations for good practices in inspection training, and inspection process audits. The study suggests that human factors aspects should be highlighted on the training material and the audit checklists.

The response to the research questions presented in the introduction is the following:

1) Is the proposed method capable of performing a quantitative and qualitative analysis of the risks associated with human reliability in the Fluid Penetrant Inspection process? Yes. The qualitative analysis identified the risks involved in the FPI Process, developing a strategy to address these risks with probabilities (quantitative approach) to prepare an action plan.

2) What preventive actions emphasize increasing human reliability that can be implemented during the Fluid Penetrant Inspection process? Actions should be taken on Environment Control, Organization Factors, Skills & Capacity and Distraction proved to be effective in reducing the probability of an operator failure significantly.

The CAPEMO model proved to be effective in assessing the risks associated with human factors involved in the FPI inspection process and showed that actions could be taken to reduce the possibility of missing a crack when inspecting a critical part.

The next possible works are as follows: (1) studying the influence of human factors on different NDT process using the CAPEMO model to investigate the causes of Operators Failures on those process and (2) extending the use of the proposed model on another process that are also heavily influenced by human factors.

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