HUMAN FACTORS IN THE SELECTION OF NEW TECHNOLOGY FOR THE OIL AND GAS INDUSTRIES

A Thesis

by

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ABSTRACT

The evolution of organizations comes with changes in two core elements: human factors and technology factors. The introduction of new technology is one of the most important processes considered to improve the performance of any system, and it contemplates the combination of human and technology elements.

When one talks about the selection of new technology to improve systems, the most important problem is that there is no model or guide to show how to start. A model is needed to explain which elements require more attention and where investment of economic and human resources is needed in order to develop a highly reliable design. In addition, the model may reduce human error, incidents, injuries, and improve productivity.

One of the problems is that there is limited access to reliable sources of information related to human and technology factors in the oil and gas industries. Even when information is available, applications are limited and the relationships between factors are unclear.

If those relationships are established there can be a clear indication of the areas that need to improve. Therefore, in many cases organizations do not implement the best technology in their systems or processes, which will limit their results and potentially introduce new problems. Likewise, many companies use “common sense” and select the state-of-the-art or most expensive technology, but do not consider the most optimal equipment to achieve their goals.

As a solution to this problem a Bayesian Network based New Technology Change (NTC) model has been developed, which semi quantitatively assesses the effect of the combination of Human and Technology Factors on the risk of process safety incidents. This model analyzes the risk by incorporating technology factors into an event tree model. The technology factors were quantified by a survey and the human factors by using statistical data from the International Association of Oil and Gas Producers. We found that the model is useful to identify a clear relationship between human factors and technology factors to quantify the change in frequency of process safety incidents, to evaluate the impact of preventive barriers and actions, and to determine which elements are better investments in order to improve the safety performance of an organization.

In summary, it has developed a methodology for the identification, evaluation, and selection of new technology by focusing on the relationship of the principal technology characteristics and human factors. When this relationship is established, the early process of selection of new technology will be impacted. Thus, it will be easier to identify the factors that can be considered in the selection of new technology, and determine how to evaluate the success or failure of its implementation.

DEDICATION

To my wife Saira and daughter Isabella

To my mother and father

To my sister and brother

To my family

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NOMENCLATURE

ADA	Americans with Disabilities Act
ASRM	Aviation System Risk Model
BBN	Bayesian Belief Network
BNM	Bayesian Network Model
EEOC	Equal Employment Opportunity Commission
HF	Human Factors
HFACS	Human Factors Analysis and Classification System
HF&E	Human Factors and Ergonomics
HSE	Health and Safety Executive
IOGP	International Association of Oil and Gas Industries
MKOPSC	Mary Kay O'Connor Process Safety Center
MLB	Major League Baseball
MLE	Most Likely Explanation
NBA	National Basketball Association
NTC	New Technology Change
SEEV	Salience, Effort, Expectancy, and Value
SRK	Skill, Rule, Knowledge
TF	Technology Factors

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I. INTRODUCTION

Everything in our world has been developed with a specific purpose. Humans, organizations, and technology evolve for better interactions and results: decreased costs, errors, incidents, and increased effectiveness, productivity, and profits. In order to achieve a perfect balance between humans and technology, people must consider how to impact the early design of our systems, the development of work environments, and the processes of selection of new technology in order to provide better tools to perform the tasks and confront problems (Vicente, 2004).

According to the International Association of Oil and Gas Producers (IOGP), in 2013 the reporting companies had 80 fatal accidents and 179 high potential events. Through the analysis of those events, IOGP determined that 444 causal factors were the causes of the events and of those 444 factors around 31% were directly related to human activities (Producers, 2014).

In many cases organizations, directors, and managers still consider that human errors are the result of improper behavior and carelessness. Therefore, they work to reduce or eliminate problems by selecting, training, and motivating people in order to control the proper operation of their systems (Lorenzo, 1990)

Highly reliable organizations and experienced managers understand that careless or improper behavior of employees account for only part of the root cause of human errors, because a considerable number of mistakes are committed by experienced, well-trained, and productive workers. Consequently, they recognize that the solutions to these problems are not as easy as blaming or firing the individuals involved in an incident. They realize that a serious approach to preventing incidents caused by human error must consider an analysis of the interactions between humans, the characteristics of equipment or systems (technology factors) that people use to perform their jobs, and the environment where the jobs are performed. The main objective must be to develop an environment focused on the elimination of error prone situations (Lorenzo, 1990).

I.1 Problem Statement

Considering that organizations, governments, and employees have learned that the majority of process safety incidents and high potential events are preventable by identifying root causes and establishing corrective actions, the real questions are: Why do we continue to have similar major incidents? Why do we continue to observe high potential events that could cause catastrophes? What will happen if our root cause analyses are correct, but incomplete? To what extent are the corrective actions implemented?

One of the biggest issues in the incident investigation process is that it is performed after fatalities, environmental damages, and property losses have occurred.

Likewise, one of the problems is that even after implementing corrective actions, similar incidents continue to occur. Organizations invest large quantities of resources investigating and analyzing how to reduce human error and how to improve technology to prevent incidents. Unfortunately, machines and humans are evaluated in different modes, and the term "human error" is connoted with a sense of blame. A technology problem is evaluated with the term "hardware failure or equipment failure", indicating that the machine fails because of human aspects and demonstrating that there is a conclusion that humans remain the real problem (Lorenzo, 1990).

I.2 Motivation

In different oil and gas companies, human factors are in relative focus and primarily deal with individual needs, for example: ergonomic equipment or user friendly software (Lorenzo, 1990). Machines, equipment, or systems are developed with the purpose of helping humans to achieve different goals, but if something is not working in the organization, humans are blamed. However, it is important to consider that a great number of human errors result from the design of the work situation (the task, equipment, and environment) (Lorenzo, 1990). Therefore, we need to analyze deeper and understand the interactions between humans and technology Identifying how one affects the other can improve our incident investigations and corrective actions. Hence, humans are failing because the analysis of the technology that they use is incomplete.

One of the most popular citation in an organization is to "solve a problem by acquiring the most expensive or state of the art technology", but in many cases this "solution" introduces new problems and incidents. The biggest deviation is in the process of selection and acquisition of new technology while not considering the interaction of the technology with the final user. An evaluation of how the characteristics of the equipment or system will help the user is needed. This highlights the need to evaluate and understand the effects of the relationship between human factors and technology factors.

The basic strategy is to reduce the frequency of human factors in process safety incident by understanding and using the effect of technology in order to support humans.

I.3 Research Objective

The main objective of this thesis is to develop a systematic method for the identification, evaluation, and selection of new technology through the evaluation and analysis of the relationship between human factors and technology factors. In order to achieve this goal we have to determine:

- Which human and technology factors need to be considered for the selection of new technology.

- How to develop a model to analyze the relationship between technology factors and human factors related to the causes of high potential events.

- The quality of the relationships among technology factors and human factors by identifying which technology factor has the strongest effect over a particular human factor in order to define where organizations should invest their resources.

- How technology factors can affect human factors and reduce the probability of human error as part of the root causes of future incidents.

I.4 Research Methodology

The research was focused on the development of a model establishing the interactions of technology factors and human factors identified as part of the root causes of high potential incidents.

The research will start with a literature review about safety performance indicators in different oil and gas companies around the world and by analyzing key indicators such as: number of fatalities, fatal incident rate, number of lost work days, total recordable injury rate, lost time injury frequency, high potential events, and number of medical cases. The purpose of this analysis was to identify trend analysis, benchmarking, areas where organizations should focus to prevent incidents, identify trends of these events and their causes: process (conditions) and people (acts).

The analysis of the safety performance indicators will provide the necessary information to identify the acts of people, which are part of the root causes of the events under review. The people's acts will be analyzed to determine which human factors are involved. The human factors will be evaluated quantitatively to determine the weight of each factor in the incidents. At this point, the thesis will focus on the detailed analysis of the human factors of the high potential events. A high potential event is any incident or near miss that could have realistically resulted in one or more fatalities.

The research will continue with a literature review in order to find the principal elements (technology factors) to consider in the selection of new technology, explaining in detail the primary characteristics of each one. The technology factors will be analyzed to identify their relationship with human factors. The purpose of this analysis will be to determine the relationship between the technology factors and the human factors in the prevention of high potential events. The relationship will be evaluated qualitatively, giving a qualification that goes from Strongly Correlated to Not Correlated. The correlation will evaluate the degree of positive effects of technology factors on human factors. Strongly correlated is selected when a technology factor clearly reduces the probability that a human factor is part of the root cause of an incident. Finally, not correlated is selected when the technology factor doesn't change the probability that a human factor is part of the root cause of an incident.

The next stage will be to develop a Bayesian Network based on the New Technology Change (NTC) model that semi-quantitatively assesses the effect of the combination of human factors and technology factors on the risk of process safety incidents.

Finally, using the Bayesian Network, the relationship between incidents, human factors, and technology factors will be evaluated by considering the different combination of interactions between the three elements and analyzing the influence of each technology factor over the human factors in order to reduce the probability of an incident. The idea is to understand which combination of technology factors or which technology factor is more likely to decrease the probability that human factors be part of the root causes of high potential events. With these results, organizations will have a better understanding of the root causes of high potential events; therefore, organizations can reduce the probability of an incident, decrease costs, errors, incidents, and increase effectiveness, productivity, and profits.

The figure 1 summarizes the complete research methodology of the thesis.

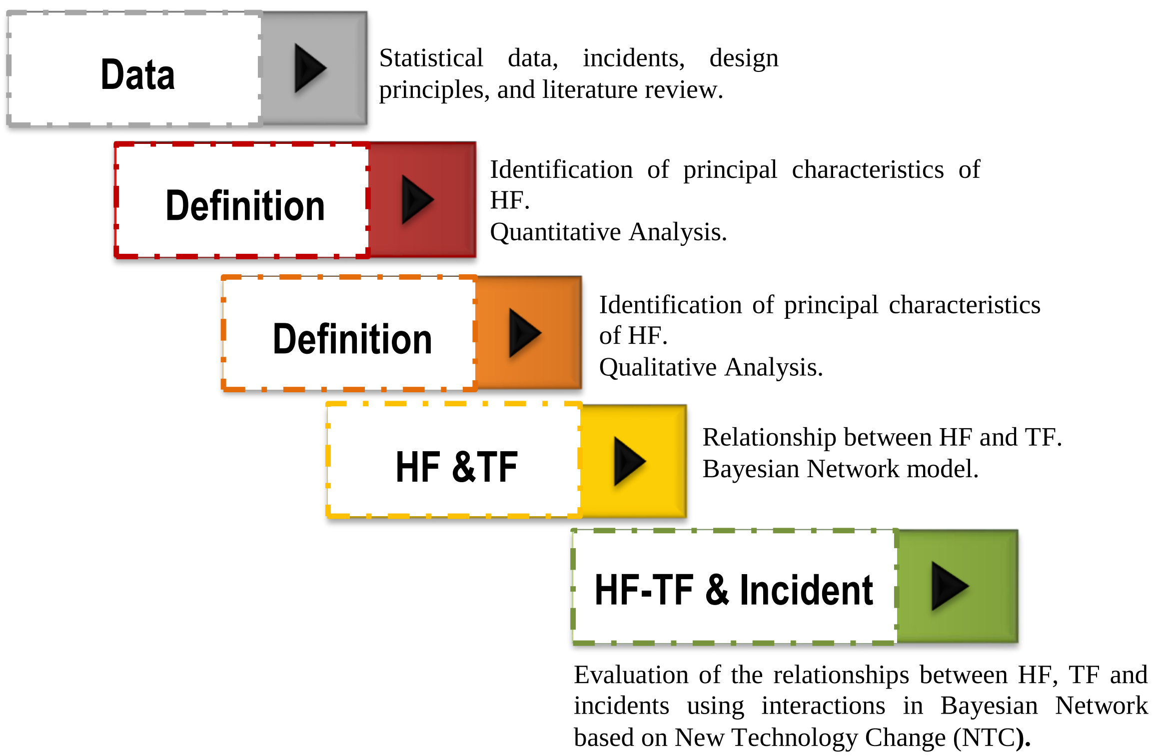

Figure 1. Research methodology.

II. HUMAN FACTORS

"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" (H. a. S. Executive, 2015a). Human factors consider a systemic evaluation of the task, the person, and the organization (H. a. S. Executive, 2015a).

The main goals of Human Factors are to increase safety, increase user satisfaction, and enhance performance (Wickens, 2004).

The task analysis contemplates work environment, workload, equipment or technology, procedures, regulations, and rules. The task must be designed with ergonomic rules in accordance with human capabilities and limitations. Likewise, this process includes an evaluation of the physical and mental state that a person could have under regular, special, or emergency conditions. Human Factors that could be considered as part of this analysis are attention, perception, decision making, stress, and fatigue (H. a. S. Executive, 2015a).

The person evaluation considers competence of the individual, personality, risk perception, and skills. It is important to understand that individual attributes can determine the behavior of a person in complex situations. Therefore, characteristics such as personality are fixed, but others such as attitudes and abilities could be improved (H. a. S. Executive, 2015a).

Finally, the organization analysis considers elements such as culture of workplace, general resources, leadership, communications, organizational learning, training, incentives program, supervision, organizational structure, and interaction with other organizations. Organizational factors can determine the behavior of employees (H. a. S. Executive, 2015a).

Human Factors are typically divided into three main areas of specialization: cognitive factors, physical factors, and social factors (Wickens, 2004)

An individual's cognitive factors are essentially:

- Perception
- Attention
- Memory
- Decision making
- Problem solving
- Learning
- Stress (Wickens, 2004)

Physical factors are:

- Anthropometry
- Fatigue

- Biomechanics
- Metabolic processes in performing physical work (Wickens, 2004)

Social factors:

- Social interactions among groups of people
- Global environment interactions: workers, management, patients, family members
- Communication
- Group and team dynamics
- Cultural influences (Wickens, 2004)

II.1 Human Error

Reason's model explains that errors are more than a simple manifestation or a problem related with a single person. Instead they occur because of the system and organization, and are likely due to weaknesses in the environment. Furthermore, errors have a limited number of forms, and are not as abundant as many people consider (Reason, 1990).

Therefore, error can be defined as:

- Failure of humans to perform: adequately, acceptably, and/or appropriately
- With regard to some standard: judged by actor or judged by observer

- Potential consequences: reduced effectiveness/system performance and/or safety (Reason, 1990)

Error encompasses all occasions in which a planned sequence of mental or physical activities fails to achieve an intended outcome and is not attributable to chance.

Likewise, Reason's model considers the main characteristics and mechanisms of errors, and divides them into three types: slips, lapses, and mistakes. Violations are not part of this classification because of their nature as is shown in the figure 2.

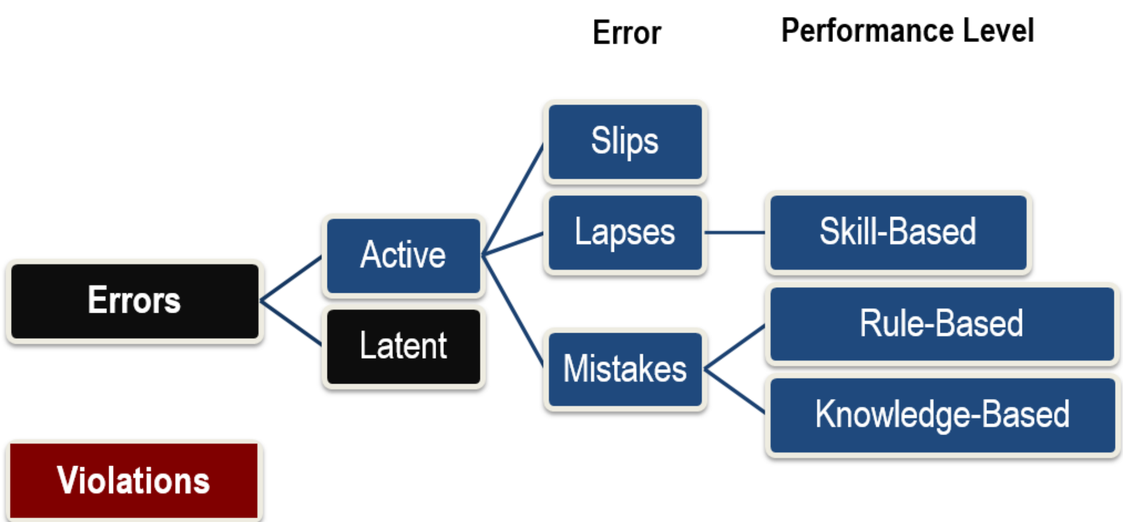

Figure 2. Human error theory. Reason's model (Reason, 1990).

II.1.1 Errors as opposed to violations

Errors are unintentional, informational, and individual.

Violations are deliberate, and the root cause is a motivational problem and part of the organizational context.

Errors are divided into:

- Active errors: effects felt immediately.
- Latent errors: adverse consequences can lie dormant for a long time. (Reason, 1990)

II.1.2 Errors associated with performance levels

Rasmussen's (1983) Skill, Rule and Knowledge (SRK) framework for levels of performance are divided into:

Skill-based behavior: rapid actions with high automaticity

- Example: walking, riding a bike, navigating a familiar route

Rule-based behavior: applying learned rules to a familiar situation

- Example: strategizing for familiar sports/games
- Applying "strong-but-wrong" rules (which work in most cases, but will not in this situation)

Knowledge-based behavior: problem-solving in an unfamiliar situation

- Example: navigating in an unfamiliar city, solving a novel problem (Reason, 1990; Thomas Ferris, 2014)

3 basic types of active error (H. a. S. Executive, 2015a; Reason, 1990; Thomas Ferris, 2014):

Slips: performing intended actions incorrectly/in wrong sequence

- Usually during performance of "automated" activities (skill-based performance)

Lapses: forgetting to perform an intended action

- Failure of prospective/working memory
- Also during skill-based performance

Mistakes: forming the wrong intention, but successfully performing the intended action

- Occur due to lack of knowledge (knowledge-based mistakes) or misapplied rules (rule-based mistakes)

II.1.3 Violations

- Violations are deliberate but not necessarily reprehensible (Reason, 1990; Thomas Ferris, 2014). Violations are characterized for the next elements and classification:

    - Can be deviations from practices deemed necessary to maintain safe operation of a potentially hazardous system.
    - Can be committed by operators, managers, designers, patients, etc.

- Routine violations are habitual acts due to: (Reason, 1990; Thomas Ferris, 2014)
    - a) natural human tendency to take path of least effort
    - b) relatively low risk, benign consequences, indifference
    - Workarounds: clues to the need for redesign

- Exceptional violations occur in particular set of circumstances, and the degree of fault depends on intention (e.g., sabotage) (Reason, 1990; Thomas Ferris, 2014)
    - Does design motivate violation? The most important thing is to know why the person committed the act.

II.2 Biomechanics

Biomechanics is derived from the word “bio” meaning living and the word “mechanics” referring to forces acting on objects to create motion. Therefore, biomechanics has been defined as the study of the movement of living things using the science of mechanics (Knudson, 2007).

People are interested in the study of biomechanics because they can determine how to improve human abilities and reduce limitations in everyday tasks. Many products and features with built structures require consideration to support physical interaction by humans.

Biomechanics applications include reduction or treatment of injury and improvement of performance. Other applications of biomechanics are related to human-computer applications such as: analysis of gait, exercise physiology, human-tool interaction models, and design of devices for sports and health (e.g. prostheses). Likewise, the benefits of biomechanics can be seen in, for example, the remodeling of diabetic gastrointestinal tracts, gastrointestinal tracts in health and disease, and in support of people with cerebral palsy. The latest biomechanics applications are focused on the mechanical behavior of biological systems (e.g. cells, bones, molecules) in order to develop new nano- and microtechnology devices (Bronzino, 2008; Knudson, 2007; Levy, 2010).

The performance improvements through biomechanics can be achieved by the deep analysis and evaluation of a human's movement considering elements such as anatomical factors, neuromuscular skills, physiological capacities, and psychological (cognitive) abilities (Knudson, 2007).

The reduction or treatment of injury through biomechanics focuses on movement safety by providing information about the potential injury mechanisms. Also taken into consideration are the mechanical properties of tissues and the mechanical loadings of a human's body during different activities. Thus, biomechanics help physicians to prescribe rehabilitative exercises, assistive devices, support objects that correct deformities or joint positioning, and technique changes or instructions that allow a person to improve performance. Likewise, engineers and occupational therapists use biomechanics to design work tasks, equipment, work stations, and prosthetics (artificial limbs). To achieve these goals practitioners of biomechanics focus on how to model types of bones, muscles, tissues, the muscle force-length relationship, the muscle force-velocity relationship, joint articulating surface motion (e.g. essential for design prosthetic devices), the interaction of humans with tools and equipment, and the design of devices to improve human performance. Biomechanics applies to a wide range of fields such as: neuromuscular, cardiovascular, orthopedic, cellular, molecular, concussion and health, and bio-fluids (Bronzino, 2008; Knudson, 2007; Levy, 2010).

The nine principles for the application of biomechanics are:

I. **Force-Motion:** the group of forces acting over an object to change their actual state.
II. **Inertia:** the property of an object to resist the modification in its state of motion.
III. **Range of motion:** overall motion used in a movement.
IV. **Balance:** ability of a person to control their body.
V. **Coordination:** optimal combination of muscle actions and timing to produce a movement.
VI. **Segmental Interaction:** the combination of muscle segments through the joints to produce a specific movement.
VII. **Spin:** rotations imparted to projectiles, for example: the rotation applied to a football.
VIII. **Lift:** the force used to create an effect in the projection of an object, for example: the creation of a curve effect.

IX. **Optimal Projection:** the optimal range of projection angles to achieve the desired goal for a specific object (Knudson, 2007).

II.3 Anthropometry

The word Anthropometry is derived from the Greek word “anthropo” meaning pertaining to humans and the Greek word “metry” meaning measurement. Therefore, Anthropometry is the study and measurement of human body dimensions considering bones, muscles, and adipose tissue (Prevention, 2015; Wickens, 2004).

Many products and features of built structures require consideration of these shapes/sizes to support physical interaction by humans such as cars, bicycles, furniture, tools, clothing, doorways, aisles/corridors, and workplace environments.

Anthropometry is a vital science to evaluate health, dietary status, disease risk, and body composition changes that occur during a human’s life. The study of Anthropometry is important because humans come in all shapes and sizes, for example: height, weight, or circumference (head). Thus, if you want to design a new technology it is very important to take into account the body characteristics of the final users; for example, the needs of a National Basketball Association (NBA) team than a Major League Baseball (MLB) team would be different. The goal of most designers is to create something that can accommodate the majority of people or the designer's largest audience. In order to achieve that goal, the designer contemplates the existing members and potential members, flexible staffing or job rotation, and the rules and regulations of organizations such as the Equal Employment Opportunity Commission (EEOC) and Americans with Disabilities Act (ADA) (Wickens, 2004).

Why do we not design for 100 percent of the population? Because there is a great variability due to factors such as age, sex, race, and ethnicity. For example, considering the racial and ethnic factors, if you design a piece of equipment for 90% of Americans, it will fit for:

90% of Germans

80% of French

65% of Italians

45% of Japanese

25% of Thai

10% of Vietnamese (Thomas Ferris, 2014)

In summary, the purpose of anthropometry is to gather high quality body measurement data using standardized examination procedures and methods. The idea to design something for 100 percent of the population is not economically viable, thus when selecting new technology, the organization must identify clearly the final population and the intended goals (Prevention, 2015; Thomas Ferris, 2014; Wickens, 2004).

II.4 Perception

Perception is the process and ability used by people to translate what is perceived through senses (see, hear, touch, etc.) into a coherent and unified view of the world, and how people understand their environment(Wickens, 2004). Perception involves the extraction of meaning from the collection or sequence of information administered by the senses. Even knowing that the border between perception and comprehension is fuzzy. The difference between perception and comprehension relies mainly in the time factor, the first one is more automatic, taking less time than the second one (Wickens, 2004).

A human's perception of risk depends on factors such as danger or fear caused by the familiarity that a person has about a specific situation and potential consequences. Another important factor is the sense of control that a person has over the situation (Flin R, 1996).

Perception results from the combination of three simultaneous processes: bottom-up feature analysis, unitization, and top-down processing. The first one is related with short term memory and the last two with long term memory (Wickens, 2004).

Bottom-down processing is how much an element stands out from the background and is noticeable from its environment; likewise, can be defined as: the state of condition of being prominent or the salience of environmental events. Top-down processing is defined as the association of past experience and perceived context which helps correctly guess a stimulus or event, even without specific identifiable features. The components of this type of processing are mental models, goals, motivations, experience, and expectations. The unitization process is defined as the outcome of a combination of features, symbols, or events that occur together and whose results are familiar according to the past experience of people (Wickens, 2004).

Perception of risk is not as simple as hazard identification. The factors most likely to lead to amplification or alteration of perception of risk to health and safety are:

- Hazard identification
- Evaluation of risk associated with hazards (Under or Over-estimation of risk)
- Risk communication
- Determination if the perception of risk is close to what happened in reality
- Age and work experience influences the perception of risk
- Past experiences
- Cultural aspects
- Regulations
- Education and training
- Personal attitudes (impatience/carelessness)(Knowles, 2002)

Studies have founded that perception can be supported by maximizing bottom-up processing (increasing legibility, avoiding confusion through similar messages), top-down processing (avoid confusion, exploit redundancy, create context, use short words, and increase automaticity and unitization by using familiar perceptual representations (e.g. familiar fonts or icons)) (Knowles, 2002).

II.5 Fatigue

Fatigue can be defined as the transition state between alertness and somnolence. Likewise, fatigue is the state in which the body, after prolonged physical or mental activity, does not have sufficient energy to maintain the original level of activity, alertness, or processing. Finally, another definition refers to the symptoms generated by excessive working time or poorly designed shift patterns affecting mental or physical performance, and resulting in injuries, illness, or incidents (H. H. a. S. Executive, 2015; Wickens, 2004).

Fatigue, as a stressor, is considered as one of the most important factors that creates problems related to attention, stress, and contributing to the root causes of incidents. Fatigue is important to consider when predicting the consequences of prolonged shift duration, continuous performance, or sustained operations. One of the major concerns related to fatigue is the potential risk to health and degradation in performance.

Fatigue may result from long periods of continuous operations or long periods of little to no activity (For example: long periods of vigilance or waiting periods between activities). Among the most important factors related to fatigue are:

- Elements such as workload, type of work (physical, mental or both), work activity (e.g. monotony and repetitive), shift timing, duration and shift rotation, social considerations, and number of breaks between activities must be analyzed as factors related to fatigue.
- Changes in working conditions need to be risk assessed
- Unusual jobs or tasks (e.g. night jobs, overtime, and shift-swapping), must be particularly analyzed, considering the risks and factors generated by the interruption of the natural process of life. For example: sleep disruption or affection of circadian rhythms, what involves sleep during the day, daytime noise and a natural reluctance to sleep during daylight.
- This human factor can lead to employee errors or violations at work (H. H. a. S. Executive, 2015).

II.6 Stress

Stress is defined as the adverse reaction that people experience due to excessive pressures or other types of demands placed on them at work, home or in society. (H. a. S. Executive, 2015b) In medicine, stress is defined as the physical, mental, or emotional factor that causes bodily or mental tension. Stresses can be external (from the environment, psychological, or social situations) or internal (illness, or from a medical procedure) (MedicineNet.com, 2010). The causes of stress are called stressors, and can be divided in three types: physical, psychological, and task-related (Wickens, 2004).

- (Physical) Environmental: noise, vibration, heat, lighting conditions, movement
- Psychological: anxiety, fatigue, frustration, anger, fear
    - Task-related: complexity/difficulty, time pressure, risks or consequences of failure (High mental workload).

Stress affects people in different modes and what can stress one person can be something normal to another. Among the factors that determine if a person feels stress are: (H. a. S. Executive, 2015b)

- Background and culture
- Personality
- Skills and experience
- Personal circumstances
- Health status

Therefore, some effects of stress in people can be:

- Emotional effects (e.g., frustration).
- Physiological effects (heart rate, pupil diameter, perspiration, hormone release).
- Cognitive/information processing effects (Thomas Ferris, 2014).

The Health and Safety Executive (HSE) has identified six factors that can result in stress if they are not managed properly: (H. a. S. Executive, 2015b)

- Demands: workload related with a job position.
- Control: level of governance the employees have over their work.
- Support: all the elements provided by an organization to help employees in their work.
- Relationships: qualification of the work environment from the point of view of the employees; how comfortable they feel in the work.
- Role: employees demonstrate if they understand their role and responsibilities in the organization.
- Change: employees understand, feel comfortable, and are part of organizational changes.

Finally, different factors have been identified as a solution to remediate stress. Among the most important are:

- Remove environmental stressors
- Change strategy or task goals in order to avoid monotony and increase the challenges
- Training, especially in emergency situations
- Support memory functions (e.g., recognition rather than recall)
- Support efficient communication (e.g., language, icons, and modality)
- Increase the access to information supporting the work or task
- Design display and required responses to be in accord with the users' mental model (natural mapping) (UMass, 2015; Wickens, 2004)

II.7 Attention

Attention is defined as a mental process used by a person to register some stimuli and ignore others, and is a filter for stimuli received from the environment. It is a concentration of mental activity, and is divided into three interrelated categories: ("Human Attention & Situational Awareness," 2015; Thomas Ferris, 2014; Wickens, 2004)

- **Focused Attention:** ability to process an input with great depth, and to suppress unwanted/irrelevant sources of input
  - When people ignore all the elements surrounding a special situation which is the most important at a particular moment.

- **Divided Attention:** ability to attend to several targets/inputs in parallel (but with less depth than focused attention). Attending at the same time to simultaneous activities rather than paying equal attention to several tasks.

- **Selective Attention:** ability to select particular inputs for conscious processing, and to what extent focused versus divided attention is used. It is when people are involved in different situations at the same time, with two or more simultaneous tasks, and they attend one and ignore the other.

In order to explain the difference between the three types of attention, many people prefer to use the searchlight metaphor. The focused attention is as the bright, narrow beam, the divided attention is as the less bright wide beam, and the selective attention is narrowing the light by adjusting the width of the beam.

Attention is a resource over which people have complete and conscious control. The attention process is linked to a variety of functions such as: selectivity, focus, sustained concentration, or vigilance (Das, 2008). Christopher Wickens explains that researchers of human time-sharing have determined that the success or failure of divided attention is based on four major factors: resource demand, structure, similarity, and resource allocation or task management (Wickens, 2004).

Resource demand is explained in terms of how difficult it will be to perform a task, considering mental resources and time. The structural similarity refers to the parallel between two or more different tasks and the degree of automation of their users. Finally, task management is focused on how both time and priority between multiple tasks is distributed (Wickens, 2004).

The SEEV (Salience, Effort, Expectancy, and Value) model of attention allocates the four elements used by people to determine how to concentrate their attention.

- **Salience:** bottom-up attention allocation.
- **Effort:** cost of switching attention/multitasking.
- **Expectancy:** top-down attention allocation.
- **Value:** (task relevance) x (display information).

II.8 Decision Making

Decision Making is defined as the process of selecting choices by setting goals, gathering information, assessing alternatives, weighing evidence, choosing alternatives, taking action, and finally evaluating the consequences (UMass, 2015).

Decision Making generally involves the next steps:

- The person has to select one alternative from a number of options.
- The person has some information about the different options.
- The process of selection is associated with uncertainty; it is not clear which is the best option.
- The decision making involves risk. (Wickens, 2004)

Decision Making can be represented by different phases:

I. Identify the decision to be made.
II. Obtain the major quantity of information and clues to evaluate the different options involved in the process.
III. Determine the possible alternatives.
IV. Generating, evaluating, and selecting a hypothesis by considering the information (evidence) gathered in the previous steps.
V. Planning and selecting the best option among the available alternatives.
VI. Evaluation of the decision and consequences (Wickens, 2004).

Rasmussen's SRK (skill, rule, knowledge) model describes a skill-rule and knowledge-based behavior as a different decision making processes, which is based on the level of experience and the decision situation. For example: people who are extremely experienced with a task prefer to process the input at the skill-based level. Likewise, depending on their style, there are factors that can lead to different decision making processes, and those factors are shown in the table 1 (Wickens, 2004):

Introduces intuitive rule-based decisions	Introduces analytical knowledge-based decisions
Experience	Unusual situations
Time pressure	Abstract problems
Unstable conditions	Alphanumeric rather than graphic representation
Ill-defined goals	Requirement to justify decision
Large number of cues	Integrated views of multiple stakeholders
Cues displayed simultaneously	Few relationships among cues
Conserve cognitive effort	Requires precise solution

Table 1. Factors that lead to different decision-making processes (Wickens, 2004).

Decision making is a vital process in the evolution and improvement of an organization which takes years, but is cost effective. Enhancing the decision making process is the organization's responsibility, and can be achieved by improving the abilities, knowledge, communication process, task design, decision support systems, and training in the organization. (Wickens, 2004)

III. TECHNOLOGY FACTORS

In the book *"The design of everyday things"* Donald Norman present the design characteristics that you must observe in any equipment, technology or device in order to help users and reduce the likelihood of future problems. Likewise, Donald Norman explains that the design principles consider that all the devices, software, and equipment must be functional, easy to use, intuitive, and attractive. When people use any type of technology, they face two gulfs: the gulf of execution, understanding how it operates and gulf of evaluation, assessing the outcome (Norman, 2013).

The Gulf of Execution and Gulf of Evaluation are integrated by the next elements:

- Gulf of execution: signifiers, constraints, mappings, and conceptual model.
- Gulf of evaluation: feedback and conceptual model (Norman, 2013).

Donald Norman defines discoverability and understanding as how to figure out what a product does, how it works, and what operations are possible when we interact with a product.

Norman's model elements of discoverability are listed below:

Affordances: refer to all the potential actions that are possible, but easily discoverable only if they are perceived. Affordances establish all the bases to develop a relationship between a physical object and a person. An affordance is also defined as the relationship between the properties of an object and the capabilities of the person that determine how the object could possibly be used. In summary, affordances are all the factors that you have in a technology for determining what actions are possible (for example: buttons, knobs, screens, etc.) (Norman, 2013).

Signifiers: refers to any mark, sound or clue, any indicator that communicates appropriate behavior to a person. Determine where the actions should take place. Signifiers can be deliberate and intentional. For example, all the elements that you have in a computer to identify that it has a touch screen (Norman, 2013).

Constraints: are the barriers or elements that the system has in order to guide people's actions and eases interpretation of the possible operations in equipment in order to prevent human error. Constraint examples are: physical (interlocks, lock-in, and lockouts), cultural, semantic, and logical (Norman, 2013).

Mappings: is the design of layout of controls and displays in equipment. It is how you establish the distribution of the elements in your technology (e.g. buttons, screens, etc.). Mapping is the relationship between the elements of two sets of things. It is the relationship between a control and its result. Natural mapping results when a person immediately understands how elements are related e.g. in a thermometer the increase of the temperature goes with the movement up of the mercury inside of it (Norman, 2013).

Conceptual Model: is how the design of the equipment projects all the information needed to create a good idea of the system. A conceptual model is an explanation, usually very simple, of how something works. Conceptual models are passed from person to person or from manuals. A conceptual model is valuable providing understanding how things will behave. A good conceptual model allows us to predict the effects of our actions and relies in good communication (Norman, 2013).

Feedback: is how the equipment communicate the results of an action and the current state of the equipment. The characteristics of the feedback are: planned, prioritized, immediate, informative, precise, and clear. Poor or too much feedback can be even worse than no feedback because it is distracting, uninformative, annoying, irritating, and anxiety provoking (Norman, 2013).

In summary, we can identify and understand the technology factors used in this thesis under the questions in the figure 3:

Affordances	How do I use it?
Signifiers	What clues do I have about it?
Constraints	What am I able to do? What am I unable to do?
Mapping	Where I am? And where can I go?
Conceptual model	How does it generally work?
Feedback	What is it doing now?

Figure 3. Understanding the technology factors (adapted from Norman, 2013).

The first approach to evaluate the effects of technology factors on human factors will be the identification of the principal characteristics of each of the nine human factors under evaluation.

The second step will be the evaluation of the correlation existing between the six technology factors on each of the human factors as is shown in the figure 4. The technology factor that most greatly affects the performance of the human factor under analysis or reduces its negative effects as a root cause of an incident will receive a qualification of 6 (strongly correlated), and the technology factor with the lowest effect will receive a 0 (not correlated).

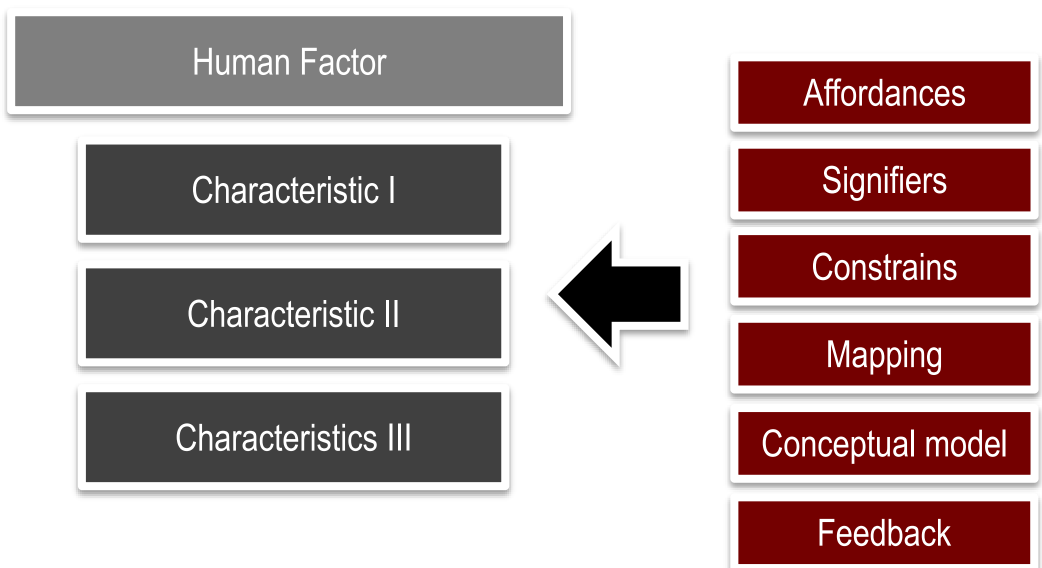

Figure 4. Human and technology factors correlation.

The third step will be to challenge the previous analysis by the evaluation of the effects of technology factors on human factors, using a survey applied to a group of experts with a combination of academic and industrial experience.

III.1 Emotional Design

An additional element that organizations have to consider in order to give a sense of belonging to all the employees in the process of selection of new technology, is the emotional side of technology, a factor that gives a sense of ownership to the person who use it, improving the interaction and relationship between human and machine (Norman, 2004).

There is a strong emotional component to how products are designed and put to use. The emotional component is integrated by three principal aspects: Visceral design, Behavioral design, and Reflective design (Norman, 2004).

The visceral design is focused on the appearances, the behavioral design is concentrated on the satisfaction and the effectiveness related to the use of the technology, and the reflective design is focused on how the people reflect themselves over the object (Norman, 2004).

These three elements are interlaced with all the designs, but in many cases are not considered or are very poorly correlated with the design. This is because of the common tendency to place cognition against emotion. Many designers contemplate that cognition is more related with the rational and logical side of the person. On the other hand, emotion is more connected with the irrational side of the person. The reality is that emotions are an inseparable part of cognition. You can select a technology that at the same time suggest effectiveness, strength, attraction, and emotions as love or happiness. It is what Apple Inc.

called a tool for the heart, something useful, but at the same time attractive, beautiful (Norman, 2004).

It is not uncommon to find people in organizations hating the things with which they interact in their work every day, creating a sense of frustration and anger. With the introduction of new technology arises the opportunity of integrate solutions and emotions into the process and organizations, not only additional elements that support the operation, with the purpose of obtaining the best of the person and of the relationship between human and machine (Norman, 2004, 2013).

IV. RANKING THE TECHNOLOGY FACTORS

The model of this thesis considers the relationship between technology factors and human factors, and their effects over incidents as is shown in the figure 5. In this thesis the relationship is established by combining two different methods to create the most accurate final ranking. The first one was developed by considering how technology factors affect the most important characteristics of each of human factor in order to determine how new technology can prevent them from being part of the root causes of a high potential event.

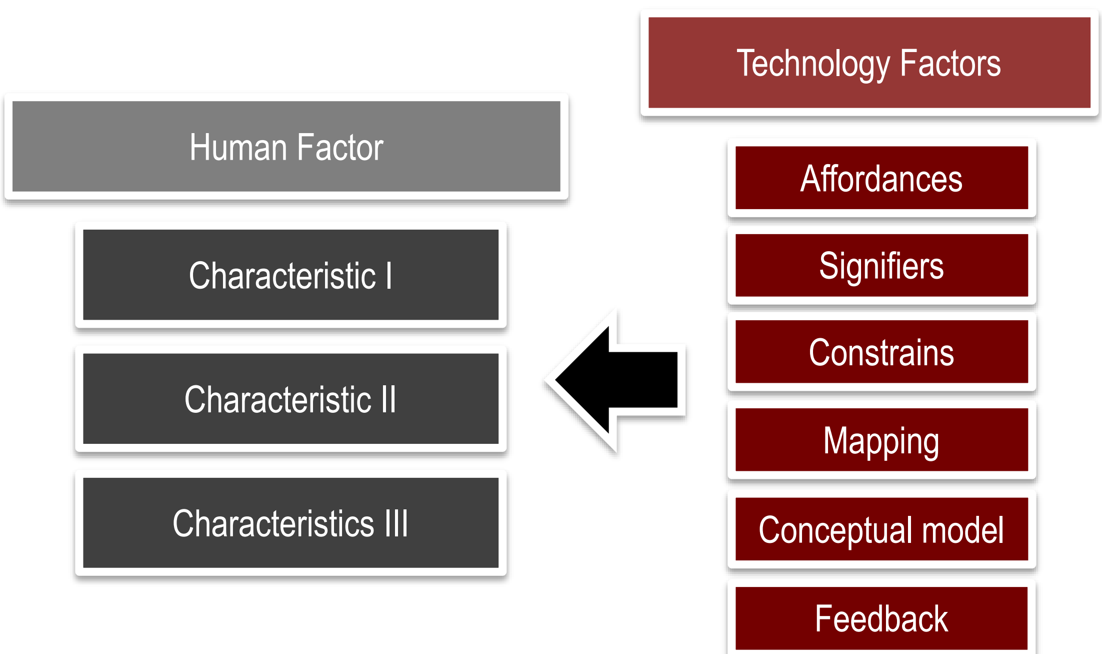

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Figure 5. Technology factor effects.

The results considering the first method are shown in the table 2:

	Affordances	Signifiers	Constraints	Mapping	Conceptual Model	Feedback
Fatigue	2	1	4	6	3	5
Human Error	2	1	6	3	4	5
Violations	1	3	6	4	2	5
Attention	1	3	5	4	2	6
Perception	1	6	3	2	4	5
Stress	1	2	4	3	6	5
Decision Making	3	2	4	1	6	5
Anthropometry	4	3	5	6	1	2
Biomechanics	4	2	5	6	3	1

Table 2. First relationship between human and technology factors.

As a result of this method, it can be concluded that the strongest relationships between human and technology factors are: Fatigue with Mapping, Human Error with Constraints, Violations with Constraints, Attention with Feedback, Perception with Signifiers, Stress with a Conceptual Model, Decision Making with a Conceptual Model, Anthropometry with Mapping, and Biomechanics with Mapping. We can observe that none of the human factors had a strong relationship with the technology factor “Affordances”. The three technology factors that correlated showed the largest numbers of strong relationships were: “Constraints”, “Mapping”, and “Conceptual Model.”

The second model was a survey, which format is shown in the figure 6, *(study number IRB2015-0548. Human factors in the selection of new technology for the oil and gas industries)* which has the same objective and methodology as the first one, but in this case the relationships were determined by using the expert judgment of the faculty and students of the Mary Kay O'Connor Process Safety Center (MKOPSC). These experts were considered because of their academic background and industrial experience in personal, process safety, and human factors (TAMU, 2015).

The objective of the survey was to determine the strongest relationships between technology factors and human factors by identifying which technology factor has the strongest effect over a particular human factor. This will help organizations find where they should invest their resources. The end result will be a reduction in the probability that these particular human factors will be part of the root causes of future incidents.

The face to face method was used for the application of the survey. For the study, 20 faculty and students were invited to participate from MKOPSC. It is important to mention that this method was focused more on the quality of the data than in the quantity of surveys.

The relationship between technology factors and human factors was evaluated by considering how each of the 6 technology factors listed affects or influences each of the 9 human factors.

The participants were asked to rank the list of technology factors over each human factor, where number 6 is the strongest relationship and decreases from 5 to 1. The number 1 was used to identify the weakest perceived relationship or effect of the technology factor over the human factor.

SURVEY: Effect of Technology Factors in Human Factors in the selection of new technology for the oil and gas industries.

The objective of the survey is to determine the strongest relationships among Technology Factors and Human Factors by identifying which Technology Factor has the strongest effect over a particular Human Factor, in order to define where organizations should invest their resources. The end result will be a reduction in the probability that those Human Factors will be part of the root causes of future incidents.

* Strong Correlated (6), Very Correlated (5), Correlated (4), Neutral (3), Slightly Correlated (2), Not Correlated (1)

#	Technology Factors	Evaluation (Ranking)								
		Fatigue	Human Error (Mistakes)	Human Error (Violations)	Attention	Perception	Stress	Decision making	Anthropometry	Biomechanics
1	**Affordances (How do I use it?)** Affordances refer to the potential actions that are possible, but easily discoverable only if they are perceived. Affordance is a relationship between a physical object and a person. E.g. A glass affords transparency and a chair affords support.									
2	**Signifiers (What clues do I have about it?)** Refers to any mark or sound, any perceivable indicator that communicates appropriate behavior to a person. Determine where the actions should take place. Signifiers can be deliberate and intentional. E.g. Elements to know that a computer has a touch screen.									
3	**Constraints (What can I do? What cannot I do?)** Barriers that the system has in order to guide people's actions and eases interpretation of possible operations of equipment. E.g. Physical constraint: interlocks, or lockouts.									
4	**Mapping (Where I am? And where can I go?)** The control layout design and displays in equipment. Relationship to controls and their effect. Natural mapping results when a person immediately understands how elements are related. E.g. Control distribution in equipment.									
5	**Conceptual Model (How does it generally work?)** A conceptual model is an explanation, usually very simple, of how something works. Conceptual models are passed from person to person or from manuals. A good conceptual model allows us to predict the effects of our actions and relies on good communication.									
6	**Feedback (What is it doing now?)** How the equipment communicates the results of an action and the current state of the equipment. E.g. A sound, alarm, or change in the color of a button.									

Figure 6. Survey format (TAMU, 2015).

The results of the second method were obtained by using the mean, median, and mode of all the data collected. The final survey results are shown in the table 3:

	Affordances	Signifiers	Constraints	Mapping	Conceptual Model	Feedback
Fatigue	2	4	5	3	1	6
Human Error	1	3	6	5	2	4
Violations	1	4	6	3	2	5
Attention	1	3	5	4	2	6
Perception	1	6	4	3	2	5
Stress	1	2	5	6	3	4
Decision Making						
Anthropometry	4	5	3	6	2	1
Biomechanics	2	5	1	6	4	3

Table 3. Second relationship between human and technology factors.

From this method, the strongest relationships between human and technology factors are: Fatigue with Feedback, Human Error with Constraints, Violations with Constraints, Attention with Feedback, Perception with Signifiers, Stress with Mapping, Anthropometry with Mapping, and Biomechanics with Mapping. Thus, we can observe that none of the human factors had a strong relationship with the technology factors "Affordances" or "Signifiers". Finally, the two technology factors who were correlated with the largest number of strong relationships with the human factors were "Mapping" and "Conceptual Model." The results of the survey did not showed a clear relationship between this Decision Making and technology factors because the relationships established by the majority of the people were different, without the opportunity of support or define a clear and final ranking.

The final ranking, shown in the table 4, was obtained by identifying the similarities and differences between both methods.

	Affordances	**Signifiers**	**Constraints**	**Mapping**	**Conceptual Model**	**Feedback**
Fatigue	2	4	5	3	1	6
Human Error	2	1	6	3	4	5
Violations	1	3	6	4	2	5
Attention	1	3	5	4	2	6
Perception	1	6	3	2	4	5
Stress	1	2	5	6	3	4
Decision Making	3	2	4	1	6	5
Anthropometry	4	3	5	6	1	2
Biomechanics	4	2	5	6	3	1

Table 4. Third relationship between human and technology factors.

We can observe that there is no major variance between (results of both methods or in the BN model) the relationships of the human factors: Human Error, Violations, Attention, Perception, Anthropometry, and Biomechanics. However, there are significant variations between the rankings of the human factors: Fatigue, Stress, and Decision Making. Thus, considering both methodologies, the ranking selected for “Fatigue” will be which was obtained from the survey method because according to the analysis of experts, the strongest relationships between this human factor a is with the technology factors “Feedback” and “Constraints” identifying that these technology factors can help a person to increase their satisfaction and reduce fatigue when using a new technology. Likewise, the same criteria was considered for the human factor “Stress.”

On the other hand, the best ranking for “Decision Making” is from the first method because the results of the survey do not show a clear relationship between this human factor and technology factors. In the first method the strongest relationships are with the technology factors “Conceptual Model”, “Feedback”, and “Constraints.” This method is the best option because with these three elements a person can obtain information to evaluate options before making a decision.

Similarly, in this case the first method is better because here the relationships between “Decision Making” and technology factors help to understand how people interact with technology, being confident of their actions because they have an idea of how the new technology operates, have feedback, and elements to avoid errors.

During the process, the people who took the survey submitted comments and suggestions to improve the format and application methodology.

The process of ranking selection (placing 1 through 6 without repeating a number), eliminates the opportunity for people to equally qualify the importance of the relationships of two or more technology factors over one human factor. In other words, that means that a person could be forced to decide which of the six relationships are more important over the others, even when the person thinks that two or more are equally important.

One option to improve the quality of data in the model is to dichotomize the data between “correlated” and “not correlated.” Thus, the relationships between 1 and 3 were replaced by the number 0 and the relationships between 4 and 6 were replaced by the number 1.

The second option is to re-apply the survey, and this time provide the opportunity for people to qualify the relationships without any restriction and allow them to repeat the numbers in the same evaluation (one human factor with the six technology factors) as many times as they require. Thus, for example, one person could decide to give 6 to all the relationships between one human factor and the technology factors.

The table 5 shows the application of dichotomize the data, identifying the elements correlated and not correlated.

	Affordances	**Signifiers**	**Constraints**	**Mapping**	**Conceptual Model**	**Feedback**
Fatigue	0	1	1	0	0	1
Human Error	0	0	1	0	1	1
Violations	0	0	1	1	0	1
Attention	0	0	1	1	0	1
Perception	0	1	0	0	1	1
Stress	0	0	1	1	0	1
Decision Making	0	0	1	0	1	1
Anthropometry	1	0	1	1	0	0
Biomechanics	1	0	1	1	0	0

Table 5. Fourth relationship between human and technology factors.

Finally, the participants submitted comments and suggestions to improve the format and application methodology of the survey. Thus, the survey was reviewed for format and content with the purpose of clarity and ease of understanding by future participants. The new format

Another opportunity area identified during the survey process was that the relationships between human and technology factors will increase or decrease depending of the degree of standardization of the expert judgment (evaluation panel) because of the difference in years of experience and academic background.

In order to improve the accuracy of the data, the evaluation panel must be composed of experts in safety, human factors, and the technology under evaluation, with the same years of experience and academic background. The company must decide between one or more evaluation panels, but it should preserve the same experts in safety and human factors in order to increase the knowledge throughout the procedure.

The format and content of the survey was reviewed with the purpose of clarity, and easy understanding and response by future participants.

Thus, the second and third format are presented in the figures 7 and 8 as a new options of survey for future work with the goal of easier evaluation and analysis.

SURVEY: Effect of Technology Factors in Human Factors in the selection of new technology for the oil and gas industries.

The objective of the survey is to determine the strongest relationships among Technology Factors and Human Factors by identifying which Technology Factor has the strongest effect over a particular Human Factor, in order to define where organizations should invest their resources. The end result will be a reduction in the probability that those Human Factors will be part of the root causes of future incidents.

* Strong Correlated (6), Very Correlated (5), Correlated (4), Neutral (3), Slightly Correlated (2), Not Correlated (1)

#	Human Factors	Evaluation (Ranking)					
		Affordances	Signifiers	Constraints	Mapping	Conceptual Model	Feedback
1	Human Error						
2	Violations						
3	Attention						
4	Perception						
5	Decision Making						
6	Biomechanics						
7	Anthropometry						
8	Fatigue						
9	Stress						

Figure 7. Second example of survey format considering comments of participants (TAMU, 2015).

SURVEY: Effect of Technology Factors in Human Factors in the selection of new technology for the oil and gas industries.

The objective of the survey is to determine the strongest relationships among Technology Factors and Human Factors by identifying which Technology Factor has the strongest effect over a particular Human Factor, in order to define where organizations should invest their resources. The end result will be a reduction in the probability that those Human Factors will be part of the root causes of future incidents.

*** Strong Correlated (6), Very Correlated (5), Correlated (4), Neutral (3), Slightly Correlated (2), Not Correlated (1)**

#	Technology Factors	Evaluation (Ranking)								
		Fatigue	Human Error (Mistakes)	Human Error (Violations)	Attention	Perception	Stress	Decision making	Anthropometry	Biomechanics
1	**How do I use it?** Refers to the potential actions that are possible, but easily discoverable only if they are perceived. Elements that provide strong clues to understand the operation of things. This establish the relationship between a physical object and a person. Examples: • A glass affords transparency and a chair affords support. • A button affords to push it, a switch affords to flip it, a knob affords to turn it, and slots are for inserting things. • The holes in a scissors are affordances: they allow the fingers to be inserted. • Handles in an object suggest how to move it.									
2	**What clues do I have about it?** Refers to any mark or sound, any perceivable indicator that communicates appropriate behavior to a person. Determine where the actions should take place. Signifiers can be deliberate and intentional. Examples: • Elements to know that a computer has a touch screen (drawing, word, or photo). • Elements that show in which direction you can turn a knob. • The traditional browser on the computer screen provides a signifier, with the position of the scrollbar showing how much more of the document remains.									

Figure 8. Third example of survey format considering comments of participants.

V. HIGH POTENTIAL EVENTS

According to the International Association of Oil and Gas Producers (IOGP), Human Factors and Ergonomics (HF&E) is a multidisciplinary methodology that is concentrated in the interaction of people, work, work organization, equipment, and environment (Producers, 2014).

The IOGP defines a high potential event as any incident or near miss that could have realistically resulted in one or more fatalities. The causes of high potential events are identified as causal factors and are divided into two separate groups: people (acts) and process (conditions).

From 2010 to 2013 the IOGP identified 1764 causal factors in high potential events. These causal factors are distributed as shown in the table 6.

Table 6. IOGP casual factors in high potential events from 2010-2013 (Producers, 2014).

Categories	Causal Factors	2013	2012	2011	2010
Process (conditions)	Organizational: Inadequate work standards / procedures	44	54	20	37
Process (conditions)	Organizational: Inadequate hazard identification or risk assessment	35	61	24	47
Process (conditions)	Organizational: Inadequate training / competence	29	36	15	22
Process (conditions)	Tools, Equipment, Materials & Products: Inadequate design / specification / management of change	29	16	18	13
Process (conditions)	Tools, Equipment, Materials & Products: Inadequate maintenance / inspection / testing	29	37	12	21
Process (conditions)	Tools, Equipment, Materials & Products: Inadequate defective tools / equipment / materials / products	28	27	13	16

Table 6 (Continued).

Categories	Causal Factors	2013	2012	2011	2010
Process (conditions)	Organizational: Inadequate communication	26	36	15	19
Process (conditions)	Organizational: Inadequate supervision	24	44	18	31
People (acts)	Inattention / Lack of awareness: Improper decision making or lack of judgement	24	38	21	23
People (acts)	Use of Tools, Equipment, Materials and Products: Improper use / position of tools / equipment / materials / products	22	21	17	9
Process (conditions)	Protective Systems: Inadequate / defective protective barriers	21	22	9	10
Process (conditions)	Protective Systems: Inadequate / defective warning systems / safety devices	14	8	15	13
People (acts)	Use of Protective Methods: Failure to warn of hazard	12	31	13	9
People (acts)	Inattention / Lack of awareness: Lack of attention / distracted by other concerns / stress	11	21	8	15
People (acts)	Following Procedures: Violation unintentional (by individual or group)	11	23	15	27
People (acts)	Following Procedures: Violation intentional (by individual or group)	9	7	6	9
People (acts)	Use of Protective Methods: Inadequate use of safety systems	9	19	12	2
People (acts)	Use of Protective Methods: Equipment or materials not secured	9	15	9	3
Process (conditions)	Organizational: Poor leadership / organizational culture	9	10	9	15
People (acts)	Following Procedures: Improper position (in the line of fire)	8	13	3	9
People (acts)	Following Procedures: Improper lifting or loading	5	11	9	5
People (acts)	Use Protective Methods: Personal Protection Equipment not used or used improperly	4	8	3	6
Process (conditions)	Organizational: Failure to report / learn from events	4	3	2	4
Process (conditions)	Protective Systems: Inadequate / defective personal Protective Equipment	4	2	1	3
Process (conditions)	Work Place Hazards: Congestion, clutter or restricted motion	4	5	3	3
Process (conditions)	Work Place Hazards: Hazardous atmosphere (explosive/toxic/asphyxiant)	3	6	5	6
Process (conditions)	Work Place Hazards: Storms or acts of nature	3	2	2	0

Table 6 (Continued).

Categories	Causal Factors	2013	2012	2011	2010
People (acts)	Use of Tools, Equipment, Materials and Products: Servicing of energized equipment / inadequate energy isolation	3	5	3	6
People (acts)	Following Procedures: Overexertion or improper position / posture for task	2	1	1	3
People (acts)	Following Procedures: Work or motion at improper speed	2	5	3	3
People (acts)	Use of Protective Methods: Disabled or removed guards, warning systems or safety devices	2	4	3	1
Process (conditions)	Work Place Hazards: Inadequate surfaces, floors, walkways or roads	2	5	2	5
Process (conditions)	Protective System: Inadequate security provisions or systems	2	4	3	1
People (acts)	Inattention / Lack of Awareness: Fatigue	1	1	4	4
People (acts)	Inattention / Lack of Awareness: Acts of violence	0	2	1	0
	Total	**444**	**603**	**317**	**400**

The statistical analysis by IOGP demonstrates that:

- 179 high potential events were reported in 2013
- 444 causal factors (process-conditions and people-acts) were assigned for the 179 high potential events

The IOGP identified the top six common causal factors related to the fatal accidents and high potential events from 2010 to 2013. These causal factors are:

I. Process (conditions): Organizational: Inadequate training / competence.

II. People (acts): Inattention / Lack of Awareness: Improper decision making or lack of judgment.

III. Process (conditions): Organizational: Inadequate work standards / procedures.

IV. Process (conditions): Organizational: Inadequate supervision.

V. Process (conditions): Organizational: Inadequate hazard identification or risk assessment.

VI. People (acts): Following procedures: Improper position (line of fire) (Producers, 2011, 2014).

The database collected by the IOGP was used to understand and analyze high potential events using the incident investigation of process safety events. This analysis considers the causal factors of high potential events from 2010 to 2013. The IOGP investigations identified between 1 and 16 causal factors assigned per event.

From 2010 to 2013 the IOGP identified 624 people acts as part of the root causes of high potential events from 2010 to 2013. These people acts shown in the table 7.

Table 7. IOGP people acts in high potential events from 2010-2013 (Producers, 2014).

Categories	Causal Factors	2013	2012	2011	2010
People (acts)	Inattention / Lack of awareness: Improper decision making or lack of judgement	24	38	21	23
People (acts)	Use of Tools, Equipment, Materials and Products: Improper use / position of tools / equipment / materials / products	22	21	17	9
People (acts)	Use of Protective Methods: Failure to warn of hazard	12	31	13	9
People (acts)	Inattention / Lack of awareness: Lack of attention / stress	11	21	8	15
People (acts)	Following Procedures: Violation unintentional (by individual or group)	11	23	15	27
People (acts)	Following Procedures: Violation intentional (by individual or group)	9	7	6	9

Table 7 (Continued).

Categories	Causal Factors	2013	2012	2011	2010
People (acts)	Use of Protective Methods: Inadequate use of safety systems	9	19	12	2
People (acts)	Use of Protective Methods: Equipment or materials not secured	9	15	9	3
People (acts)	Following Procedures: Improper position (in the line of fire)	8	13	3	9
People (acts)	Following Procedures: Improper lifting or loading	5	11	9	5
People (acts)	Use Protective Methods: Personal Protection Equipment not used or used improperly	4	8	3	6
People (acts)	Use of Tools, Equipment, Materials and Products: Servicing of energized equipment / inadequate energy isolation	3	5	3	6
People (acts)	Following Procedures: Overexertion or improper position / posture for task	2	1	1	3
People (acts)	Following Procedures: Work o motion at improper speed	2	5	3	3
People (acts)	Use of Protective Methods: Disabled or removed guards, warning systems or safety devices	2	4	3	1
People (acts)	Inattention / Lack of Awareness: Fatigue	1	1	4	4
People (acts)	Inattention / Lack of Awareness: Acts of violence	0	2	1	0
	Total	**134**	**225**	**131**	**134**

From the previous database, it is clear that there are ten main human factors: human error, violations, biomechanics, decision making, perception, attention, anthropometry, fatigue, and stress. The 624 people acts are distributed between these ten human factors as shown in the figure 9:

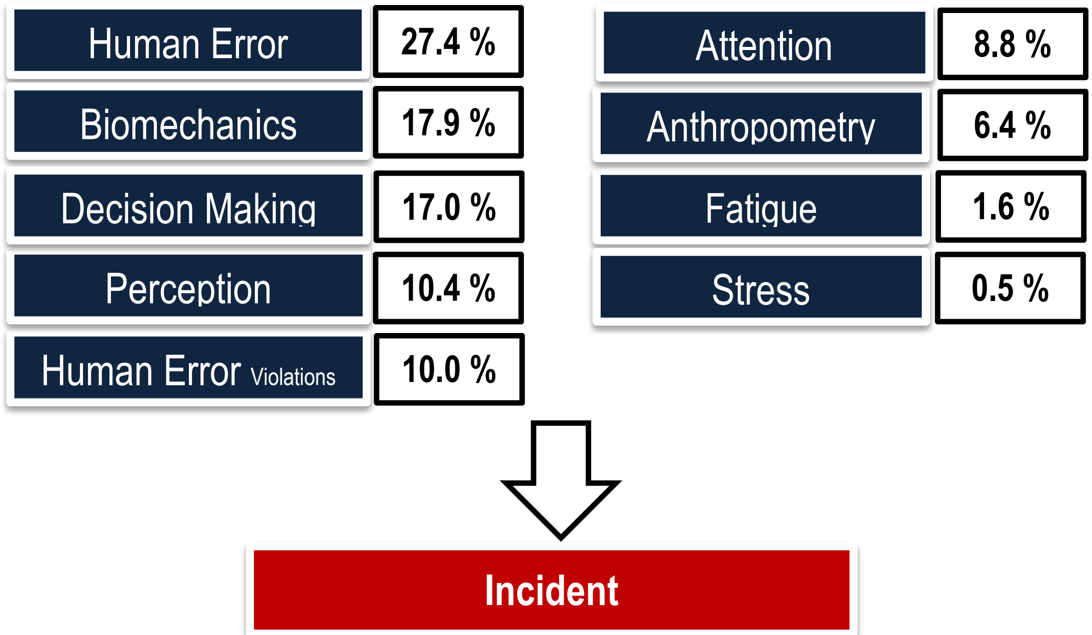

Figure 9. People acts (human factors) as root cause of high potential events.

From 2010 to 2013 the IOGP identified 693 organizational factors as part of the root causes of high potential events from 2010 to 2013. These people acts are distributed accordingly as shown in the table 8.

Categories	Causal Factors	2013	2012	2011	2010
Process (conditions)	Organizational: Inadequate work standards / procedures	44	54	20	37
Process (conditions)	Organizational: Inadequate hazard identification or risk assessment	35	61	24	47
Process (conditions)	Organizational: Inadequate training / competence	29	36	15	22
Process (conditions)	Organizational: Inadequate communication	26	36	15	19
Process (conditions)	Organizational: Inadequate supervision	24	44	18	31
Process (conditions)	Organizational: Poor leadership / organizational culture	9	10	9	15
Process (conditions)	Organizational: Failure to report / learn from events	4	3	2	4
	Total	**171**	**244**	**103**	**175**

Table 8. IOGP organizational-casual factors in high potential events from 2010-2013 (Producers, 2014).

From analysis of the database, the IOGP identified seven factors: procedures, hazard identification, training, communication, supervision, leadership, and failure to report events. The 639 organizational factors are distributed between the ten human factors as shown in the figure 10:

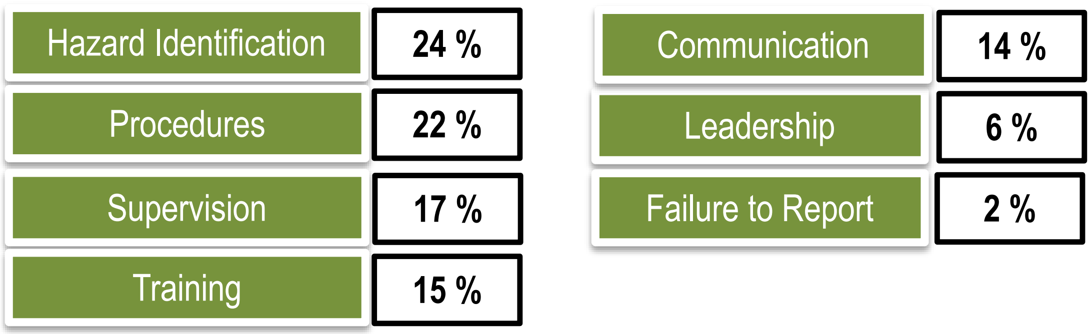

Figure 10. Human factors for the selection of new technology.

VI. BAYESIAN NETWORK

The Bayesian Network Model (BNM) was based on the Selection of New Technology model and semi-quantitatively assesses the effect of the combination of human factors and technology factors on the risk of process safety incidents.

The Bayesian Network analysis considers the quantitative evaluation of the relationship between human factors and high potential events in the oil and gas industries from 2010 to 2013. According to the statistics provided by the International Association of Oil and Gas Producers (IOGP), the root causes of high potential events are divided in two groups: "People Acts" and "Process Conditions."

The IOGP analysis of high potential events allows us to identify which people acts and the corresponding nine human factors are related to the root causes of these types of incidents. The human factors are human error (mistakes), human error (violations), perception, attention, decision making, stress, fatigue, anthropometry, and biomechanics.

The IOGP statistical analysis of the human factors performed in the thesis model was used to develop the simulation of the effects of the relationship between human factors and high potential events as shown in the figure 11.

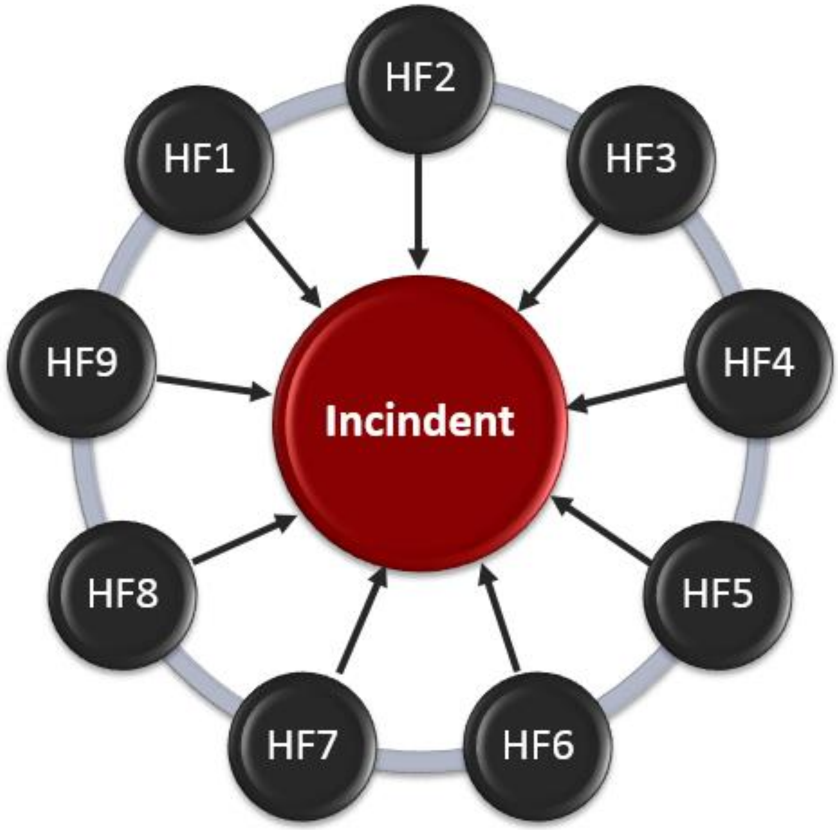

Figure 11. Bayesian Network, the effect of human factors over incidents.

The construction of the model continues with the analysis of the interaction between technology factors and human factors, and the interaction will be focused how technology factors can interact with human factors in order to reduce their negative effects on incidents.

The Bayesian Network analysis considers the qualitative evaluation of the relationship between technology factors and human factors with the reduction of the probability of high potential events in the oil and gas industries based on Donald Norman's design model and the statistics of the IOGP.

The analysis of the design model allows us to identify the six technology factors involved with the selection of new technology with the purpose of providing better resources to people, improving their performance, and reducing the probability of an incident. The technology factors are affordances, signifiers, conceptual model, mapping, constraints, and feedback as is shown in the figure 12.

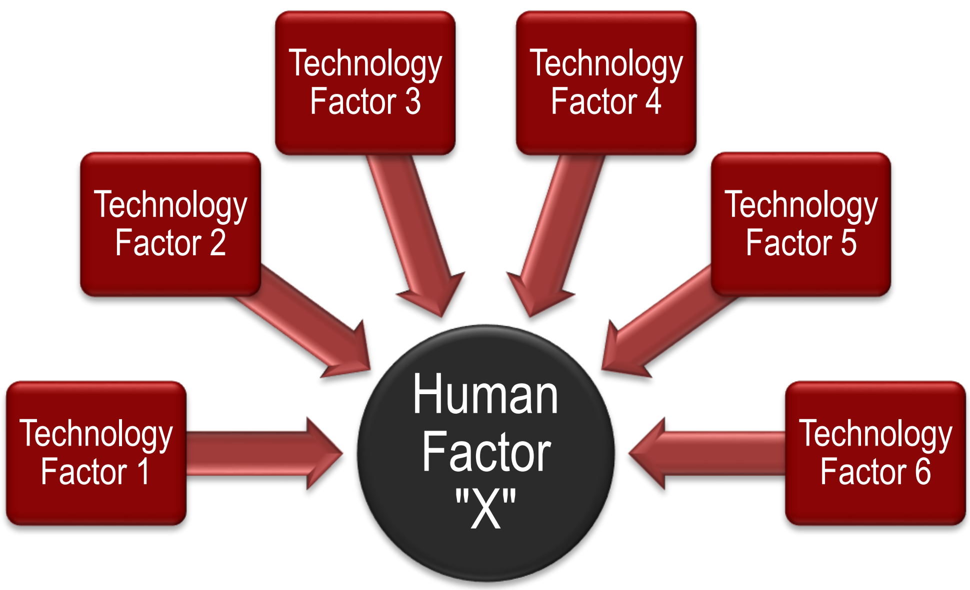

Figure 12. Bayesian Network, the effect of technology factors over human factors.

It is important to mention that the purpose of this phase of the analysis is not to determine the root causes of an incident, but to identify how investing in technology factors can reduce the probability of an incident. Likewise, the idea is to identify which technology factors are strongly correlated with overall human factors as well as with specific group factors. The interactions among those factors are modeled using influence diagrams with the data of the third relationship between human and technology factors (Table 4). The next step will be the construction of the conditional probabilistic tables to build the Bayesian Network model by using the diagrams previously developed as is shown in the figure 13 (Neil, 2013).

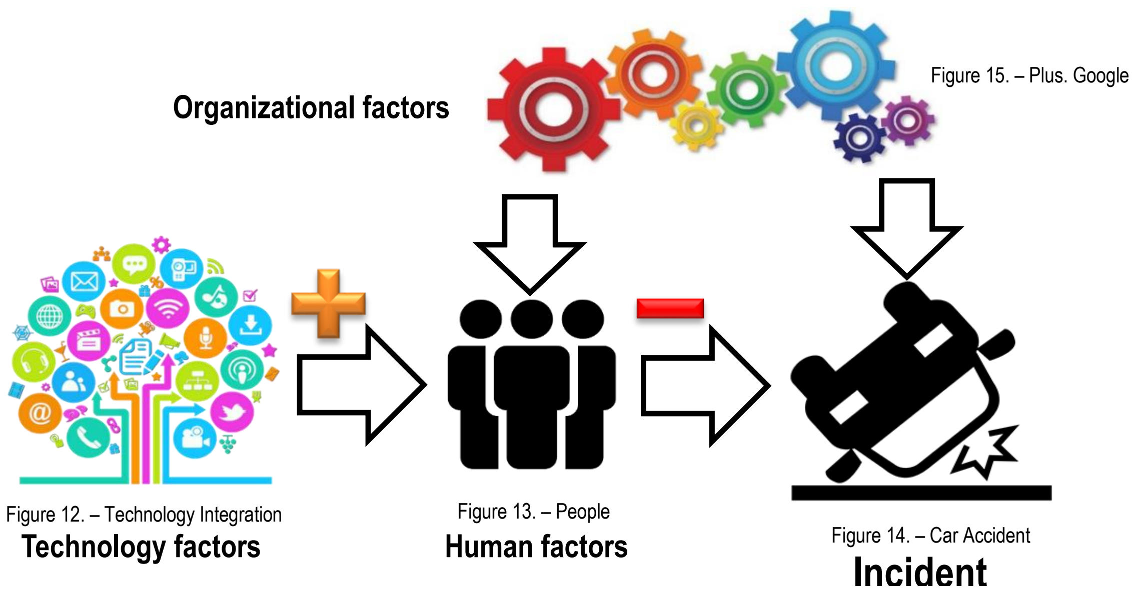

Figure 13. Bayesian Network, factors in selection of new technology.

In the Bayesian Network Model (BNM) the analysis continues analyzing how the probability of occurrence of the incident is affected by the relationship between the six technology factors and the nine human factors. Each of the technology factors is connected with each of the human factors creating 54 nodes, establishing the relationship between all human factors and all technology factors. Finally, the human factors are connected with the incident creating 9 additional nodes. In total, the BNM is integrated by 63 nodes. The final model is shown in the figure 14:

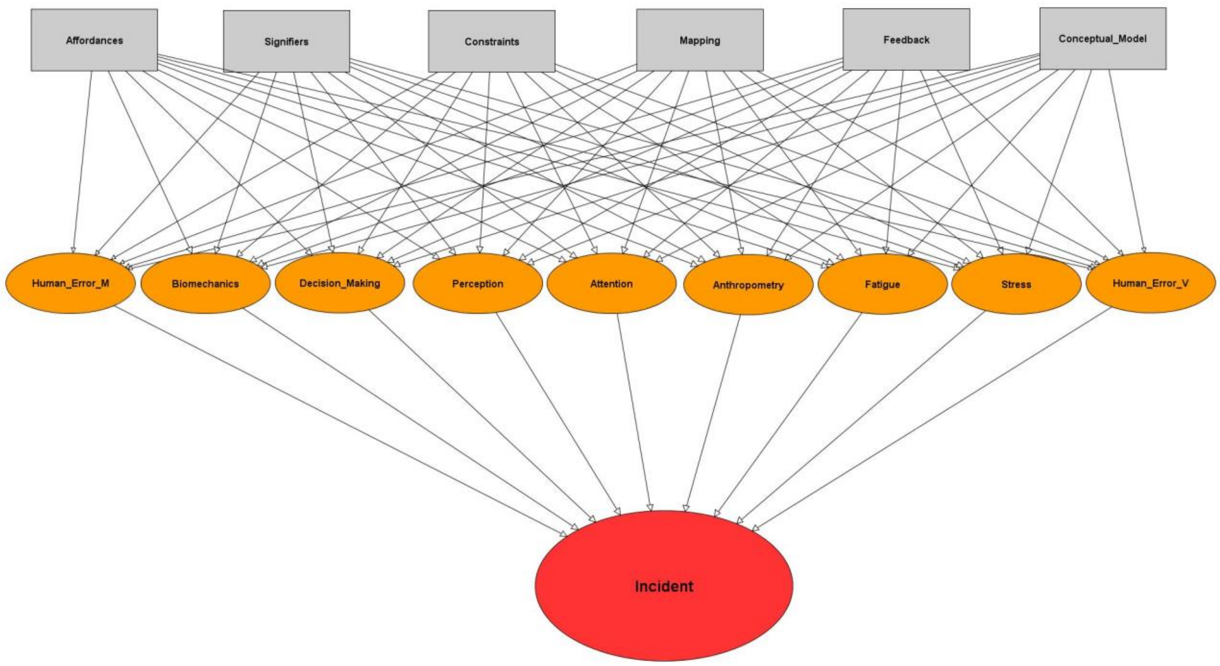

Figure 14. Bayesian Network HF & TF model.

The state zero of the BNM considers the same probability of occurrence or no occurrence (occurrence 50% and no occurrence 50%) for all the human factors as well as for the incident. At this stage the model presents all the technology factors at the same level; none of them have more weight than the rest as is shown in the figure 15.

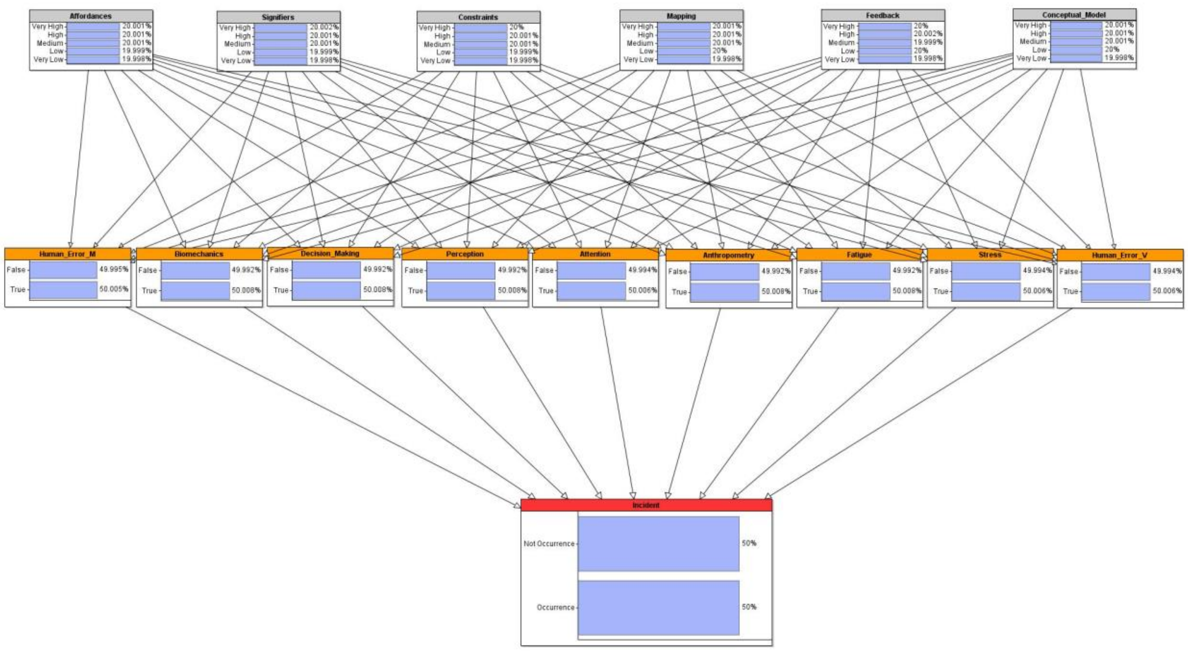

Figure 15. Bayesian Network model.

The AgenaRisk software is used to analyze the effects of different technology factors on the probability of a high potential event. The combination of technology factors causes significant variable effect on the human factors and high potential process safety events. The strongest combination resulted from combining the six technology factors which resulted in a reduction of 65.9% of the probability of occurrence of a high potential event as shown in the table 9.

All	**Occurrence**	**Not Occurrence**
Human Error	16.3%	83.7%
H.E. Violations	16.3%	83.7%
Attention	16.3%	83.7%
Perception	16.3%	83.7%
Stress	16.3%	83.7%
Fatigue	16.3%	83.7%
Decision Making	16.3%	83.7%
Biomechanics	16.3%	83.7%
Anthropometry	16.3%	83.7%
Incident	**34.1%**	**65.9%**

Table 9. The effect of all the technology factors over human factors and high potential events.

As we will observe in the next tables, some technology factors contribute more than others to the likelihood of a high potential event and to reduce the probability that human factors are part of the root causes of those incidents.

However, as we can observe in the figure 16 the best individual effect results in the application of the technology factor “Constraints” which results in a reduction of 54.3% of the probability of occurrence of a high potential event. The combination of technology factors gradually decreases the likelihood of human factors as part of the root causes of an incident and the likelihood of an incident.

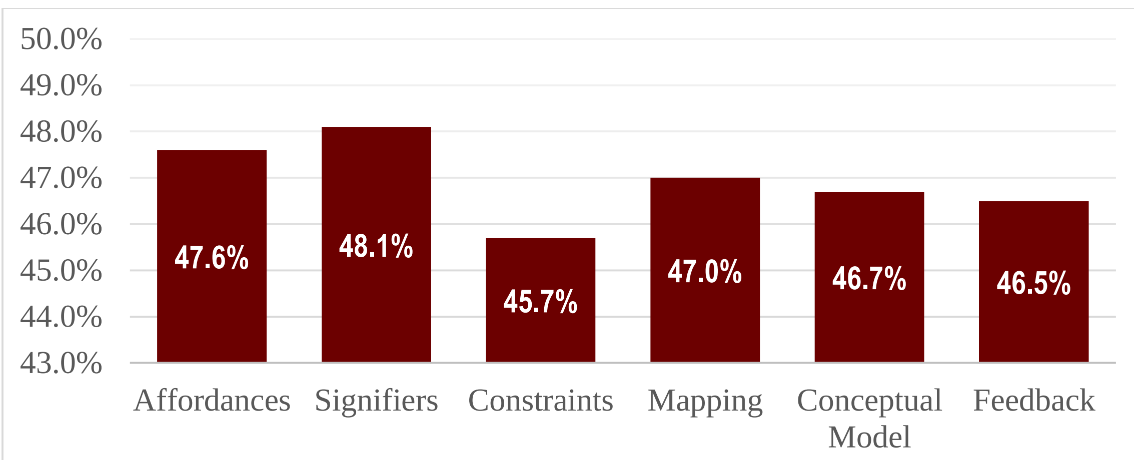

Figure 16. TF combination effects in a high potential.

Likewise, the model shows the highest relationship between technology factors and human factors. The figure 17 shows the human factors that are most positively affected by each of the technology factors.

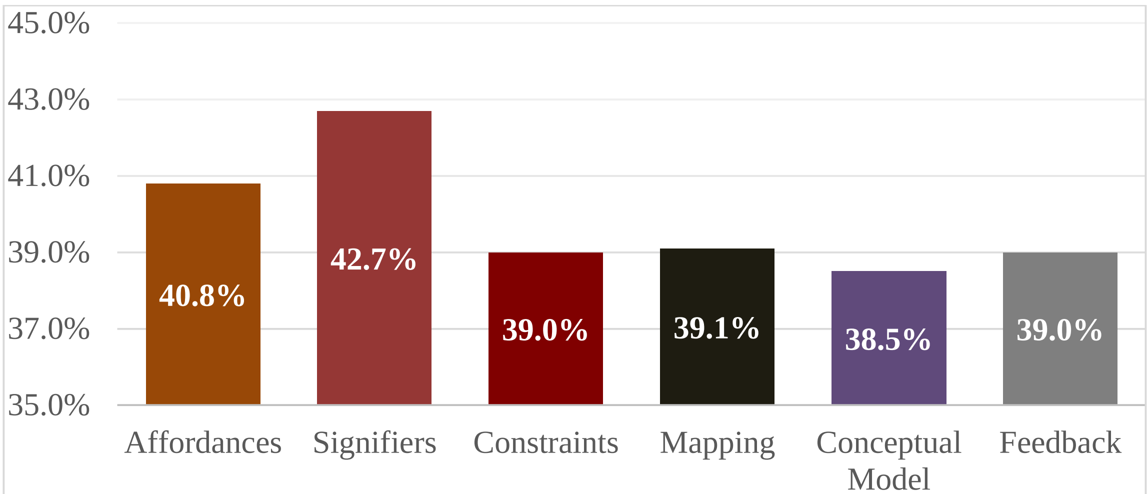

Figure 17. Effect of TF over HF.

Continuing with the results analysis, the effects of the combination of technology factors is shown in the figure 18; the best effective tri-combination of technology factors considers constraints, feedback, and conceptual model, which results in a reduction of around 60% of the likelihood of an incident.

A tetra-combination of the most effective technology factors was analyzed and results in a 63.1% likelihood of reduction of a high potential process safety event. Thus, the different combination of technology factors will result in a reduction of the probability of incidents and the probability that the human factors are part of the root causes of incidents.

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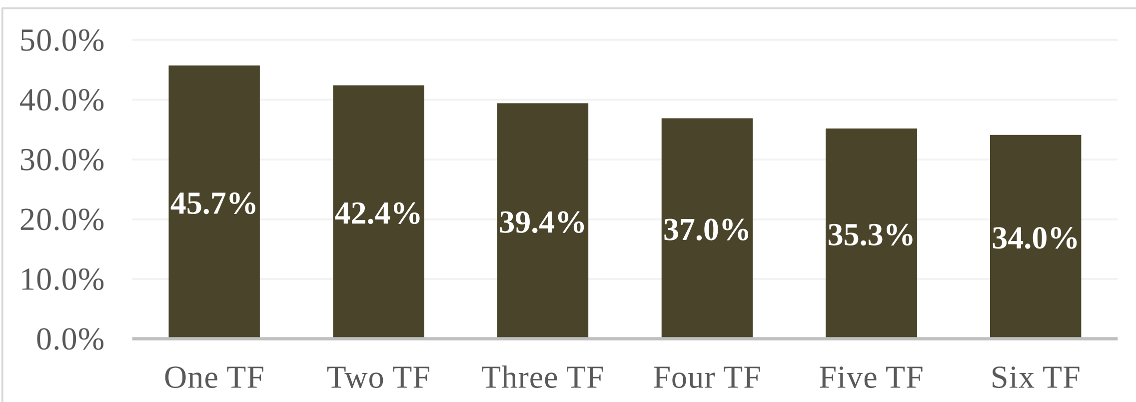

Figure 18. TF combination effects in a high potential.

In the Bayesian Network Model (BNM) the analysis observes how the probability of occurrence of human factors as the root cause of an incident are affected each of the technology factors mentioned in the study. In the tables 10, 11, and 12 we can observe the effects of each technology factor over the probability that the human factors are part of the root causes of a high potential event. Likewise, those table shows the strongest relationship between human factors and each technology factor by identifying which human factors are more affected by each technology factor.

Affordances	Occurrence	Not Occurrence	Signifiers	Occurrence	Not Occurrence
Human Error	46.3%	53.6%	Human Error	48.2%	51.8%
H.E. Violations	48.2%	51.8%	H.E. Violations	44.5%	55.5%
Attention	48.2%	51.8%	Attention	44.6%	55.6%
Perception	40.8%	59.2%	Perception	42.7%	57.3%
Stress	48.2%	51.8%	Stress	46.3%	53.7%
Fatigue	46.4%	53.6%	Fatigue	48.2%	51.8%
Decision Making	44.5%	55.5%	Decision Making	46.4%	53.6%
Biomechanics	42.7%	57.3%	Biomechanics	46.4%	53.6%
Anthropometry	42.6%	57.4%	Anthropometry	44.5%	55.5%
Incident	**47.6%**	**52.4%**	Incident	**48.1%**	**51.9%**

Table 10. Affordances and Signifiers affect over human factors and high potential events, and human factors with a strong relationship with each of these technology factors.

Constraints	Occurrence	Not Occurrence	Mapping	Occurrence	Not Occurrence
Human Error	39.0%	61.0%	**Human Error**	44.6%	55.4%
H.E. Violations	39.1%	60.9%	**H.E. Violations**	42.7%	57.3%
Attention	40.8%	59.2%	**Attention**	42.7%	57.3%
Perception	46.4%	53.6%	**Perception**	48.2%	51.8%
Stress	40.9%	59.1%	**Stress**	44.5%	55.5%
Fatigue	40.9%	59.1%	**Fatigue**	39.1%	60.9%
Decision Making	42.7%	57.3%	**Decision Making**	48.2%	51.8%
Biomechanics	40.9%	59.1%	**Biomechanics**	39.1%	60.9%
Anthropometry	40.8%	59.2%	**Anthropometry**	39.1%	60.9%
|Incident	**45.7%**	**54.3%**	**Incident**	**47.0%**	**53.0%**

Table 11. Constraints and Mapping effect over human factors and high potential events, and human factors with a strong relationship with each of these technology factors.

Conceptual Model	Occurrence	Not Occurrence	Feedback	Occurrence	Not Occurrence
Human Error	42.7%	57.3%	Human Error	40.8%	59.2%
H.E. Violations	46.4%	53.6%	H.E. Violations	40.9%	59.1%
Attention	46.4%	53.6%	Attention	39.0%	61.0%
Perception	39.0%	61.0%	Perception	44.5%	55.5%
Stress	39.0%	61.0%	Stress	41.0%	59.0%
Fatigue	44.5%	55.5%	Fatigue	40.8%	59.2%
Decision Making	38.5%	60.5%	Decision Making	40.9%	59.1%
Biomechanics	44.5%	55.5%	Biomechanics	48.2%	51.8%
Anthropometry	48.2%	51.8%	Anthropometry	46.4%	53.6%
Incident	**46.7%**	**53.3%**	**Incident**	**46.5%**	**53.5%**

Table 12. Conceptual Model and Feedback effect over human factors and high potential events, and human factors with a strong relationship with each of these technology factors.

In the tables 13, 14, and 15 we can observe the effects of the combination of technology factors over the probability that the human factors are part of the root causes of a high potential event. Likewise, each table shows the strongest relationship between human factors and each technology factor by identifying which human factors are more affected by each technology factor.

Two -Constraints -Feedback	**Occurrence**	**Not Occurrence**
Human Error	30.3%	69.7%
H.E. Violations	30.3%	69.7%
Attention	30.3%	69.7%
Perception	41.0%	59.0%
Stress	33.8%	66.2%
Fatigue	30.3%	69.7%
Decision Making	33.8%	66.2%
Biomechanics	39.1%	60.9%
Anthropometry	37.3%	62.7%
Incident	**42.4%**	**57.6%**

Table 13. The effect of two technology factors over human factors and high potential events.

Three -Constraints -Feedback -Conceptual Model	Occurrence	Not Occurrence
Human Error	24.0%	76.0%
H.E. Violations	27.1%	72.9%
Attention	27.0%	73.0%
Perception	30.4%	69.6%
Stress	24.0%	76.0%
Fatigue	28.8%	71.2%
Decision Making	24.0%	76.0%
Biomechanics	33.9%	66.1%
Anthropometry	35.6%	64.4%
Incident	**39.4%**	**60.6%**

Table 14. The effect of three technology factors over human factors and high potential events.

Four -Constraints -Feedback -Conceptual Model -Mapping	**Occurrence**	**Not Occurrence**
Human Error	19.9%	80.1%
H.E. Violations	21.2%	78.8%
Attention	21.2%	78.8%
Perception	28.8%	71.2%
Stress	19.9%	80.1%
Fatigue	24.1%	75.9%
Decision Making	22.5%	77.5%
Biomechanics	25.6%	74.4%
Anthropometry	22.6%	77.4%
Incident	**37%**	**63%**

Table 15. The effect of four technology factors over human factors and high potential events.

If the analysis of the model continues, but in this case observes the effects of having a high potential event in reverse (from bottom to top), the model shows that the most likely explanations (MLE) of having a high potential event are human error and constraints with 57.6% and 55.2%, respectively, as is shown in the figures 19 and 20.

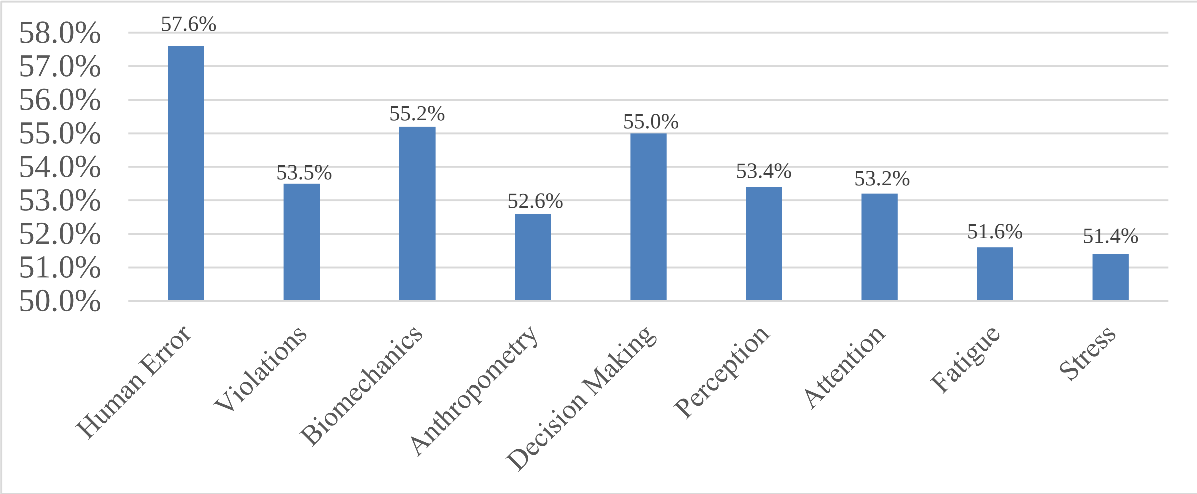

Figure 19. MLE human factors in a high potential.

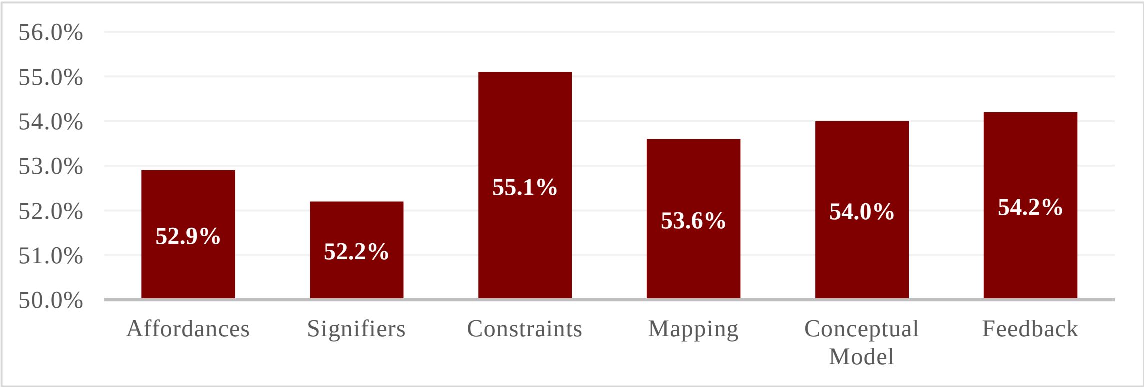

Figure 20. MLE technology factors in a high potential event.

VII. SAFETY RISK MODELS USING BAYESIAN NETWORK

Bayesian Belief Network (BBNs) has been used to develop different risk models to understand the interactions between human error, organizational factors, and categories of new technologies (previously selected by advisors) in order to reduce the likelihood of an incident. Each type of technology addresses one type of problem. These new technologies were previously selected with the idea of reducing the likelihood of fatal aviation accidents. James Luxhoj developed the models "Probabilistic Causal Analysis for System Safety Risk Assessments in Commercial Air Transport or Aviation System Risk Model (ASRM)," shown in the figure 21, and "Risk Analysis of Human Performance in Aviation Maintenance" with the idea of analyzing and understanding the behavior of interactions between the root causes of incidents, organizational factors, and a specific collection of new technologies (Luxhoj, 2002a, 2002b).

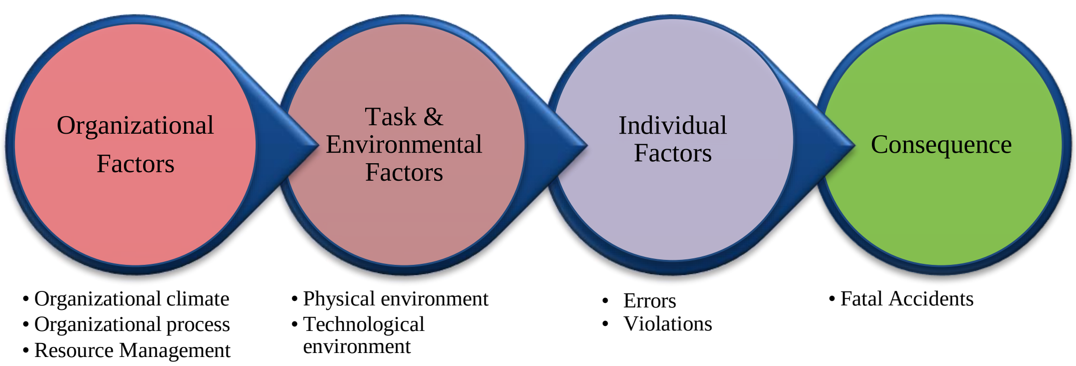

Figure 21. Aviation System Risk Model (ASRM) (Luxhoj, 2002b).

This model supports the idea that the relationship between human and technology factors must be considered as a fundamental part of the process of the selection of new technology. This interaction provides a better understanding of which technology elements have more influence over different human factors (figure 22) to prevent incidents. Thus, through the use of a specific group of characteristics, people can reduce the negative effects of human factors. Therefore, the better understanding of technology factors is a fundamental part of the process of the selection of new technology and in the development of a preventive culture.

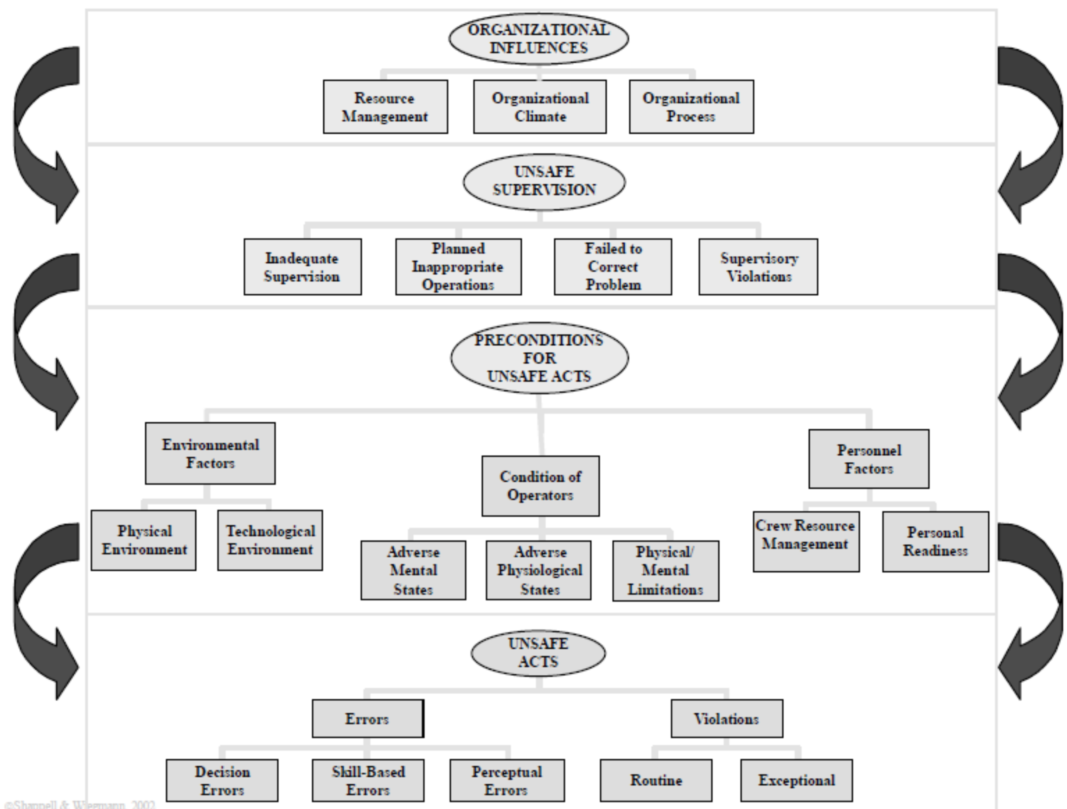

Figure 22. The human factors analysis and classification system (HFACS) (S. A. Shappell, and D.A. Wiegmann, 2000).

James Luxhoj analyzed the interaction between organizational factors, task, and human factors by using the human factors analysis and classification system known as HFACS. HFACS is an analytical approach used to classify human error based on the human error model of James Reason. This approach differentiates and distinguishes between organizational influences (organization), preconditions for unsafe acts (task conditions), and unsafe acts (errors and violations) (Luxhoj, 2002a; S. Shappell, 2000; S. A. Shappell, and D.A. Wiegmann, 2000).

The model developed in this study, shown in the figure 23, considers a new approach to the incident investigation process in the oil and gas industries by working to identify, analyze, and evaluate the negative or positive effects of human factors that are part of the root causes of high potential events. Likewise, this model addresses a new idea of how new technology can be selected by identifying specific characteristics that improve the human factors performance and reduce the likelihood of an incident.

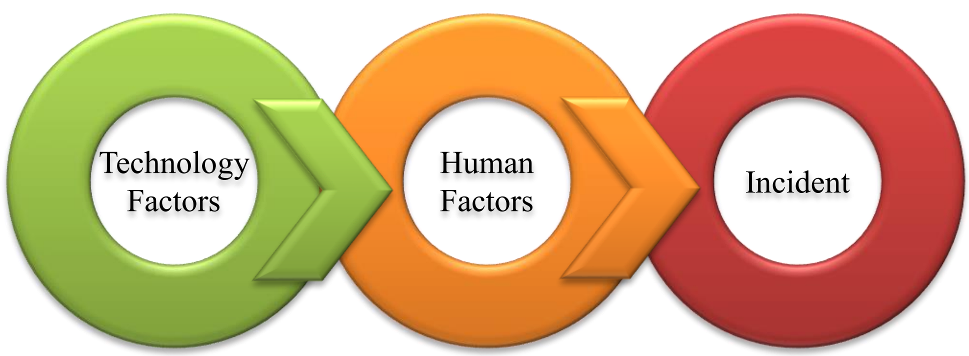

Figure 23. The human factors in the selection of new technology model.

The principal similarities between James Luxhoj's model and this model are explained in the table 16:

ASR model	HF and TF model
Identifying the root causes of a group of incidents.	
Referring to expert knowledge or expert beliefs in absence of data.	
Trying to understand the effect of new technology to prevent incidents.	
Analyzing the causal factor interactions.	
Using probabilistic Bayesian Belief Networks.	
Combining human taxonomy.	

Table 16. The principal similarities between James Luxhoj's model and HF and TF model (Luxhoj, 2002b).

The main differences between James Luxhoj's model and this model are explained in the table 17:

ASR model	HF and TF model
Applied to the Aviation Industry.	Applied to the Oil and Gas Industries.
Analyzes the effect of a specific group of new technologies to prevent specific incidents.	Analyzes the effect of technology characteristics to prevent incidents.
Analyzes human factors based on the James Reason human error model and HFACS classification.	Analyzes human factors based on the identification of people acts as root causes of IOGP incidents.
Includes the analysis of the effect of organizational factors and task and environment characteristics.	Focuses only on the effect of technology characteristics in human factors.
It is not clear how the advisors selected the technologies used in the model.	It is clear how the technology factors have been evaluated by experts.

Table 17. The principal differences between James Luxhoj's model and HF and TF model (Luxhoj, 2002b).

The point of comparing both methods is to understand how technology is evaluated in different fields in order to reduce the likelihood of incidents. ASR model and HF & TF model are focused on how to improve human performance through technology by identifying, analyzing, and selecting the best technology depending on the type of industry, work, work characteristics, goals, and other constraints with the purpose of investing the organization's resources in the best option. The ASR model is focused on the evaluation of groups of technologies, but the HF & TF focuses on the basic characteristics of any technology in order to analyze different technologies and not only what is included in specific groups. However, the points to highlight in both models are the systemic approach to evaluate different factors that are part of the root causes of incidents, the development of methods to take the most advantage of the technologies that an organization can buy, and the development of methodologies to reduce the uncertainty (in absence of data) in the relationships between humans and technology.

Finally, the ASR model provides more ideas about the next steps that the HF & TF could follow in order to improve the accuracy of the results and evaluate with other points of view the effects of technology in organizations in order to reduce the probability of an incident.

VIII. CONSIDERATIONS FOR THE MODEL

The model developed in this study considers the relationship between human factors, technology factors, and high potential events with the purpose of understanding how the selection of new technology can reduce the likelihood of an incident. However, it does not consider the effects of other elements such as organizational factors or the task and employee characteristics.

The model did not consider the interactions and dependent relationships between the different factors, because this is the first approach to creating this type of model in the Oil and Gas Industry. Thus, simplification is important as a first step to test the efficacy of this model.

The model must be tested in a real scenario to update the data and increase the quality and accuracy of the model.

The Bayesian network technique provides a good comparison analysis. However, the high potential events reported by the IOGP may include incidents that are not related to process safety (transportation incidents and near-misses).

The survey should be applied without any restriction, with the opportunity to repeat numbers that qualify the relationships in the same evaluation (one human factor with the six technology factors) as many times as the participants desire. Thus, for example, one person could decide to give 6 to all the relationships between one human factor and the technology factors.

The reapplication of the survey must consider standardization of the demographic and situational factors between the participants in order to improve the accuracy of the data.

IX. CONCLUSIONS AND FUTURE WORK

The human and technology factors model provides a good analysis to identify the effects and relationships between human factors, technology factors, and high potential events.

The relationship between technology and human factors are essential to monitor and improve organizational safety performance, preventing the occurrence of an incident. Additionally, this must be considered a fundamental part of the process of the selection of new technology.

The job or task analysis must be the first step in the process of selection of new technology. This analysis will provide the needs and goals of the organization and the human factors that will be part of the process.

We have a model that provides a semi quantitative evaluation of the effects and benefits of the analysis of technology factors over human performance. Likewise, the model identifies the role and influence of each factor, and the combination of technology factors over human factors to prevent incidents.

The idea of considering “Human error” as a human factor and root cause of the incidents may be incomplete, and it must be analyzed further because we need to identify what is causing the human mistakes.

The selection of new technology should be developed using a systematic approach. The petrochemical industrial organizations should focus on the most effective technology incorporation process.

An efficient process of identification, selection, and incorporation of new technology would be able to detect and fix these deficiencies and faults in the process safety system and faults.

Complement the model by analyzing the effect of organizational factors, task, and environmental characteristics in conjunction with the technology factors to reduce the likelihood that human factors become part of the root causes of high potential events.

This will include analyzing and improving the survey application process and format, as well as implementing the model to evaluate different types of technologies. It will also include revalidating the developed model using direct process safety indicators and review its effectiveness, as well as developing groups of technologies based on their type or the problem that can be solved through them. Finally, it will also include creating an expert advisory panel to assist with the model validation, and testing the model in a real scenario to update the data used and increase the quality and accuracy of the model.

REFERENCES

Bronzino, D. P. J. (2008). *Biomechanics: Principles and Applications* (T. F. Group Ed. Second Edition ed.). Boca Raton, FL: CRC Press.

Das, H. B. J. P. (2008). Attention, Attention Rating and Cognitive Assesment: A Review and a Study. http://web.b.ebscohost.com/ehost/pdfviewer/pdfviewer?vid=7&sid=8e6560e5-3e79-4958-a2aa-12fbdc03d504%40sessionmgr115&hid=125

Executive, H. a. S. (2015a). Introduction to human factors. from http://www.hse.gov.uk/humanfactors/introduction.htm

Executive, H. a. S. (2015b). What is stress? , from http://www.hse.gov.uk/stress/furtheradvice/whatisstress.htm

Executive, H. H. a. S. (2015). Human factors: Fatigue. from http://www.hse.gov.uk/humanfactors/topics/fatigue.htm

Flin R, M. K., M Fleming, and Gordon R (1996). Risk Perception and Safety in the Offshore and Gas Industry (pp. 110). Aberdeen: Health and Safety Executive Books.

Human Attention & Situational Awareness. (2015). *AviationKnowledge.* from http://aviationknowledge.wikidot.com/aviation:human-attention-situational-awareness:what-are-the

Knowles, D. (2002). Risk perception leading to risk taking behaviour amongst farmers in England and Wales. In A. C. Ltd (Ed.).

Knudson, D. (2007). *Fundamentals of Biomechanics* (Springer Ed. Second Edition ed.). New York, NY: Springer Science,Business Media, LLC,.

Levy, J. H. (2010). *Biomechanics : principles, trends and applications* New York: New York : Nova Science Publishers,.

Lorenzo, D. K. (1990). *A manager's guide to reducing human errors*. 2501 M Street, NW: Chemical Manufacturers Association, Inc.

Luxhoj, J. T. (2002a). Probabilistic Causal Analysis for System Safety Risk Assessments in Commercial Air Transport. http://shemesh.larc.nasa.gov/iria03/p02-luxhoj.pdf

Luxhoj, J. T. (2002b). Risk Analysis of Human Performance in aviation Maintenance. 1-9. http://www.faa.gov/about/initiatives/maintenance_hf/library/documents/media/mx_faa_(formerly_hfskyway)/16th_symposium/risk_analysis_of_human_performance_in_aviation_maintenance.pdf

MedicineNet.com. (2010). Definition of Stress. from http://www.medicinenet.com/script/main/art.asp?articlekey=20104

Neil, N. F. M. (2013). *Risk Assessment and Decision Analysis with Bayesian Networks*. Boca Raton, FL: CRC Press.

Norman, D. (2004). *Emotional Design*. New York, NY: Basic Books.

Norman, D. (2013). *The Design of Everyday Things*. New York, NY: Basic Books.

Prevention, C. f. D. C. a. (2015). National Health and Nutition Examination Survey (NHANES); Anthropometry Proces Manual. from http://www.cdc.gov/nchs/data/nhanes/nhanes_09_10/bodymeasures_09.pdf

Producers, I. A. o. O. a. G. (2011). Human Factors Engineering in Projects. Report 454. 2015, from http://www.ogp.org.uk/pubs/454.pdf

Producers, I. A. o. O. a. G. (2014). Safety Performance Indicators - 2013 DATA. 108. Retrieved from IOGP website: http://www.iogp.org/#*

Reason, J. (1990). *Human Error* (October 26, 1990 ed. Vol. 1). Inited Kingdom: Cambridge University Press.

Shappell, S. (2000). The Human Factors Analysis and Classification System - HFACS (pp. 19). Savoy, IL: FAA Civil Aeromedical Institute.

Shappell, S. A., and D.A. Wiegmann. (2000). The Human Factors Analysis and Classification System-HFACS (Vol. 2015). Oklahoma City, OK: Civil Aeromedical Institute.

TAMU, I. R. B. (2015). Human Factors in the selection of new technology for the oil and gas industries. (D. o. Research, Trans.) (pp. 2): Texas A&M University.

Thomas Ferris, P. (2014). Human Operator in Complex Systems. Class Material. Industrial Engineering. Texas A&M University. TAMU.

UMass. (2015). Decision making process. 2015, from http://www.umassd.edu/fycm/decisionmaking/process/

Vicente, K. (2004). *The Human Factor*. New York, NY: Routledge.

Wickens, C. (2004). *An Introduction to Human Factors Engineering* (L. Jewell Ed. Second Edition ed.). London: Pearson.