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Relationship between Human-Managerial and Social-Organizational Factors for Industry Safeguards Project: Dynamic Bayesian Networks

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Abstract

This methodology intends to identify the Relationship Network between Human-Managerial and Social-Organizational Factors considering the Dynamic behaviour and Work Environment to build preventive actions based on the approximation calculation of the top event. During methodology discussion and testing we can: establish new criteria for Designing Safeguards in the Case of Chemical Industry Control Instrument Interfaces, Regional-Global Culture Features, and Probability Analysis for Human Errors; understand rare event analysis with no history to design possible Future Accident Scenarios; and Identifying, developing and testing safeguards for behaviour adjustment and Culture through Tribal Rituals, Operational Groups, Intellectual Capital for Failure Processes, Human Reliability Factors, Change of Habits, Educational Transformation Programs. This work intends to discuss the new concept of systemic failure (first phase) and related tools for the calculation of reliability. In the new concept, before the fault is active, there is an entire relation-ship between technical, human, social and organizational factors. In a second phase, it is intended to explore the relationships between Human Factors in the work environment indicating what is a safe behaviour and what is the possibility of change over time and environments in routine and emergency. When constructing barriers, and investigating accidents, it is important to explore the role of the leader and the possibility of making the wrong decision. Still in the second phase the socio-functional relations and the possibility of triggering the fault of the operational culture are dis-cussed. The cultural environment has a great influence on the existence of bad habits through rituals of preservation of what is right. It is important for database construction to understand how the executive function works in planning and controlling tasks. The simplicity of analysis of cognitive processing functions and analysis in task planning does not allow advancing the investigation of human error. Phase 3 of research will focus on the analysis of physical-cognitive and organizational criteria that may be the cause of human error or accident or can be barriers to non-existence. In this discussion, we intend to deepen in the subjects: role of the cognitive function in the transformation of the information; evaluate the man-task interface, indicating where the main gaps are; evaluation of the human machine interface by the cognitive side and organizational (stress and leadership); use of the cross matrix to identify barriers in the control panel trying to avoid the failure caused by cognitive gaps due to social phenomena. Finally, in phase 4, a solution is sought for the search for more effective preventive and corrective actions in the current situations of uncertainty through dynamic Bayesian Networks for Human Factors and Human Behaviour.

Keywords: Dynamic Bayesian Networks - Industry Safeguards - Human-Managerial - Social-Organizational.

1 Introduction

The relations between human factors which can provoke events with economic losses must be observed from a nebulous environment (low visibility) and possibility of complex system. Initially, let us go consider that involved factors on accident are multidisciplinary and within a historical existence. These factors can have complex relations that require different measurement methods, some direct on the phenomena in question and some indirect, from some existing variables in the workplace. On this paper, we pretend to provide a methodology for configuration and control of events, with high process losses in the industry with risk activities. This case will be applied to the Chemical Industry.

The operating routine and its deviations can lead to failure and accident [1]. Failure warnings are in the intermediate state, where the process, product, equipment, and staff (or individual) are constant change and can reach the systemic failure state. When this state is established visible consequences occur such as system stop, loss of quality, waste generation, waste of time, reduced billing and others. However, today, in a period of high pressure from society, the sustainability of industrial businesses and critical activities depends on maintaining a positive image.

Therefore, should be avoided the impact of accidents, chemical leaks and incorrect managerial attitudes regarding social responsibility by identifying the relationship network between human-managerial-social-organizational factors, dynamic behavior and the work environment to build preventive actions based on the top event approximation calculation.

Hazard enablers human elements are classified as technological (risk and complexity), managerial (stress and leadership) and behavioral (cooperation, commitment, competence and communication - C4t) [2]. These elements are designed at the beginning of the business and should protect the system from overloading as these elements may degrade over time, it is related to design criteria. Human factors, on the other hand, may be active or inactive, circulating with a certain failure energy and may have economic consequences, it is related with operational routine.

In this context, Human elements are related to *design resistance* while human factors are related to failure or hazard energy during operation, or *operational charge*. This load is dynamic due to the workplace and the types of cultural and behavioral influence within the organizational environment. While resistance is embedded in static patterns that need to be revised due to: the influence of social phenomena, and the degradation of barriers (caused by time and physical attacks). This degradation promotes a new balance of forces for installed safeguards. Unfortunately, the load and resistance is very dynamic.

A research was done by applying questionnaires to operational groups of an industry. The questionnaires were based on principles of risk perception, aspects of cognition, understanding of the workplace and especially knowledge about the human factors in work activities.

1.1Human Factors Construction

Understanding the implementation of individual or group Human Factors for Routine and Emergency enables effective safeguards to be established to prevent accidents. The Composition of Systemic Failure, depends on active cultural, educational, learning, practice and behavior in transient situations. The dynamics of behavior resulting from these factors are understood and classified to achieve the resilience of the individual under threat can find the solutions. The same can be said of group or organizational resilience, where many other factors are understood, classified and analyzed to result in operational culture [3].

The characteristic human factors for work in routine and emergency situations are constructed by chronological facts in the history of worker, and in respective competence, such as: culture, affection, individual and linguistic, concepts, experience and practices, work, group, work cycle, work organization and maturity.

1.2Human-Managerial-Social-Organizational Factors

[4] and [5] indicate that human performance factors may cause failure and accident. These factors may be: the interface between worker with equipment and tasks; the relationship between individuals or groups; and the managerial characteristics. [7] discussed about hazard energy but do not formulate devices (doors) that enable the flow of this energy. The model proposed in this work treat the human elements from project and the construction of accident by human factors failures in operational situations. Thus, the human elements enablers flow of hazard energy opening the way toward the accident. This flow comes from a chain of events that occurs from human factors in nine-tier in industry operating, from the influence of culture to failure until the disaster.

The human elements that are part of the project are discussed in the topics organizational culture, safety and technology. These elements may change from design to operational phase, indicating that the energy of the events will or will not go towards the accident, depending on the operating culture installed on the shop floor.

Some structures (social or technical) may degrade and respond differently to each operating situation causing unexpected behavior. In this paper, it is proposed the existence of interconnected human factors that can create hazard energy compared to the projected barriers (human element). Therefore, if during operation some structures are failing, when combined, they can increase the "hazard energy". In this context, it is studied the flow of hazard energy generated, increased or decreased in the human factors, in nine levels passing through the human elements from the project, with or without degradation, allowing or not performing of failure, or accident or disaster.

1.3 Behavior and Dynamic Risk

The subjects discussed here are considered Dynamic Risks based on social culture, technologies, and Industrial Operation. The triggering and development of chain events depend on characteristics installed in the design to avoid the happen of these events. These characteristics dubbed as “resistance” can go into degradation during operations bringing situations where humans initiate and keep the failure cycle.

In the analysis of prediction of team behavior, and technical processes, we should identify which cultural biases and possibilities of human errors that are not avoided. Thus, it is possible to adjust cognitive gaps in order to promote resilience in relation to the dynamic risk to avoid degradation of design barriers (resistance) and the increase of cognitive workload.

The human elements to prevent failure must be reviewed according to environmental threats such as climate and organizational changes. In complex processes and high impact activities, is important to make a careful analysis to write procedures and delimit behavior patterns in Industrial Operation [6]. Analysis of routine abnormal occurrences in chemical (TDI, Polycarbonate, MDI, Sulfuric Acid), Oil and Gas (LPG) industries indicates the need for careful task analysis that goes beyond simply describing the steps with their goals, or only hierarchical analysis with times, auxiliary memory and necessary training [7]. It is necessary to gather the information and requirements of the legislation and analyze the environment of the task.

1.4Workstation

The Workstation project indicates physical, cognitive and organizational requirements to be met. The behavioral variability of the leader and the team is inserted as important information for future human performance, types of decision-action and what knowledge is required. The stability of cognitive-intuitive and emotional functions indicates a prepared structure for decisions under stress and high risks (emergency), as well as decisions and compliance with standards in normal situations [8].

On the one hand are product, process, and operations technology for effective production, on the other are the people and influences of a cultural field with social phenomena in the form of communication, group work, and the relationship of compromises with organizational goals. In the middle are the interfaces, the instruments that translate information and knowledge into action in the field. May be considered interfaces in the production routine: (a) computer screens for process control; (b) written procedures with linguistic symbols and signs; (c) leaders who have the ability to translate group sentiments and information from technology through language dictionaries that attempt to overcome cultural difficulties in carrying out critical activity.

The complexity to discuss the causes of systemic failure, and to perceive human risk, may be high. The lack or decrease of risk perception in the critical task causes ineffective prevention-correction-mitigation actions to avoid the failure or accident.

This event indicates the disruption in the flow of information in the cognitive field (communication and mind map) affecting the accomplishment of the task (failure in equipment or process). Thus, machines, processes and products are not properly controlled because of the lack of attitude or practical-theoretical knowledge to make decisions in standard situations.

The not recognition of an abnormal scenario and the trust on the pre-established pattern may be an indicator of future negative events in the safety (accident) or in the production (plant shutdown). The failure in risk perception can occur in execution (function in routine and emergency), planning (standards and writing procedures) and diagnosis of task. The Regulation of Human Elements in the Project is based on three groups: technology, management and behavior.

The description of the Organizational Standards, Policies and Procedures make up the tools and criteria for measuring, controlling, reviewing and investigating the complexity and causal link of human error and failure. These tools aim to optimize the processes and execution of critical tasks without social and environmental impacts, establishing requirements for Culture, Technology and People.

Workstation complexities vary according to: cognitive relations, visibility of events, and intensity of the risks of unexpected events. We distribute these relations as: (1) Simple activity involving operator and machine in workstation, few people and simple task - cognitive; (2) Integrated manufacturing activities that rely on automated systems (linear manufacturing - cognitive); (3) Industrial continuous processes with recycling and complex relationships, Risks and complexity can be high due to communications and heavy information flow – cognitive and intuitive; (4) network of industrial units where the appropriate culture is fair, no omissions or underreporting occur. Sometimes discussing industry theory 4.0 is easier than practicing since, unfortunately, we have not yet reached this ideal culture level, we still live with the blame culture – cognitive and intuitive.

1.5 Systemic Failure

Organizational Standards, Procedures and Operating Instructions should be structured to avoid trigger situation in routine where systemic failure begins, may to provoke sufficient hazard energy to reach the level of accident and even a crisis by chain reaction.

The study of the task and the analysis of the failure based in the operator's discourse allow us to recognize the current patterns and to estimate new ways of team act. This analysis is presented for groups of operators, and discuss resulting hypotheses from the occurrences investigation in routine identifying cycles of socio-technical events and outliers with projection of future accidents. The variables identified in the routine study through task analysis, failures and occurrence of abnormal events, compose a set of parameters and indicators that represent a certain culture with its informal rules allowing predictive analysis of systemic failure.

On the other hand, as operations can cause a structural high load on the system promoting events that generate accidents or environmental impacts. This discussion is related with the human factors in the operational routine and the possibility of control loss due to failure of barriers, such as procedures or interfaces between men and machines.

The characteristic failure of the socio-technical system, systemic failure, is the result of behavioral heuristics resulted from human errors, incorrect decisions and bad habits related to processes, equipment and products. Thus, the operating culture has relations with the task and the informal rules acquired in the operation.

Knowledge about systemic failure allows integrating the calculation of reliability from factors that connect the different functions (maintenance, operation, process, people, culture and leadership). This systemic failure is constructed as a result of structural design deficiencies or operational.

These deficiencies,

- ✓ are result from improper cultural characteristics and affect safety
- ✓ occur due to individual failure triggers at specific points in the production system.

Management models, that control dynamic risk resulting from human factors, social and climate change, are presented to reduce the probability of failure and energy loss.

The application of task failure analysis [6] techniques in advanced systems increases the identification of the causal nexus, verifies where and how much the hazardous energy flow, analyzes the cost-benefit of installing barriers, and tracks the results.

Therefore, root cause investigation should be considered in complex systems where latent failures occur in the human, managerial, organizational, and technical dimensions. This research recognizes systemic failure and indicates the characteristics that are repeated in the risk installation. The research base material is the shift book that contains process, production, safety, maintenance, environment, and personal data from the work team. After task diagnosis and variables, it is possible to predict the production behavior indicating the revision of barriers from the use of mathematical modeling.

Barriers must be studied to prevent failure, incident, accident and also the crisis caused by a disaster. Thus, it is important to analyze the cognitive gaps for emergency contingency team.

1.6 Reliability Calculation - Systemic Bayesian Network

In complex systems, the quantification of human reliability occurs considering that, the characteristics of the System are connected by energy, mass, flow data that are collected, processed, and represent the current state of each function in reliability. In the event of a systemic failure it must be considered that the individual reliability functions are integrated and what is the level of impact on the top event occurrence [9].

The Bayesian networks based reliability calculation method is best suited because it represents the complex relations between performance factors and events that include modeling uncertainty [10] as well as providing flexibility to the component variables of a system and representing the dynamic nature of the human-machine interface [11]. The discussion on Bayesian Networks of Human Factors and Hazard Energy Enablers indicates which design criteria are involved with human elements, which barriers may degrade over time, and the likely human factors that hazard energy can course through routine structures and processes of critical activity in the industry and highly complex services.

2 Methodology

This experimental methodology develops tests to calibrate a systemic failure model. This model resulted from the discussion of human and technical errors in the execution of the task by authors [4], [5], [12] and from the confirmation of process safety managers and specialists in the Chemical Industry. Model calibration is done as part of an operational mass awareness training on the causes of human error in the dimensions: principles, cognition, work and human factor management. This discussion aims to relate the responses of the operation to the amount of hazardous energy flow. The steps of this methodology are:

(1) Theoretical Systemic Failure Model: life cycle; (2) Identify Operational and Technological Context; (3) Model Adapted to Model Applied in Context; (4) Sensitize and provoke paradigms: concept, scenario, situation and decision-making - risk perception issue; (5) Model Analysis Adapted with Intensity and Visibility of Human Factors; (6) Identify Hazard Enabling Factors and

Failure Processes; (7) Define Specific Bayesian Network Architecture with Intensity and Visibility; (8) Develop Failure Energy Algorithms.

The classification and prioritization of human, organizational, managerial, social and technological factors indicate what are the most important factors and the relationships between them in a systemic failure model. This model that attempts to approach the complexity of multiple dimensions and pathways for energy loss is the starting point for consensus with the shift group to define a more real model of what happens.

This work is initially divided into six levels:
(L1) Project and Product - physical configuration, technology demands and requirements;
(L2) Management Aspects - leadership, work organization, stress level, conflict between policies and practices;
(L3) Safety Behavior (personality, attitude and motivation, dynamic skills, good practices) and C4t (competence, commitment, cooperation and communication).
Nucleation brings together the physical and cognitive interfaces: relationship between human, technical, social and organizational factors bringing effects; human-machine process interfaces in the operational routine, planning and control of the critical task;
(L4) Sociotechnical Culture: organizational, security, global, regional, social phenomenon, just blame, formal and informal workplace rules, information flow;
(L5) Human and social error: deviations, omission, commission, violation, wrong decision, bad habits - rituals, routine and emergency, failure life cycle (feedback);
(L6) Failures and Consequences: routine and emergency, organizational processes and image loss, process losses (time), logistics processes, cost increases, loss of revenue, failure, incident, accident and consequence;

3 Results and Discussions

(1) Theoretical Systemic Failure Model: life cycle

Some assumptions are discussed in the choice of model:

- ✓ we seek the relationships between factors to identify regions with probable human errors, where hazardous energy concentration occurs;
- ✓ the fact that human error exists is not the main problem; the concern is to analyze the impact or intensity to build appropriate barriers that address dynamic threats;
- ✓ by understanding the relationships between factors, it is better to understand how to intervene by changing the form;
- ✓ at high risk learn in practice using simulators for virtual tools;

A Theoretical Model, Figure 1, is suggested for the Chemical Industry indicating types of factors, elements and situations with their characteristics, relationships, visibility and intensity. The human factors and elements that permeate industrial activities are multidisciplinary and dynamic. These factors are directly worker related and include the organization, safety, management and technology dimensions.
Investigating and disseminating knowledge from human error is a form of training adopted by high risk multinationals. The dimensions considered, which is included in the [13] model, and which

are part of the Theoretical Model are: Culture and Organization; Cognition (perception, communication and decision); Technology; Management; Analysis, Measurement and Control of Human Factors and Elements.

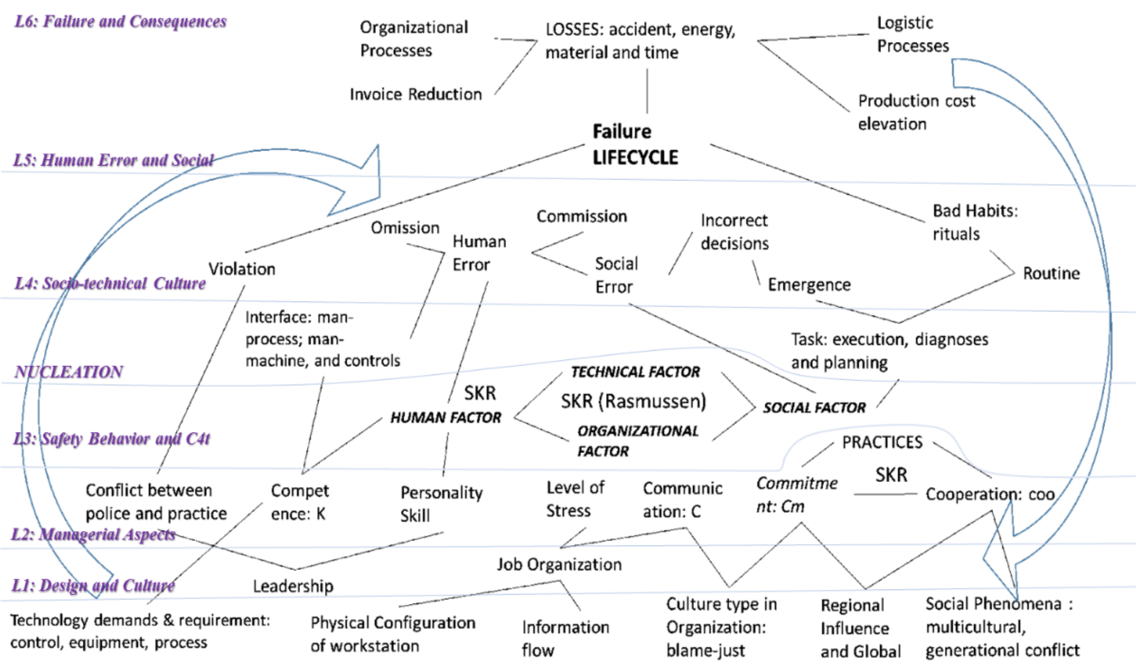

Figure 1 - Theoretical Systemic Failure Model: life cycle

(2) Operational and Technological Context

A questionnaire, visit, reading procedures and reports are conducted to identify the operational and technological context. Context identification is based on plant history, observations, technologies, operation, people, and culture involved in the process.
It is necessary to consult reports, evaluate the workstation and consult manager and operational mass to map the types of failure and cultural aspects of the environment.

TECHNOLOGICAL ASPECTS.
What type of product technology, process technology, process control and process safety? What is the risk level? For the following subjects: product quality, process, activity, billing and accident. What is the complexity of processes, automation, task, recycle - Cognitive effort versus Physical effort by type of function and activity? What are critical technologies and interfaces? Man, process, computer, task and machine?
SOCIAL ASPECTS.
What are the aspects, cultural biases that strengthen or hinder Security? What are the Social Phenomena and Failures that occur in routine with low visibility or evident? Generational conflicts, gender, multiculturalism and others? The type of Linguistics and Communication, underreporting occurs and what is the level of culture of guilt or fair? Analyze accidents and social events. What stress level is installed and why? What type? Physiological or cognitive? How is the team and company compatibility and leaderships regarding the Work Organization? Level of measuring fair culture or guilt: underreporting, omission, commission. What are the impacts of

4Cs: Communication, Competence, Cooperation and Commitment on human error and bad habits. What are the archetypes that reach leaders, supervisors and managers? What is the Leadership style in centralization, listening, determination and resilience? Investigate and describe key Human Factors based on Accident and Failure History - Reporting, Speech, and Observation (operating condition, abnormalities, human factors).

(3) Systemic Failure Model in the Operational Context

According to Figure 1, for analysis of systemic failure, some aspects of the failure life cycle were removed. *We removed:* (L6) invoice reduction, logistic processes (L5) incorrect decisions (L4) violation, emergence (L3) competence (L1) physical configuration of workstation, social phenomena: multicultural, generational conflict.
Because: this chemical industry in analysis is new, the product is new, the managers and supervisors have experience in failure and human errors, the technology is advanced, the best, the team development was harmonized without formation of little politic groups.
We installed: We could install some different facts as excessive discipline in Japanese culture, but it is not the case.
Because: is not the case.

(4) Sensitize and provoke paradigms: concept, scenario, situation and decision making - risk perception issue.

To improve the risk perception was applied a methodology what will be able to make a diagnosis based in principal principles and risk, cognition and practices, workstation and human factors. In the Figure 2, we can map the different question levels involved in this stage. This is the beginning of the Bayesian network construction according to the chemical industry's operating routine.

The questions were elaborated in different dimensions. **The culture**: what are the accepted principles and what are the weaknesses and strengths for security; **The operation**: where cognitive functioning is related to routine practices that can lead to an accident - causes and consequences of risk perception; **The project**: an analysis of what criteria are appropriate for the workstation during the routine including panel and field actions; **The management**: where human factor risks and team and leadership characteristics are discussed by 4Cs, complexity, technology and measurements. Human and organizational factors run through these dimensions and are verified through the response of the provoked situations.

Questions elaborated should be related with failure, risk, culture and human factors. The research is done in all operational mass and the perception on the answer will indicate the energy hazard intensity of human factors (operational charge) or human elements (resistance).

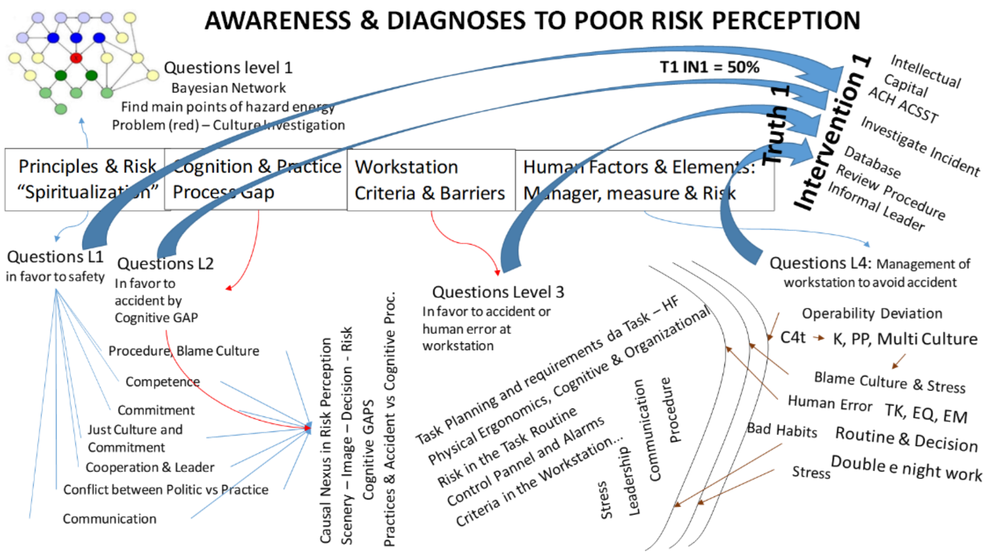

Figure 2 - Awareness & Diagnoses to Poor Risk Perception

(5) Model Analysis Adapted with Intensity and Visibility of Human Factors

Human social and technical organizational factors, raised from the literature review [4], [5], [12], [14] and expert opinion brought a list of factors and elements for the creation of the questionnaire. From this questionnaire (4) the factory factors were raised and measured by the intensity.

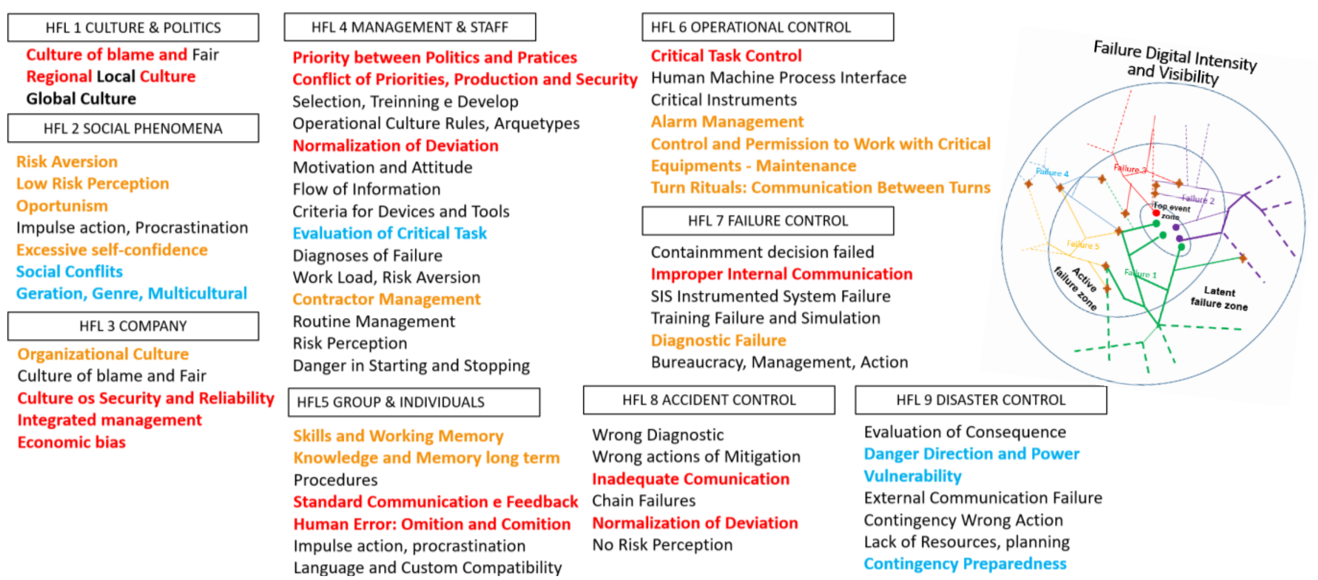

Figure 3 - Model Analysis Adapted with Intensity and Visibility of Human Factors

They were rated for the amount of hazardous energy (operating load) for human factors and their ability to resist the passage of this energy through human elements. Red means low ability to resist hazard energy, orange is intermediate, and blue refers to high resistance. In this way the fingertip of the process failure is represented. At this time the visibility analysis was not addressed.

(6) Identify Hazard Enabling Factors and Failure Processes

After the human factors measurement identification, the hazard enabling Factors are indicated. Each human element is analyzed and applied a filter, how can see on Figure 4. Human factors and elements have inverted colors: high flow of hazard energy by human factors is red, low ability to resist the passage of hazard energy is red.

Human Factors: Competence (Comp); Cooperation (Coop); Risk; Complexity (Cpx); Leader; Stress; Behavior (Bhv); Communication (Comm).

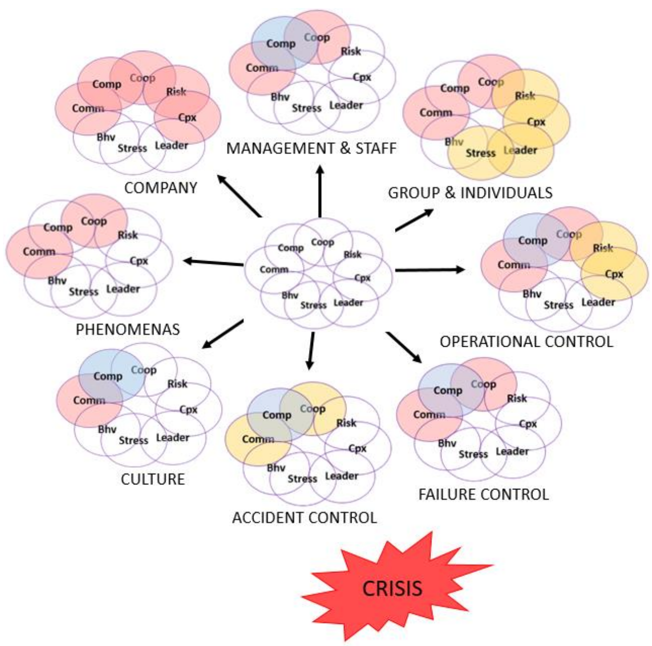

Figure 4 –Hazard Enabling Factors - distribution of resistances or facilities by network level

(7) Define Specific Bayesian Network Architecture with Intensity and Visibility

In this stage is elaborated the Specific Bayesian Network Architecture, Figure 5. In this structure, there are relations and connections between enabling ports.

This setting is dynamic and new factors may disappear or appear and improve or worsen resistance. Aspects such as technological and organizational changes are quite evident for these changes, on the other hand, change of culture and changes of social phenomena in the workplace are not easily visible making it difficult for safety culture makers.

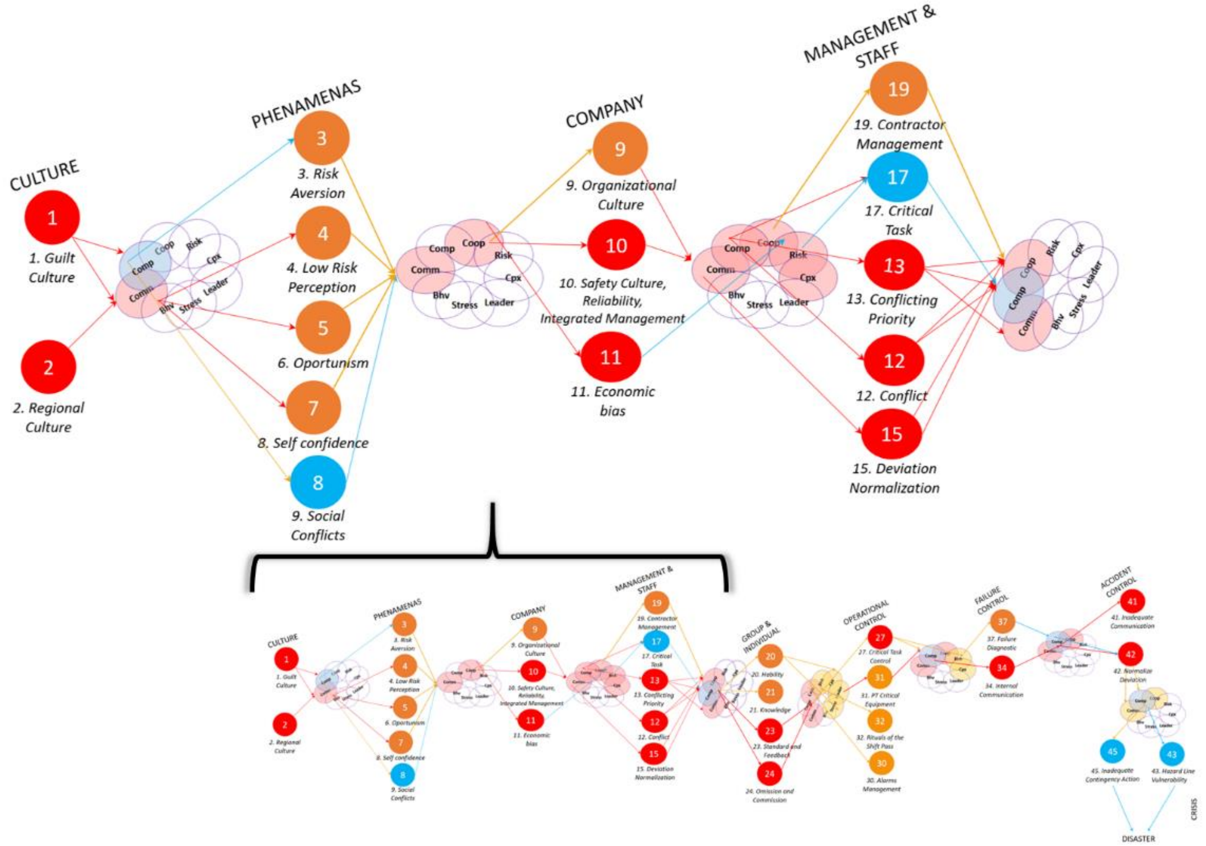

Figure 5 - Specific Bayesian Network Architecture

(8) Develop Algorithms for Failure Energy Calculation between Elements (degraded design) and Factors (operational events);

• Find the relationship between Operation Load and Project Resistance;
• Characterize between impact intensity and factor visibility;
• List project-related issues and operational condition;
• Measuring operator response and through at least 3 ways of addressing the same problem will come interpretations: principle, cognition and practice, job criterion - human errors, human factor management;
• The resultant of resistance to hazardous energy that can be degraded by the environment is the load, or operating pressure to prevent accident;
• Danger Energy Resistance and Load Rating;

Through the answers is indicated how to organize human factors and elements by intensity and visibility, Figure 6.

HUMAN ELEMENT PROJECT		PRINCIPLES*		COGNITION AND PRACTICES		WORKSTATION*		HUMAN FACTOR*	
		VISIBILITY	INTENSITY	VISIBILITY	INTENSITY	VISIBILITY	INTENSITY	VISIBILITY	INTENSITY
MANAGEMENT	LEADER								
	STRESS								
TECHNOLOGY	RISK								
	COMPLEXITY								
BEHAVIOR	COMPETENCE								
	COMMUNICATION								
	COMMITMENT								
	COOPERATION								
OBSERVATION:									

OPERATIONAL SITUATION HUMAN FACTOR		PRINCIPLES*		COGNITION AND PRACTICES		WORKSTATION*		HUMAN FACTOR*	
		VISIBILITY	INTENSITY	VISIBILITY	INTENSITY	VISIBILITY	INTENSITY	VISIBILITY	INTENSITY
CULTURE	FAULT								
	REGIONAL								
SOCIAL PHENOMENAS	RISK								
	RISL PERCEPTION								
	OPPORTUNITY								
	SELF CONFIDENCE								
	SOCIAL CONTROL								
COMPANY	ORGANIZATIONAL CONTROL								
	SECURITY CONTROL								
	ECONOMIC BIAS								
OBSERVATION:									

OPERATIONAL SITUATION HUMAN FACTOR		PRINCIPLES*		COGNITION AND PRACTICES		WORKSTATION*		HUMAN FACTOR*	
		VISIBILITY	INTENSITY	VISIBILITY	INTENSITY	VISIBILITY	INTENSITY	VISIBILITY	INTENSITY
OPERATIONAL CONTROL	TASK								
	EQUIPMENT								
	RITUALS								
	ALARM								
FAILURE CONTROL	DIAGNOSTIC								
	INTERNAL COMMUNICATION								
ACCIDENT CONTROL	INADEQUATE COMMUNICATION								
	DEVIATION STANDARDIZATION								
CRISIS	INADEQUATE CONTINGENCY								
	DANGER LINE								
OBSERVATION:									

Figure 6 - Design: Human Elements & Operation: Human Factors Chosen

4 Conclusions

Human elements are related to *design resistance* while human factors are related to failure or hazard energy during operation, or *operational charge*. This load is dynamic due to the workstation and the types of cultural and behavioral influence within the organizational environment. While resistance is embedded in static patterns that need to be revised due to: the influence of social phenomena, and the degradation of barriers (caused by time and physical attacks).

The operating routine is very dynamic. In this work, the different colors describe the inputs and outputs of the factors in a variable way, since the barriers for the passage of hazard energy interact with each other. Using a qualitative and quantitative methodology with a large challenge due to the dynamism of the process. Thus, for the Bayesian network to function and be validated, the dependence of design elements and human factors must be measured and related.

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