REPUBLIQUE ALGERIENNE DEMOCRATIQUE ET POPULAIRE
Ministère de l'Enseignement Supérieur et de la Recherche Scientifique
École Nationale Polytechnique

Departement: Risk Management Engineering
Speciality: QHSE-GRI
End Of Studies Project Thesis
in fulfilment of the requirements for: QHSE-GRI Engineer’s Degree

Improving Commitment to Process Safety Management within the Power Plant of CAP-DJINET

HARFOUF Ayoub
MOUMENE Raid

Directed by:

M A. KERTOUS	Assistant professor at ENP
M F. LEGUEBEDJ	Assistant professor at ENP

Presented and defended publicly on 25 - 07 - 2021 in front of the jury composed of:

President	Mr. M. BOUSBAI	Associate professor at ENP
Examiner	Ms. S. BENTAALLA	Associate professor at ENP
Examiner	Ms. M. FODIL	Associate professor at ENP
Supervisor	Mr. A. KERTOUS	Assistant professor at ENP
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SPE
CAP- DJINET

Département : MRIE
Filière : QHSE-GRI
Mémoire de projet de fin d'études
Pour l'obtention du diplôme d'ingénieur d'état en QHSE-GRI

Amélioration De L'engagement Process Safety Management Au Sein De La Centrale De Cap-Djinet

HARFOUF Ayoub

MOUMENE Raid

Sous la direction de :

M A. KERTOUS	Maître-Assistant (ENP)
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Présenté et soutenu publiquement le 25 - 07 - 2021 devant le jury composé de :

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Encadreur	F. LEGUEBEDJ	Maître-Assistant (ENP)

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Dedication

To those who want it

H. Ayoub

I dedicate this modest work, To my dear parents, for all their sacrifices and support throughout my studies.

M. Raid

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Our thanks go first to our advisors Mr. A. KERTOUS, assistant professor at the ENP and Mr. F. LEGUEBEDJ, assistant professor at the ENP, without whom this work would not have been possible. We thank them for their advice and their help at each stage of our work.

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We also thank Mrs. M.FODIL , associate professor at the National Polytechnic School of Algiers for having accepted to join this jury as examiner.

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We would also like to thank all of our professors in the MRIE department, for having provided us with guidance during these past years.

ملــخص :

ينصب تركيز هذا العمل على تحسين االلتزام بنظام إدارة سالمة العمليات (RBPS) داخل شركة توليد الطاقة (SPE) في رأس جنات . تعد ثقافة السالمة المرنة (RSC)نظام أمان اجتماعيًا تقنيًا يتكون من قدرات الموظفين مثل باإلضافة إلى البروتوكوالت وال نظمة في المنظمة. في دراستنا ، استخدمنا نهج البحث الكمي لتقييم مرونة الثقافة المنية. لذلك ، قمنا بتصميم استبيان لجمع البيانات التي ستكون بمثابة بيانات إدخال لنموذج ثقافة السالمة المرنة لتحديد مؤشر مرونة السالمة .

كلمات مفتاحية: العمليات ، السالمة ، RBPS،ثقافة السالمة ، المرونة ، التقييم.

Résumé :

Le foucus de ce travail est d'améliorer l'engagement au système de gestion de la sécurité des processus (RBPS) au sein de la société de production d'énergie de Cap-Djinet (SPE).

La culture de sécurité résiliente (RSC) est un système de sécurité socio-technique qui se compose des capacités des employés ainsi que des protocoles et des systèmes dans une organisation.Dans notre étude, nous avons utilisé une approche de recherche quantitative pour évaluer la résilience de la culture de sécurité.

Par conséquent, nous avons conçu un questionnaire pour collecter des données qui serviront de données d'entrée du modèle de culture de sécurité résiliente pour déterminer l'indice de résilience de la sécurité.

Mots clés : processus, sécurité, RBPS, culture de sécurité, résilience, évaluation.

Abstract:

The focus of this work is to improve commitment to the Process Safety Management System(RBPS) in the Cap-Djinet Power Production Company (SPE).

Resilient safety culture (RSC) is a socio-technical safety system that consists of employee capabilities as well as protocols and systems in an organization.In our study, we used a quantitativeresearch approach to assess the resilience of safety culture.

Therefore, we elaborated a questionnaire to collect data to serve as input data of the resilient safety culture model to determine the safety resilience index.

Key words: process,safety,RBPS,safety culture,resilience,assess.

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List of abbreviations:

BP: Behavioural preparedness

BRN: Broad resource network

CA: Counterintuitive agility

CCPS: Center for Chemical Process Safety

CFI: Confirmatry Factor Index

CO: Conceptual orientation

CSM: Constructive sense making

DP_A: Diffused power and accountability

DSC: Deep social capital

FTA: Fault tree Analysis

LR: Learned resourcefulness

LV: Latent Variable

MV: Measured Variable

NNFI: Normed Fit Index Tucker Lewis index

PH: Practical habits

PS: Psychological safety

RBPS: Risk-Based Performance Standards

RMSE: Root Mean Square Error of approximation (RMSEA),

RSC: Resilient Safety Culture

SPSS: Statistical Package for the Social Sciences

Introduction

For decades, some major accidents have occurred in highly reliable industries. Complex safety management systems and high-level safety culture may possibly help reduce the number of common accidents, but these classical methods may not be enough to prevent accidents and extraordinary accidents. Therefore, needs to adopt new standards such as process safety management system (RBPS) to improve the safety of these systems.

In a world where is dynamic change and the need to be always ahead of the competition and seek sustainability. The catastrophic losses in major accident pointed the need to go beyond traditional management systems that are more focused on continuous improvement which means that we are always going to be waiting for things to occur. We mention that no improvement can be made, if progress can't be measured.

In this light, to use safety culture more effectively in the ultra-secure system, a new concept of "resilient safety culture" is proposed. However, due to the lack of research and its qualitative nature, we are more interested in using numerical methods to quantitatively assess the safety culture of the system.

In the first two chapters we put our project into context and we highlight the research background and significance then we introduce Process Safety Management system (RBPS) and its pillars and take the first element which is process safety culture and we emphasize it.

In the third chapter we elaborate questionnaire based on Arun's Garg model and we test the reliability of the questionnaire and its consistency using Statistical Package for the Social Sciences (SPSS).

In fourth chapter we model the safety culture resilience and the data collected using questionnaire serve as input to our model, also we analyze goodness of fit of our model using confirmatory factor analysis.

In the fifth chapter we use intelligent analytics to automate the calculations process and design a work flow using Alteryx the connect the output of the workflow to Tableau then design a dashboard in order to have a better visualization of data.

Chapter 01

Context of The Project

Introduction

In this first chapter, we present the group Sonelgaz and the power plant of Cap Djinet, then we explain the research background and significance then we explain the purpose of the study then methodology used to achieve our objectives.

1.1. Presentation of the group Sonelgaz:

Sonelgaz is the historical operator in the field of electric and gas energy supply in Algeria. Created in 1969, Sonelgaz has been working for half a century to serve the Algerian citizen by providing him with this energy source essential to daily life.

With the promulgation of the law on electricity and gas distribution through pipelines, Sonelgaz went from a vertically integrated company to a holding company managing a multi-company and multi-trade industrial group.

The Sonelgaz Group is considered as one of the biggest employers in the industrial landscape. Indeed, its workforce has been growing steadily over the years. At the end of December 2018, the Sonelgaz Group employs 91,218 agents (including 65,749 permanent and 25,469 temporary), all socio-professional categories combined.

SONELGAZ is composed of three branches of activity: production, transport, distribution and marketing of electricity and gas, both in Algeria and abroad.

- **Production:**

it is the activity consisting in transforming the calorific or hydraulic energy into mechanical and then electrical energy.

- **Transport:**

this activity includes the transport of electricity and gas.

- **Electricity and gas distribution:**

consists of supplying all industrial customers and domestic subscribers.

Also, that SONELGAZ has always played a leading role in the economic and social development of the country. Its contribution in the realization of the national energy policy are commensurate with the significant achievement programs in rural electrification and public distribution of gas, which have raised the rate of coverage in electricity to over 99% and the penetration rate of gas to over 52%.

1.2. General description of the plant:

1.2.1. Presentation of the combined cycle power plant of CAP DJENAT:

The combined cycle power plant of RAS DJENET, is an electricity production plant, located at the seaside, east of Algiers, near the city of Boumerdes.

The choice of this site is made on the basis of the following criteria:

- **Proximity to important consumers, located in particular in the Rouïba-Reghaia industrial zone.**

- **Possibility of extension.**
- **Favorable underground conditions, does not require deep foundations.**

The combined cycle power plant of Cap Djinet, whose construction was decided in order to reinforce the electric power supply of the country, is mainly composed of three (3) modules of combined cycle power plant with single shaft (CCPP) as well as the systems which support the balance of the plant (BOP). Each module of the CCPP has one (1) gas turbine (Model: SIEMENS SGT5-4000F), one (1) associated HRSG, one (1) steam turbine (Model: SIEMENS SST5-3000 H-IL) and a common hydrogen cooled generator (Model: SIEMENS SGEN 5-2000 H) located on the same shaft between the gas turbine and the steam turbine.

The gas turbines are designed to burn natural gas as the base fuel and diesel fuel as the backup fuel.

1.2.2. **Description of the process:**

The electricity generation system is composed of two cycles, which explains its name of combined cycle.

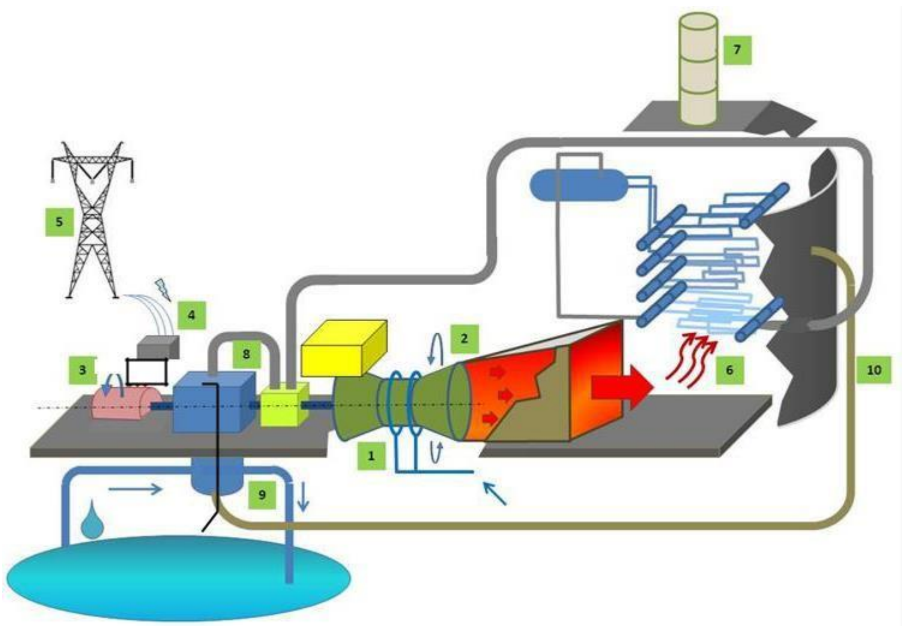

Figure 1-1 Process description

The first cycle is the gas turbine (1). This consists of four stages: in the first stage there is a compressor which compresses air to feed a second stage containing the combustion chamber where natural gas is burned. Once the combustion is completed, the hot gases turn the blades of the third expansion stage of the combustion turbine. The latter is attached to a shaft which drives an alternator (3) which produces electricity. The transformer (4) raises the voltage so that it can be fed into the electricity grid (5).

The second cycle takes place at the exit of the hot gases from the gas turbine (2). These gases are injected into a recovery boiler (6) and then discharged into the atmosphere through the chimney. Their composition is about 86% air, 9% water vapor and 4% CO_2. The steam produced in this boiler is used in a steam turbine (8), itself coupled to the alternator shaft (3). The steam, after having given back its energy, is sent to a condenser (9) to be sent back to the recovery boiler as water (10). This water is then vaporized again. The electrical energy supplied by the alternator will be evacuated through the alternator circuit breaker or group circuit breaker to then go to the main transformer which will see the voltage of 15,5KV to 400KV. After the main transformer TP, energy supplied will transit through the line circuit breaker (SF6 shielded station) to supply the 400KV network at the Affroun, Akbou and Si Mustapha stations. It should be noted that just before the TP transformer, part of the electrical energy produced is drawn off and fed into the TS draw-off transformer to transform the 22KV alternator output voltage into 6KV and thus supply the group's electrical auxiliaries. This is a self-supply of the group's own auxiliaries which will consume about 8MW per unit. We will therefore provide a unitary power BU (factory terminal) of 168 MW per unit. The total power supplied to the network.

1.3. purpose of the study:

Despite the efforts of organizations to improve safety performance, shortfalls of the strategies have been reported in numerous studies around the globe. However, previous studies in countries with more organized sectors show that adopting a resilient safety culture by organizations has a tendency of improving safety performance. As safety culture is dynamic which differs with contexts, the purpose of this study is to achieve two objectives: assessing safety culture and then determining the resilience of the safety culture in the thermal power plant of Cap Djinet; and determining the key components for ensuring the resilience safety culture of combined cycle power plant with regards to safety performance.

1.4. methodology:

in order to improve the commitment to CCPS process safety management system, quantitative research approach is used. Data was collected using a structured questionnaire. A total of 50 questionnaires were distributed to workers by safety manager to serve as respondents to the study the population of the study comprises managers engineers and operators within combined cycle power plant across the Northern region (Cap Djinet) in Algeria. Structural equation modeling (SEM) was used to assess resilience safety culture.

1.5. research background and significance:

The concept of resilient safety culture is making progress in research and practice. Several studies have emerged in recent years, emphasizing the need for a paradigm shift in the organization’s safety culture. The results of these studies provide information about the mechanisms by which resilient safety culture can take root in an organization. According to reports, different aspects of resilient safety culture have a positive impact on organizational safety performance. Resilience safety culture, which originates from the resilience engineering approach builds on the organization’s cognitive, behavioral and managerial capabilities to “anticipate, monitor and learn” to manage safety risks and build an ultra-safe organization [1]. The approach has been recognized as a potential solution to the lack of effectiveness of traditional safety management and safety culture approaches in responding to the changing and unforeseen safety risks associated with the increasingly complex nature of sociotechnical systems [2].

Chapter 02

Process Safety Management System (CCPS)

Introduction

In this chapter we will introduce process safety management system (RBPS) and its pillars with brief description of each pillar then we highlight the way from process safety system to safety culture and its importance in today's very dynamic industrial environment.

RBPS Guidelines:

2.6. RBPS Guidelines:

In general, the RBPS management system is meant to address process safety issues in all operations involving the manufacture, use, or handling of hazardous substances or energy.

2.6.1. Terminology

based on CCPS Risk based process safety management system we emphasize below several definitions of many terms of particular importance used within this project. [3]

2.6.1.1. Process Safety Management

A management system that is focused on prevention of, preparedness for, mitigation of, response to, or restoration from catastrophic releases of chemicals or energy from a process associated with a facility.

2.6.1.2. Risk-based process safety

RBPS is the CCPS's process safety management system approach that uses risk-based strategies and implementation tactics that are commensurate with the demand for process safety activities, availability of resources, and existing organizational culture to design, correct, and improve process safety management activities.

2.6.1.3. Effectiveness

Effectiveness is the combination of process safety management performance and process safety management efficiency. An effective process safety management program produces quality results with minimum consumption of resources.

2.6.1.4. Improvement

Improvement means doing better in performance or efficiency, or both, with respect to a starting point or a goal.

2.6.2. Process safety management (RBPS):

Risk Based Process Safety Management Guidelines help organizations design and implement and improve more effective process safety management systems. These Guidelines provide methods and ideas on how to design a process safety management system, correct a deficient process safety management system, or improve process safety management practices. The RBPS approach recognizes that all hazards and risks in an operation or facility are not equal; consequently, apportioning resources in a manner that focuses effort on greater hazards and higher risks is appropriate. Using the same high intensity practices to manage every hazard is an inefficient use of scarce resources. A risk-based approach reduces the potential for assigning an undue amount of resources to managing lower-risk activities, thereby freeing up resources for tasks that address higher-risk activities. This approach is a paradigm shift that will benefit all industries that manufacture, consume, or handle hazardous chemicals or energy by encouraging companies to:

- Evolve their approach to accident prevention from a compliance-based to a risk-based strategy.
- Continuously improve management system effectiveness.
- Employ process safety management for non-regulatory processes using risk-based design principles.
- Integrate the process safety business case into an organization's business processes.
- Focus their resources on higher risk activities.

This new framework for process safety(2007) builds upon the original process safety management ideas published by the CCPS in the late 1980s, integrates industry lessons learned over the intervening years, applies the management system principles of "plan, do, check, act", and organizes them in a way that will be useful to all organizations - even organizations with relatively lower hazard activities - throughout the life cycle of a process or operation. An RBPS management system addresses four main accident prevention pillars.

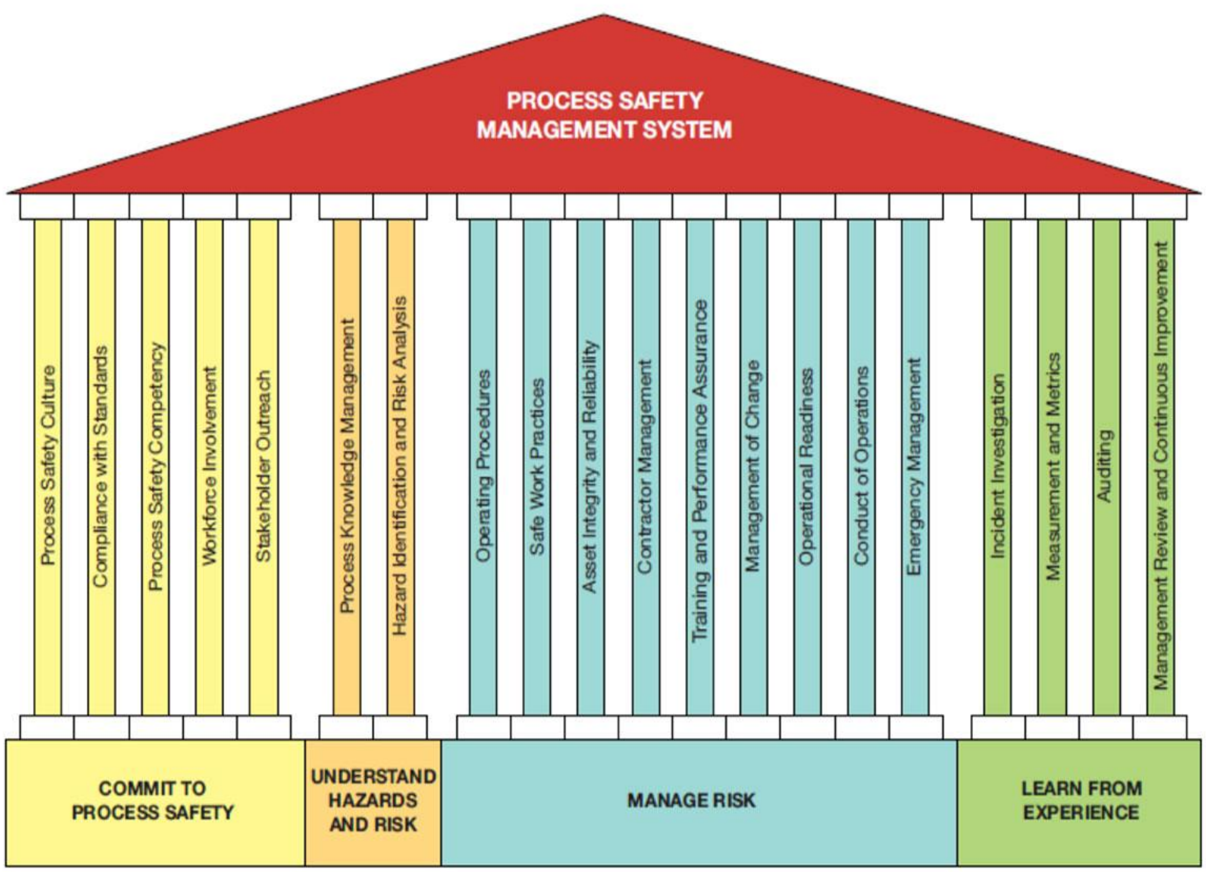

Figure 2-1 Process safety management system pillars and elements

2.6.3. **RBPS management system four main pillars:**

Risk-based process safety (RBPS) is based on four pillars:

2.6.3.1. **commitment to process safety:**

Is the cornerstone of process safety excellence. Management commitment has no substitute. Organizations generally do not improve without strong leadership and solid commitment. The entire organization must make the same commitment. A workforce that is convinced mat the organization fully supports safety as a core value will tend to do the right things, in the right ways, at the right times, even when no one is looking. This behavior should be consistently nurtured, and celebrated, throughout the organization. Once it is embedded in the company culture, this commitment to process safety can help sustain the focus on excellence in the more technical aspects of process safety.

2.6.3.2. **understand hazards and risk:**

make organizations able to better allocate limited resources in the most effective manner. Industry experience has demonstrated that businesses using hazard and risk information to plan, develop, and deploy stable, lower-risk operations are much more likely to enjoy long term success.

2.6.3.3. **Managing risk:**

focuses on three issues: prudently operating and maintaining processes that pose the risk, managing changes to those processes to ensure that the risk remains tolerable, and preparing for, responding to, and managing incidents that do occur. Managing risk helps a company or a facility deploy management systems that help sustain long-term, incident-free, and profitable operations.

2.6.3.4. **Learning from experience:**

involves monitoring, and acting on, internal and external sources of information. Despite a company's best efforts, operations do not always proceed as planned, so organizations must be ready to turn their mistakes - and those of others - into opportunities to improve process safety efforts.

The least expensive ways to learn from experience are to apply best practices to make the most effective use of available resources, correct deficiencies exposed by internal incidents and near misses, and apply lessons learned from other organizations. In addition to recognizing these opportunities to better manage risk, companies must also develop a culture and infrastructure that helps them remember the lessons and apply them in the future. Metrics can be used to provide timely feedback on the workings of RBPS management systems, and management review, a periodic honest self-evaluation, helps sustain existing performance and drive improvement in areas deemed important by management. Focusing on these four pillars should enable an organization to improve its process safety effectiveness, reduce the frequency and severity of incidents, and improve its long-term safety, environmental, and business performance.

2.6.4. Commit to Process Safety:

commit to process safety is the first pillar, this pillar is supported by five RBPS elements. The element names, along with the short names used throughout the RBPS Guidelines, are:

2.6.4.1. Process Safety Culture:

Developing, sustaining, and enhancing the organization's process safety culture is one of five elements in the RBPS pillar of committing to process safety. This chapter describes what process safety culture means, what the attributes of a sound culture are, and how organizations might begin to enhance their own culture.

2.6.4.2. Compliance with Standards:

Identifying and addressing relevant process safety standards, codes, regulations, and laws over the life of a process is one of the five elements in the RBPS pillar of committing to process safety. Maintaining adherence to applicable standards, codes, regulations, and laws (standards), the attributes of a standards system, and the steps an organization might take to implement the standards element. List of work activities that support these essential features and presents a range of approaches that might be appropriate for each work activity, depending on perceived risk, resources, and organizational culture. for improving the effectiveness of management systems and specific programs that support this element, metrics could be used to monitor this element, and management reviews may be appropriate.

2.6.4.3. Process Safety Competency:

Is related to the knowledge and training elements of the RBPS system the competency element involves increasing the body of knowledge and, when applicable, pushing newly acquired knowledge out to appropriate parts of the organization, sometimes independently of any request.

2.6.4.4. Workforce Involvement:

Promoting the active involvement of personnel at all levels of the organization is one of five elements in the RBPS pillar of committing to process safety. addressing the diversity of worker’s roles can fulfill in support of process safety management system development, implementation, and enhancement.

2.6.4.5. Stakeholder Outreach:

Having good relationships with appropriate stakeholders over the life of a facility is one of the five elements in the RBPS pillar of committing to process safety. A process for identifying, engaging, and maintaining good relationships with appropriate external stakeholder groups (outreach) should be in place; the attributes of an outreach system and the steps an organization might take to implement outreach depend on perceived risk, resources, and organizational culture.

2.7. Process safety versus Occupational safety:

Process safety includes the prevention of unintentional releases of energy, chemicals or other hazardous materials; whereas occupational safety generally refers to classic health and safety, normally associated with the prevention of trips, slips and falls. Process safety can be complicated to understand by people external to it and needs clear and concise communication to succeed; occupational safety is easier to understand because it affects us all. Understanding the importance of occupational safety is easy, we are all taught at a young age not to run with scissors! Understanding the details of process safety often requires complex technical knowledge that we as engineers need to work hard to translate to ensure it is understood.

Process safety considers the consequences of accidents at the human so it protects workers and the public alike, environmental and business level this is why the consequences of not implementing process safety can be far reaching, affecting people living locally to the site or even consumers. Negligence can have a wide impact.; occupational safety considers consequences at a human level only. [4]

2.7.1. **Safety:**

Safety is defined as the absence of accidents where accident is an event which lead to unacceptable loss [5].Product designs used to be manageable because the interactions of the components were well understood, but today it's becoming more difficult owing to the system's complexity. This increased complexity has resulted in new issues. Because there is no complete control over the socio-technical system, complexity is ignored when creating safety solutions [1]. Most systems used traditional risk management strategies to deal with risks in the past, which were based on prior experience, failure reporting, and risk assessments based on historical data. Organizational issues, functional performance variations, and unanticipated outcomes are now being blamed.

2.7.1.1. **Organizational culture:**

Organizational culture gives way to safety culture [6] When individuals interact, this word is used to describe behavioural patterns, formal philosophy, game rules, organizational atmosphere, embedded skills, and cognitive paradigms [7]. Several research on safety culture have been conducted, but it is clear that safety culture is not fully understood because many writers define safety culture differently or use some terminology interchangeably.

Safety management, safety climate, and safety culture are all concepts that are used interchangeably and make the precise meaning of safety culture ambiguous. The safety atmosphere is influenced by the safety culture [7]. Safety management is a written and institutionalized risk-control strategy, but it cannot reflect actual practice. The term "safety culture" is used in this context. The deployment of safety management resources, methods that represent the actual work environment, is influenced by the safety culture.

2.7.1.2. **Safety culture:**

Safety culture diverges from organizational culture. kinds of behavior patterns, formal philosophies, game rules, organizational atmosphere, comprehensive skills, habits of thinking, and paradigms when people interact [7]. There are many studies on safety culture, but it is found that safety culture is not fully understood because many authors have different definitions of safety culture or some terms are interchangeable. Safety culture is divided into subcultures, as shown in Figure 1, which shows the interrelationships between different cultures. There are some terms that can be used interchangeably to obscure the exact definition of safety culture, namely safety management, safety atmosphere and safety culture, but they are all different. The security atmosphere depends on the security culture [7]. safety management is documented and is a standardized risk control system, but the actual safety management system does not reflect the actual situation. This is where the term safety culture is used. It is the safety culture that influences the deployment of safety management resources and represents the actual work environment procedures.

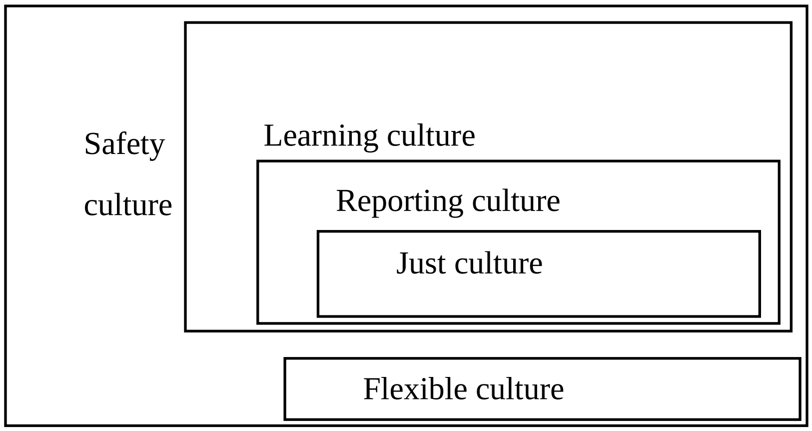

Figure 2-2 Safety culture and its relationship with other culture types [8]

2.7.2. **Why safety management systems and safety culture:**

The vision of a safety culture should be to ensure that the organization has the essential elements in place that make it resilient to hazard and associated risk. Not only must it be resilient to hazards inherent in its operations and routine activities, it must be resilient to the ongoing changes in the organizational business climate. It must maintain a safety culture in spite of changes in leadership, management style, personnel, technology, and all aspects of what goes into an organization's survival and success. A culture can be dynamic, static, evolving, or restrictive. Safety culture, which we will discuss, is the essence of an organization and determines how it makes decisions, maintains or loses direction and coherency, and meets its objectives. Unless the safety professional understands the safety management system and safety culture, probability for long-term success will be restricted. One of the initial perceptions that must be overcome is the idea that safety programs are permanent. Their intent may be to incorporate fundamental principles, but the environment in which they are used is ever changing—people change, conditions change, budgets change, management direction changes, etc. At the same time, a culture changes slowly and adjust to these ever-changing conditions. If the safety process does not take into account what safety culture is, safety efforts, while well intentioned, will be resisted just as a body resists a virus.

2.7.3. **Safety Culture and Major Accidents:**

There is little doubt that safety culture is a much-discussed subject across the high hazards industries and is seen by many to offer a possible solution to avoiding the conditions that pave the way for a major accident. In table 1 below are some events that the investigations have found clear indication of defective safety culture.

Event	Brief Description	Indication of defective safety culture
Chernobyl (1986)	On Monday, April 28, 1986, at 1:24 an experiment to check the use of the turbine during rundown as an emergency power supply for the reactor went catastrophically wrong.	No indication that a risk assessment preceded the test. High demand to increase production that put pressure on the experimenting team.
Challenger (1986)	The Space Shuttle Challenger disaster occurred on January 28, 1986, when the NASA Space Shuttle orbiter Challenger (OV099) broke apart 73 seconds into its flight.	NASA managers had known contractor Morton Thiokol's design of the SRBs contained a potentially catastrophic flaw in the O-rings since 1977, but failed to address it properly.
Columbia (2003)	The Space Shuttle Columbia disaster occurred on February 1, 2003, when Columbia disintegrated over Texas and Louisiana as it re-entered Earth's atmosphere.	The position of Shuttle Program Manager, where one individual was responsible for achieving safe, timely launches and acceptable costs, which are often conflicting goals.
Texas City (2005)	On March 23, 2005, a massive explosion occurred at the BP Texas City Refinery, in Texas City.	Miscommunication problem – at a management meeting held on the morning the start-up was scheduled to take place, the decision was made not to proceed, because the storage tanks that received the heavy liquid were full. However, operators were not told of this decision and went ahead with the startup, as originally planned. Further to this, at shift handover the operators log book was brief and uninformative and there was no oral communication either.
Buncefield (2005)	Sunday December 11, 2005, the Buncefield Oil Storage Depot in Hertfordshire, United Kingdom, had a series of explosions with at least one very large explosion.	A culture developed where keeping operations going was more important than safe processes, which did not get the attention, resources or priority status they required.
Macondo (2010)	On the evening of 20 April 2010, a 'well control event' allowed hydrocarbons to escape from the Macondo well onto Transocean's Deepwater Horizon oil rig in the Gulf of Mexico.	Managers misread pressure data and gave their approval for rig workers to replace drilling fluid

Table 2-1 Safety culture and major accidents

Note: You will find a simplified diagram of these events in Appendix E.

2.7.4. **Resilient safety culture:**

Resilient safety culture is a new concept which has been proposed in order to cover the weaknesses of safety culture. It is a safety culture with resilience, learning, continuous improvements and cost effectiveness [1]. Resilient safety culture is based on three factors:

2.7.4.1. **Psychological/cognitive capability:**

Psychological/ cognitive capabilities of organizational resilience is based on constructive sense making and conceptual orientation [9]. shows the network of psychological/ cognitive resilience of an organization. Organizations can foster a positive, constructive conceptual orientation through a strong sense of purpose, core value, a genuine vision and a deliberate use of language [10]. Strong core values coupled with sense of purpose and identity encourage an organization to frame conditions in ways that enable problem solving and action rather than in ways that lead to either threat rigidity or dysfunctional escalation of commitment [10]. Constructive sense making enables firms and employees to interpret and provide meaning to unprecedented events. Collective sense making relies on language of organization to construct meaning, describe situations and imply both understanding and emotion. It requires attitude that balances the contradictory forces of confidence and expertise against skepticism, caution and search for new information. Each situation is unique and contains features that may be subtle but that can be powerful in shaping consequences, relations and actions [11]The mindset that enables a firm to move forward is blend of expertise, opportunism, creativity and decisiveness despite uncertainty. Cognitive foundations require a strong knowledge on reality and desire to question fundamental assumptions. The ability to conceptualize solutions which are novel and appropriate is desired [12].

2.7.4.2. **Behavioural capability:**

Behavioural capability is based on behavior which helps get rid of any problems they face with their own ability and resources. Learned resourcefulness, ingenuity and bricolage are all the characteristics which are needed to cope with various challenges [10] [9]. It can be developed using practiced resources fullness and counterintuitive agility along with useful habits and behavioural preparedness [12]. The ability to follow dramatically different course of action from what is the norm is behavioural elements of organizational resilience. Behavioural resilience also relies on development of practical habits which are useful which provide first response to an unexpected threat. Organization which develop values that lead to habit of investigation as compared to assumption, routines of collaboration rather than antagonism and traditions of flexibility rather than rigidity. Behavioural preparedness helps bridge gap between divergent forces of learned resourcefulness and counterintuitive agility and convergent forces of useful habits. It also means organization learns from situations that emerge and unlearns obsolete information.

2.7.4.3. **Managerial/contextual capability:**

Managerial / contextual capability of organizational resilience requires relationships within and outside an organization to facilitate effective responses to environmental complexities. It contains psychological safety, deep social capital, diffuse power and accountability and broad resource networks [9] [12]. Psychological safety is the degree to which people perceive their work is conductive to taking interpersonal risks. When people perceive psychological safety, they are more willing to take these risks. Climate of psychological safety need to be established for organizational resilience [13]. Deep social capital evolves from respectful interactions within the organizational community. Interactions which are rooted in trust, honesty and self-respect. These interactions build informal intimacy and creates collaborative sense making. It facilitates growth in intellectual capital. Also, it enhances resource exchange. It also eases cross functional collaboration between different kinds of people in an organization. It enhances deep bonds beyond immediate transactions and creates long term partnerships. Finally, it creates network of support and resources [11]. Diffused power and accountability are another factor associated with creation of managerial resilience. Resilient organizations are not managed by hierarchical structures but by self-organization which create holographic structure where each part is small replica of the whole organization. Resilient individuals have ability to forge relationships with others likewise resilient firms share relationships with supplier and strategic alliances for sharing resources. Resources gained through the network sharing promotes an assortment of interpretations for alternative applications of these resources. This leads to innovation leading to cultivation of constructive sense making [12]. Figure 2-3 shows the network of safety resilience in an organization.

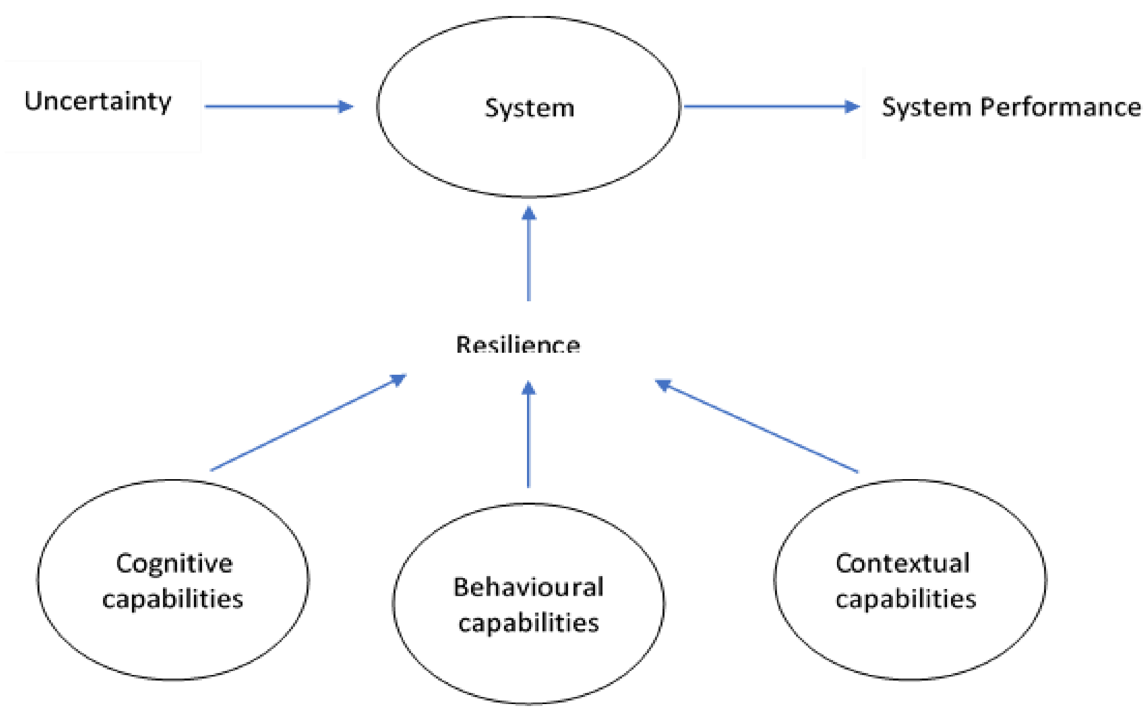

Figure 2-3 The network of resilient safety culture [14]

Chapter 03

Questionnaire Elaboration

Introduction

To gather information from respondents in order to assess the resilience safety culture, questionnaires provide a relatively cheap, quick and efficient way of obtaining large amounts of information from a large sample of people. Data can be collected when interviews would be impractical once the data are collected, we analyze the respondent’s answers using statistical tests to check validity and reliability of the questionnaire.

3.1. Questionnaire elaboration:

We elaborated the safety culture questionnaire to assess safety culture resilience based on Arun Garg 42 elements [14], these 42 are grouped in three constructs. The first is the Psychological capability (just culture) which has 2 subconstructs: Conceptual orientation, Constructive sense making. The second is the Behavioural capability (reporting culture) which has 4 subconstructs: Learned resourcefulness, Counterintuitive agility, Practical habits, Behavioural preparedness. The third is the Managerial capability divided in 4 subconstructs: Deep social capital, Broad resource network, Psychological safety, Diffused power and accountability. 50 questionnaires were distributed to employees (engineers, operators, managers), Likert scale from 1-5 was used, where 1 on the low side or lower agreement and 5 on the higher side or higher agreement.

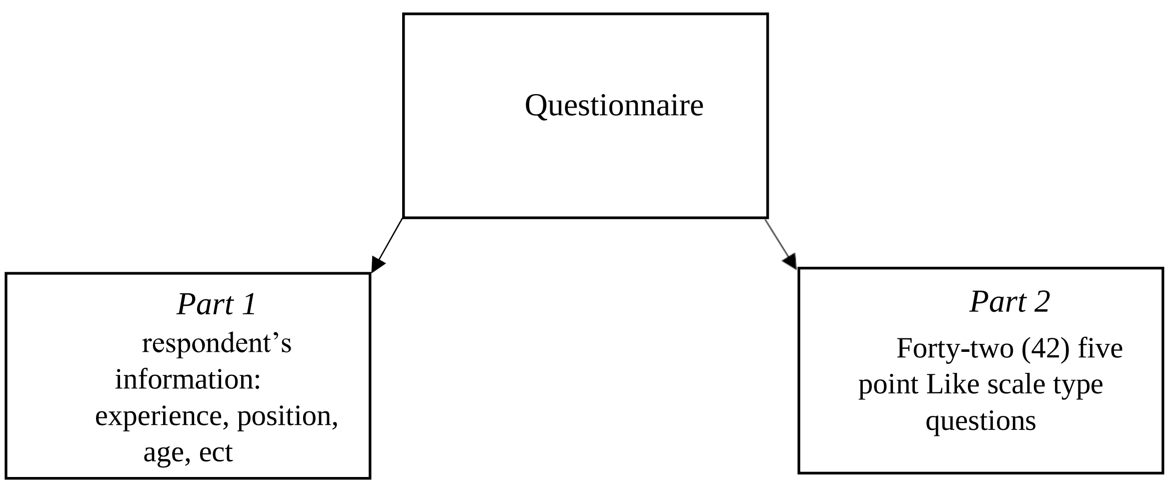

Figure 3-1 Questionnaire parts

3.2. Method

Quantitative research approach was used in addressing the objectives of the study. Data was collected using a structured questionnaire elaborated in two parts. The first part inquired about the demography of the respondents and their position within organization. The second part inquired about the safety culture elements [14]. The questionnaire consisted of a total of 42 Likert-type questions.

3.2.1. Population and sample:

The sample for this analysis was derived from workers that completed the safety culture questionnaire as part of the improvement of commitment to process safety management system. The fifty (50) questionnaires distributed clearly stated that the anonymity is a high priority and they answer voluntarily to ensure the reliability and consistency of the results. Thirty-eight questionnaires received after being completed by employees.

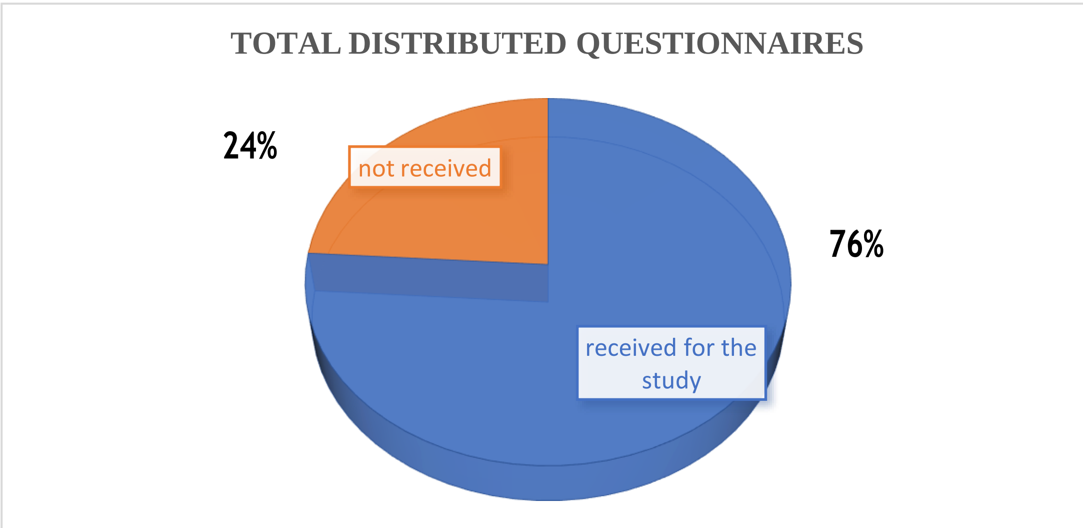

Figure 3-2 pie chart of total distributed questionnaires

3.2.2. Questions

Our study consisted of forty-two (42) Likert-type questions, which were adopted from the Arun Garg elements [14] dealing with different aspects of resilient safety culture. Each question from the survey elaborated has the correspondent element. (see Appendix A for an illustration of the questionnaire and scale elaboration).

3.2.3. Likert scale:

Likert scale are widely used in survey research and it is very powerful tool to collect data. The validity of quantitative research is a measured validity. Thus, the instrument which is used to collect data on the variables measured is important. Some variables are not directly observable or measurable. Instead, they are measurable through behaviors and actions, data can be acquired using a questionnaire. to measure such variables. The scale was introduced by Likert (1932) and consists of a series of questions which are considered as indicators. However, many scholars have argued that naturally, in the Likert scale, the choice or answer is only the data organized on an ordinal or categorical scale [15] and this means that the non-parametric tests could be more suitable for Likert scale.

1	2	3	4	5
Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

Figure 3-3 Five-point Likert scale

3.2.3.1. Parametric tests versus non parametric tests:

Nonparametric tests are more robust than parametric tests. In other words, they are valid in a broader range of situations (fewer conditions of validity) but the advantage of using a parametric test instead of a nonparametric equivalent is that the we will have more statistical power than the non-parametric ones. In other words, a parametric test is more able to lead to prove that the results are not due to chance. Most of the time, the p-value associated to a parametric test will be lower than the p-value associated to a nonparametric equivalent that is run on the same data; and to justify the use of parametric tests on data, the two sets of tests have the same error type which is type 1 [16].

3.2.4. Measures:

For the statistical analysis, SPSS 23.0 was used. Exploratory factor analysis was used to examine the construct validity of the safety culture questionnaire.38 questionnaire were analyzed.

3.2.4.1. Data inspection:

we inspected data we have and found that there are some missing answers for each question, as shown in table below:

Element/ question	X2	X3	X12	X27	X28	X30	X31	X38	X39	X40	X41	X42
Missing	2	3	4	4	3	3	3	3	3	3	3	3
Missing%	4.00%	6.00%	8.00%	8.00%	6.00%	6.00%	6.00%	6.00%	6.00%	6.00%	6.00%	6.00%

Table 3-1 Data inspection for questions

After inspecting each element/question we inspected missing answers for each questionnaire, as shown in table below:

Questionnaire	Missing answers	Percentage (%)
Number 9	1	2%
Number 10	4	10%
Number 13	1	2%
Number 16	2	5%
Number 17	9	21%
Number 22	1	2%
Number 28	1	2%
Number 29	9	21%
Number 32	2	5%
Number 33	1	2%
Number 35	2	5%
Number 36	1	2%
Number 38	3	7%

Table 3-2 Data inspection for questionnaires

From table above we see that there is two (2) questionnaires were missing answers exceed 20% so we exclude these questionnaires from the analysis as good practice and to avoid research bias.

3.2.4.2. Data cleansing:

In such type of data, data cleansing is crucial step for further analysis because it allows us to avoid incoherent results, in our data there was some missing values so we replaced the missing values using SPSS by the median nearby point as best practice.

3.2.5. Reliability and consistency:

To assess resilience safety culture using quantitative assessment approach like in our case, it is important to highlight the necessity of reliable and consistent input data.

3.2.5.1. Cronbach's alpha:

Cronbach's alpha reliability coefficient is used normally ranges between 0 and 1, the closer Cronbach's alpha coefficient is to 1.0 the greater the consistency of the items in the scale. We analyzed the Cronbach' α of all questionnaire then by construct and subconstruct and the results are shown in table below:

Cronbach's α total item	Cronbach's α For construct	Cronbach's α for subconstruct	elements/questions	abbreviation
		0.4	X1 X2 X3 X4	CO
	0.7	0.7	X5 X6 X7 X8 X9	CSM
		0.8	X10 X11	LR
0.959		0.8	X12 X13 X14 X15	CA
		0.9	X16 X17 X18 X19 X20	PH
	0.9	0.8	X21 X22 X23 X24	BP
		0.8	X25 X26 X27 X28 X29 X30	DSC
		0.8	X31 X32 X33 X34	BRN
		0.9	X35 X36 X37 X38	PS
	0.9	0.7	X39 X40 X41 X42	DP_A

Table 3-3 Cronbach'α results

Interpretation: Cronbach's α greater than(>) 0.7 is acceptable for this kind of research and our results show that there is high reliability of the questionnaire with α = 0.959 .also for subconstructs all of them were higher or equal to 0.7 except the conceptual orientation subconstruct which was 0.4 but this is not limitation to our study because the overall Cronbach's α is high enough .

3.2.6. Best practice:

After collecting the questionnaires, the researchers required a reference or criterion for comparing all the resilience safety culture indicators with the questionnaire. Although resilience safety culture elements for subconstructs were compared, it was not enough since it is believed that the plant is not able to recognize its weaknesses. As there is no reference in the literature, a reference questionnaire elaborated by [17] was used. This reference questionnaire was used as the best practice with regard to the safety experts and statisticians' comments.

3.2.6.1. The Measurement Problem:

In order to know that we are resilient is safety culture – not just subjectively, but also objectively or practically – industry and society need some way of demonstrating the presence of safety culture. In practice this means that there must be some way of quantifying safety culture. Strictly speaking, it must be possible to confirm the presence of safety culture by means of intersubjective verification. To the extent that safety culture is an external, public phenomenon, the way in which it is experienced and described by one individual must correspond or be congruous with how it is experienced and described by other individuals. In other words, it must be possible for different individuals to talk about safety culture elements in such a manner that they can confirm that they understand it in the same way. It must specifically be possible for an individual carefully to describe safety culture components so that others can confirm or verify that their experiences of the phenomenon, their understanding of safety culture, 'fits' the description. It is not just a question of whether people recognize the term 'safety culture' and subjectively experience that they know what it means. Intersubjective verification means going beyond the lack of disagreement ('I don't know what this means') to an explicit act of communication in order to establish that the term is not just recognized but that it actually means the same to two or more people.

3.2.6.2. Strength and limitations of the study:

There is no full control over the socio-technical system, complexity is not taken into consideration when designing the safety systems [1]. a limitation that is recurrent in the literature is the nature of the self-report of the questionnaire.

Conclusion

The reliability and consistency of the questionnaire is the key corn stone of sociotechnical studies, statistical tests applied on this questionnaire such as the reliability test (Cronbach's alpha) which was highly significant allow as to proceed for further application on safety culture modelling and this what chapter four is about.

Chapter 04

Resilient safety culture model

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Introduction:

In this chapter we will model the resilient safety culture of the received data set using quantitative assesment approach in order to measure improvement because no improvement can be made if progress can't be measured.

4.1. Structural equation modelling

Structural equation modelling (SEM) is a methodology for representing, estimating, and testing a network of relationships between variables (measured variables and latent constructs).

Since modelling of Socio-technical Systems is still in the research phase, fixing a theoretical model is important for further studies.

Analysing research data and interpreting results can be complex and confusing. Traditional statistical approaches to data analysis specify default models, assume measurement occurs without error, and are somewhat inflexible. However, structural equation modelling requires specification of a model based on theory and research, is a multivariate technique incorporating measured variables and latent constructs, and explicitly specifies measurement error. A model (diagram) allows for specification of relationships between variables.

4.1.1. The purpose of the model:

in the most common form of SEM, is to account for variation and covariation of the measured variables (MVs). Path analysis (e.g., regression) tests models and relationships among MVs. Confirmatory factor analysis tests models of relationships between latent variables (LVs or common factors) and MVs which are indicators of common factors. Special cases of SEM are regression, canonical correlation, confirmatory factor analysis.
definition

4.1.1.1. Definitions :

- A **model** is a statistical statement about the relations among variables.
- **Specification** is formulating a statement about a set of parameters and stating a model.
- A **measured variable** (MV) is a variables that is directly measured whereas a latent variable (LV) is a construct that is not directly or exactly measured.
- A **latent variable** could be defined as whatever its multiple indicators have in common with each other. LVs defined in this way are equivalent to common factors in factor analysis and can be viewed as being free of error of measurement.

4.1.1.2. Maximum Likelihood Estimation :

ML is the default for many model-fitting programs, ML estimation is simultaneous, estimates are calculated all at once. If the estimates are assumed to be population values, they maximize the likelihood (probability) that the data (the observed covariances) were drawn from the population (the expected covariances). Maximum likelihood estimation methods are appropriate for nonnormally distributed data and small sample size. We were able to use it in different estimations after testing the nonnormally distribution of variables in the used model.

Fit indices indicate the degree to which a pattern of fixed and free parameters specified in the model are consistent with the pattern of variances and covariances from a set of observed data.

Examples of fit indices are chi-square, CFI, NNFI, RMSEA, Which were estimated to confirm the degree of fitting of the factors.

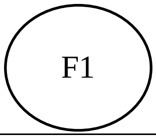
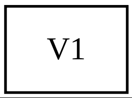
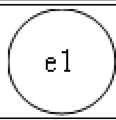
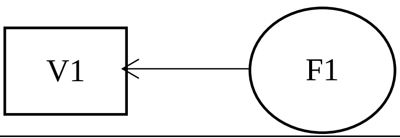
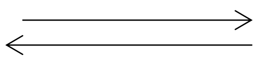
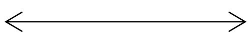
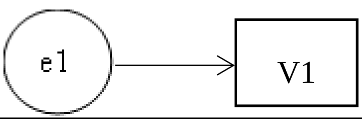
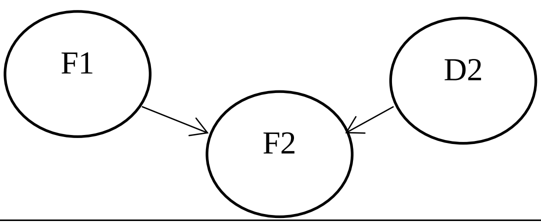
Diagram Symbols	Meaning of Symboles
	latent construct (F1), factor, unmeasured variable
	measured variable (V1), observed variable
	Error (e1)
	path coefficient for regression of a latent variable (F1) on an observed variable (V1)
	Direct relationship
	Covariance or correlation
	error (e1) associated with measured variable (V1)
	path coefficient for regression of one latent variable (F1) onto another latent variable (F2), residual error (D2) in prediction of F2 by F1.

Table 4-1 Structural equation modeling

4.1.1.3. SEM process:

A suggested approach to SEM analysis proceeds through the following process: [18]

1. review the relevant theory and research literature to support model specification
2. specify a model (e.g., diagram, equations)
3. determine model identification (e.g., if unique values can be found for parameter estimation; the number of degrees of freedom, df, for model testing is positive)
4. select measures for the variables represented in the model
5. collect data
6. conduct preliminary descriptive statistical analysis (e.g., scaling, missing data, collinearity issues, outlier detection)
7. estimate parameters in the model assess model fit

8. respecify the model if meaningful
9. interpret and present results.

4.2. Quatitative assessment aproach:

Resilient safety culture was modelled by Arun Garg in 2019 to be able to identify where the weakness lies in the safety culture. In this paper, resilient safety culture is identified using three sub systems and associated factors as gathered from published literature.

This model allows for calculating the relative probability of safety culture using the three sub-systems which in turn are interrelated using parallel and progressive relationships. Details will be shown next as defined by the researcher.

Resilient safety culture is based on three factors:

1) Psychological/cognitive capability

2) Behavioural capabilities

3) Managerial/contextual capabilities to anticipate, monitor, respond and learn in order to manage risks in a resilient organization.

These three constructs are based on ten sub-constructs as shown in figure below and those sub-constructs are constituted of 42 elements with an unequal number of elements under each sub-construct.

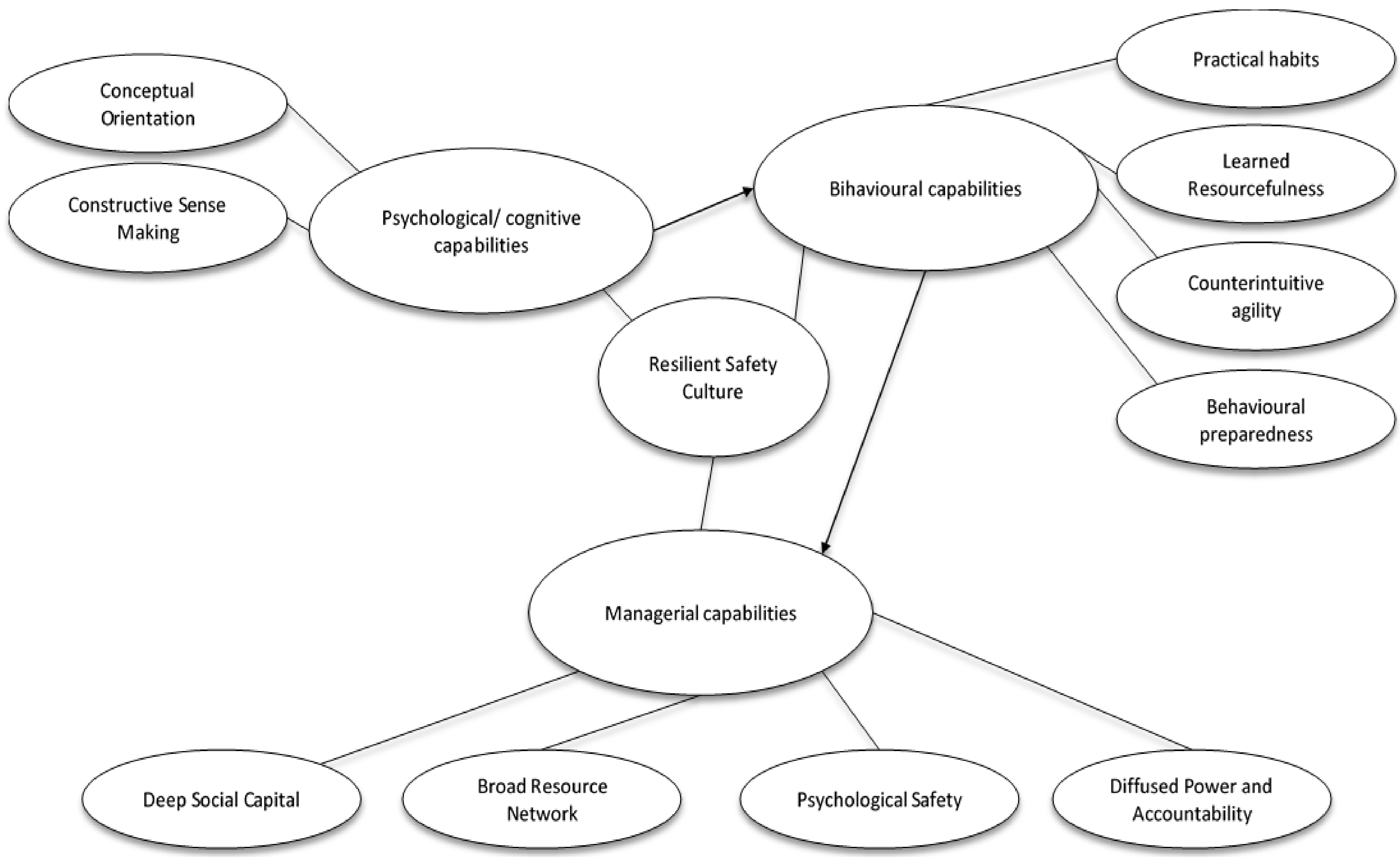


Figure 4-1 The network of resilient safety culture its constructs and sub-constructs

4.2.1. Psychological capabilities

Psychological/ cognitive capabilities of organizational resilience is based on constructive sense making and conceptual orientation.

Figure 4-2 shows the network of psychological/ cognitive resilience of an organization.

Organizations can foster a positive, conceptual orientation through a strong sense of purpose, core value, a genuine vision and a deliberate use of language.

Strong core values coupled with sense of purpose and identity encourage an organization to frame conditions in ways that enable problem solving and action rather than in ways that lead to either threat rigidity or dysfunctional escalation of commitment.

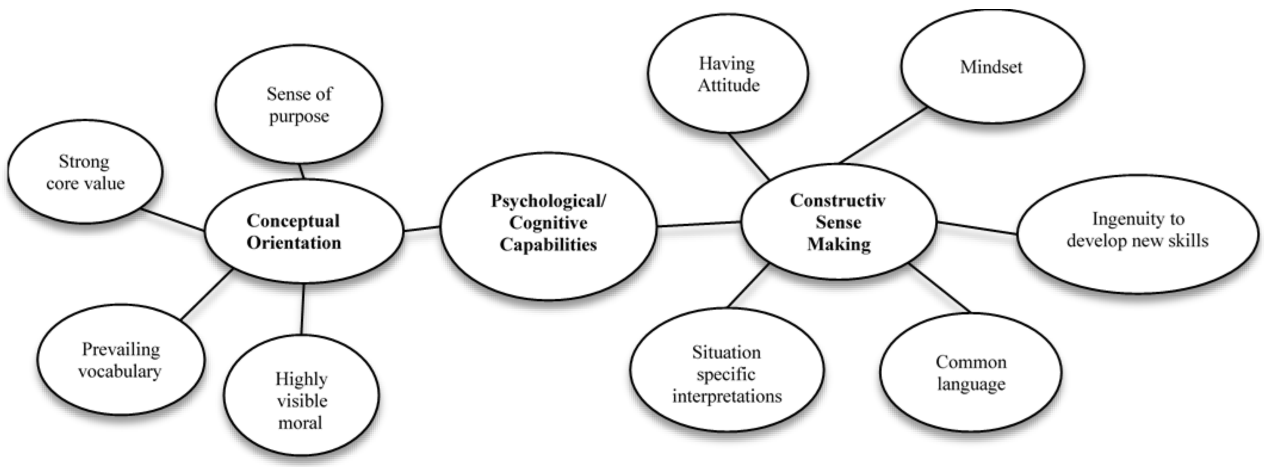


Figure 4-2 The network of cognitive capabilities of an organization

Constructive sense making enables firms and employees to interpret and provide meaning to unprecedented events. Collective sense making relies on language of organisation to construct meaning, describe situations and imply both understanding and emotion. It requires attitude that balances the contradictory forces of confidence and expertise against scepticism, caution and search for new information. Each situation is unique and contains features that may be subtle but that can be powerful in shaping consequences, relations and actions. The mindset that enables a firm to move forward is blend of expertise, opportunism, creativity and decisiveness despite uncertainty. Cognitive foundations require a strong knowledge on reality and desire to question fundamental assumptions. The ability to conceptualize solutions which are novel and appropriate is desired.

4.2.2. Behavioural capabilities

Behavioural capabilities is based on behaviour which helps get rid of any problems they face with their own ability and resources. Learned resourcefulness, ingenuity and bricolage are all the characteristics which are needed to cope with various challenges. Figure below shows behavioural capabilities constructs.

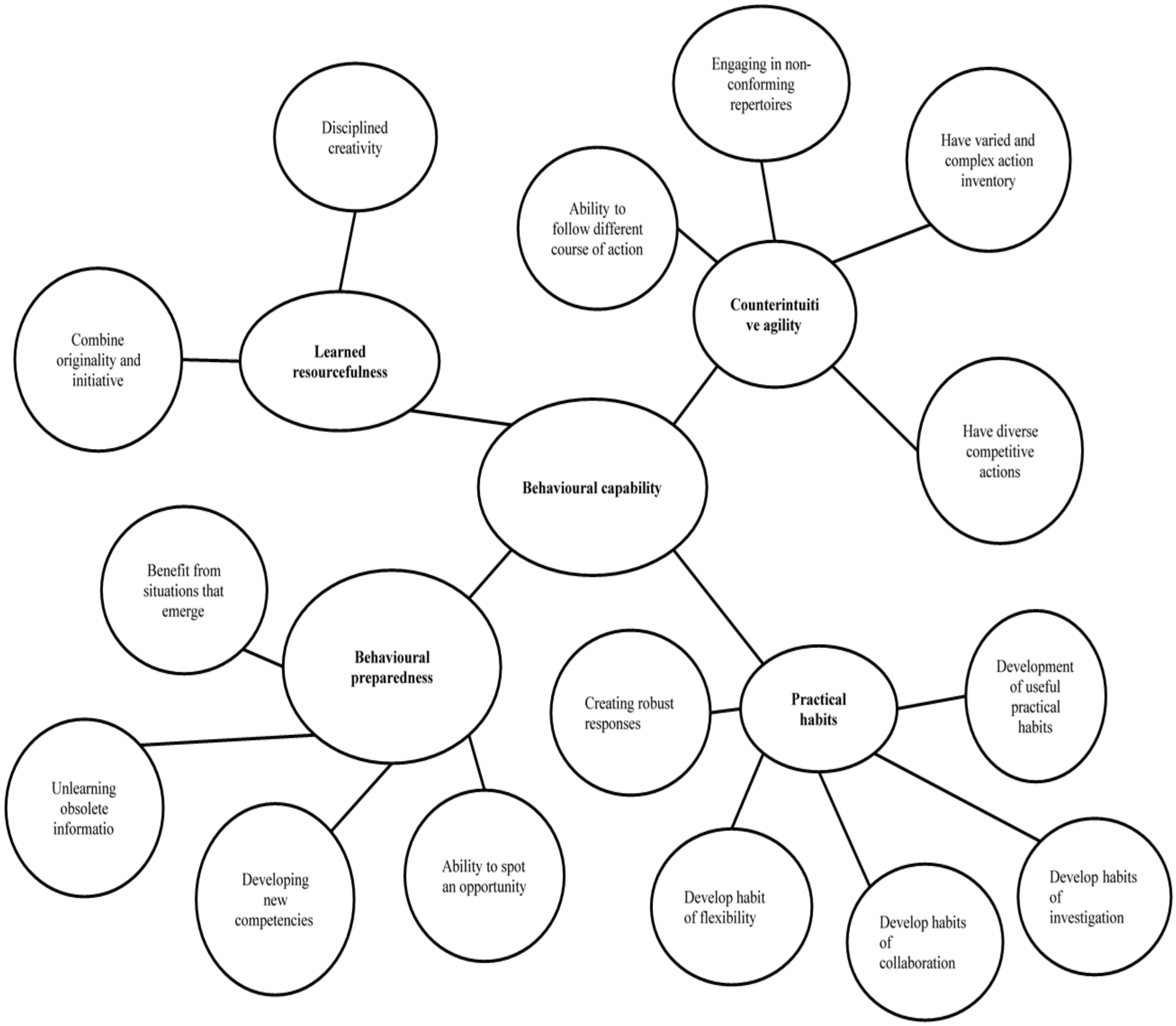


Figure 4-3 The network of behavioural capabilities of an organization

4.2.3. Managerial capabilities

Managerial / contextual capabilities of organizational resilience requires relationships within and outside an organization to facilitate effective responses to environmental complexities. It contains psychological safety, deep social capital, diffuse power and accountability and broad resource networks. Figure below shows the network of managerial resilience in an organization. Psychological safety is the degree to which people perceive their work is conductive to taking interpersonal risks.

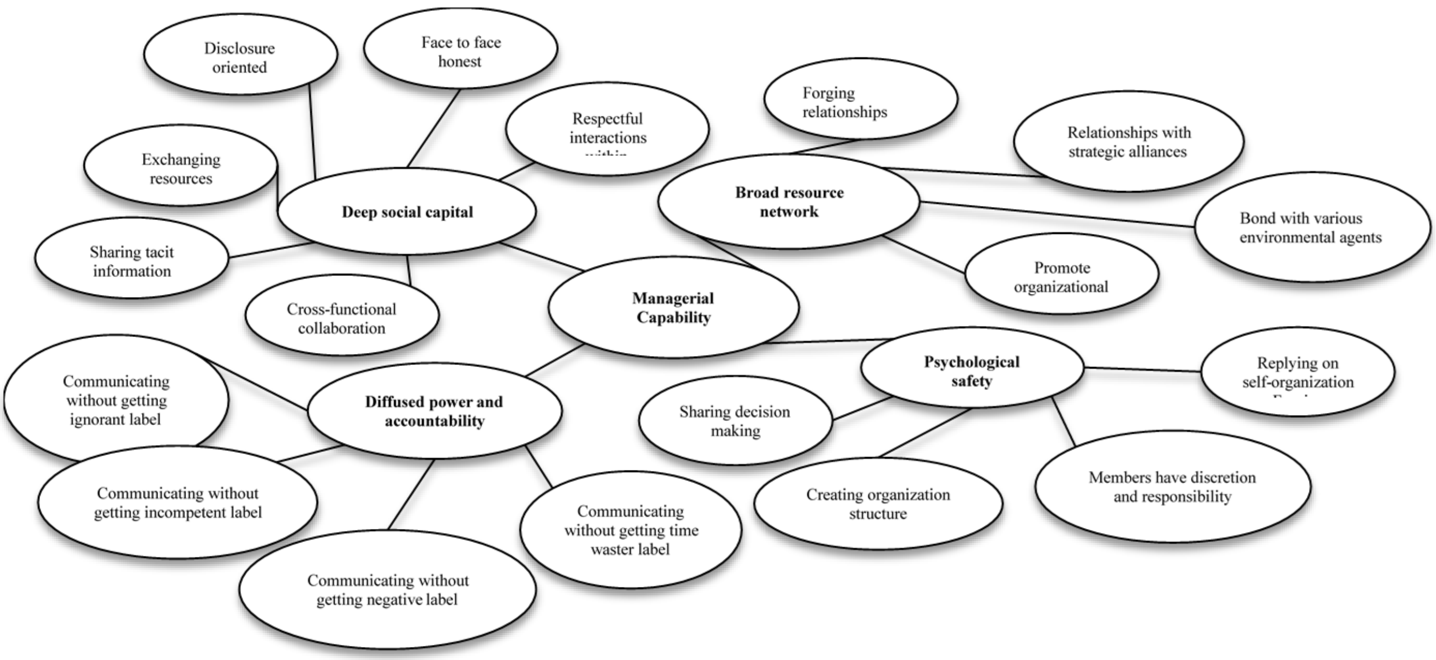


Figure 4-4 The network of contextual capabilities of an organization

4.3. Methodology:

In order to quantify RSC, we calculated relative probability of safety culture, the probability of failure and relative importance index. This specific model was never used for a powerplant, it should be tested using confirmatory factor analysis process.

4.3.1. Research bias :

In addition to using evaluation version of software (SPSS, AMOS and GRIF) Data sample is small which not only made the work more tough that without a doubt affected the final results .

4.4. Confirmatory Factor Analysis (CFA):

Before normality tests and starting the analysis collected data was cleaned and inspected by calculating the standard deviation of variables, it shouldn't be close to zero, detecting outliers, then missing data was replaced by the median of nearby variables,

The model was identified by determining the chi-square, degrees of freedom and probability level. Structural Equation modelling, however, estimate parameters in the model assess model fit, it relies on several statistical tests to determine the adequacy of model fit to the data, result is respecifying the model if meaningful. [19]

the table below shows the used indexes of good fit:

Measure	Name	Description	Good fit if:
X2	Model Chi Square	Assess overall fit and the discrepancy between the sample and fitted covariance matrices. Sensitive to sample size. H0: The model fits perfectly.	p-value< 0.05
(A)GFI	(Adjusted) Goodness of Fit	GFI is the proportion of variance accounted for by the estimated population covariance. Analogous to R2.AGFI favors parsimony.	GFI ≥ 0.95 AGFI≥0.90
(N)NFI TLI	(Non)Normed Fit Index Tucker Lewis index	An NFI of .95, indicatesthe model of interest improves the fit by 95% relative to the null model. NNFI is preferable for smaller samples. Sometimes the NNFI is called the Tucker Lewis index (TLI)	NFI ≥ 0.95 NNFI ≥0.95
CFI	Comparative Fit Index	A revised form of NFI. Not very sensitive to sample size. Compares the fit of a target model to the fit of an independent, or null, model.	CFI ≥.90
RMSEA	Root Mean Square Error of Approximation	A parsimony-adjusted index. Values closer to 0 represent a good fit.	RMSEA < 0.08
(S)RMR	(Standardized) Root Mean Square Residual	The square-root of the difference between the residuals of the sample covariance matrix and the hypothesized model. If items vary in range (i.e. some items are 1-5, others 1-7) then RMR is hard to interpret, betterto use SRMR.	SRMR <0.08
IFI	the Incremental Fit Index (IFI)	adjusts the Normed Fit Index (NFI) for sample size and degrees of freedom	IFI>0.9

Table 4-2 Measurements of Goodness of fit (Marquier, 2019)

Confirmatory factor analysis was done using the software AMOS SPSS 23, figure below shows the path drawn in AMOS, the used data is imported from SPSS after the screening when it was all set. In the full path shown the 42 elements are the observed variables from X1 to X42.

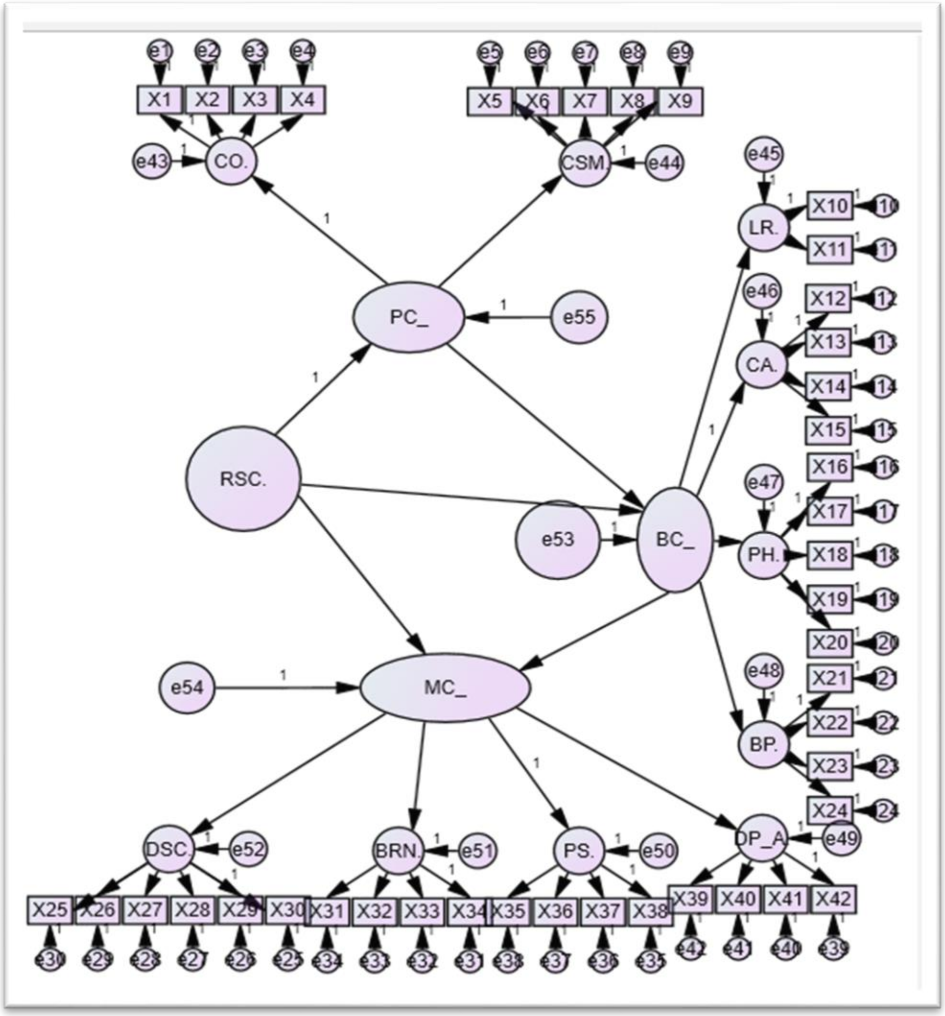
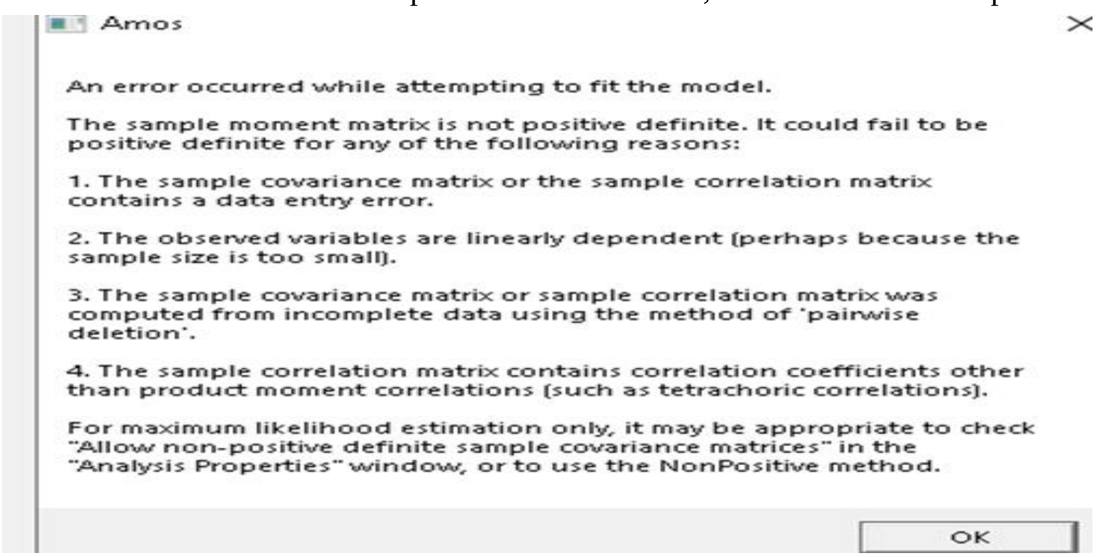


Figure 4-5 RSC forty two elements path

But there was some issues with that path it shows this error, due to the small sample size.



Amos

An error occurred while attempting to fit the model.

The sample moment matrix is not positive definite. It could fail to be positive definite for any of the following reasons:

1. The sample covariance matrix or the sample correlation matrix contains a data entry error.

2. The observed variables are linearly dependent (perhaps because the sample size is too small).

3. The sample covariance matrix or sample correlation matrix was computed from incomplete data using the method of 'pairwise deletion'.

4. The sample correlation matrix contains correlation coefficients other than product moment correlations (such as tetrachoric correlations).

For maximum likelihood estimation only, it may be appropriate to check "Allow non-positive definite sample covariance matrices" in the "Analysis Properties" window, or to use the NonPositive method.

OK

Figure 4-6 Error generated by AMOS

It is possible to consider sub-constructs as observed varibles using data from SPSS and run the estimation, the figure below shows the two level path used :

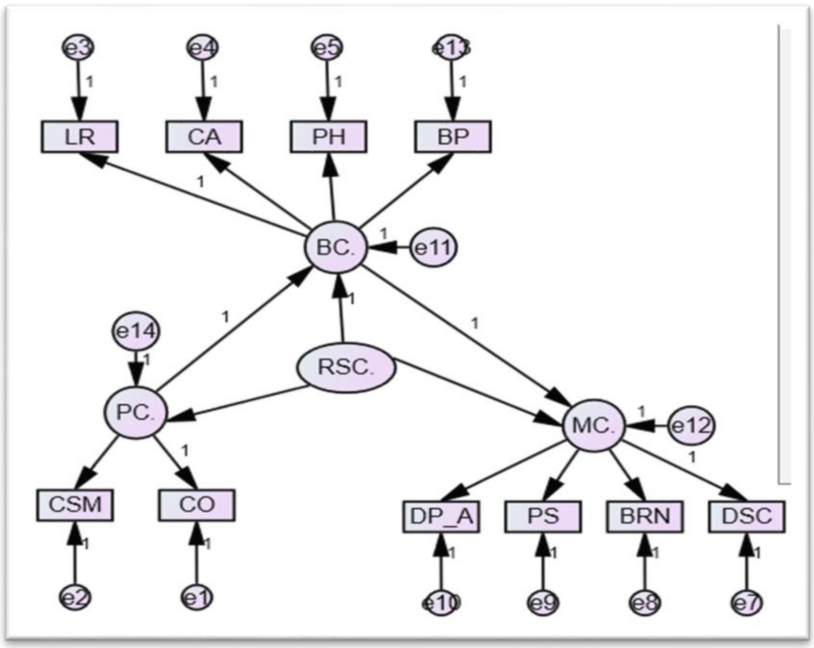


Figure 4-7 RSC ten (10) elements path

In order to analyse the confirmatory factors,minimisation history, standardised estimates, risidual moments and modification indices were ticked in analysis properties as shown in figure below :

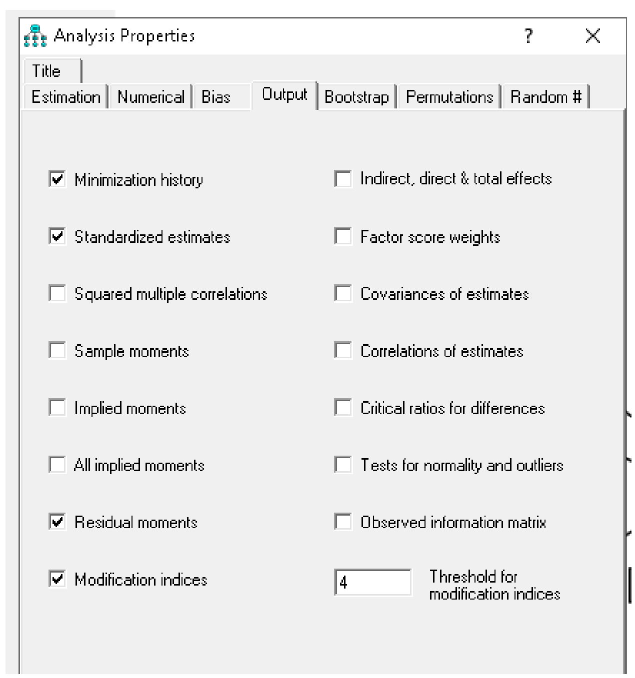


Figure 4-8 Analysis proprties

If unacceptable model fit is found, The Lagrange multiplier test provides information about the amount of chi-square change that results if fixed parameters are freed. The Wald test provides information about the change in chi-square that results if free parameters are fixed.

4.5. RSC Indexes:

Once resilient safety culture model is identified, the network needs to be measured through use of application of qualitative as well as quantitative data or their combination.

Complex network theory is used to quantify the resilience and use this new complex relationship between various cultures by calculating the relative probability of safety culture using the three sub-systems which in turn are interrelated using parallel and progressive relationships. More detail afterward.

One of the major challenges of quantification of RSC is that the attributes that determine RSC need to be measured through constructs and indicators which are complex and often interrelated. In our thesis applied Weighted probabilities, FTA and RII on the model proposed by Arun Garg, to be able to analyse complex and interrelated constructs and indicators. in order to demonstrate the failure path of the weak links in the RSC model.

We adapted these models to evaluate the RSC of the powerplant, results are used for monitoring the progress or comparing it with the resilience levels of other national powerplants.

Quantification of RSC using :

- Weighted probabilities
- RII
- FTA

How probability is calculated

$$P_{Xi} = \frac{\sum_{j=1}^{N} L_{ij}}{N * M}$$

L_i: Likert scale answer for the i^{th} question
M: Maximum value in the Likert scale
N: Number of answers

Note: Since we are using Likert scale (answer is from 1 to 5) the probability range is from 0.2 to 1.

4.5.1. Weighted probabilities:

An example is used to illustrate how the relative probabilities of the factors are calculated. Figure below shows a simplified example of behavioural capabilities network using complex network theory.

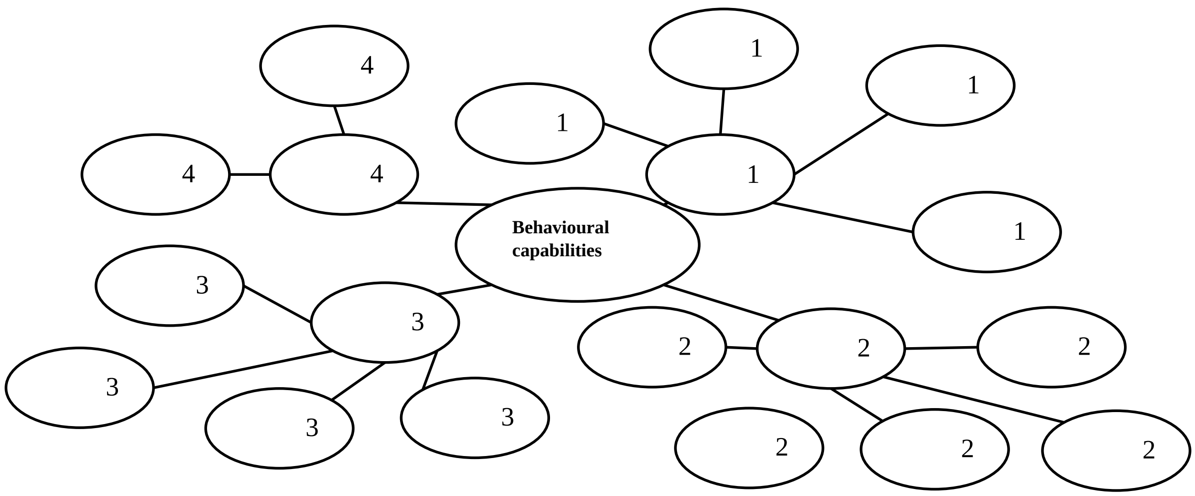


Figure 4-9 Behavioural capabilities network

Figure bove Example of behavioural capabilities network for denoting node symbols

Equation 1 shows the superior factor's probability which is calculated using summation of weighted inferior factors.

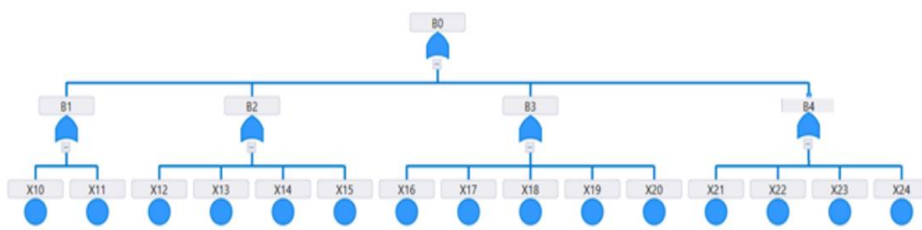


Figure 4-10 Proposed fault tree for "Behavioural capability" B0

$$P = \sum_{i=1}^{n} a_i p_i$$

Equation 1 Sum of weighted probabilities

P is the relative probability of superior factors, a is the factor weight and p is the probability of that factor. The reliability probability of this sub-system is calculated using *equation 1*. P is the total probability of this sub-system where as p1 is the probability of the node 1 which is calculated using the equation 1 and 2 relationships using p11, p12, p13, p14 likewise other probabilities like p2, p3, p4 can be calculated. The weight of node 1 is a1 whereas a11 is the weight for node 11. Equation 2 calculates the probability for relationships which means happening together.

$$P = a_1 p_1 + a_2 p_2 + a_3 p_3 + a_4 p_4$$

$$p_1 = a_{11} p_{11} + a_{12} p_{12} + a_{13} p_{13} + a_{14} p_{14}$$
$$p_2 = a_{21} p_{21} + a_{22} p_{22} + a_{23} p_{23} + a_{24} p_{24} + a_{25} p_{25}$$
$$p_3 = a_{31} p_{31} + a_{32} p_{32} + a_{33} p_{33} + a_{34} p_{34}$$
$$p_4 = a_{41} p_{41} + a_{42} p_{42}$$

*Note :*node 1 denotes “counterintuitive agility”, node 11 denotes “ability to follow different course of action”, node 12 denotes “engage in non-conforming repertoires”, node 13 denotes “have varied and complex action inventory”, node 14 denotes “have diverse competitive actions”. Similarly other nodes are denoted. By using this method, other two remaining sub system’s relative probability can be calculated. So the relative probability of the whole system of resilient safety culture can be calculated using equation below. Using equation below, relative probability of the progression relationships is calculated which means factors happen in-sequence. Superior factor’s probability is the product of inferior factors.

$$\prod_{i=1}^{3} p_i$$

<table>
<tr><td colspan="2">Constructs</td><td colspan="2">Sub-Constructs</td></tr>
<tr><td rowspan="2">1</td><td rowspan="2">Psychological capability</td><td>1</td><td>Conceptual orientation</td></tr>
<tr><td>2</td><td>Constructive sense making</td></tr>
<tr><td rowspan="4">2</td><td rowspan="4">Behavioural capability</td><td>3</td><td>Learned resourcefulness</td></tr>
<tr><td>4</td><td>Counterintuitive agility</td></tr>
<tr><td>5</td><td>Practical habits</td></tr>
<tr><td>6</td><td>Behavioural preparedness</td></tr>
<tr><td rowspan="4">3</td><td rowspan="4">Managerial capability</td><td>7</td><td>Deep social capital</td></tr>
<tr><td>8</td><td>Broad resource network</td></tr>
<tr><td>9</td><td>Psychological safety</td></tr>
<tr><td>10</td><td>Diffused power and accountability</td></tr>
</table>

Table 4-3 Tables of constructs/ sub-constructs

<table>
<tr><td>Construct</td><td>Sub-construct</td><td>a_j</td><td>N°</td><td>Element</td><td>a_{jk}</td></tr>
<tr><td rowspan="9">Psychological capability (just culture)</td><td rowspan="4">Conceptual Orientation</td><td rowspan="4">0,5</td><td>1</td><td>Sense of purpose</td><td rowspan="4">0,25</td></tr>
<tr><td>2</td><td>Strong core value</td></tr>
<tr><td>3</td><td>Prevailing vocabulary</td></tr>
<tr><td>4</td><td>Highly visible moral purpose</td></tr>
<tr><td rowspan="5">Constructive Sense Making</td><td rowspan="5">0,5</td><td>5</td><td>Having Attitude</td><td rowspan="5">0,2</td></tr>
<tr><td>6</td><td>Mindset</td></tr>
<tr><td>7</td><td>Ingenuity to develop new skills</td></tr>
<tr><td>8</td><td>Common language</td></tr>
<tr><td>9</td><td>Situation specific interpretations</td></tr>
</table>

Table 4-4 Eelements and their weights /psychological capability

Construct	Sub-construct	a_j	N°	Element	a_{jk}
Behavioural capability (reporting culture)	Learned resourcefulness	0,25	10	Disciplined creativity	0,5
			11	Combine originality and initiative	
	Counterintuitive agility	0,25	12	Ability to follow different course of action	0,25
			13	Engaging in non-conforming repertoires	
			14	Have varied and complex action inventory	
			15	Have diverse competitive actions	
	Practical habits	0,25	16	Development of useful practical habits	0,2
			17	Develop habits of investigation	
			18	Develop habits of collaboration	
			19	Develop habit of flexibility	
			20	Creating robust responses	
	Behavioural preparedness	0,25	21	Ability to spot an opportunity	0,25
			22	Developing new competencies	
			23	Unlearning obsolete information	
			24	Benefit from situations that emerge	

Table 4-5 Eelements and their weights /behavioural capability

Construct	Sub-construct	a_j	N°	Element	a_{jk}
Managerial Capability (Flexible and learning cultures)	Deep social capital	0,25	25	Respectful interactions within organization	1/6
			26	Face to face honest interaction	
			27	Disclosure oriented intimacy	
			28	Exchanging resources	
			29	Sharing tacit information	
			30	Cross-functional collaboration	
	Broad resource network	0,25	31	Forging relationships	0.25
			32	Relationships with strategic alliances	
			33	Bond with various environmental agents	
			34	Promote organizational slack	
	Psychological safety	0,25	35	Communicating without getting ignorant label	0,25
			36	Communicating without getting incompetent label	
			37	Communicating without getting negative label	
			38	Communicating without getting time waster label	
	Diffused power and accountability	0,25	39	Sharing decision making	0,25
			40	Creating organization structure	
			41	Members have discretion and responsibility	
			42	Replying on self-organization	

Table 4-6 Eelements and their weights /managerial capability

The equation below shows how to calculate relative probabilities:

$$P_i = \left[\sum_{j=1}^{n} \sum_{k=1}^{m} a_j . a_{jk} p_t \right]$$

$n: Number\ of\ elements\ under\ the\ sub - construct.$
$m: Number\ of\ sub - constructs\ under\ the\ construct.$

4.5.2. FTA:

There are many methods for system fault analysis including inductive and deductive approaches. In an inductive approach, failure states are examined and analysed. Examples of inductive approaches are Preliminary Hazard Analysis (PHA), Failure Mode Effect and Criticality Analysis (FMECA), Fault Hazard Analysis (FHA), Failure Mode and Effect Analysis (FMEA), and Event Tree Analysis (ETA).

Fault analysis techniques are generally used in systems safety and reliability assessment in order to provide a probabilistic estimation of the reliability of the system.

The fault tree model of RSC is used to evaluate the RSC and it could be used to monitor/compare resilience levels in further of two organisations with remote and urban locations but we adopted this concept for modelling RSC so that a probabilistic estimation of RSC can be made.

The OR gate corresponds to set union and probability of OR gate can also be written as follows:

$$P(A\ or\ B) = P(A \cup B) = P(A) + P(B) - P(A \cap B)$$

The AND gate represents a combination of independent events. This is equivalent to intersection of the input event set and probability of AND gate can also be written as follows:

$$P(A\ and\ B) = P(A \cap B) = P(A)P(B)$$

All the constructs of RSC follow an AND gate which is progressive relationship as defined by [14]. This is assumed that resilience level can only be achieved if employees can perceive about safety (psychological) and also have behavioural capability and have managerial system in place. In the absence of any of these three, there is no resilience in the culture. However, in the case of measuring sub-constructs and indicators, OR gates are used. This is mainly because OR gates are parallel relationship which allows achieving a construct (or sub-construct) partially even one sub-construct (or indicator) are absent. As an example, some degree of 'Behavioural capability' (which is a construct) within an organisation is possible to achieve even some of its measuring sub-constructs or indicators are absent.

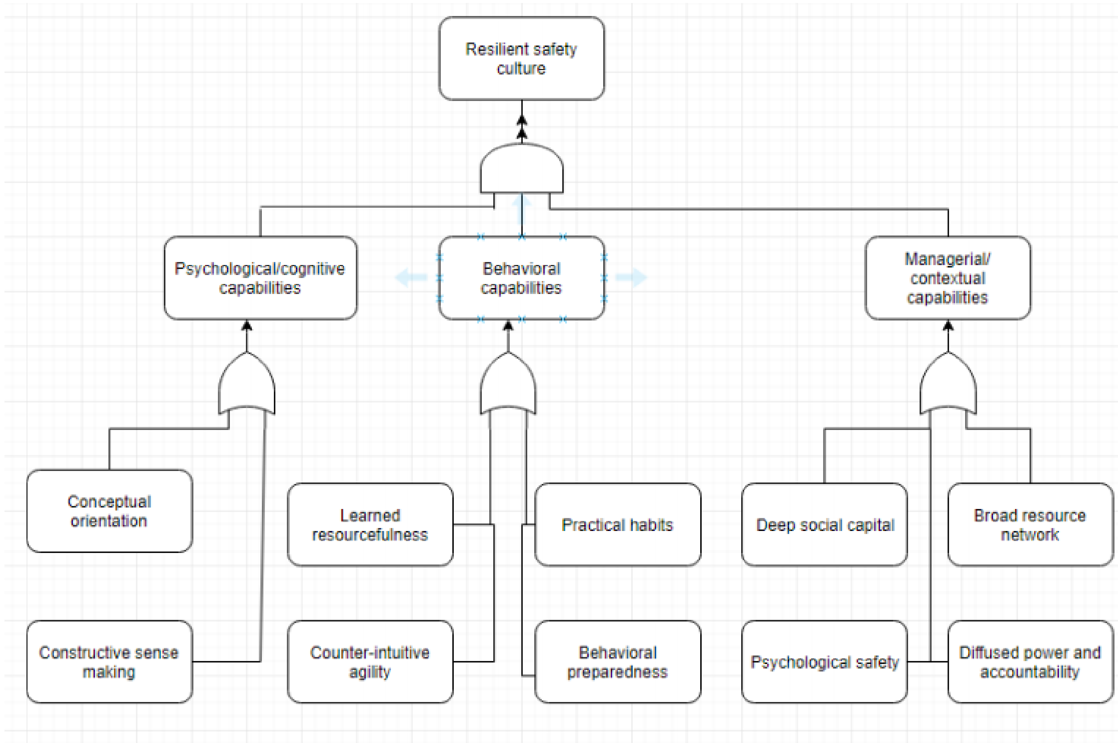


Figure 4-11 Fault Tree of RSC

Before using GRIF the probability of failure of all ten subconstruct was calculated, to e entered as base events in GRIF, the trial version of GRIF doesn't allow entering more than 50 elements then GRIF Fult TREE Module was used to calculate the probability of failure of RSC.

illustration of the construct "Behavioural capability" denoted by B0. After OR gate, B1, B2, B3, B4 are its sub constructs namely "Learned resourcefulness", "Counterintuitive agility", "Practical habits", Behavioural preparedness". X10 to X24 are the basic events or indicators. There are 42 indicators in the whole RSC. Probabilities of achieving each construct and sub-construct are estimated by conducting the survey among employees within the organisation.

The figure below is a screenshot of the used fault tree in GRIF, the law of probability is constant with the weight of each base event.

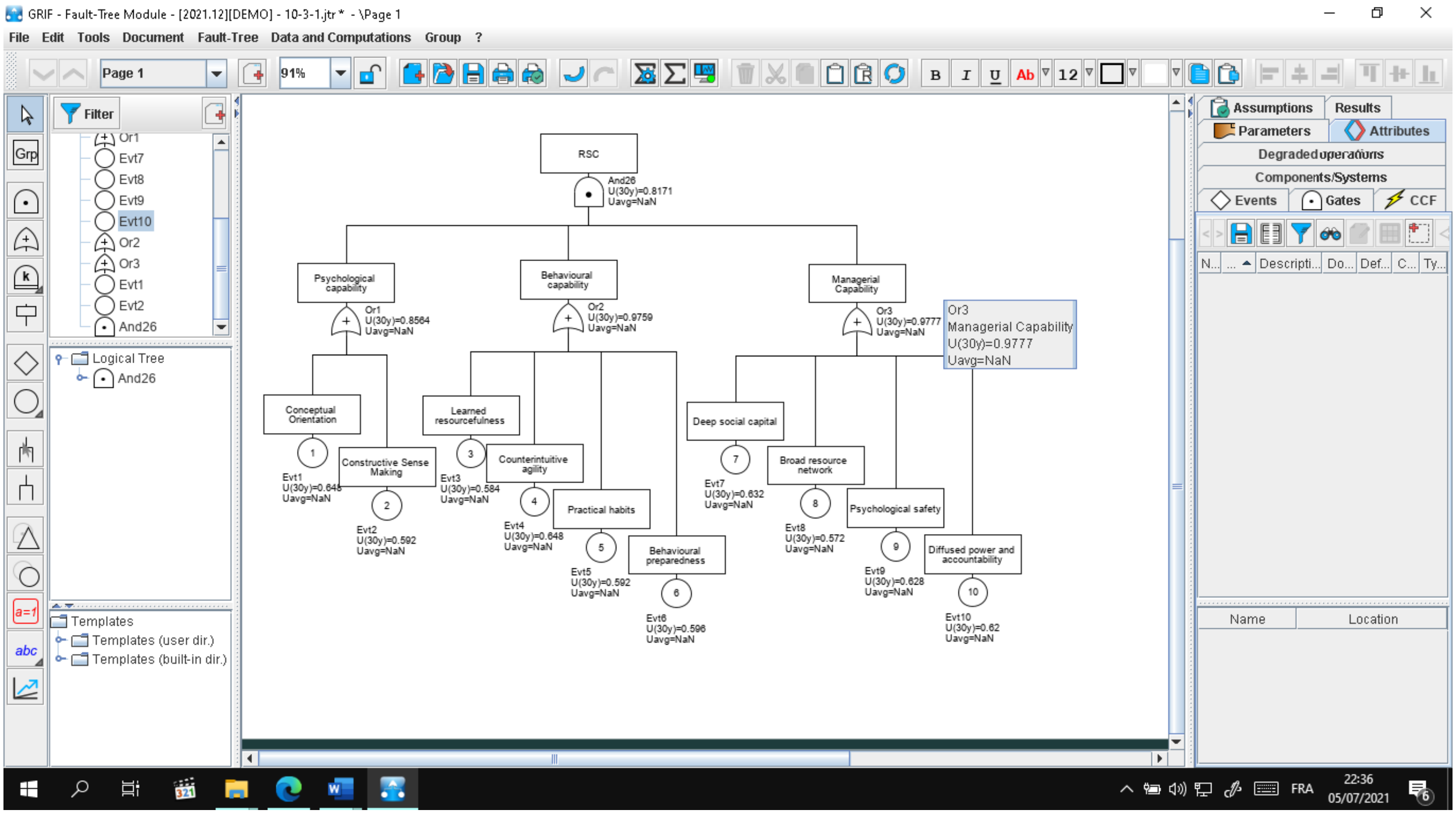


Figure 4-12 Fault tree in GRIF

4.5.3. RII

Relative importance index method (RII) is used to quantify the relative importance of all the 42 indicators of RSC

This can help identify weak links that can lead to future compromise of safety. This index was used by the conceptualizers to demonstrate how that can be applied to measure the impact of remoteness of job location on RSC.

$$RII = \frac{\sum W}{N * A}$$

Where RII= relative importance index, W= weighting given to each factor by respondents (Likert scale range from 1 to 5), A= highest weight (in this case it is 5) and N=total number of respondents. The RII value has a range of 0 to 1 where 0 is not inclusive, the higher the RII, the more important is the factor or indicator.

4.6. Results

Outliers some logical tests using excel were made to ensure that there is no otliers, as an example period of work couldn't be really close to age (20 years old with more than 15 years of experience)

Standard deviation was calculated for all respondents and the minimum is 0,543462 for ID2.

ID	1	2	3	4	5	6	7	8	9
STDEV	0,827873	0,543462	0,785353	0,768203	0,827873	0,890871	0,768203	0,81823	0,842803
ID	10	11	12	13	14	15	16	17	18
STDEV	0,771149	0,664964	0,890871	0,995739	1,044639	0,664964	0,543462	0,907265	0,661973
ID	19	20	21	22	23	24	25	26	27
STDEV	0,785353	1,044639	1,057582	0,897527	1,087186	0,907265	0,661973	0,842803	0,688421
ID	28	29	30	31	32	33	34	35	36
STDEV	0,792896	0,792896	0,771149	0,995739	0,81823	1,087186	0,688421	1,057582	0,897527

Table 4-7 Table of standard deviation

Normality tests Skewness/Kurtosis were done to all measured variables as well as the latent variables, the result (Appendix C) of the test shows that both indexes are superior than 2.2 for all latent variables which means that they are not normally distributed except for PH and X3 with acceptable standard errors. We could generalise and say that all variable are not normally distributed and we could use Maximum Likelihood for estimation.

4.6.1. Confirmatory factor analysis (CFA):

4.6.1.1. Model identification

Chi-square = 97,344
Degrees of freedom = 33
Probability level = ,000

4.6.1.2. Estimate parameters

Maximum likelihood estimated the regression weights of the relationships between latent and observed variables.The weights that were assigned with a value of 1 are recommended by the software (AMOS) in order to stop the estimations or else it would go infinitely and display errors.

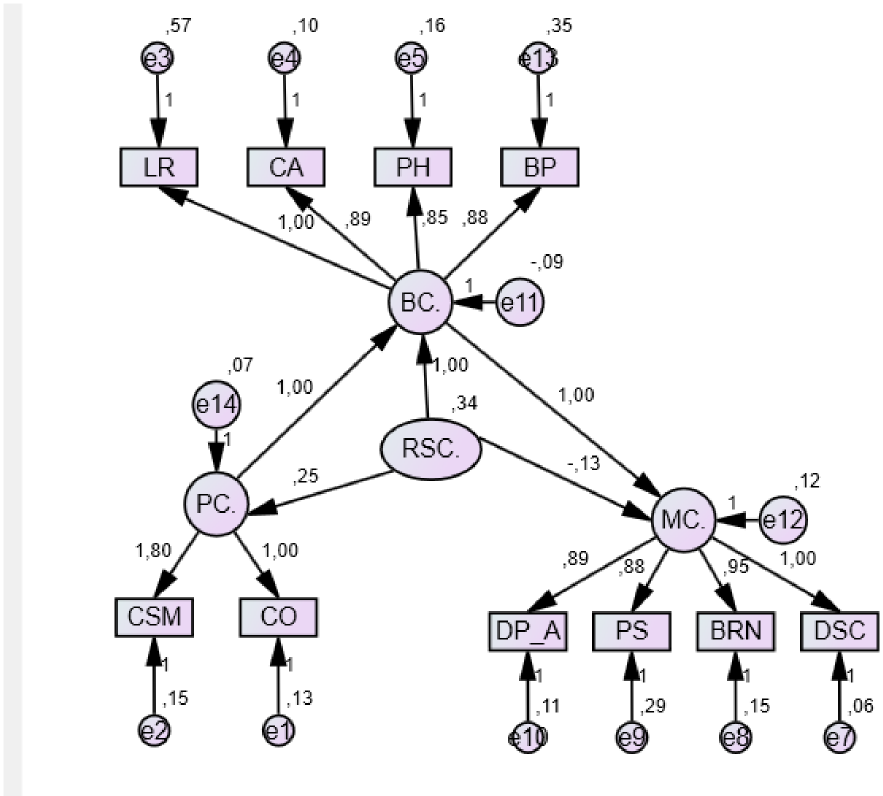


Figure 4-13 Estimate paramaters with AMOS

Table below shows the regression estimation with the P value:

Regression Weights			
	Estimate	P	interpretation
PC.<---RSC.	0,25	0,724	Low(with low significance)
BC.<---PC.	1		Imposed
BC.<---RSC.	1		Imposed
MC.<---BC.	1		Imposed
MC.<---RSC.	-0,131	0,774	Low (with low significance)
CO<---PC.	1		Imposed
CSM<---PC.	1,798	***	High (with high significance)
LR<---BC.	1		Imposed
CA<---BC.	0,891	***	High(with high significance)
PH<---BC.	0,851	***	High(with high significance)
DSC<---MC.	1		Imposed
BRN<---MC.	0,949	***	High(with high significance)
PS<---MC.	0,88	***	High(with high significance)
DP_A<---MC.	0,894	***	High(with high significance)
BP<---BC.	0,882	***	High(with high significance)

Table 4-8 Table of Regression Weights

4.6.1.3. Goodness of fit indexes

PCFI	GFI	AGFI	TLI	CFI	RMSEA	P	CMIN/DF
0.751	0,9	0,502	0,7	0,787	0,241	0	3,04

4.6.1.4. Respecify the model is meaningful

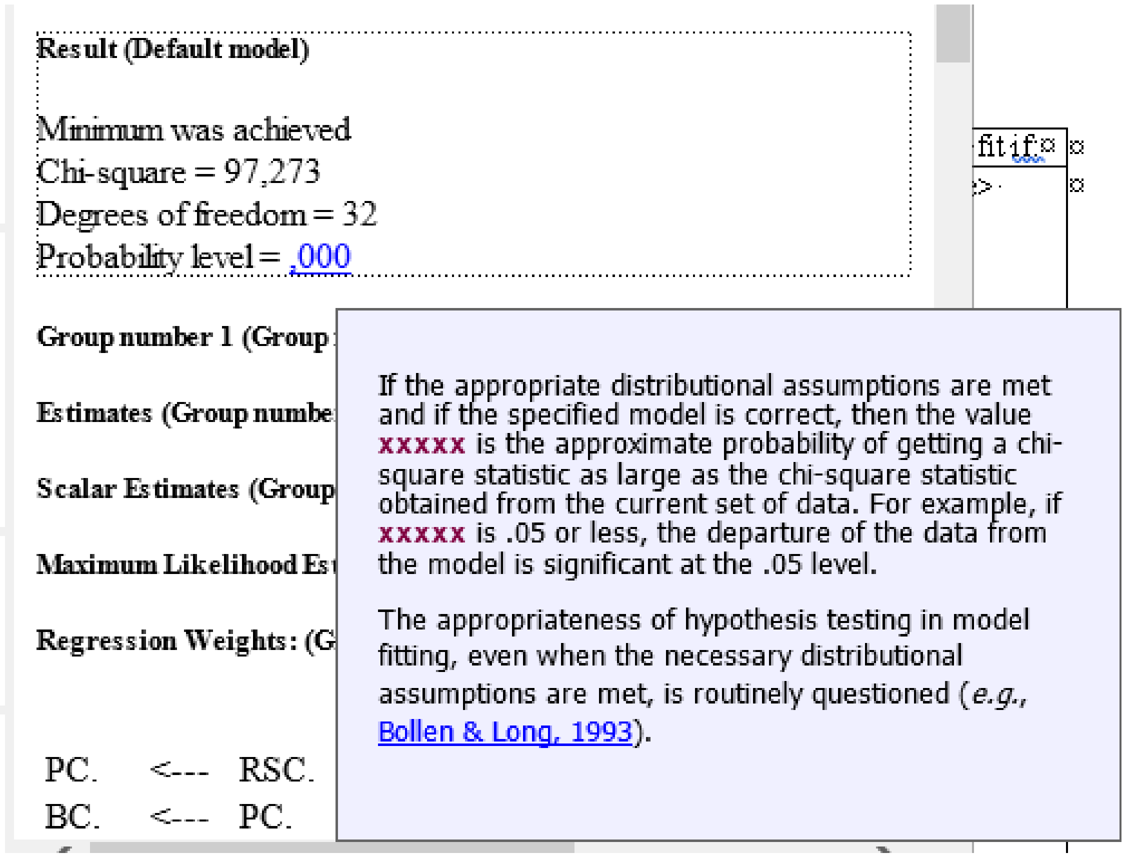


Figure 4-14 screenshot of Amos (identification)

4.6.1.5. Discussion

Goodness of fit indexes estimated using Amos 23.0 are shown below :

p < 0.0001 good fit (statisticly significant)
RMSEA= 0.241> 0.8 not a good fit
square (97,273, df = 32, p < 0.0001)

PCFI=0,751 > 0.7
GFI=0,71 > 0.7
AGFI=0,502 < 0.7
TLI=0,7 = 0.7
CFI=0,787 < 0.7
RMSEA=0,241 > 0.8
CMIN/DF=3.04 < 5

The baseline model showed acceptable fit on CFI (0.992). acceptable and RMSEA (0.241) is above 0.8 which means not agood fit TLI, CFI and GFI,PCFI are all above 0.7 with tolerable values.,AGFI bellow 0.7 which is not a very goog fitting signe, fit was found with chi-square (97,273, df = 32, $p < 0.0001$).

The fit of the model is good but not perfect, to improve the fitting goodness AMOS gives modification indices, in CFA we are interested in the modification indices of measured variables errors.

Modification Indices

Covariances:

	M.I.	Per Change
e13<-->e12	11,997	0,155

The biggest value of M.I between errors is not high, Not much remarkable changes could be made to the observed variables if changes were made in order to improve the fitting measures.

4.6.2. RSC INDEXES

Tables bellow show the result of all three indexes:

4.6.2.1. Fault tree probabilities :

Using Grif we could get the results shown below:

Fault Tree Probbilities

Sub-construct	CO	CSM	LR	CA	PH	BP	DSC	BRN	PS	DP&A
P	0,715	0,839	0,571	0,738	0,807	0,837	0,797	0,934	0,797	0,876
RII	9	3	10	8	5	4	6	1	6	2

Construct	PC	BC	MC
P	0,954	0,996	1
RII	3	2	1

RSC
0,95

Fault tree probabilities are really high and close and the probability of failure for resilient safety culture is considered high .

4.6.2.2. Weighted probabilities :

weighted probabilities

Sub-construct	CO	CSM	LR	CA	PH	BP	DSC	BRN	PS	DP&A
P	0,735	0,7	0,656	0,717	0,722	0,636	0,637	0,672	0,619	0,594
RII	1	4	6	3	2	8	7	5	9	10

Construct	PC	BC	MC
P	0,718	0,683	0,631
RII	1	2	3

RSC
0,309

*Discussion :*The relative probability of RSC is low, By the looking at the measured relative probability of the constructs and the sub-constructs it is not very obvious because their indexes are relatively high.

4.6.3. Weighted probabilities by employee level:

Since we collected information about the studied population we have the level of the employee (Hourly worker, First level supervisor, Manager) we used index Weighted probabilities to calculate for each group.

weighted probabilities (Hourly worker)

Sub-construct	CO	CSM	LR	CA	PH	BP	DSC	BRN	PS	DP&A
P	0,76	0,73	0,708	0,767	0,743	0,704	0,692	0,738	0,671	0,633
RII	2	5	6	1	3	7	8	4	9	10

Construct	PC	BC	MC
P	0,745	0,731	0,683
RII	1	2	3

RSC
0,372

weighted probabilities (First level supervisor)

Sub-construct	CO	CSM	LR	CA	PH	BP	DSC	BRN	PS	DP&A
P	0,638	0,59	0,475	0,588	0,62	0,5	0,533	0,55	0,513	0,55
RII	1	3	10	4	2	9	7	5	8	5

*Note :*Learned resourcefulness has the lowest RII with 0.475 it needs to be rechecked .

Construct	PC	BC	MC
P	0,614	0,546	0,536
RII	1	2	3

RSC
0,18

weighted probabilities (Manager)

Sub-construct	CO	CSM	LR	CA	PH	BP	DSC	BRN	PS	DP&A
P	0,775	0,74	0,7	0,675	0,8	0,5	0,517	0,525	0,525	0,525
RII	2	3	4	5	1	8	7	6	6	6

Note : Broad resource network, psychological safety and Diffused power and accountability have the same index which pose a problem of which one of them is more important.

Construct	PC	BC	MC
P	0,758	0,669	0,523
RII	1	2	3

RSC
0,265

4.6.3.1. Radar chart of relative probability of subconstructs:

We plot the the relative probability data subconstruct into a radar chart for the three groups (hourly workers,first level supervisor,managers) to better visualize the data.

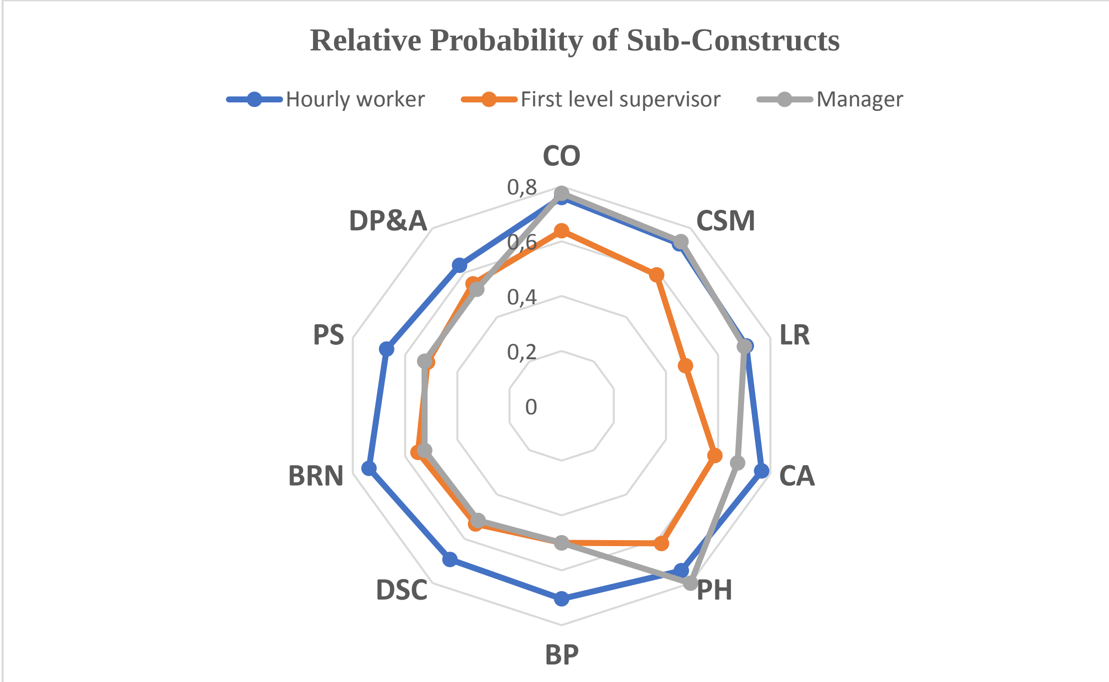


Figure 4-15 Relative Probability for Sub-Constructs

Discussion : we clearly see how relative probability for hourly workers has more surface than the other two employee levels.

Hourly workers and managers have close probabilities of psychological capabilities, in another hand managers share relatively the same Managerial Capabilities and BP probabilities with first level superiors. But hourly workers have bigger Managerial capabilities probabilities.

4.6.3.2. Radar chart of relative probability of constructs:

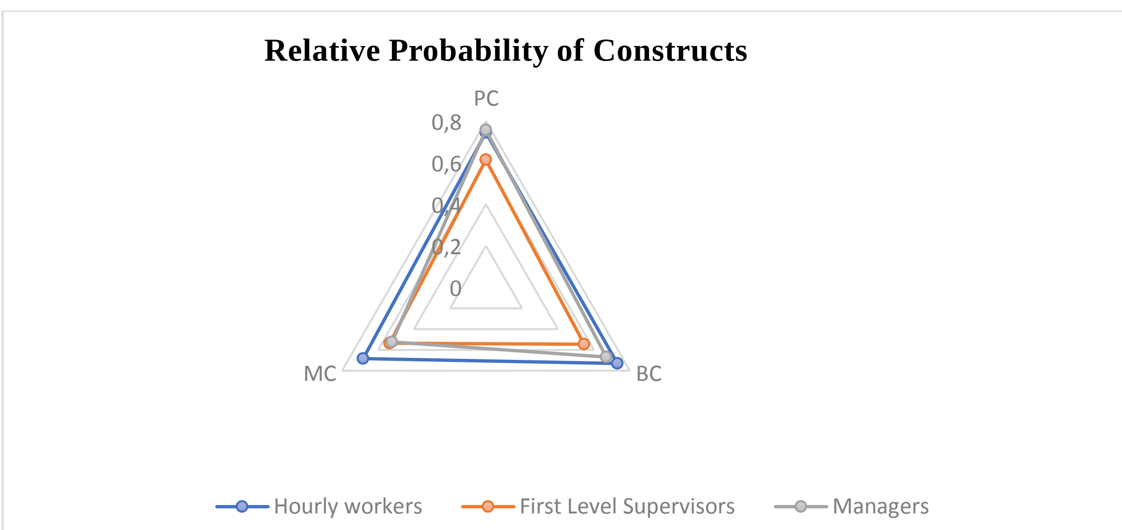


Figure 4-16 Relative Probability of Sub-Constructs

*Discussion :*this radar diagram of the three constructs shows that hourly workers have the largest triangle. Same as the previous diagram this one shows clearly that hourly workers have more managerial capabilities, shares the same high level psychological and behavioural capabilities with managers. First level supervisors and managers have a relatively low.

4.6.3.3. Graphical representation of relative probability RSC:

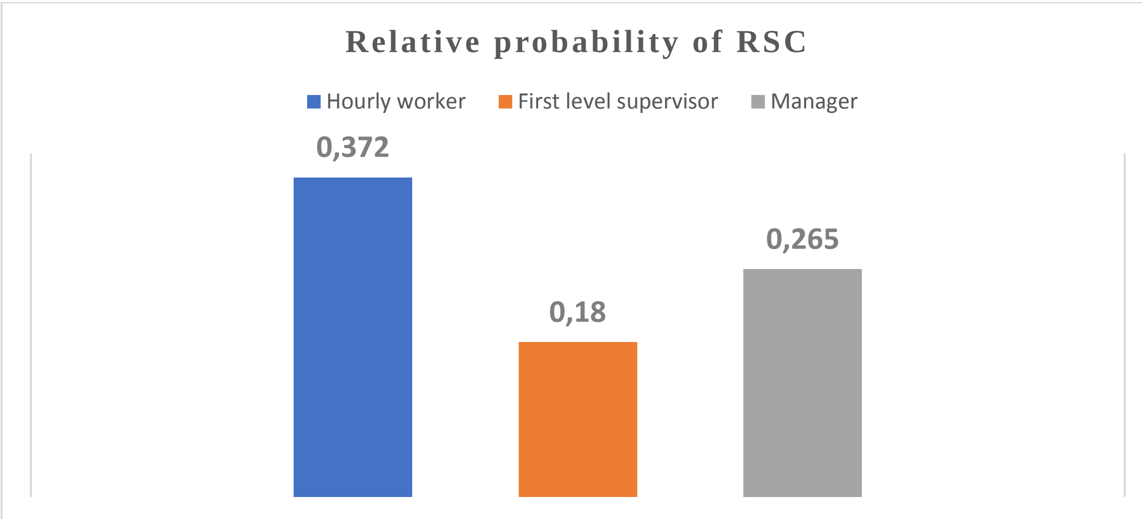


Figure 4-17 Relative probability of RSC

Discussion : relative probability of RSC for Hourly workers is the biggest among the other two levels with 0.372 , we also seeing that first level supervisors is the lowest with 0.18, relative probability of managers is 0.265.

4.6.4. Ways of improvement:

A platform for improving commitment to process safety through a safety cultural approach. The result was a list of ten general principles:

1. Organizational transformation is self-transformation. If we accept the premise that cultures are created from the interaction between people, the various groups and professional communities need to be involved in dialogue to define both problems and solutions.

2. Goals should be moderate and relate to everyday realities. Unless improvement measures can be related to the daily tasks and reality of the problem owners, it will not have lasting effects.

3. Change must be viewed as a long-term project. While the boxes and arrows of an organization chart can be moved in a matter of minutes, changing the way people work requires years of persistence.

4. The goal should not be organization-wide consensus, but creating a common language and understanding between groups. Differentiation between groups can be a vital resource for safety. Multiple perspectives are a source of requisite variety that can increase the chance of weak danger signals being detected somewhere in the organization.

5. Combine ‘push’ and ‘pull’. Top-down change efforts will fail unless there is a motivation for change at the sharp end of the organization.

6. Considerate organizational symbolism. For instance, organizational stories are powerful conveyors of culture and can emphasized to illustrate the problems to be solved, or the early wins in the change process.

4.7. Conclusion

It is assumed that resilience level can only be achieved if employees can perceive safety culture,the psychological and also have behavioural capability and having managerial system in place. In the absence of any of these three, there is no resilient safety culture [14].

The quantification of RSC and its constructs and sub-constructs allowed us to inspect its elements, and define the weak paths which were mostly in the managerial capabilities and RII defined the order by which improvement should be made. management initiates and contributes, but the operators must be involved in continuous dialogue. Personnel on the ground have expert knowledge on hazards, work processes and situational demands. This must be acknowledged, respected and utilized.

Chapter 05

Integration of Intelligent Analytics

Introduction:

In this chapter, we show how we can benefit more of our data using two of the most powerful tools in data analytics and data visualization. furthermore, we link these tools to make finding data insights more accessible and easier especially when there are different parameters which can make the engineer intimidated. additionally, what's the point of having large amount of data which can be a very powerful asset for the company to improve its safety performance without being able to visualize it and find different data patterns.

5.1. Intelligent analytics:

In order to be able to see the big picture of data, especially in a world where we are having more and more data to interpret this can be time consuming and difficult to manipulate.

5.1.1. Alteryx:

Alteryx is very powerful tool to analyze data with an automated workflow that can perform the same succession of operations over and over without needing to perform them manually each time unlike the traditional spreadsheet programs.

5.1.2. Data visualization:

Analyzing data is crucial to have some insights on data but to see the overall picture, good visualization is vital when data represents a complex system.

5.1.3. Tableau:

The Tableau platform is known for taking any type of data from almost any system and turning it into actionable information quickly and easily. It is as simple as drag and drop. Additionally, it is Alteryx friendly so that the analytics done with Alteryx are easily visualized in Tableau.

5.2. Advantage:

Intelligent analysis has many advantages over traditional statistical analysis methods, especially when dealing with complex multi-threaded environments. Due to the use of algorithmic analysis methods, intelligent analysis eliminates the biases that individual analysts may impose.

Intelligent analytics are used to enable engineers to proactively predict situations before they become problems or missed opportunities. These engineers can use this information to make informed decisions, develop effective strategies, and drive continuous improvement in each situation.

5.3. Why these tools:

Safety staff analyses this type of data regularly and it's time consuming because the traditional spreadsheets programs often make the regular analysis calculations easy and organized but don't have an automated workflow is complex and not easy to make changes on it.

Powerful data visualization and analysis requires clean data sets. Alteryx provides us with reusable, self-service data preparation workflows, so we can spend less time preparing data and more time analyzing data in Tableau. Alteryx can easily prepare, combine, and visualize all data sources, and apply advanced spatial and predictive analytics without coding to help you extract the most value from your data.

5.4. Analytics decision process:

Combining different analytics tools give us a satisfactory result on our analysis but when it comes to choose between on or another or both, we find ourselves in confusing situation and to facilitate the decision process we put it into the diagram shown below:

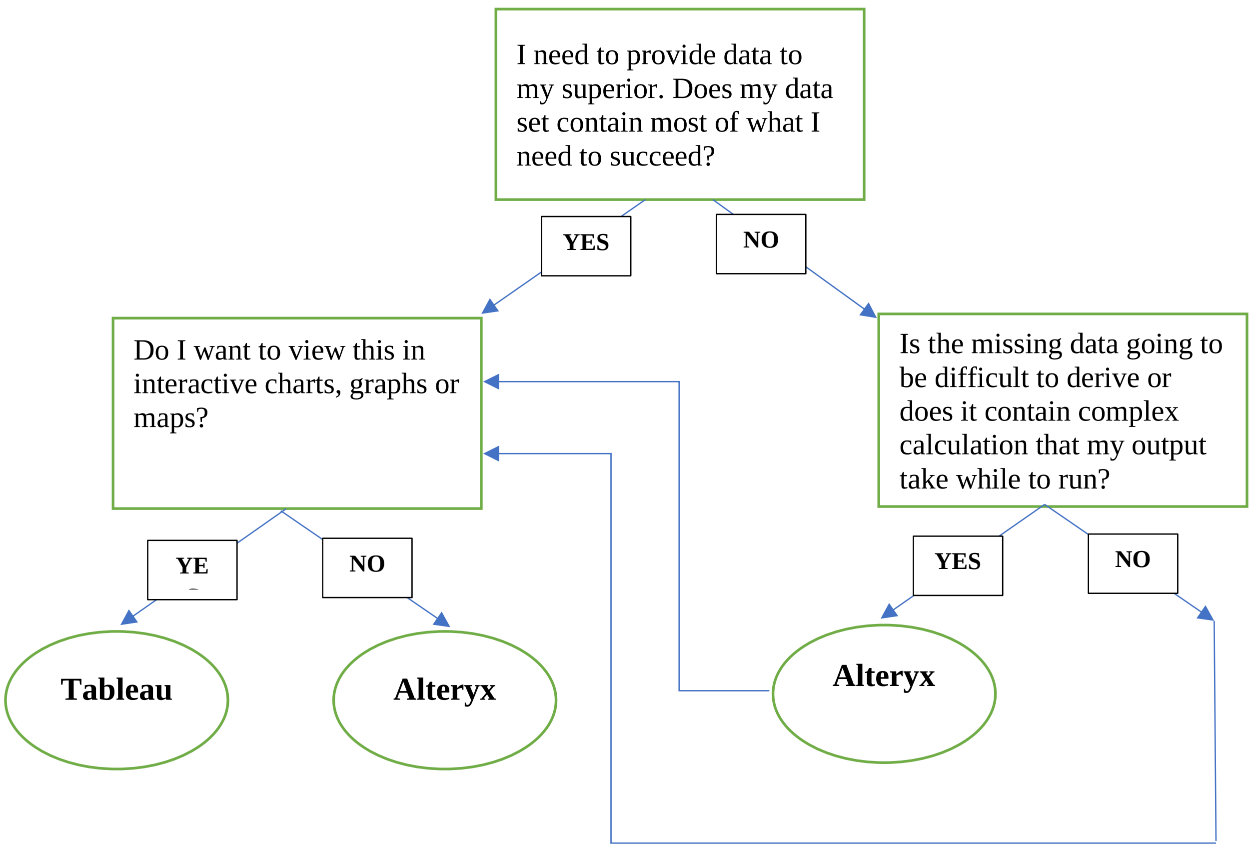


Figure 5-1 Analytics decision process

5.5. Design Alteryx workflow:

To design this workflow, we are using Alteryx designer version 2019.2. we connect tools with the drop and drag option to automate the workflow to prepare data with Alteryx and then visualize it in Tableau. (steps to build workflow in Alteryx are explained in Appendix B).

The workflow and the tool used are shown in figure below:

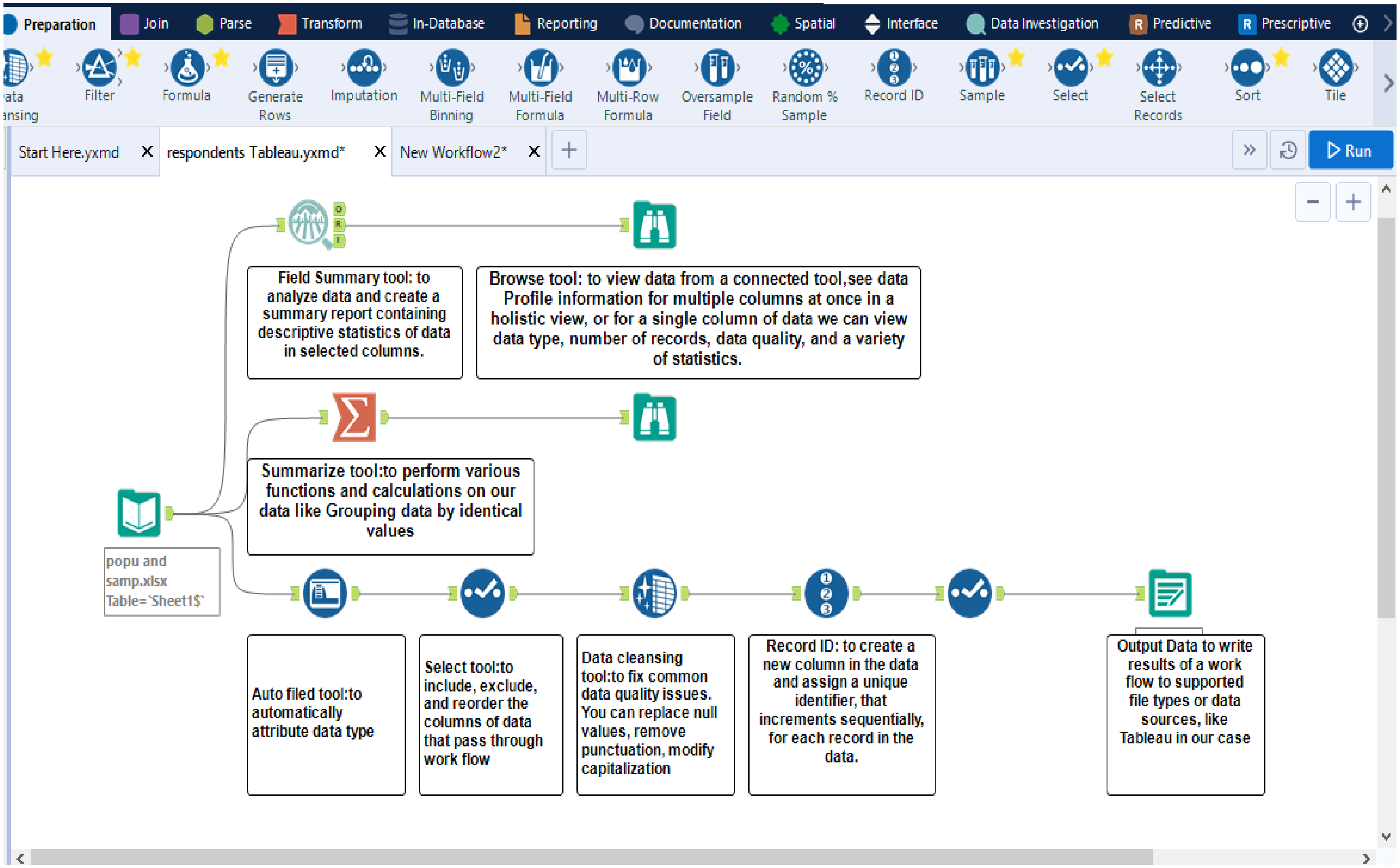


Figure 5-2 Automated workflow designed with Alteryx

5.5.1. Connect with tableau:

Alteryx support a large file types outputs such as SQLite, Microsoft Excel, Comma Separated Value and Tableau.

To connect with Tableau, we drag the output tool and choose tableau data source the we run the work flow.

5.5.2. Visualize the insights:

We visualize our dataset in some of Tableau interactive visualization (for the same data set: information about respondents), which have been generated and change from dashboard to other easily.

5.5.3. Design dashboard

Based on respondent's information we will group them into a dashboard to better understand different distributions and tendencies in our set of the data.

The visualizations are shown in figures below:

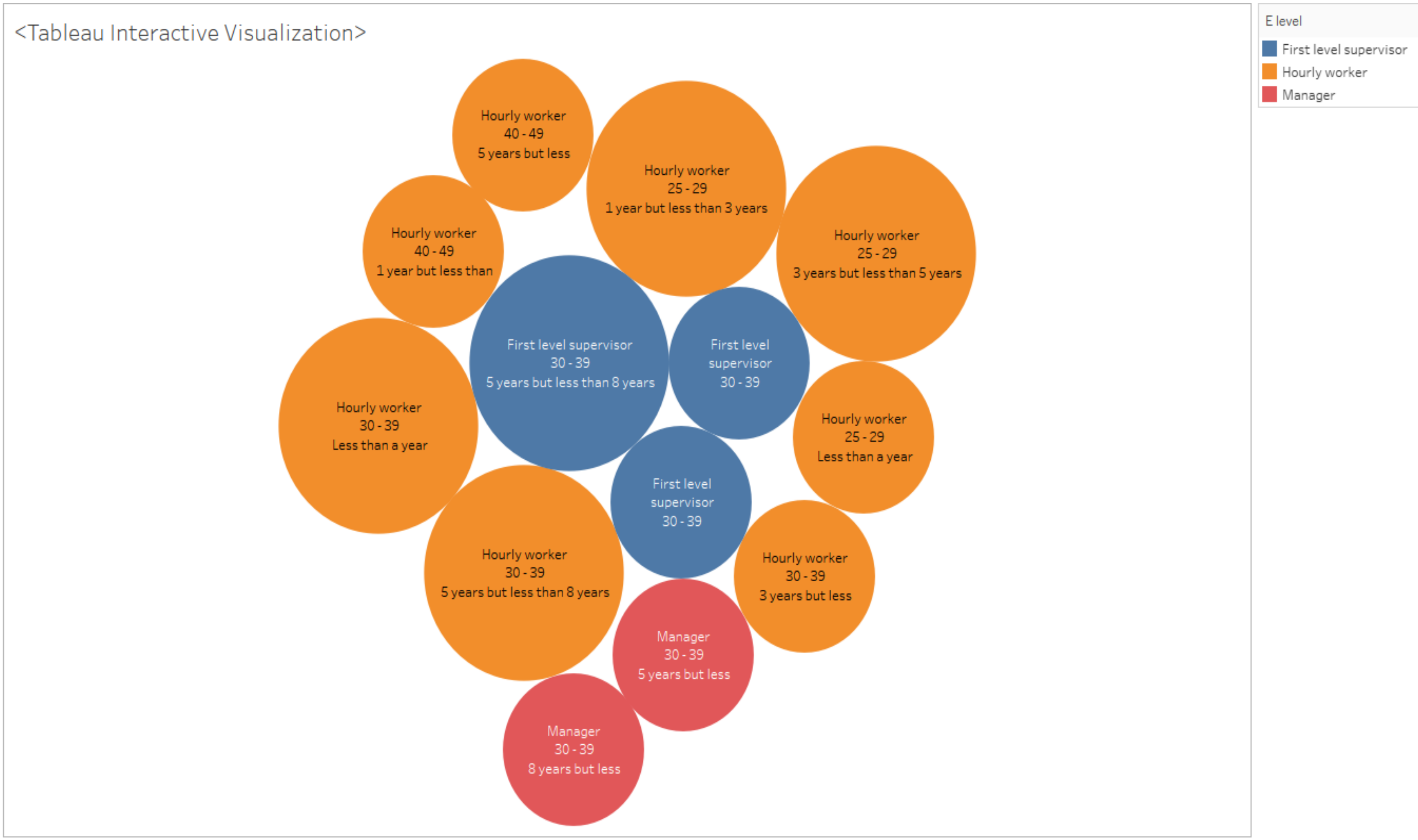


Figure 5-3 A grouped bubble chart from Tableau

<Tableau Interactive Visualization>

		Period				
E level	Age	1 year but less than 3 years	3 years but less than 5 years	5 years but less than 8 years	8 years but less than 10 years	Less than a year
First level supervisor	30 - 39			4	2	2
Hourly worker	25 - 29	4	4			2
	30 - 39		2	4		4
	40 - 49	2		2		
Manager	30 - 39			2	2	

Figure 5-4 A highlight table dashboard with Tableau

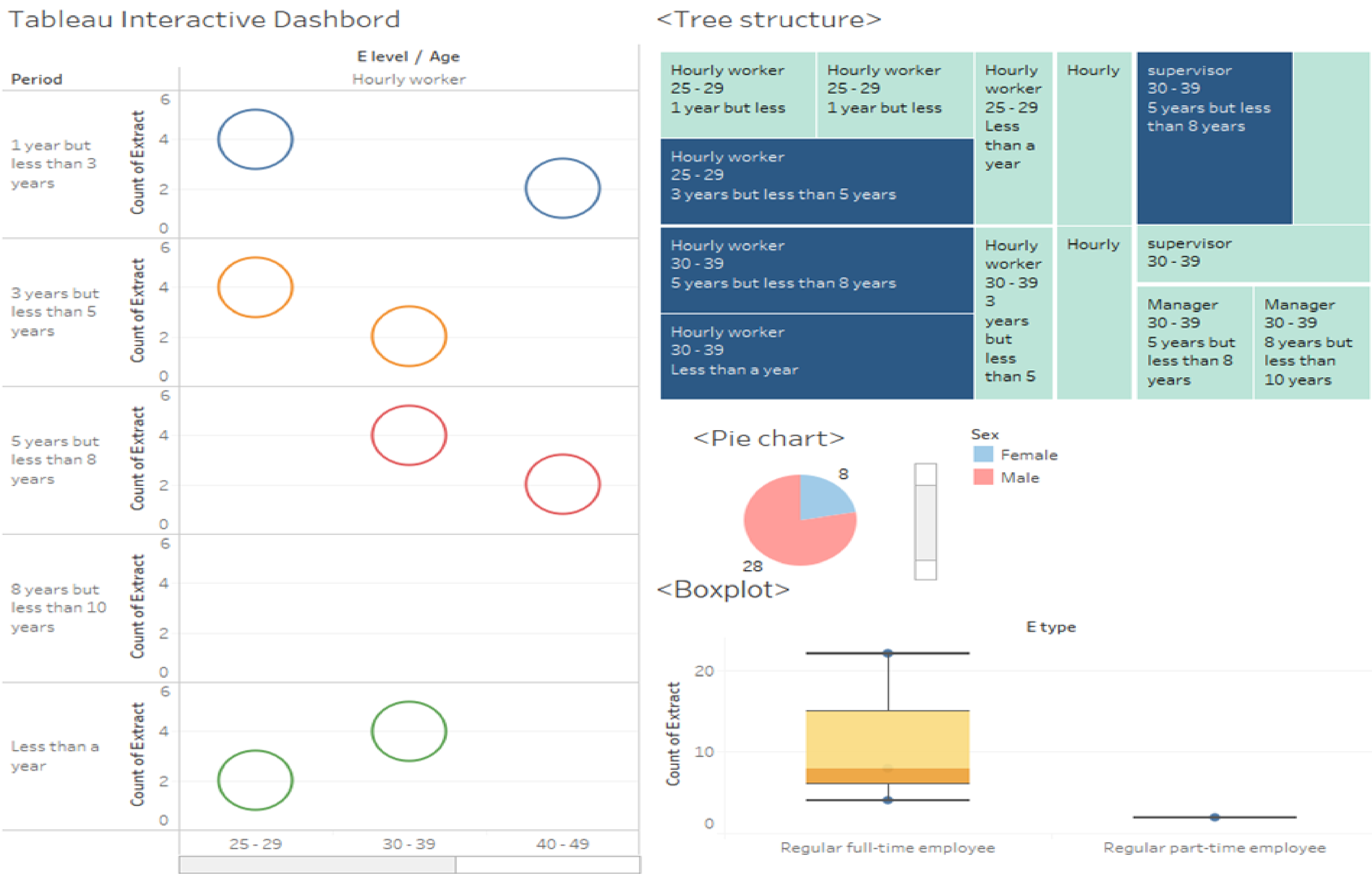


Figure 5-5 Dashboard with Tableau

Conclusion:

Providing an automated workflow which can be connected easily to a dashboard will make the process of analyzing data more accessible.reliable questionnaire and model with acceptable goodness of fit will help the company replace the qualitative approaches by reliable quantitative ones to improve its commitment to process safety because there is no improvement if progress can't be measured.

General conclusion

Selecting the strategy of improvement depends on the problem that needs to be solved, and there is a need to quantify improvement efforts. safety culture the first element of process safety management system (RBPS) is the key corn stone toward improving commitment to process safety management system.

The study assessed the resilient safety culture by elaborating questionnaire using five-point Likert scale with measured reliability and its Cronbach's α is equal to 0.959 using SPSS which is a satisfying result for reliability. This questionnaire will serve as input for the resilient safety culture model.

The resilient safety culture model is based on Arun Garg's 42 elements, the calculations were performed using SPSS, AMOS and Microsoft Excel where different constructs were modeled and confirmatory factor analysis was carried to indicate the model's goodness of fit.

Findings of the analysis show that our model's goodness of fit is acceptable as statisticians' best practice. Once the model's goodness of fit was confirmed, we used relative probabilities to measure the probability of failure of resilient safety culture and then calculate resilient safety culture index which is equal to 0.309. this is due to the weakness recorded on Diffused power and accountability subconstruct and Behavioural preparedness and Learned resourcefulness subconstruct so there is the need to create awareness on recognized safety concerns, coupled with a dynamic risk response attitude to ensure consistent improvement in safety culture resilience.

Additionally, we included intelligent analytics to automate the process of analyzing respondents information using Alteryx which was connected to Tableau to visualize data in a dashboard and have better data insights.

Although the findings of the study provide a potential for improving commitment to process safety, it is limited by a number of factors. The low response rate is a major limitation to the study. Furthermore, the reliability and validity of self-reporting survey methods is also a concern due to possible biases from respondents. However, this limitation was largely minimized in this study by ensuring voluntary participation and anonymity of respondents as well as confidentiality of respondents' responses.

For future research, enhanced data can be used to put the research results into a broader perspective. More importantly, the dimensions of the resilient safety culture can be further evaluated to determine the impact of the different dimensions on process safety. This can be accomplished through a longitudinal study to accurately observe the impact of safety culture change on the overall commitment to process safety performance.

Appendix A: Questionnaire

I. ABOUT ME

In this section you are asked to provide some information about yourself and your position. This information is requested because workers from different job levels might have varying opinions. The Panel will use the information from this section to break down results in a meaningful way while preserving the anonymity of all respondents.

WHAT IS YOUR JOB LEVEL?

- ☐ Hourly Worker
- ☐ Foreman / First Level Supervisor
- ☐ Superintendent
- ☐ Manager
- ☐ Other

HOW LONG HAVE YOU WORKED IN THE POWER PLANT INDUSTRY?

- ☐ Less than a year
- ☐ 1 year but less than 3 years
- ☐ 3 years but less than 5 years
- ☐ 5 years but less than 8 years
- ☐ 8 years but less than 10 years
- ☐ 10 years but less than 15 years

WHAT IS YOUR GENDER?

- ☐ Male
- ☐ Female

WHAT IS YOUR AGE?

- ☐ Under 20
- ☐ 20 – 24
- ☐ 25 – 29
- ☐ 30 – 39
- ☐ 40 – 49
- ☐ 50 or above

WHAT TYPE OF WORKER ARE YOU?

- ☐ Regular Full-Time BP Employee
- ☐ Regular Part-Time BP Employee
- ☐ Contractor

		Strongly Disagree 1	Disagree 2	Neutral 3	Agree 4	Strongly Agree 5
1	I have a formulated process of my career in company					
2	Each of us is responsible for our words, our actions, and our results					
3	Tasks, objectives and how to achieve them are discussed sufficiently at my workplace					
4	I am not too often forced to work to the limits of my abilities.					
5	I have received sufficient introduction and training to be able to perform all my tasks, also in the event of disturbances or in risk situations.					
6	I have an introduction to new skills and training to be able to perform all my tasks, also in the event of disturbances or in risk situations.					
7	I understand the language used by the staff members					
8	I have the necessary knowledge to handle an emergency situation.					
9	Standards of accountability are consistently applied to all employees.					
10	Safety is reinforced as a priority throughout your organization regardless of cost.					
11	When an employee reports a safety concern, appropriate action is taken					
12	Any safety concerns raised are treated with high urgency in my organization					
	Lorsqu'un employé signale un problème de sécurité, des mesures appropriées sont prises.					
13	Reporting of errors/incidents is priority even if there is lack of time					
14	Actions inventory related to safety has high priority in my orgIanization					
15	Safety is reinforced as a priority by the development of useful practical habits					
16	If an incident occurs, the leadership addresses the Issue and share lessons learned.					
17	If an incident occurs, the workers discuss the Issue and share lessons learned.					
18	If an incident occurs, the company addresses the Issue and encourages flexibility.					
19	In my organization robust responses to changes has been prepared.					
20	When the changes happen, my organization focus on how to spot the opportunity.					
21	In my organization, developing new competencies is highly encouraged.					
22	In my organization, unlearning obsolete information is highly encouraged					

23	We take benefit from situations that emerge and learn positive lessons					
24	In my organization, people spend time building trust with each other					
25	In my organization, people give open and honest feedback to each other /In my organization, whenever people state their view, they also ask what others think					
26	In my organization, teams/groups are confident that the organization will act as their recommendations					
27	My organization gives people control over the resources they need to accomplish their work					
28	My organization encourages people to share tactic information from across the organization.					
29	My organization encourages people to get answers from across the organization when solving problems.					
30	My organization encourages people forging relationships from across the organization.					
31	My organization works together with the outside community to meet mutual needs					
32	My organization works together with the outside community to protect the environment.					
33	My organization creates systems to measure gaps between current and expected performance					
34	Communicating without getting ignorant label					
35	Communicating without getting incompetent label					
36	Communicating without getting negative label					
37	Communicating without getting time waster label					
38	My opinion regarding my work and possible changes is being considered					
39	My organization gives employees equal measures of authority and responsibility.					
40	My organization supports employees who take calculated risks					
41	In my organization, teams/groups have the freedom to adapt their goals as needed					
42	In my organization, teams / groups have the freedom to tailor their goals as needed.					

Appendix B: Steps to build workflow

A workflow consists of connected tools that perform different functions to process data. When you build a workflow, you add and connect tools. You also configure those tools and workflow properties. To build a new workflow **select File > New Workflow**.

Workflow connections move in a downstream direction, vertically or horizontally, based on the workflow layout you choose in the workflow Configuration window.

Add or Remove Tools

To add a tool to a workflow, select any tool from the tool palette and drag it onto the workflow canvas, or right-click the workflow to access a menu to insert tools.

To remove a tool from a workflow, select the tool, and use the Delete key on your keyboard.

Connect Tools

To connect tools in a workflow, drag a tool from the tool palette onto the canvas near the output anchor of another tool. You can also drag the output anchor from an existing tool to the tool you just added.

Connections go in through the left side (or top) of a tool and out through the right side (or bottom) of a tool. Some tools accept multiple inputs indicated by multiple input anchors. Some tools have optional inputs indicated by a gray input anchor. All tools with an output anchor can be output to multiple streams.

Select a tool to display the incoming and outgoing connector indicators. The connector input to a tool displays in green. The connector output from a tool displays in blue.

Tool Right-Click Options

Select a tool on the canvas, then right-click to display a menu with these options:

Cut: Cut the selected tool from the canvas.

Copy: Copy the selected tool.

Delete: Delete the selected tool.

Zoom >>>>**Select to:**

Zoom In

Zoom Normal: Cancel zoom.

Zoom Out

All: Zoom to fit all tools in the window.

Selected tools: Zoom to fit all selected tools in the window.

View Possible Connections: View a list of possible tool connections to or from a selected tool.

Add to New Container: Adds the selected tool or tools to a Container Tool. Visit Tool Container Tool for more information.

Bring to Front: Send the selected tool to the front if tools are overlapping. This is useful for layering Comment boxes or ordering overlapping tool annotations. Visit Comment Tool for more information.

Send to Back: Send the selected tool to the back if tools are overlapping. This is useful for layering Comment boxes or ordering overlapping tool annotations. Visit Comment Tool for more information.

Toggle between Make Outgoing Connections Wired and Make Outgoing Connections Wireless to change how the connections display. Input and output anchors with a wireless connection display the wireless connection icon, which presents colored bars indicating the number of connections coming into or out of an anchor (connection becomes invisible unless the tool is selected):

One bar equals one connection.

Two bars equal two connections.

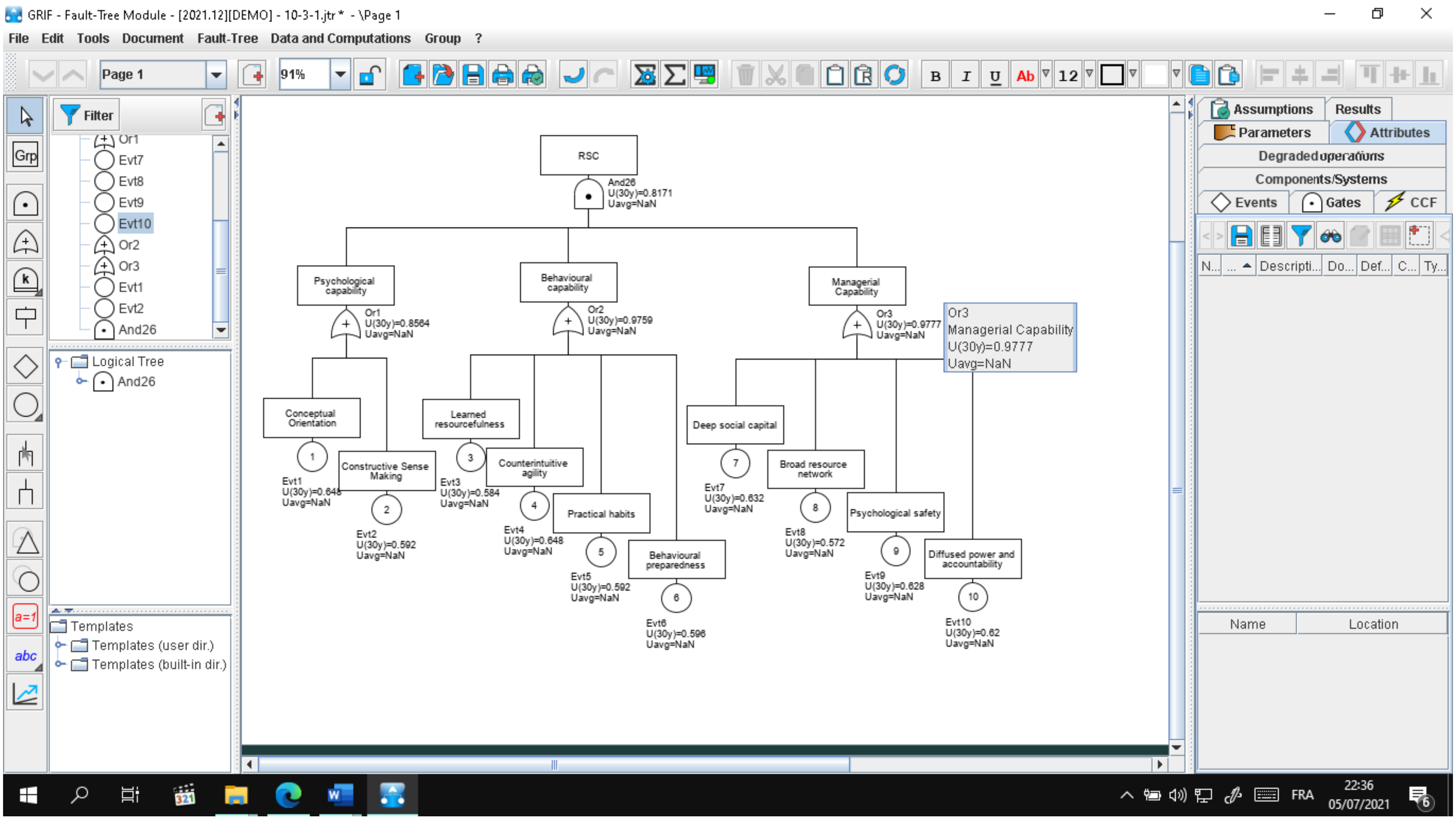
Three bars equal three or more connections.

Appendix C: Kurtosis skewness

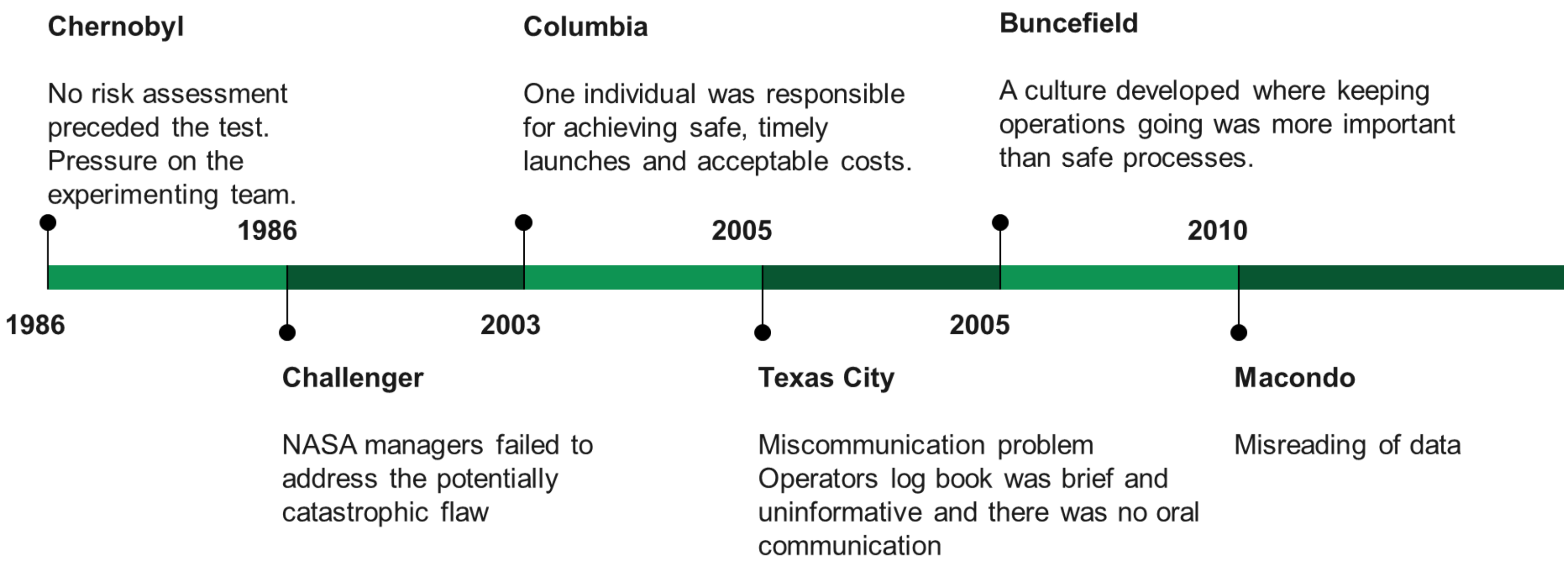
Calculation were perfomed using SPSS.

		CO	CSM	LR	CA	PH	BP	DSC	BRN	PS	DP_A	PC	BC	MC	RSC
N	Valide	36	36	36	36	36	36	36	36	36	36	36	36	36	36
	Manquant	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Asymétrie		-0,351	0,243	-0,904	-0,82	-1,155	-0,561	-1,234	-1,283	-0,105	-0,856	-0,042	-0,852	-1,307	0,015
Erreur standard d'asymétrie		0,393	0,393	0,393	0,393	0,393	0,393	0,393	0,393	0,393	0,393	0,393	0,393	0,393	0,393
Kurtosis		-0,476	-1,149	0,128	0,602	3,217	0,568	1,574	1,544	-0,036	1,372	-1,321	1,142	1,951	-0,509
Erreur standard de Kurtosis		0,768	0,768	0,768	0,768	0,768	0,768	0,768	0,768	0,768	0,768	0,768	0,768	0,768	0,768

Appendix D: Fault Tree of RSC in GRIF



Appendix E: Diagram of events that the investigations have found clear indication of defective safety culture.



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