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The Impacts of Safety on Sustainable Production Performance in the Chemical Industry

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By

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The Impacts of Safety on Sustainable Production Performance in the Chemical Industry

By

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Certificate of Ethical Approval

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This is to certify that the above named applicant has completed the Coventry University Ethical Approval process and their project has been confirmed and approved as Medium Risk

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Statement of Collaborators Agreement

This agreement, by and among:

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Hereafter referred to as the "Works", and we mutually agree to include the works within Danu's thesis, titled: The Impacts of Safety on Sustainable Production Performance in the Chemical Industry.

1. The work no 1, is included in Chapter 2, Systematic Literature Review.
2. The work no 2, is included in Chapter 4, Qualitative Findings.
3. The work no 3, is included in Chapter 4, Qualitative Findings and Chapter 5, Quantitative Findings.

ACCEPTED AND AGREED by the following signatories:

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Abstract

Sustainability has become an essential objective for many organisations. As an industrial sector closely related to sustainability issues, the chemical industry has been striving to achieve sustainable production. The chemical industry is crucial and very strategic in many countries, including Indonesia. In Indonesia, the chemical industry was the third-largest contributor to the GDP, which was a major contributor to pushing them to become one of the 20 countries with the largest economies in the world. This industry is a fundamental component of how countries function and, as such, can be both an enabler and inhibitor of sustainability. Given its importance, it is unsurprising that the sector has recently received increasing attention in the extant literature base. However, less consideration has been given to the importance of safety in sustainable production and how this may challenge performance in the sector. This research investigates how safety performance has impacted sustainable production performance and how other factors influence their relationship.

At the beginning of the research, 62 peer-reviewed articles were carefully selected, mapped, and assessed using the systematic literature review methodology. Thematic analysis was performed to unravel the relationship mechanisms between safety performance and sustainable production performance and synthesised them into five propositions. One of the important contributions of this work is the development of a conceptual framework that formalises the relationships between safety and sustainable production performance in the chemical industry.

After the initial framework was formed, 14 case studies were collected from various types of chemical industries. Qualitative data were collected and analysed from the 19 informants involved in this study. The cases reveal how safety performance positively impacts sustainable production performance in the chemical industry. Strong indications suggest a safety culture and the so-called Collective Mindfulness are the antecedents for safety performance, but the impacts of chemical industry characteristics remain unclear.

Following the results of the qualitative phase of this study, a series of testable hypotheses were formulated based on the empirical and theoretical evidence presented thus far to investigate the aforementioned relationships. Quantitative data was collected through an online survey to verify these hypotheses. The survey collected 221 responses and structural equation modelling (SEM) was utilised to analyse the quantitative data. The results from the quantitative phase confirm and strengthen the findings from the previous phase. Safety performance influenced sustainable production performance positively and both safety culture and collective mindfulness are confirmed to be the antecedents of safety performance. Furthermore, the quantitative phase clarifies the role of industrial characteristics: it influences the relationship between safety performance and sustainable production performance.

The outcomes of this research have made significant contributions to various areas of knowledge, particularly those aligned with current discussions on sustainability, safety, and Collective Mindfulness (CM). First, this study has investigated the extent of safety impacts on the performance of sustainable production in the chemical industry. Furthermore, this study also explores the underlaying mechanisms of the relationship between safety performance and sustainability performance. Second, this study analyses the extent of industrial characteristics affecting the relationship between safety performance and sustainability performance. Finally, this study is the first to propose a framework that explains the relationship mechanism between safety and sustainability.

Keywords: chemical industry, safety performance, sustainable production performance, semi-structured interview, structural equation modelling.

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Chapter 1: Introduction

1.1 Background

Sustainability has become an important objective for many organisations. The term was first introduced in 1987 but was more widely recognised after the world's first Earth Summit in Rio in 1992 (Nawaz, Linke and Koç, 2019) as: “meeting the needs of the present without compromising the ability of the future generations to meet their own needs” (Jilcha and Kitaw, 2017). The concept has been discussed globally in the last few decades and many have argued that sustainability is the solution for existential threats faced by humanity in the modern world. Sustainability offers substantial and maintainable benefits to the world by integrating development in three domains or pillars: economics, environment, and society (Nawaz, Linke and Koç, 2019). Following the advancement of technology, many have applied the concept of sustainability and tried to maintain the earth’s capacity to support life in all its diversity. However, there are many cases in which, when the issue of sustainability is being addressed, the safety aspect is disregarded, bringing adverse consequences for sustainable performance.

Humanity has been using fossil fuel since the 19th century. Until this day, fossil fuel is still used for the majority of energy consumption in the world, but inescapably its usage has a negative impact on the environment. The excessive burning of fossil fuel in the last few decades has been a major contributor to global warming, to which one of the Sustainable Development Goals (SDGs), i.e., affordable and clean energy (United Nations General Assembly, 2015), has been dedicated. Nuclear energy systems, which contribute 16% of global energy generation, are one of the keys to achieving this goal (Meshkati, 2007). However, nuclear plants are highly risky for safety and the environment. The risks are such that Meshkati (2007) argued that global security and sustainability are hostages to nuclear safety. Reviewing the Chernobyl nuclear accident, Meshkati (2007) concluded that organisational safety culture plays a crucial role in ensuring the safety of sustainable energy systems.

While Meshkati (2007) proposed some strong arguments to support its conclusion, the research was solely based on a single case, which may be difficult to generalise. Sovacool et al. (2016) reviewed historical accident data in the entire low-carbon energy field (biofuels, biomass, geothermal, hydroelectricity, hydrogen, nuclear power, solar and wind energy) between 1950 and 2014. During this period, 686 accidents were reported and collectively, they caused 182,794 human fatalities and a US$265.1 billion loss in property damage. Averaging those numbers, each accident in this field inflicted 267 fatalities and a huge loss of US$ 389 million. Though many have argued that low carbon energy is the key to achieving affordable and clean energy, the loss caused by this sector might be sufficient to offset any benefits received.

Another field where the application of sustainable development has an adverse consequence is the construction industry. To protect the environment, the concept of green buildings has been promoted in many countries. However, Chow and Chow (2005) found that the concept has problems complying with the existing prescriptive fire codes. One example is the green buildings with an atrium, which in fact, are more vulnerable to fire and smoke safety than conventional buildings. In line with Chow and Chow (2005), Rajendran et al. (2009) found some evidence that Leadership in Energy and Environmental Design (LEED) certified buildings that have a higher accident rate than traditional non-LEED buildings. Roberts et al. (2016) have also identified that a single fire event can negate several, if not all, elements of green design, and proposed integrating fire safety codes with sustainable construction codes.

Over the years, the usage of chemical substances in commerce has continued to grow, both in the number of chemicals used and the amount of usage. Considering that many chemicals' substances are known to have negative effects, many people have been promoting the application of "green chemistry" principles to protect both the environment and people from harm. Green chemistry is a suite of 12 enabling principles intended to lead to chemical products and processes that are more efficient, use fewer toxic materials, and produce less waste (Anastas & Warner, 1998). However, during the conceptualisation of environmental sustainability and green chemistry, occupational safety and health has not been fully considered. Lange (2009) argued that if green chemistry is implemented without any consideration to workers, all the benefits of sustainability cannot be truly realised. Benefits gained, both for workers' health and environment, and cost saving, can be maximised when worker hazards and risks have been considered since the design stage of the product under consideration. Phan et al., (2012) proposed eliminating hazards in chemicals by using a hierarchy of controls and prevention through design principles in green chemistry.

Examples in three different fields above have all illustrated how the absence of safety in implementing environmental sustainability can have adverse consequences. This argument is not new. McQuaid (2000) explained the importance of understanding the link between safety and sustainability, and further claimed that improving the health and safety in an organisation will help achieve sustainable development goals. Hajmohammad and Vachon (2014) supported this view with their study. They conducted a survey among 251 Canadian plants and concluded that the safety culture is associated with several performance indicators linked to sustainable development. Camuffo et al. (2017) also conducted a quantitative study and found that safety positively correlates with elements of organisational sustainability, including lean operations, involvement and empowerment of the workforce, and capability development.

One of the industrial sectors that has a close tie with the sustainability issue is the chemical industry (Driessen *et al.*, 2013). The characteristics of this industry are considered unique, compared to other industries, requiring workers that are both trained and skilled. The chemical industry also often employs high technology equipment and thus, is capital-intensive (Lee *et al.*, 2015). It is linked very tightly to practically every other sector of the economy (Ruiz-Mercado et al., 2014). In many countries, the chemical industry is crucial and very strategic, thus making it indispensable in improving both the economy and well-being of its population (Alkaya & Demirer, 2015; Ruiz-Mercado et al., 2014).

Similarly, in Indonesia, the chemical industry also plays a crucial role. According to the Ministry of Industry's roadmap, the chemical industry is one of the prioritised industries in Indonesia (Ekon RI, 2018). The Indonesian government continues to develop the chemical industry as a strategic sector that plays a vital role in national development. The Ministry believes that the success of national industrial development is significantly influenced by the profile of the chemical industry (Budiyanto, 2016). As a supplier of raw materials for downstream industries, the chemical industry sector is expected to have adequate capacity and always maintain good and stable performance. The importance of the chemical industry is evident from its substantial contribution to the Indonesian Gross Domestic Product (GDP). In 2022, the chemical industry was the third-largest contributor (Baheramsyah, 2023). Despite being a developing country, Indonesia is one of the 20 countries with the largest economies globally (Ahdiat, 2023). This underscores the significant role of the chemical industry in Indonesia. However, although the chemical industry contributes massively to the global economy and society's well-being, it also impacts the health and safety of both the environment and humans negatively (Abou-Elela *et al.*, 2007; Alkaya and Demirer, 2015).

Even though there have been many efforts to attain sustainable production, the financial and economic benefits are mostly where the focus is, and safety aspects are largely ignored (Stephanopoulos and Reklaitis, 2011). This is counterproductive, as an industry cannot be said to be fully sustainable only because it is viable economically; it also has to be both conscious of the environment, and socially accountable (Gavrilescu and Chisti, 2005). Despite being equally critical in accomplishing SDGs, many consider the social pillar to be the least important among the three pillars of sustainability (Ruiz-Mercado et al., 2014).

The environment and workers' health and safety are argued to be among the key indicators of the chemical industry's impact on societal well-being (Ruiz-Mercado et al., 2014). Being key indicators, the environment and workers' health and safety are considered to be part of the social pillar (Nawaz, Linke and Koç, 2019). However, the importance of health and safety seems to be misunderstood, as many efforts to achieve sustainability often disregard the safety and health aspects (Kishimoto, 2013). Ironically, there is much evidence that has shown that the social pillar is not the only pillar impacted by the absence of safety, but that all pillars are harmed (Chow and Chow, 2005; Kishimoto, 2013; Sovacool *et al.*, 2016). Considering the issue, it is consequential to have a complete understanding of the relationship between safety and sustainability.

This study offers several contributions to the safety and sustainability literature. First, it shows the research gaps for further study, in order to understand the extent of the relationship between safety and sustainable production performance in the chemical industry. Second, it also uncovers the mechanism of the relationship between the two. Lastly, it offers practical suggestions to the chemical industry and other industry sectors with similar characteristics. The framework proposed in this study could be deployed into a practical workbook consisting of self-assessment procedures. Although this is not the first study that relates safety and sustainability, this is considered to be the first literature review that produces a framework to explain the mechanisms of the relationship between the two.

The objective of this study is to investigate how safety performance might affect sustainable production performance, and the factors influencing this relationship. The study contributes to the knowledge in this field by proposing a framework that explains the relationship between safety performance and sustainable production performance. This study is the first to unravel the relationships between safety and sustainability in the form of a framework. The framework demonstrates the strong correlation between safety performance and sustainable production performance, thereby challenging the existing belief that safety plays only a minor role and merely contributes to the social pillar, i.e., one of the sustainability pillars.

1.2 Theoretical Foundation

Safety, Safety Culture, and Safety Issues in the Chemical Industry

The US Agency for Healthcare Research and Quality defines safety as the ‘freedom from accidental injury’, while the International Civil Aviation Organization defines it as ‘the state in which harm to persons or of property damage is reduced to, and maintained at or below, an acceptable level through a continuing process of hazard identification and risk management’. The American National Standards Institute similarly defines safety as ‘freedom from unacceptable risk’. Consequently, safety goals are usually defined in terms of a reduction in the measured outcomes over a given period of time. Safety has become a concern globally in that even ISO published ISO 45001 as a framework to manage health and safety in the workplace (Soltanifar, 2022). This standard provides guidelines for organisations to prevent both injury and ill health, and create safe and healthy workplaces (British Standards Institution, 2015).

Guldenmund (2000) pertinently summarised definitions of safety culture from various research. He highlights definitions by the Advisory Committee on the Safety of Nuclear Installations (ACSNI), i.e. “The safety culture of an organisation is the product of individual and group values, attitudes, perceptions, competencies, and patterns of behaviour that determine the commitment to, and the style and proficiency of, and organisation's health and safety management”, as the most explicit, outlining most of the assumed contents of the safety culture.

During the 1980s, and even more intensively in the 1990s, the EU Member States, industry, environmental groups, NGOs (Non-Governmental Organizations) and academia, worked more closely to develop regulations and risk assessments pertinent to chemical management. In addition, there were noticeable drivers that have caused these changes: the requirements of the regulations that have noticeably increased (REACH Directive contributed greatly), the growing interest in sustainable development around the world (including in the EU), and the increased public awareness of environmental risk (Kallenberg, 2009).

The increased awareness and attention to safety regulations were partly triggered by some well-known incidents of hazardous chemicals in products, for instance brominated flame retardants (BFRs) in several products such as electronics and textiles (Kallenberg, 2007), China-produced plastic toys that contain lead in dangerous levels (Smitt, 2007), dioxin in animal feed and benzene in Perrier (Wiener, 2006), and phthalates in plastics (Wiener and Rogers, 2002). Those and many other unspecified cases, which have been covered extensively by the media, have been the topic of discussion in many forums, both formal and informal, and become the reason for the growing interest from the EU Member States and also the general public (Kallenberg, 2009).

Zohar was the first to use the term "safety culture" decades ago (Mohammadfam *et al.*, 2022). Following disastrous accidents in various fields such as the oil and gas industry, aviation, and nuclear power plants, Zohar introduced the concept of safety culture in the 1990s (Schwatka and Rosecrance, 2016). The concept was particularly significant as it explains how the psychological process in an organisation can affect safety in the organisation (Singh and Verma, 2020).

Safety culture is the result of a combination of values, perceptions, pressures, competence level and attitudes in an organisation which will set the level of effectiveness of its safety management system (Choudhry, Fang and Mohamed, 2007; Antonsen, 2009; Mohammadfam *et al.*, 2022). How people in an organisation understand safety policies and practices, and how the organisation prioritises safety is encompassed by its safety culture (Braunger *et al.*, 2013). Generally, safety culture can be used to measure the level of safety in an organisation, since it summarises various important aspects (Payne *et al.*, 2009; Grabowski *et al.*, 2010). The absence of a safety culture within an organisation can pose several challenges in implementing safety and health protocols (Morgado, Silva and Fonseca, 2019). Adequate support for workers needs to be provided to ensure their safety in the workplace (Tjahjono, 2009).

Previous studies have provided various definitions of safety culture (Guldenmund, 2000):

- Safety culture encompasses the shared attitudes, beliefs, perceptions, and values among employees regarding safety (Cox and Cox, 1991).
- Safety culture refers to the collection of characteristics and attitudes within organisations

and individuals that prioritise the necessary attention to safety issues in nuclear plants (International Safety Advisory Group, 1991).

- Safety culture comprises the set of beliefs, norms, attitudes, roles, and social and technical practices aimed at minimising risks and protecting employees, managers, customers, and the public from hazardous conditions (Pidgeon, 1991).
- The concept of safety culture emphasizes that an organisation's safety performance is influenced by its beliefs, attitudes, actions, policies, and procedures (Ostrom, Wilhelmsen and Kaplan, 1993).
- In a total safety culture (TSC), every individual takes responsibility for safety and actively pursues it on a daily basis (Geller, 1994).
- An organisation's safety culture is shaped by the values, attitudes, perceptions, competencies, and behavioural patterns of individuals and groups, which determine their commitment, style, and proficiency in managing health and safety (Lee, 1996).
- The International Safety Advisory Group's (1991) report on safety culture also takes a normative approach, defining it as "a necessary framework within an organization" and "the attitude of staff at all levels in responding to and benefiting from the framework". Establishing a safety culture involves specifying requirements at different levels, including policy, managerial, and individual levels.

There are several different concepts on how to measure safety performance (Christian *et al.*, 2009). Many studies argue that accident and injury rates are the best measurements for safety performance (Smith *et al.*, 2006; Christian *et al.*, 2009). In contrast, there was also an earlier study that believes safety performance can be measured by safety compliance and safety participation in the organisation (Griffin and Neal, 2000). Another study argues that safety performance can be represented by both safe and unsafe behaviour (Martínez-Córcoles *et al.*, 2011).

Being a high-risk industry, safety continues to be a major issue in the chemical industry. In the Netherlands, a series of major accidents have occurred in the chemical industry in recent decades (Zwetsloot, van Middelaar and van der Beek, 2020). Although some of the accidents did not occur during the production process in chemical plants, they did happen during the transportation and storing process, which is still the responsibility of the chemical companies (Zwetsloot, van Middelaar and van der Beek, 2020; Umeokafor, Umar and Evangelinos, 2022).

Another study revealed safety issues in the chemical industry. It reviewed 46 full reports by the U.S. Chemical Safety and Hazard Investigation Board and found a surge of accident rates in the chemical industry (Rashid, Tabish and Athar, 2022). Among those reports, some accidents were catastrophic as they caused thousands of deaths for both employees and neighbouring residents. The infamous Bhopal accident is one of those disastrous events. The increase in both frequency and intensity of accidents is likely to have been caused by the many policies implemented to improve economic benefits in the industry (Rashid, Tabish and Athar, 2022). Unfortunately, these policies have led to many optimisation decisions, which eventually caused the chemical industry to have even more complex process plants. The complex process plant contains many hazards, such as fire, explosion, toxicity, both in liquid and gas form, and many more, that can cause fatalities (Rashid, Tabish and Athar, 2022).

Sustainable Production and Sustainable Production Performance

Sustainable production is defined as the development of products and services by processes and procedures that are: pollution free; energy and natural resource efficient; economically viable; secure and safe for workers, communities and consumers; and socially and creatively beneficial for all working (Veleva and Ellenbecker, 2001; Macchi, Savino and Roda, 2020).

The principles of sustainable production are illustrating the ties between the environmental, social, and economic frameworks within which development and consumption take place (Machado, Winroth and Ribeiro da Silva, 2020). This concept and principles of sustainable manufacturing provide both a vision and long-term objectives for industries that want to become more sustainable; however, it is still inadequate to implement a more sustainable production in industries by relying on vision and long-term objectives alone (Gani *et al.*, 2022). Tools are required to help industries identify the issues with their current production processes and then to establish specific objectives and the measuring of progress in the direction of sustainable production (Zhang et al., 2020).

To help companies measure their sustainable production performance, there are several international standards that have been published. The ISO 14000 series for environmental management standards by the International Organization for Standardization (ISO) is probably the most recognised (Hillary, 2017). ISO 14001 gives guidance for organisations to manage their environmental system in order to protect the environment (British Standards Institution, 2015). In addition, ISO 14031 was also published to help organisations evaluate their environment performance (British Standards Institution, 2021). ISO also published ISO 26000 as a guidance for social responsibilities (Moratis and Cochius, 2017). To address sustainable production specifically, indicators of sustainable production (ISPs) were developed (Veleva and Ellenbecker, 2001). Indicators used to measure sustainable production performance are the usage of energy (Choy *et al.*, 2016) and material (Veleva and Ellenbecker, 2001; Pusavec, Krajnik and Kopac, 2010), impact on the environment (Veleva and Ellenbecker, 2001; Nikolopoulou and Ierapetritou, 2012), workers' health and safety (McQuaid, 2000; Veleva and Ellenbecker, 2001), and impact on the community (Veleva and Ellenbecker, 2001; Lv, Li and Mitra, 2020). These indicators can also be used as an input to manage their production's environment, social and economic aspects.

Safety and Sustainable Production Performance

Linking safety and sustainability is not a novel idea. There has been much research that suggested the importance of safety in supporting sustainable development. The earliest research that studied the connection might be that by McQuaid (2000), who argued that improving organisations' health and safety condition will increase the achievement of sustainable development. Meshkati (2007) reviewed the Chernobyl accident and concluded that to ensure a sustainable energy system, an organisation's safety culture needs to be regarded as the most important. Kishimoto (2013) voiced concern regarding new unknown risk. Noticing that the latest development to achieve sustainability may bring new unknown risk, Kishimoto (2013) suggested developing a new framework for risk assessment that can be used for creating sustainability-related designs. Nawaz et al. (2019) also argued that safety and sustainability are closely linked. Furthermore, safety can offer operationalisation for sustainability, since both fields share the same pillars, i.e., economy, environment, and society.

A recent study argued that assessment of sustainability and risk should be combined and suggested using a successful safe and sustainable-by-design approach (Hauschild *et al.*, 2022).

The study considered that assessing risk and sustainability is important and might be a decisive factor in making decisions when developing systems that involve technology changes, ranging from production systems to infrastructure (Hauschild et al., 2022).

Another study suggested graphical approaches to achieve sustainability in the process industry and cleaner production. Their study collected 48 standard and commonly used visual tools to be reviewed and analysed, then evaluated the potential capability of those visual tools to encompass the ability to improve cleaner production, by reducing the consumption of resources such as water, energy or material, over an extended period, and to prevent any damage to the health and safety of humans and the environment (Wang *et al.,* 2022).

Although many have studied the relationship between safety and sustainability, those studies discussed only the broad topic of safety and sustainability. Studies that focused on more specific topics, such as sustainable production performance, are still lacking. Furthermore, how exactly safety can influence sustainability still remains untouched. A study that uncovers the mechanism of the relationship between those two fields is needed.

1.3 Research Aim, Question and Objectives

Even though a great deal of discussion on the importance of safety in the context of sustainable development has taken place, safety is often considered to be a part of the social pillar (Nawaz et al., 2019). Kishimoto (2013) noted that the effort that has been devoted to achieving sustainability might be contradictory to the effort made on health and safety. Many cases have shown that the absence of safety will also harm the economic and environmental pillars of sustainability. Thus, there is a need to understand the impacts of safety on sustainable production, and how exactly safety can influence sustainable production performance in the chemical industry. Additionally, how the characteristics of the chemical industry play their role in influencing the relationship between safety and sustainable production performance needs to be made clearer.

Inspired by the above-mentioned phenomena, this research attempts to structure the line of enquiries and thoughts, by setting out the first research questions:

RQ1: To what extent does safety impact the performance of sustainable production in the chemical industry, and what is the mechanism?

Compared to other industries, the chemical industry has unique characteristics, which subsequently have received increased attention in the extant literature base in recent years (Lee et al., 2015). Research by Lee et al. (2015) details that the chemical industry typically utilises high technology as a core component of its operations, adding greater complexity and a higher likelihood that more accidents occur, as well as being capital-intensive. Champion et al. (2017) noted the rare occurrence of major accidents in chemical production, but the effects are typically catastrophic when they do occur with numerous examples of major incidents happening in recent times. Some of the most prominent incidents include the vapour cloud explosion of the BP Texas City Refinery in March 2005, the dust explosion of the Imperial Sugar Refinery in October 2008, and the explosion and oil spill of the Deepwater Horizon oil rig in April 2010. Noticing how the chemical industry has its own unique characteristics that influence the safety performance of the industry, the second research question are set as follows:

RQ2: To what extent do the chemical industry's characteristics affect the relationship between safety and sustainable production performance?

1.4 Significance of the Study

This study offers several contributions to the safety and sustainability literature. First, it shows the research gaps for further study, in order to understand the extent of the relationship between safety and sustainable production performance in the chemical industry. Second, it also uncovers the mechanism of the relationship between the two. Lastly, it offers practical suggestions to the chemical industry and other industry sectors with similar characteristics. The framework proposed in this study could be deployed into a practical workbook consisting of self-assessment procedures. Although this is not the first study that relates safety and sustainability, this is considered to be the first literature review that produces framework to explain the mechanisms of the relationship between the two.

1.5 Thesis Overview

Apart from this initial chapter, this thesis consists of seven subsequent chapters, which are summarised as follows:

Chapter 2 begins by providing an explanation about how the Systematic Literature Review (SLR) was executed. It expounds on the methodologies employed for data collection, delineates the selection criteria applied, and elaborates on the procedures utilised for data analysis and synthesis. Furthermore, it proceeds to unveil the findings of the SLR, commencing with a bibliometric analysis, followed by the presentation of article profiles and the identification of emergent themes. This chapter subsequently engages in a comprehensive discussion of the results and culminates by developing a theoretical framework based on the outcomes.

Chapter 3 unveil the research methodology, delving into an examination and rationale for the research philosophy, research approach, research strategies, and research methods adopted in this study. Anchored in a pragmatic standpoint, this research validates the use of a sequential mixed-methods research design and offers comprehensive insights into the procedures employed for data collection and analysis, encompassing both qualitative and quantitative studies. Finally, the chapter assesses the concerns regarding research validity and reliability in both qualitative and quantitative studies, as well as in the context of the mixed-methods sequential design.

Chapter 4 detailed the first empirical data collection, which involved a qualitative case study. Commencing with a pilot study, this chapter subsequently conducted within-case analyses on a total of fourteen cases, denoted from case Alpha to case Omega. Following the within-case analysis, the chapter proceeded to explain the implementation of cross-case analysis, aimed at identifying commonalities and emerging patterns among the cases. Ultimately, the chapter drew comparisons between the findings from the qualitative study and the theoretical framework, proposing modifications to improve the framework.

Chapter 5, on the other hand, explained the second empirical data collection phase, involving a quantitative study. An online survey was employed to generate statistically robust and generalisable findings applicable to a broader population. The collected data underwent analysis utilising the partial least squares structural equation modelling (PLS-SEM) technique. This phase served two objectives: further validation of Propositions 1 and 4 with a larger sample size and the clarification of Propositions 2 and 3, which remained unclear following the qualitative case study. Each proposition was assessed through a series of hypotheses, aiming to validate the framework's accuracy.

Chapter 6 undertakes an assessment of the findings from chapters two, four, and five, forging connections among them to derive a conclusive insight. Consequently, this chapter interrelates these findings to offer a collective interpretation and explanation that aligns with the existing knowledge on the subject. The critical findings are discussed, categorised by specific topics according to the framework established within this study. Moreover, the chapter provides a concise summary of earlier studies of a similar nature while highlighting the originality of this research. It also underlines the significance of this study, both in terms of advancing knowledge and practical implications.

Chapter 7 formulates recommendations based on the overarching conclusions drawn from the study. The chapter also acknowledges the study's limitations, offering suggestions for future research endeavours aimed at mitigating these limitations and further advancing the exploration of this topic. Finally, the study concludes by presenting brief concluding remarks.

Chapter 2: Systematic Literature Review

To understand the status of safety and its correlation with sustainable production performance in the chemical industry within literature, this study carried out a systematic literature review (SLR). This study chose to follow the methodology of systematic review which was proposed by (Tranfield, Denyer and Smart, 2003) because of distinct advantages compared to other methods, namely how this methodology can make the literature search transparent and reproducible. Originally, the NHS Centre for Reviews and Dissemination proposed this methodology (SLR) in 2001. The NHS Centre for Reviews and Dissemination has demonstrated the comprehensiveness of this method, which include the identification of research areas, selection of studies, quality assessment, data extraction, and data synthesis (Tranfield, Denyer and Smart, 2003). Systematic Literature Review (SLR) has several advantages such as the ability to deliver rigorous and transparent process, cover studies that are relevant, explanatory findings, and produce empirical output that potentially could lead to the next improvement in research (Denyer and Tranfield, 2009). These advantages distinguish SLR from any other techniques in conducting the literature review, which have several disadvantages such as lacking rigour and unaudited process, resulting in biased results.

2.1 Methodology

To understand the status of safety and its correlation with sustainable production performance in the chemical industry within the literature, this study carried out a systematic literature review (SLR) in line with the same methods as Tranfield et al. (2003). There are several other literature review methods such as semi systematic, which is good for research with broader topic within diverse discipline that use broad research question, or integrative review that is suited for study aim to combine different perspective. However, SLR is more suited for this study, which has specific research question and aim to synthesize what the collection of studies are showing (Snyder, 2019). The SLR has several advantages, such as the ability to deliver rigorous and transparent process, cover studies that are relevant and have explanatory findings, and produce empirical output that potentially could lead to the next improvement in research (Denyer and Tranfield, 2009). These advantages differentiate SLR from other literature review methods, which frequently lack rigour and audit trails, resulting in biased results.

2.1.1 Data Collection

Even though the safety of everyone is very important, the focus of this study is safety at an organisational level, while primarily discussing safety issues in the system, or in the management system, either in the design or at an operational level. The last criterion is that articles selected were required to explicitly or implicitly discuss the correlation between safety and sustainable production performance within the scope of the chemical industry.

Five research databases – EBSCO Academic Complete, EBSCO Business Complete, EBSCO GreenFile, ABI/Inform and Scopus – were used to collect relevant articles and to ensure that all related papers were included and accommodated the interdisciplinary view of the subject under review. Search strings (SS - a combination of keywords) were created for each online database to retrieve as many publications as possible related to safety, sustainable production, and the chemical industry (see Table 1). During the search process, the publication dates were limited to until 2020, while there was no limitation for the earlier publication date in order to capture all relevant articles.

Table 1. Search strings used in the study.

Code used	Formula used in this study for search strings
SS-1	"Safe*" OR "accident" OR "error" OR "incident" OR "near miss"
SS-2	"Sustainable product*" OR "sustainable manufactur*" OR "sustainable design" OR "non-polluting product*" OR "non-polluting manufactur*" OR "green design" OR "green product*" OR "green manufactur*" OR "sustainab*"
SS-3	"Chemical industr*" OR "chemical plant*" OR "process industr*" OR "process plant*" OR "process manufactur*" OR "chemical manufactur*" OR "petrochemical"
SS	SS-1 AND SS-2 AND SS-3

The search for relevant articles was limited to articles that were peer-reviewed, published in academic journals and the full text written in English. However, articles whose abstracts are written in English but not the full text, were not included.

Having retrieved the meta-data from publication databases, the title, abstract and full text of the articles were then screened manually using two sets of assessment criteria (Denyer and

Tranfield, 2009). The assessment criteria are shown in Table 2. Articles that met all the criteria are included in this study.

Table 2. Screening criteria used to select papers.

Title and abstract assessment criteria	Full text assessment criteria
• Peer-reviewed article only. • Only articles written in English. • The purpose of the article, the finding, and/or the implication is about safety and/or sustainable production performance. • The context of the article is the chemical industry.	• The focus of the article is safety and its correlation with sustainable production performance (failure, error, accident, etc. that can have negative effect/impact on the health/well-being of both humans and the environment). • The article concerns safety at an organisational level, regardless of its size, and not at the individual level. • The context of the article is the chemical industry, i.e., addressing a safety issue that is within the scope of the chemical industry.

2.1.2 Data Analysis

After applying the inclusion and consistency evaluation criteria, 1991 titles and abstracts were retrieved, and 374 duplicates were removed. For the remaining 1617 articles, the title and abstract screening was then carried out, resulting in 111 articles ready for full-text screening. The full text screening resulted in 62 articles, which were then exported to NVivo 12 for content analysis. Content analysis is a method employed in research to identify specific words, themes, or concepts within provided qualitative data, such as text.

Each article was read in detail, and first-order coding was established (Tabel 8). Referring to the research questions, relevant data were then extracted through the coding process. To capture and extract the relevant data in the articles, an a priori set of codes was developed (Tabel 8). These 62 articles are published in 39 peer-reviewed academic journals across a number of disciplines, covering a range of research methodological approaches that passed this quality assessment.

The coded articles were then analysed using the template analysis technique, a technique for thematically arranging and examining qualitative data in social science investigations (Brooks and King, 2014). This technique has been proved effective to analyse textual data thematically and allowed a flexibility in structuring the themes. This will subsequently assist the extraction of the relevant information. The codes can evolve due to the newly found codes, or as a result of deleting or merging existing codes throughout the process of theme formation. An overview of the screening process can be seen in Figure 1.

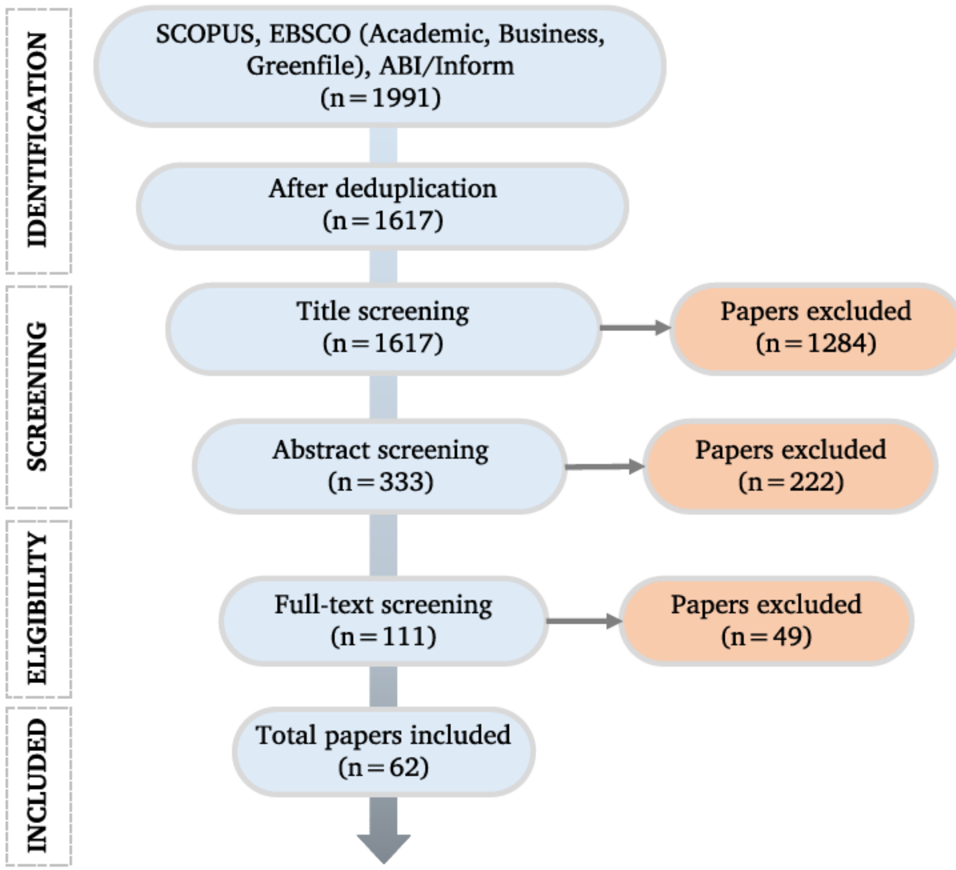


Figure 1. Article screening (based on the PRISMA flow diagram (Liberati *et al.*, 2009))

2.1.3 Synthesis

Once the articles had been coded, the next step was to analyse the emerging themes as the basis of the synthesis of the research propositions. The first order coding process then commenced to allow the collection of detailed information on explicit and/or implicit primary dimensions of safety performance, secondary dimensions, antecedents, consequences, moderating dimensions, mediating dimensions, underlying mechanisms of safety performance, and sustainable production performance. This terminology, henceforth referred to as relationship mechanisms, reflects the different ways safety performance is positioned amongst other distinctly defined constructs or variables in the literature.

Primary dimensions apply to the main constructs or variables, while in the reviewed literature, secondary dimensions or sub-dimensions represent supporting constructs or variables studied. Secondary dimensions can also represent objects of measurement used to describe primary dimensions. The definition of primary and secondary dimensions is adapted from Watts et al. (1993), as quoted in D'Souza and Williams (2000), in line with Podsakoff et al. (2006), who use the term 'dimensions' with their specific measures or variables to cover various facets of constructs. This paper adapts the definition of a construct as "a broad mental configuration of a given phenomenon" by Bacharach (1989), while a variable is "an operational configuration derived from a construct". Performance, for example, is a construct, while a variable representing performance is product safety or quality. Therefore, a variable is the more concrete manifestation of a construct (Bacharach, 1989).

In this study, the antecedents refer to primary dimension interventions, drivers, or determinants; they are constructs or variables that trigger primary dimension existence. The consequences are the implications or results of primary dimensions. The relationship between primary dimensions and consequences is strengthened or weakened by moderating dimensions, while mediating dimensions function as a bridge in this relationship. The relationship between primary dimensions and implications cannot occur when mediating dimensions are taken away. Finally, underlying safety performance mechanisms apply to mechanisms that generate the outcomes of safety performance and describe how safety performance influences the outcomes. The notion of underlying mechanisms differs from mediating dimensions as they are not the constructs or variables, but factors that make up the relationship between constructs or variables.

2.2 Systematic Literature Review Result

2.2.1 Bibliometric

A bibliometric analysis was first conducted on the 62 articles being reviewed to understand the different topics and trends emerging in the areas of safety and sustainable production from 1995 to 2020. Bibliometric analysis is a quantitative method used to assess and analyse patterns and trends within academic publications. The keywords of these articles were uploaded to

VOSviewer (version 1.6.16), a software tool for visualising bibliometric networks. The construction of the networks was carried out using keyword co-occurrence, and the "total link strength attribute" was applied as the weight attribute. Since the themes of this research, safety and sustainability, are across disciplines, using keyword co-occurrence is more suitable for analysis (Gaviria-Marin, Merigó and Baier-Fuentes, 2019). The co-occurrence of keywords analysis enables us to quantify and visualise the thematic network underlying this research (Liao *et al.*, 2018). Articles whose keywords occurred more than four times were then included in the analysis (Umeokafor, Umar and Evangelinos, 2022). Of the total 698 keywords in the articles, 23 met the threshold. The size of the nodes indicates the frequency of occurrence, and the arcs between the nodes show their co-occurrence within the same articles.

As shown in Figure 2, three clusters emerged on the map: sustainable development (red cluster), processes that support accident prevention (green cluster) and the chemical industry (blue cluster). The red cluster mainly considers the environmental sustainability issues in the pertinent industry sector. The green cluster represents the effort in ensuring the safety procedures are being upheld including the risk assessment and the decision-making processes. Finally, the blue cluster provides an industrial context on which this research is focused.

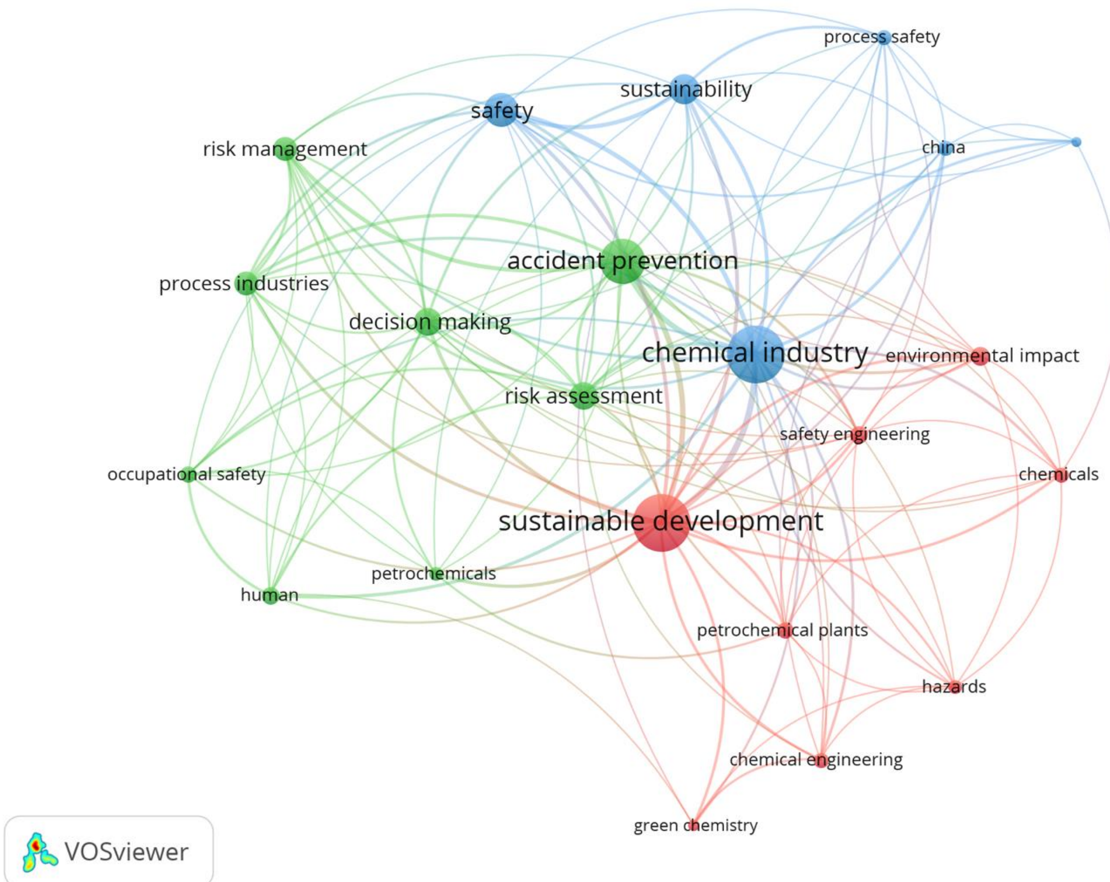


Figure 2. Distribution of the keyword themes from the selected journal articles

2.2.2 Profiles of the Articles

As can be seen in Figure 3, the oldest article found, using the chosen criteria, was published in 1995, followed by one published in 2000. After 2007, in which the chosen criteria found three published articles, articles were found in every year. The highest number is recorded in 2019 with 11 articles, which highlights the significance and relevance of the topic under discussion. The overall increased trend shows that more and more people are concerned with the same issue and have shown an interest in the topic; 2019 being the peak, shows that the topic is very current and relevant to the latest developments.

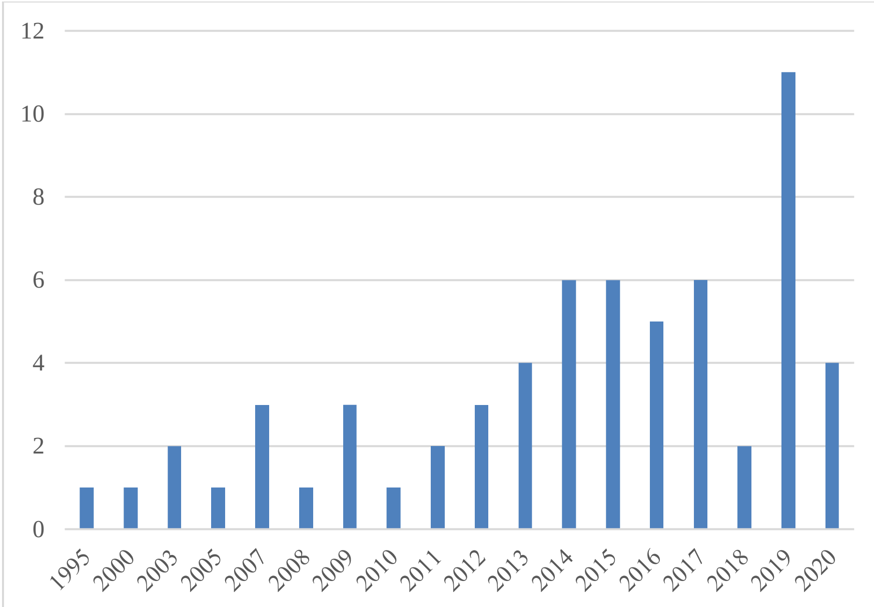


Figure 3. Number of articles over the year

Figure 4 shows the number of articles grouped by contribution. Of the final 62 articles, 17 contributed to designing new tools/strategy/framework, making it the highest on the list. Process industries are considered as high risk. Accidents, minor or major, can occur in process industries due to many causes: either related to chemicals, operational issues, human error, or inadequate process design. Despite many efforts to decrease the number of accidents, it remains high and major industrial accidents usually result in a big loss of both property and lives. This situation is probably what has caused many scholars to design, develop, and propose new tools/strategy/framework. Looking further into the articles, one finding shows that the majority of articles showed concern for error/failure. Figure 5 shows the number of articles grouped by concern for failure discussed in their study. Among the total 62 articles, only 15 do not show any concern towards error/failure, while the remainder are clearly concerned. Detecting possible failure in the current method/system is the most popular concern shown, having eight articles that discuss such concern.

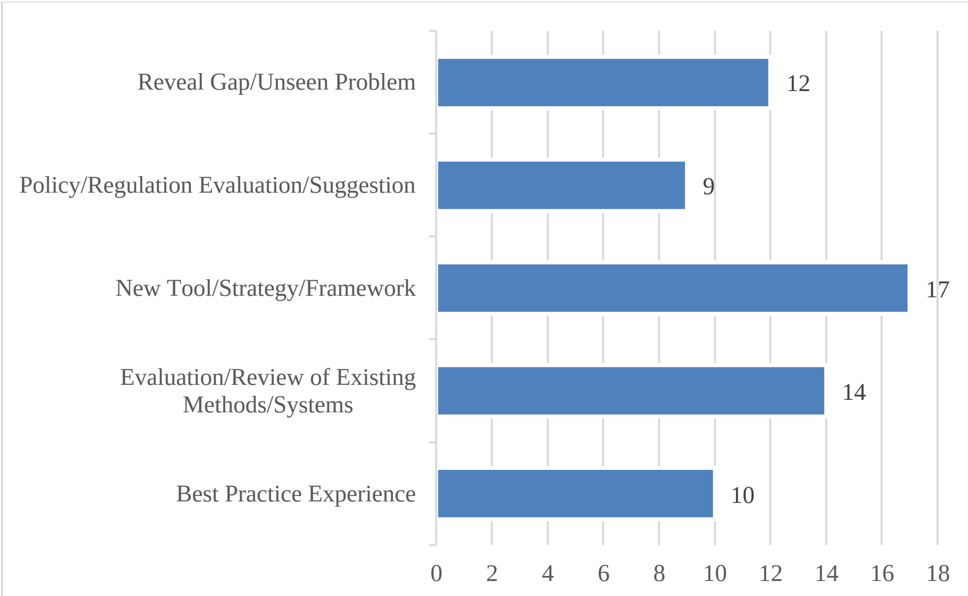


Figure 4. Number of articles according to journal contribution

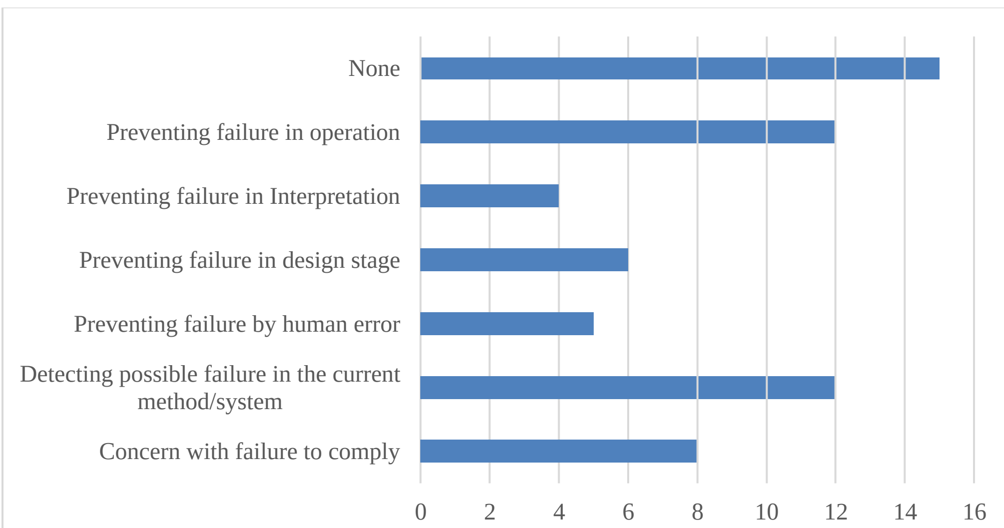


Figure 5. Number of articles according to failure concern

One similarity shared by all articles is that they all make recommendations for improvement. Figure 6 shows the number of articles grouped by type of recommendation for improvement. In the field of chemical engineering, process design is considered as a core element. Many have argued that process design is the centre point, which can bring all components of chemical engineering together. Therefore, many believe that the most effective way to eliminate or diminish the hazards to the lowest possible level is the design approach.

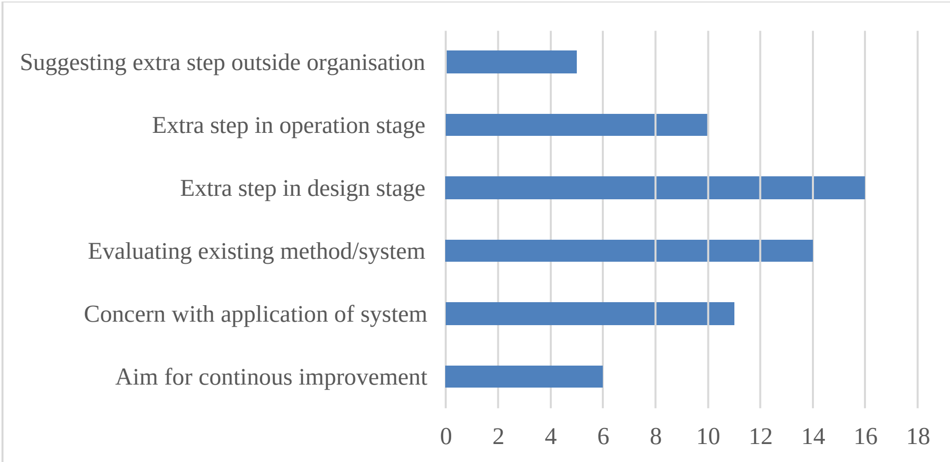


Figure 6. Number of articles according to suggested improvement

Figure 7 shows the number articles grouped by the journal theme. The 62 journal titles are grouped into eight themes: Chemical Science/Engineering/Sustainability, Engineering, Environment, Safety and/or Health, Sustainability, Economics, Resources, and Policy. Of the eight themes, Safety and/or Health has the highest number of articles published with 22 articles. Chemical Science/Engineering/Sustainability is the second highest, followed by Environment, Sustainability and Engineering.

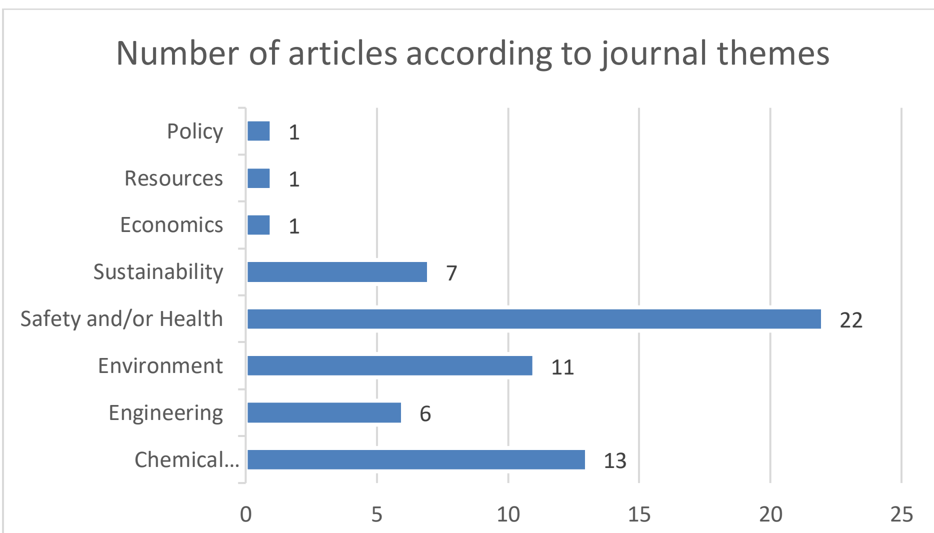


Figure 7. Number of articles according to journal themes

2.2.3 Safety Performance and Sustainable Production Performance

Safety is a relative concept that must be understood in the presence of hazard or risk. The concept of risk is related both to hazards created by humans and those created by nature; consequently, safety constitutes an ability to reduce or eliminate the likelihood of hazardous events occurring (Gobbo *et al.*, 2018). In the context of the chemical industry, where the risk is high, both to humans and the environment, safety plays a very important role.

There are several ways to measure the level of safety in an organisation, or in other words, safety performance. Griffin and Neal (2000) summarised previous studies and reported their findings. The actual safety performance of individuals at workplace can be defined by the components of performance. To distinguish safety performance at workplace there are two component that can be used: safety compliance and safety participation. The fundamental safety activities that must be done by each worker to maintain workplace safety are defined as safety compliance. While the voluntary activities that are related to safety are distinguished as safety participation.

There are several issues regarding safety performance in the chemical industry. One of the issues is the human factor, which is an essential for safety. As Sikorova *et al.* (2017) aptly summarised, the majority of accidents involving runaway reactions in the process industry are associated with the failure of controls and safeguards, or with human error. Akyuz and Celik (2015) also studied how to minimise human error in liquefied petroleum gas (LPG) storage and handling processes. Chidambaram (2016) highlighted how significant human and organisational factors are involved in accidents in all sectors of industry. An accident study in the Greek Petrochemical Industry from 1997 to 2003 showed that 73% of the accident causes were related to human factors (46%) and organisational factors (37%). A close study of incidents in Korea between 1988 and 1997 showed that most accidents (46%) occurred mainly due to operational failures, which were rooted in human factors, including lack of maintenance and lack of a culture of safety-consciousness. These statistics illustrate how significant the human safety factor is.

Another issue is how many companies in chemical industry mainly only consider safety aspect at the later/final stages. However, the cost of process improvement and operational risks can be significantly reduced if safety aspect is considered at the preliminary stage compared to the later stage. Thus, the safety aspect should be reviewed on the earlier stage, as also stated by Teh *et al.* (2019). Brzezińska, Bryant and Markowski (2019) shared the same concern, noting that although fire can result from a growing range of threats, many fire strategies still do not include a proper hazard analysis in the early stages of the project. Chidambaram (2016) also noted the inclusion of design errors, and that the contribution of process defects would produce a similar degree of contribution, as found in the incident review of the Greek petrochemical industry. Athar, Shariff and Buang (2019) and Fernandez-Dacosta *et al.* (2019) also argued that industrial disaster can be avoided through sustainable process designing at the design stage, while Kallenberg (2009) summarised several cases that have highlighted the issue of how chemicals in products are potentially hazardous, as a result of ignoring safety at design stage.

Much research in the literature noted how poor safety performance results in low sustainable production performance. When companies have low safety compliance to environmental policies, industrial practices result in the production of vast amounts of waste, the misuse of natural resources and unnecessary energy use (Chris and Khaled, 2019; Teh *et al.*, 2019; Marhavilas *et al.*, 2020; Yang *et al.*, 2020). This entails designing and implementing sustainability policies in the manufacturing sector (Abdul-Rashid *et al.*, 2017). Shamim *et al.* (2019) added that the development of a safety performance index can achieve a sustainable chemical process.

Poor safety performance can have impact on sustainable production performance in wider scope. Trasande *et al.* (2011) noted that as chemicals have become widespread in the environment in industrialised countries, the prevalence and incidences of chronic health conditions have increased. One in six US children is now obese and 2-8% are now affected by developmental disabilities. Although scientific evidence to supplement the temporal association of increasing chemical exposures with obesity is lacking, the National Research Council has estimated that 28%t of developmental disabilities are due, at least in part, to environmental factors. Casson (Casson Moreno and Cozzani, 2015) also reported several accidents, resulting in human, environmental and economic loss.

2.2.4 Chemical Industry Characteristics

The chemical industry has its own characteristics that are unique, compared to other industries. Several researchers have described these characteristics in their studies. Song et al. (2019) described the chemical industry as a high risk industry, uses high technology (Marhavilas et al., 2020), involves complex processes (Brzezińska et al., 2019) and capital-intensive (Teh et al., 2019). Additionally, it also has very strong connections to virtually every other sector of the economy (Lee *et al.*, 2015; Pashapour *et al.*, 2019; Tong, Pu and Ma, 2019; Tong *et al.*, 2020).

These characteristics require highly trained and skilled talent for the industry's operation (Lee et al., 2015). Reniers and Amyotte (2012) observed that if we examine the first few decades of the preceding century, the number of plants that handle hazardous chemicals in the world has increased significantly. This is a direct result of the variety of chemical products and processes that keep increasing. At the same time, due to increasing densities of population, those plants must be located closer to each other and consequently, closer to highly populated neighbourhoods.

2.2.5 The Importance of Safety Culture

Hajmohammad and Vachon (2014) investigated the potential benefits of a strong safety culture for organisations. Their study concluded that a safety culture is linked to several indicators of organisational performance related to sustainable development. Guldenmund (2000) defined safety culture as follows: "those aspects of the organisational culture which will impact on attitudes and behaviour related to increasing or decreasing risk". Following his definition, the culture of an organisation plays an important role in determining the level of risk within that organisation. The absence of a safety culture will cause the level of risk to be high, and therefore it is more likely that its safety performance to be low.

McQuaid (2000) noted that making a company safe is all about order, control, and good behaviour. In recent years, many researchers have shared the same concern as McQuaid. Pasman, Kottawar and Jain (2020) stressed the importance of safety culture and leadership in the process industry, highlighting that the lack of those factors can increase failure and reduce an organisation's resilience. Yang *et al.* (2020) also noted that lack of a safety culture and safety awareness of workers in Chinese chemical plants is the direct cause of accidents. Considering its importance, Amaya-Gómez *et al.* (2019) even added that every future process engineer needs to have safety culture "planted" in their education.

De Rademaeker *et al.* (2014) also supported this argument, stressing that safety culture is critical in reducing the numbers of accidents. Their study suggested that promoting safety culture in an organisation will help develop critical thinking, prevent complacency in the workplace, aim for excellence and grow responsibility in safety matters. De Rademaeker et al. (2014) noted that a well-developed safety culture can give the organisation the right response to safety-related situations and an ability to act that has considered several perspectives.

Despite its importance, the level of safety culture in an organisation is not easy to define. Safety culture is not easy to measure because it entails the assumptions and beliefs that are shared by every worker in the organisation. Sudarmo and Arifin (2018) proposed a tool to measure the level of safety culture in an organisation based on Loughborough University's Safety Climate Survey (Loughborough Safety Climate Assessment Toolkit - LSCAT). Their study suggested that important factors in measuring safety culture are management value, risk perception, safety system, work pressure, and competence level.

2.2.6 The Research Questions Discussion

RQ1 in this study seeks to understand to what extent does safety impact the performance of sustainable production in chemical industry. In the previous section, it has been discussed how, in the context of the chemical industry, where the risk is high to both human life and the environment, safety plays a very important role. There is much research that highlight the importance of safety, and where safety is absent the consequences can be catastrophic, causing heavy loss of life, health, property, and the environment (Nawaz et al., 2019). For example, Sovacool et al. (2016) analysed accidents that occurred in the low-carbon energy sector from 1950 until 2014. They studied the literature and found that during that period, there were 686 accidents recorded. Those 686 accidents caused a staggering 182,794 fatalities and property damage losses as high as $265.1 billion. On average, each time an accident occurred in the low-carbon energy sector there would be 267 human lives lost and $389 million of property damage. Those numbers are definitely not small. No matter how good the sustainability performance in energy production, it can be argued that the loss caused by the accidents is offsetting the sustainability performance. The consequences of the absence of safety are not only felt by humans, but also the environment. Sikorova et al. (2017) noted that, aside from the impact on human health, the consequences of the most major accidents were also shown to have a significant impact on the environment, social well-being and also on the biotic components of the environment. In certain cases, surface water and groundwater pollution occur which could pollute drinking water supplies in the affected area.

The findings have shed light on addressing RQ1, revealing that safety's influence on sustainable production performance in the chemical industry extends beyond the well-being of workers. It encompasses all dimensions of sustainability, including environmental and economic facets.

Nevertheless, RQ1 doesn't conclude here; it also probes the mechanisms underpinning the relationship between these factors.

RQ2 aims to understand the role of the chemical industry's characteristics in the relationship between safety and sustainable production performance. The unique characteristics of chemical industry have been discussed by much research. Lee et al. (2015) described the chemical industry as an industry that uses high technology and is capital-intensive. Additionally, it also has very strong connections to virtually every other sector of the economy. Casson Moreno and Cozzani (2015) noted how, in the case of biomass, which is part of chemical industry, the more complex the processing, the more likely it is to cause more incidents or accidents with major consequences.

The findings have provided evident signals that the characteristics of the chemical industry do, in fact, exert an impact on the relationship between safety and sustainable production performance. However, the precise role of these characteristics remains obscure and necessitates further investigation.

The discussion that has arisen from RQ1 and RQ2 has resulted in several conclusions. First, in the context of the chemical industry, where the risk is high both to humans and the environment, safety plays a very important role (Klein and Viard, 2013; Amaya-Gómez *et al.*, 2019; Song *et al.*, 2019; Marhavilas *et al.*, 2020; Yang *et al.*, 2020). Second, the unique characteristics of the chemical industry play a critical role in sustainability performance (Al-Sharrah, Elkamel and Almanssoor, 2010; Srivastava and Gupta, 2010; Chidambaram, 2016; Sikorova *et al.*, 2017; Pasman, Kottawar and Jain, 2020). However, despite the extensive discussion in the literature, accidents in the chemical industry are still considered high, resulting in the decrease in the sustainable production performance (Phimister *et al.*, 2003; Reniers, Lerberghe and Coen Van Gulijk, 2005; Trasande *et al.*, 2011; De Rademaeker *et al.*, 2014; Casson Moreno and Cozzani, 2015).

Nonetheless, as safety and sustainability share the same pillars (economic, environmental, and social), it can be argued that there is a strong linkage between the safety performance and the sustainability performance. The mechanism of how safety performance influences sustainable production performance in the chemical industry will be discussed in the following section.

2.3 Systematic Literature Review Discussion

2.3.1 Analysis and Synthesis of the Literature

In order to have an understanding about how safety performance influences sustainable production performance, this research examines how the safety-sustainability literature addresses safety performance. To make the relationship clearer, the relationship mechanism between safety performance and sustainable production performance, either stated explicitly or implicitly (Lusiantoro *et al.*, 2018), is mapped and classified into Table 3. The column in Table 3, categorises relationship mechanism according to the positioning of the safety performance construct, either as antecedent, primary dimension, secondary dimension, moderating dimension, mediating dimension, or consequences, depending on how it influences sustainable production performance. The rows show how each literature described the relationship mechanism, either explicitly or implicitly. Thus, the first row represents "safety performance as explicit antecedent" and the second "safety performance as implicit antecedent", and so on. The words in each cell are the terms used by the literature to describe safety performance and sustainable production performance and the number in bracket shows how many times the said term appears in different article.

For example, row 3 of Table 3 shows that this research identifies a correlation between safety performance and sustainable production performance as a primary dimension, and the literature addressed this explicitly (Akyuz and Celik, 2015). Through safety compliance, safety performance directly influences workers' health and safety (Champion et al., 2017); therefore, safety performance is a primary dimension of sustainable production performance. Row 3 of Table 4 further identifies that safety compliance can lead to a better natural environment and use of resources (Jacobs *et al.*, 2016); therefore, better sustainable production performance is a consequence of safety compliance.

Another example in row 3 is that this study identifies safety performance as a primary dimension, affecting the clean environment as a consequence, and this is also stated explicitly in the literature (Raksanam *et al.*, 2012).

This study further identifies, in row 7, that the relationship between safety performance and sustainable production is indirect and only exists when the improvement of technology influences the efficiency of resource consumption (e.g. amplifying the extent of technology improvement can influence sustainable production) (Accardi *et al.*, 2013). This example shows that safety performance is a mediating variable. The method of categorising the positioning of the safety performance construct is helpful in order to have a better understanding regarding the safety-sustainability literature, and how the literature indicates how safety performance affects sustainable production performance.

2.3.2 Positioning of the Safety Performance Constructs

Following Table 3, a summary of articles and their author(s) that position safety performance amongst other constructs in the safety-sustainable production performance literature, either explicitly or implicitly, is given in Table 4. From Table 4, it can be concluded that safety performance is positioned as either a primary or secondary dimension by an overwhelming majority. As shown in Table 3, as a primary dimension, safety performance can improve economic performance, health, safety, and environmental impact (Teh et al., 2019). The relationship between safety performance as a primary dimension and sustainable production performance as the consequence is mediated by consumption or usage of hazardous chemicals (Raksanam et al., 2012). The relationship is also moderated by hazardous process, level of technology, and occupational risk. The benefits of safety performance are highest when hazardous chemical usage is low, production process is less hazardous, and the level of technology is high.

Table 3. Positioning Safety-Sustainable Production Performance Constructs and Variables

Ex/Implicitly mentioned in the literature	Antecedents (number of articles)	Primary dimensions (number of articles)	Secondary dimensions (number of articles)	Moderating dimensions (number of articles)	Mediating dimensions (number of articles)	Underlying Mechanism (number of articles)	Consequences (number of articles)	Sustainable production performance (number of articles)
Explicit	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Implicit	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Explicit	Safety culture (3), safety system (4), management commitment (3), risk perception (1)	Safe handling and storage (1), accident rate (4), safety performance (7), safe design (4), safe chemicals (2), risk control (1), risk awareness (1), risk management (3), major accident (6), process safety (1)	Assessment method (1), chemical exposure (1)		Industry characteristics (6), management commitment (2), hazard identification (2), development stage (1), hazardous materials (3), technology (2), occupational risk (6), high consumption (1), accident prevention (2), hazardous process (3), supplier selection (1)	Human factors (2), sustainability assessment (1), risk assessment (3), fire strategy (1)	Sustainable transportation (1), sustainable production (13), sustainable development (9), green production (1), economic value (2), clean environment (1), major accident (1), economic resilience (1)	Accident rate (5), workers' safety and health (10), waste production (3), economic value (11)

(Continued)

Ex/Implicitly mentioned in the literature	Antecedents (number of articles)	Primary dimensions (number of articles)	Secondary dimensions (number of articles)	Moderating dimensions (number of articles)	Mediating dimensions (number of articles)	Underlying Mechanism (number of articles)	Consequences (number of articles)	Sustainable production performance (number of articles)
Explicit		Sustainable production (1), sustainable policy (1), technology (1), sustainable indicators (3), innovation (1), chemical usage (1), green chemistry (1)	Safety performance (9)		Industry characteristics (3), company participation (1), waste production (1), occupational risk (1)	Operation strategy (1)	Economic value (1), sustainable production (2), sustainable development (6)	Economic viability (6), social performance (2)
Implicit	Sustainable awareness (1)	Sustainable funding (1), green chemistry (1), chemical usage (2), sustainable policy (1), sustainable design (1), sustainable assessment (1)	Safety performance (7)		Sustainable policy (1), chemical usage (1), environmental business market (1)	Production cost (1), chemical management (1), safe design (1), factors trade-off (1), closed life cycle (1), green metric (1)	Sustainable development (2), sustainable production (2), children's health (1), waste production (2)	Clean environment (6), economic viability (1)
Explicit	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

(Continued)

Ex/Implicitly mentioned in the literature	Antecedents (number of articles)	Primary dimensions (number of articles)	Secondary dimensions (number of articles)	Moderating dimensions (number of articles)	Mediating dimensions (number of articles)	Underlying Mechanism (number of articles)	Consequences (number of articles)	Sustainable production performance (number of articles)
Explicit		Technology (2), innovation (1), process industry (1)			Risk assessment (1), safety performance (3)		Sustainable production (3), economic value (1)	Clean environment (1), high consumption (1), economic viability (2)
Implicit		Hazardous process (1)			risk assessment (1)		Sustainable production (1)	Economic viability (1)
Explicit		Risk assessment (1)			Industry characteristics (1)		Safety performance (1)	Accident rate (1)
Implicit	Awareness (1)	Sustainability policy (1)			Law requirements (1)	Political support (1)	Chemical risk management (1)	

As a primary dimension, safety performance is driven by other constructs including a safety system and management commitment as its antecedents. A good safety system in an organisation can improve safety culture and therefore safety performance, thus increasing the value of the safety performance (Athar et al., 2019a). Low levels of management commitment decrease the safety culture, and therefore safety performance (Wilding and Lewis, 2007). This argument implies that once safety culture is established, safety performance will then occur.

2.3.3 Classification of Constructs and Variables

Following the previous step, the constructs and variables of safety-sustainable production performance identified in Table 3 were further classified into higher level themes (see Table 5). This is done in order to have the patterns and relationships amongst constructs and variables that explain how safety performance affecting sustainable production performance is characterised. In line with Griffin and Neal (2000), this research classified management value, safety system, risk perception, work pressure and competence as safety culture. All constructs and variables related to knowledge and skill motivation were classified as determinants of that safety culture.

This research classified constructs and variables, such as energy and material used, natural environment, workers' health and safety, economic viability and community development, under sustainable production performance, whereas hazardous material, hazardous process, high risk, high resource consumption and waste production are classified as chemical industry characteristics. In line with Veleva and Ellenbecker (2001), these categories were further classified as indicators of sustainable production. Afterwards, all constructs and variables in relation to safety compliance and safety participation were classified as safety performance, in accordance with Griffin and Neal (2000). After all categories have been determined, constructs and variables of safety-sustainable production performance identified in Table 3 are grouped according to their similarities, and then put in the respective column.

Table 4. Respective authors of safety – sustainable production performance relationship

Safety – sustainable production performance relationship	**Number of articles**	**Authors**
Safety performance as explicit antecedent	N/A	N/A
Safety performance as implicit antecedent	N/A	N/A
Safety performance as explicit primary dimensions	28	(Barghava and Welford, 1995); (McQuaid, 2000); (Phimister *et al.*, 2003); (García-Serna, Pérez-Barrigón and Cocero, 2007); (Wilding and Lewis, 2007); (Narayan, 2012); (Raksanam *et al.*, 2012); (Reniers and Amyotte, 2012); (Klein and Viard, 2013); (De Rademaeker *et al.*, 2014); (Akyuz and Celik, 2015); (Remoundou *et al.*, 2015); (Chidambaram, 2016); (Ghasemi and Nadiri, 2016); (Jacobs *et al.*, 2016); (Champion, Van Geffen and Borrousch, 2017); (Teh *et al.*, 2019); (Brzezińska, Bryant and Markowski, 2019); (Athar *et al.*, 2019); (Athar, Shariff and Buang, 2019); (Fernandez-Dacosta *et al.*, 2019); (Shamim *et al.*, 2019); (Song *et al.*, 2019); (Chen, Reniers and Khakzad, 2019); (Tong, Pu and Ma, 2019); (Pashapour *et al.*, 2019); (Chen and Reniers, 2020); (Yang *et al.*, 2020)
Safety performance as implicit primary dimensions	8	(Hansen, Carlsen and Tickner, 2007); (Goossens *et al.*, 2008); (Xie, Li and Zhao, 2010); (Liew, Adhitya and Srinivasan, 2014); (Casson Moreno and Cozzani, 2015); (Kim *et al.*, 2017); (Sikorova *et al.*, 2017); (Amaya-Gómez *et al.*, 2019)
Safety performance as explicit secondary dimensions	12	(Kidwai and Mohan, 2005); (Lange, 2009); (Al-Sharrah, Elkamel and Almanssoor, 2010); (Tan *et al.*, 2015); (Husgafvel *et al.*, 2015); (Lee *et al.*, 2015); (Choy *et al.*, 2016); (Blum *et al.*, 2017); (Iles, Martin and Rosen, 2017); (Chris and Khaled, 2019); (Tong *et al.*, 2020); (Marhavilas *et al.*, 2020)
Safety performance as implicit secondary dimensions	7	(Fiorini and Vasile, 2011); (Trasande *et al.*, 2011); (Fujii and Managi, 2012); (Phan, Gallardo and Mane, 2012); (Holt *et al.*, 2016); (Dunjó, Cronin and Sarno, 2019); (Pasman, Kottawar and Jain, 2020)
Safety performance as explicit moderating dimensions	N/A	N/A
Safety performance as implicit moderating dimensions	N/A	N/A
Safety performance as explicit mediating dimensions	4	(Srivastava and Gupta, 2010); (González-Moreno, Sáez-Martínez and Díaz-García, 2013); (Accardi *et al.*, 2013); (Iavicoli *et al.*, 2017)
Safety performance as implicit mediating dimensions	1	(Mohsin, Qureshi and Ashfaq, 2019)
Safety performance as explicit consequences	1	(Reniers, Lerberghe and Coen Van Gulijk, 2005)
Safety performance as implicit consequences	1	(Kallenberg, 2009)

Table 5. Classification of Safety-Sustainable Production Performance constructs and variables

Central Themes	Categories	Constructs and Variables
Safety Culture	Management Value	Management commitment, organisational improvement, management priority
	Safety System	Safety system, system safety, safety management
	Risk Perception	Risk perception, self-protection, risk awareness
	Work Pressure	Work pressure, stressful environment
	Competence	Competence, worker's ability
Safety Performance	Safety Compliance	Safe handling and storage, accident rate, safety performance, safe design, safe chemicals, major accident, process safety, risk assessment
	Safety Participation	Precautionary principles, health and safety, chemical management, risk control, risk awareness, risk management
Sustainable Production Performance	Energy and Material Used	Sustainable transportation, sustainable production, sustainable development
	Natural Environment	Green production, clean environment, waste production
	Workers' Health and Safety	Major accident, accident rate, workers' safety and health
	Economic Viability	Economic resilience, economic value
	Community Development	Collective action, welfare improvement
Chemical Industry Characteristics	Hazardous Material	Industry characteristics, management commitment, hazardous materials, technology, supplier selection
	Hazardous Process	Hazard identification, development stage, hazardous process
	High Risk	Occupational risk, accident prevention
	High Resource Consumption	Resource consumption, energy consumption
	Waste Production	High emission, hazardous waste

2.3.4 Development of the Theoretical Framework

The purpose of Table 3 is to show how the positioning of the safety performance construct, either as antecedent, primary dimension, secondary dimension, moderating dimension, mediating dimension, or consequences, depending on how it influences sustainable production performance, can give a clearer picture regarding the difference in relationship mechanisms. By understanding the relationship between safety performance and sustainable production performance, followed by grouping these relationships, the influence of safety performance to sustainable production performance can be understood.

Safety culture has been determined as the antecedent of safety performance in the literature. Champion et al. (2017) argued that the key to success for the Dow Chemical Company in reducing its accident rate between 2013 and 2015 was built on a strong foundation of safety culture and leadership. A strong management system and constant devotion to process safety at all levels of the organisation are necessary to drive the reduction of process safety incidents. Athar et al. (2019a) found that managerial aspects are considered key contributors to accidents. Similarly, McQuaid (2000) argued that the emphasis placed on senior management involvement may result in the ownership of health and safety being removed from the shop floor. For this reason, the first proposition is postulated that,

Proposition 1. Safety culture is the antecedent of safety performance. The higher the safety culture, the higher the safety performance will be.

Studies in the literature have shown that a characteristic of the chemical industry is mediating the relationship between safety culture and safety performance. In a very sensitive and complex work environment, such as LPG tanker operations, the risk to safety for workers, facilities, and the environment will become even higher (Akyuz and Celik, 2015). There is no doubt that if there were any operational failure during critical processes (i.e. cargo loading), it would lead to a catastrophic accident such as a massive explosion. (Athar *et al.*, 2019) noted that chemical process manufacturing is associated with risks that cannot be eliminated. This condition requires a better safety process strategy in order to prevent accidents, which can be catastrophic when they happen in the chemical industry. This is postulated by the following proposition:

Proposition 2. Chemical industry characteristics moderate the relationship between safety culture and safety performance. The harsher the characteristics of the chemical industry, the weaker the influence of safety culture on safety performance will be.

Many have argued that safety performance is the primary dimension in influencing safety production performance. Choy et al. (2016) argued that safety is a critical issue for sustainable consumption and production. Casson Moreno and Cozzani (2015) carried out a survey of major accidents related to the production of bioenergy (intended as biomass, bioliquids/biofuels and biogas) based on past accident reports available in the open literature and in specific databases and built a data repository. Data analysis shows that major accidents have increased in recent years and their number keeps on growing, resulting in relevant human, environmental and economic losses. (Kim *et al.*, 2017) particularly noted that proper assessment and management of hydrogen fluoride is essential for a safe and sustainable chemical industry.

Griffin and Neal (2000) described safety compliance and safety participation as indicators for safety performance. González-Moreno et al. (2013) described how a more efficient and responsible use of natural resources, including energy, is an important factor in increasing sustainable production performance. Their study involved a sample of 544 companies in the Spanish chemical industry and concluded that safety compliance and participation are needed to achieve their goals.

Proposition 3. Safety performance directly influences sustainable production performance. The higher the safety performance, the higher the sustainable production performance will be.

Griffin and Neal (2000) proposed that safety culture is the antecedent of safety performance, with management value being one of the indicators of a safety culture. (Mearns, Whitaker and Flin, 2003) added risk perception and safety system as two other indicators. (Klein and Viard, 2013) stressed leader and management commitment as an important factor for successful process safety performance. Industrial regulation and standard compliance cannot be achieved without strong commitment from top level management. (Barghava and Welford, 1995) noted how the failure of the safety system was the main cause for the catastrophic incident at Bhopal. Additionally, (Remoundou *et al.*, 2015) described how the risk perception of operators, workers, residents and bystanders potentially influences the extent to which different stakeholders adopt self-protective behaviour.

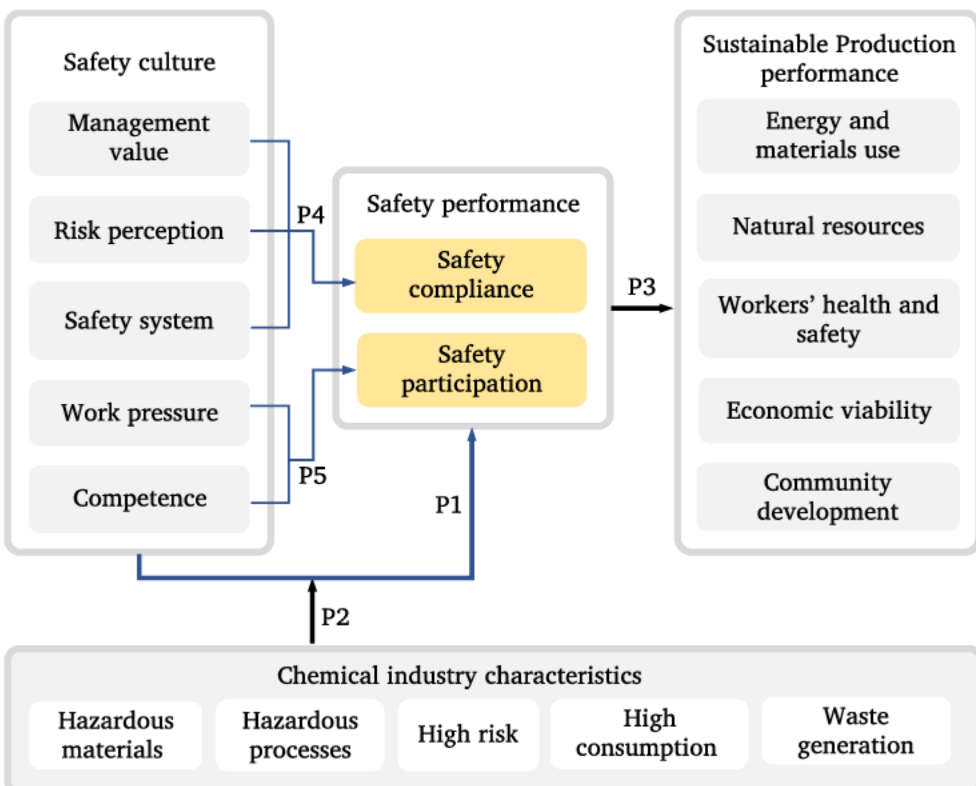
Proposition 4. Management value, risk perception, and safety systems are the antecedents of safety compliance.

Guldenmund (2000) proposed work pressure and competence as other indicators of a safety culture. (Xie, Li and Zhao, 2010) noted that the characteristics of the coal chemical industry, i.e.

labour intensive, harsh environment and intensive material handling, has increased the work pressure for their workers, which in turn has influenced the safety culture within the industry. Xie et al. (2010) also noted that new coal-based chemical technologies such as coal liquefaction, coal gasification, coal-to-methanol including its derived products, and co-production based on the coal chemical industry were carried out rapidly in China. This situation requires high competence from their workers.

Proposition 5. Work pressure and competence are the antecedents of safety participation.

The discussion above has allowed this study to recognise and become familiar with how the variables interact with each other. Finally, based on the propositions above, it enables the construction of an initial theoretical framework which formalises the relationship between safety and sustainable production performance in the chemical industry, as shown in Figure 8.



P1 – P5: Proposition 1 – Proposition 5

Figure 8. Theoretical framework of Safety-Sustainable Production Performance.

The construction of the theoretical framework represents progress in addressing both RQ1 and RQ2. It vividly portrays the extent of safety's influence on sustainable production performance and explains the underlying relationship mechanisms. Moreover, it offers insights into the role and magnitude of the chemical industry's characteristics. Nevertheless, it's important to note that this framework was derived exclusively from the findings of the systematic literature review (SLR), drawing upon data solely from existing literature. Instead of definitive answers to both research questions, the framework should be viewed as preliminary findings. To obtain more valid and reliable answer to the research questions, empirical data needed to be collected.

Chapter 3: Research Methodology

This chapter provides details of the data collection phase and analysis procedures used in this study. The chapter is structured as follows. Section 3.1 explains and justifies the research philosophy adopted. Section 3.2 outlines the research strategy, while Section 3.3 explains the limitation of mixed method. Section 3.4 describes the case study design in more detail. Section 3.4.1 explains how the case is selected, followed by Sections 3.4.2, 3.4.3, and 3.4.4 which explain the sources of qualitative data, both primary and secondary.

3.1 Research Philosophy and Paradigm

Research philosophies represent the fundamental assumptions and belief systems held by researchers, shaping their perspective on the world. These foundational beliefs and ideas about knowledge serve as guiding principles that aid researchers in the selection of the most appropriate research strategies and methodologies for their specific study (Saunders, Thornhill and Lewis, 2009). These assumptions can also be referred to as a worldview, a term used interchangeably with paradigm (Creswell *et al.*, 2007). A paradigm encompasses a set of overarching concepts, principles, and values that reflect a particular community of experts or specialists (Kuhn, 1970). For instance, researchers who lean toward quantitative methods often operate within the positivist or post-positivist paradigm, while those inclined toward qualitative approaches typically align with the constructivist paradigm. A central aspect of the ongoing debate surrounding paradigms pertains to the notion of incompatibility, positing that qualitative and quantitative paradigms cannot be harmoniously integrated (Robson, 2011).

There are two fundamental aspects of research philosophy that pertain to a researcher's ontological and epistemological positions, which are elaborated upon below. Ontology delves into the nature of reality and relates to the researcher's underlying assumptions concerning how the world functions (Saunders, Thornhill and Lewis, 2009). Within academia, two facets of ontology have gained recognition: 'Objectivism' and 'Subjectivism' (Saunders et al., 2009). Objectivism subscribes to the viewpoint that social entities exist independently of the individuals involved in their existence. It regards the phenomena under investigation as concrete and quantifiable. Given this perspective of separateness between the researcher and the research subject, objectivists often employ quantitative research methodologies (Saunders et al., 2009).

Conversely, subjectivism posits that social phenomena are shaped by the perceptions and subsequent behaviours of the individuals engaged with them. Subjectivists perceive reality as influenced by the societal context in which these phenomena emerge (Saunders et al., 2009). In essence, subjectivists believe that socially constructed events shape the world in which individuals participate in these phenomena (Guba and Lincoln, 1994). Consequently, from a research standpoint, the interpretation of human affairs holds significant implications for comprehending actions and their repercussions (Burrell and Morgan, 1979).

Epistemology pertains to what qualifies as valid knowledge within a particular field of study (Saunders et al., 2009). Within this domain, two philosophical orientations are recognized: Constructivism and positivism. A positivist perspective aligns with the philosophical stance akin to that of natural scientists. Here, reality is defined by tangible entities, such as computers and machines, which are considered inherently 'real.' These objects are perceived to exist independently of the researcher, leading positivists to assert that data collection is less susceptible to bias. Consequently, they contend that objective knowledge can be derived from direct observation (Robson, 2011). Since positivists view the social world as existing externally and autonomously from the researcher, they strive to produce findings that can be generalized to broader contexts (Saunders et al., 2009).

In contrast, interpretivism embraces an approach where knowledge is acquired through a profound understanding of phenomena achieved via in-depth exploration and subsequent analysis. Interpretivists argue that reducing complexity solely to a set of law-like generalizations leads to the loss of valuable insights (Crotty, 1998). Interpretivism underscores the role of individuals as social actors, emphasizing that knowledge is gained by immersing oneself in the societal sphere and comprehending phenomena from their perspective. This understanding is achieved through personal and empathetic engagement (Holden and Lynch, 2004). Interpretivism does not assert the generalizability of its outcomes; instead, it provides results that are specific to a particular context.

Despite the historical debates known as the paradigm wars (Tashakkori and Teddlie, 2010), there has been a notable shift away from the argument that quantitative and qualitative research cannot be effectively combined. Rather, a more pragmatic perspective has emerged among researchers. Consequently, the belief in the incompatibility between these research approaches is no longer the dominant force guiding the quest for superior research (Robson, 2011).

As Morgan (2007) points out, the way forward involves a reduced emphasis on "paradigms as a philosophical stance" and a greater emphasis on the concept of "paradigm as shared beliefs among groups of researchers." However, this doesn't mean that establishing a philosophical stance should be disregarded. Instead, it should be regarded as a reference point, a set of practices within a research discipline, rather than a set of rigid principles handed down by philosophers. This approach offers an alternative path forward (Robson, 2011). In essence, the focus should revolve around the suitability of research methods in addressing specific research questions, while the commitment to a particular paradigm and philosophical stance should be seen as a consequence of those considerations (Bryman, 2015).

Certainly, over the past two decades, researchers in the fields of social and behavioural sciences have increasingly embraced mixed-methods research as a way to move beyond the divisive philosophical dichotomies of qualitative and quantitative paradigms. It has become more common for mixed methodologists to operate within the framework of pragmatism and to be interested in both narrative and numerical data (Creswell *et al.*, 2007; Tashakkori and Teddlie, 2010). Pragmatism represents a "deconstructive paradigm that challenges concepts such as 'truth and reality' and instead prioritizes 'what works' as the truth relevant to the research questions at hand" (Teddlie & Tashakkori, 2010). This perspective draws upon various ideas, including the appreciation of both objective and subjective knowledge (Creswell & Plano Clark, 2018). It seeks to strike a balance between philosophical rigidity and scepticism in order to discover practical solutions (Johnson and Onwuegbuzie, 2004).

Pragmatism asserts that the most critical consideration regarding ontology, epistemology, and axiology is their appropriateness to the research question. Therefore, it advocates for the use of any philosophical or methodological approach that is suitable for addressing a specific research problem (Saunders et al., 2009; Robson, 2011).

In light of the array of research philosophies, this study embraces a pragmatic perspective as its foundational philosophy for conducting research. The rationale for opting for pragmatism lies in the study's objective of comprehending the relationship between safety and sustainability. Embracing a pragmatic paradigm facilitates the integration of mixed methods, encompassing both qualitative and quantitative approaches in both data collection and analysis. This amalgamation of methods brings several advantages to this research, such as triangulation and the enhancement of findings through complementary insights. Furthermore, it enables the adoption of a rigorous framework development process.

3.2 Research Strategy

Saunders et al. (2009) eloquently summarise the use of research strategies as "what is most important is not the label that is attached to a particular strategy, but whether it will enable you to answer your particular research question(s) and meet your objectives" (p. 141). They further argue that the choice of the research strategy will be guided by 1. The extent of existing knowledge, 2. The amount of time and resources available, and 3. The author's philosophical underpinnings. This study will implement a mixed-methods research to answer the empirical research questions of this study.

Mixed methods are a procedure whereby the collection, analysis, and integration of both quantitative and qualitative data in the research process is formed, within a chosen area of research, in order to gain a better understanding of the research problem (Tashakkori and Teddlie, 2010). As stated by Johnson & Onwuegbuzie (2004, p. 17), "its logic of inquiry includes the use of induction (or discovery of patterns), deduction (testing of theories and hypotheses), and abduction (uncovering and relying on the best of a set of explanations for understanding one's results." The premise of mixed methods is that the combination of both quantitative and qualitative methods means that they complement each other and allow for a more robust analysis of complex phenomena (Creswell and Clark, 2018). Therefore, it provides several advantages such as triangulation, complementarity, development and expansion of research by using different methods at different stages of inquiry. However, it also presents challenges such as time and resources, questions of skill, and convincing critics on the logic of mixing methods (Creswell and Clark, 2018).

There are several kinds of mixed-method designs, as discussed in the literature. These designs range from convergent, sequential, embedded, transformative and multi-phase designs (Creswell & Plano Clark, 2018). This study will adopt a sequential mixed-methods design, an exploratory sequential mixed-methods design (which is a two-phase sequential study). This design enables the qualitative exploration of a topic which then builds to a second, quantitative phase (Creswell & Plano Clark, 2018). Researchers mainly use this approach in developing an instrument which builds upon qualitative results and is then utilised in the quantitative data collection. Therefore, this design is also referred to as the instrument development (Creswell & Plano Clark, 2018) and the quantitative follow-up (Morgan, 1998). This design is useful when the need for a second quantitative phase emerges based on lessons learned from the initial qualitative phase. Moreover, the research can produce a new instrument as a product of the research process. The purpose of exploratory design is to generalise qualitative findings based on a few individuals from the first phase to a larger sample and population in the second phase. That is, the results of the qualitative phase develop or inform the second, quantitative method. This design is grounded on the premise that exploration is needed for one of several reasons: 1. Measures or instruments are not available, 2. The variables are unknown, or 3. There is no guiding framework or theory (Creswell & Plano Clark, 2018). Thus, it begins qualitatively, and is best suited for the exploration of a phenomenon. The design is useful when there is a need to develop and test an instrument if one is not available (Creswell & Plano Clark, 2018), or to identify relevant variables to study quantitatively when the variables are unknown. Also, it can be appropriate when a new theory or classification needs to be tested, or a nascent phenomenon must be studied in depth in order to measure the prevalence of its dimensions.

3.3 Limitations of the Mixed Method

Although the fusion of qualitative and quantitative research methods offers numerous advantages, it also presents certain challenges within each of the mixed methods designs. Notably, in the case of exploratory sequential design, a significant challenge lies in precisely defining the procedures for the quantitative phase because predicting how the initial phase of the research will influence the second is inherently complex (Creswell & Plano Clark, 2018). Additionally, there is the difficulty of determining which qualitative data to incorporate and how to effectively utilize it in shaping the quantitative instrument. Lastly, including the same participants in both phases of the study may be perceived as challenging due to the potential for introducing bias.

The following measures were taken to address these potential limitations. Firstly, the items questionnaire was tentatively composed based on the qualitative findings. These questionnaires were then validated based on the pre-test and pilot studies with both academics and practitioners. Secondly, the designed interview guide included specific questions which focus on outcome variables related to a firm's safety performance, in order to facilitate the transition to the instrument development in the interim phase. Finally, a large sample size from the chemical industry, represented by various organisations' sizes and product types, was sought to maintain the generalisability of the findings. This sample did not include previously used participants and companies in the qualitative phase to avoid bias. The specific research methods, i.e., the data collection and analysis procedures, are elaborated in the subsequent sections beginning with the qualitative phase and followed by the quantitative phase.

3.4 Qualitative Case Study

The case design entails making determinations about specific theoretical elements of the case study, such as the research topic, research inquiries, criteria for selecting cases, the unit of analysis, and the data sources (Yin, 2013). According to Yin (2013), the case design is an important and beneficial stage in establishing the connection between the research issues and the field investigations. More specifically, the research questions present what must be discovered, whereas the case design determines what must be investigated and how it must be studied in order to answer the research question.

3.4.1. Case Selection

The subsequent crucial step in case design for multiple case study research involves the selection of cases. Yin (2013) outlines two criteria for identifying potential cases. First, cases where similar outcomes are anticipated can serve as "literal" replications. Second, cases can be chosen for "theoretical" replication, which means selecting cases where contrasting results are expected.

However, the existing literature suggests that case selection can extend beyond these two categories (Fletcher, 2017). Specifically, when investigating organizational-level phenomena, it becomes imperative to choose cases based on the characteristics of the firms, as these attributes are vital for addressing the research inquiries (Yin, 2009). These characteristics frequently encompass industry, company size, organizational structure, profit or not-for-profit status, public or private ownership, geographical reach, and the extent of vertical or horizontal integration, among others.

Based on the identified research questions, this research will focus on companies in the chemical industry that have high risk, such as those for which safety is an important issue, and also regard sustainability as an important objective. To guide the selection of cases further, they are filtered through a set of inclusion criteria. The cases will include:

- A company that produces physical goods for sale.
- A company in the line of work that is categorised as a chemical industry (petrochemical, agrochemical, pharmacy, polymer, paint, and oleochemical).
- A company that has sustainable production as an important objective.

In order to identify prospective participating companies operating in the chemical industry, the study sought the input of the Indonesian Ministry of Industry, the authoritative government body that regulates the industry sector in Indonesia. Based on the input, companies within the chemical industry were approached. Those companies responded positively and agreed to participate in the study. The companies involved in this study exhibit diversity in terms of the nature of their products, organisational size (measured by the number of employees, ranging from 100 to 10,000), and market scope (regional, national, and international markets).

Those companies received official invitations to take part in the research, which also included a consent document and an informational document. The consent form covered aspects like conducting interviews, recording them, and using the data for research. The information sheet provided an overview of the research's goals and objectives, along with outlining the rights of the participants involved in the study.

3.4.2. Source of Qualitative Data

Having completed the process of case selection, the subsequent crucial decision revolves around selecting the data sources to be collected for constructing the case studies and determining the data collection methodology. The research strategy employed here is a deductive one, coupled with a qualitative approach for data collection. Thus, consistent with this research strategy, the data to be gathered will be of a qualitative nature.

The primary objective of data collection is to acquire the most comprehensive and contextually rich data possible, addressing the specific research issues (Saunders et al., 2009). Prior to commencing the site visits, it is essential for the researcher to possess a clear understanding of the sources from which data will be procured. The selection of data types is contingent upon the research questions and the unit of analysis. In cases like this, where comprehensive research is sought, employing multiple data sources is recommended, as they facilitate the triangulation of findings (Benbasat, Goldstein and Mead, 1987).

The objectives of planning data sources are to ensure adequate coverage of the research questions, efficient utilization of data collection time, and provision of guidance for the researcher. The strategy can be adjusted as the project progresses, considering the researcher's discretion, unexpected observations, and constraints and opportunities encountered during data collection (Miles, Huberman and Saldana, 2019).

Typically, qualitative case study research often integrates information from multiple data sources to substantiate its research findings (Yin, 2009). These sources encompass a variety of forms:

1. Documentation – This includes written materials spanning from internal memoranda to external newspaper clippings and formal reports. Examples encompass brochures, news articles, website content, case studies, videos, podcasts, and blogs.

2. Archival records – These consist of organizational documents such as charts, as well as records related to services, personnel, or finances.

3. Interviews – These conversations can take the form of structured, semi-structured, or unstructured dialogues with participants. Typically, these interviews involve the researcher posing questions tailored to address specific research problems. It's important to note that interviews of this nature are not repurposed for other investigations, unlike some other types of data.

4. Direct observation – This entails immersing oneself in the field environment, keenly observing and documenting details, actions, or subtleties. This type of data collection is frequently employed in participant observation research, where the researcher offers their observations of the phenomenon as it unfolds in the field.

Among the data sources considered, interviews emerged as the most suitable choice for this study. Direct observation was ruled out due to its time-consuming nature, which would lead to a longitudinal study—an outcome not aligned with the research's objectives. Similarly, archival records, such as organizational charts and financial documents, were deemed inappropriate, as they wouldn't yield insights into the study's focus. Physical artefacts were irrelevant to the research since their examination would shift the research toward a technological perspective, whereas the intention was to maintain an actor-focused approach. Consequently, primary data was primarily obtained through interviews with company officials. Documentation served as a secondary data source, aiding in cross-referencing interview responses and offering technical insights into the company and its product. These secondary sources included the company's website, product or service brochures, and news articles.

3.4.2.1. Primary Source of Data

In the field of operations management (OM), interviews stand out as a widely favoured data collection method among researchers engaged in case study investigations (Voss, Tsikriktsis and Frohlich, 2002). Interviews are characterized as in-person, spoken interactions in which one individual, typically the interviewer, seeks to gather information from and gain insights into another person, commonly referred to as the interviewee (Rowley, 2012). The interviewee is encouraged to discuss their viewpoints, convictions, actions, or encounters, be it in their capacity as a citizen, user, consumer, or employee. Within the realm of organizational studies research, the process of selecting the interviewee carries significant importance. The interviewee can be chosen either as an individual employee or as a representative of their team, organization, or industry.

The fundamental objective of interviews is to facilitate the researcher in gathering "information," acquiring insights, or gaining a deeper comprehension of opinions, attitudes, experiences, processes, behaviours, or future projections (Bryman, 2015). For instance, when conducting interviews with members of an organization to discern the essential skills needed for reshaping the organization's focus, the interviewer might be in pursuit of "information" such as which specific activities held paramount significance in this transformation, what new knowledge was acquired to facilitate the transformation, accounts of particularly positive or negative experiences, and the interviewees' forecasts concerning the organization's future capabilities.

Interviews serve as a means to gather this information, whether from an individual or a group of individuals (Rowley, 2012).

In this study, the particular emphasis on the intersection of safety and sustainability necessitated access to interview participants possessing specialized knowledge, unique insights, and extensive exposure to both facets. When research questions demand specialized expertise for their resolution, it becomes imperative to identify individuals holding pivotal roles capable of comprehending, experiencing, and elucidating a particular phenomenon (Meuser and Nagel, 2009). This approach to selecting interviewees is commonly referred to as expert interviewing. For instance, key individuals in charge of implementing a corporate strategy to transform an organization could be considered as such experts. In such cases, interviews are preferred as they not only yield a wealth of details and insights but also because these key informants are likely to offer an exceptionally comprehensive and expert viewpoint on the subject of investigation.

Interview Design

The interviews were designed to be semi-structured, which means that the interview did not employ a precise list of questions, but rather focused on specific topics of questions (Miles & Huberman, 1994). This technique is especially effective for exploratory research since it allows interviewees to express their account of the phenomenon within the boundaries of the themes defined, but without being constrained by concrete questions such as those used in surveys. The questions could be adjusted to unique circumstances but still focus on the relevant study topics. This allows the data collecting findings to be unconstrained by the framework of the interview questions and also allows for the capture of variability in the context of companies (Miles & Huberman, 1994). Therefore, an interview theme was set instead of using questions with a more restricted structure.

The theme was derived from the research questions and the objectives set for this study. Table 6 presents the interview themes which directed the questions in the interviews. The first and second columns present the theme and sub-theme according to the theoretical framework that had been developed. Probing questions within each theme are listed in the third column.

Table 6. List of questions used in the interviews.

Theme	Sub-Theme	Question
Interviewee Introduction	Company Background	Is your company classified as a chemical industry? What are the products? What is the production rate?
	Personal Background	What is your formal position in the company? What are your responsibilities?
		Do you understand the safety practice in your company?
Chemical Industry Characteristics	Intro	Can you tell me about the production process in your company?
	Hazardous Materials	Are any hazardous materials used in your company?
	Hazardous Process	In your opinion, which is the process that has high risk?
	High Consumption	Roughly, how much materials and energy are consumed by your company every month?
	Waste Generation	Roughly, how much waste is generated by your company every month?
	High Risk	In your opinion, how high is the risk when working for your company?
Safety Culture	Intro	What can you say about safety culture in your company?
	Management Value	What is the management's attitude towards safety?
	Risk Perception	Are workers in your company aware of the risks of their job?
	Safety System	How does your company ensure the safety of its workers?
	Work Pressure	Is there any target or deadline that has to be fulfilled by the workers?
	Competence Level	What is the qualification for most workers in your company?
Safety Performance	Safety Compliance	In your company, is there any safety-related regulation that is difficult to comply with?
		Are there any difficulties in complying with safety-related regulation?
	Safety Participation	What is the most successful safety-related programme in your company?
		What is the participation rate in safety from workers?
Sustainable Production Performance	Intro	How sustainable do you think your company is?
	Resources Used	Is there any renewable resource used in your company?
	Natural Environment	How does your company process its waste?
	Workers' H&S	What is the most important health and safety issue in your company?
	Economic Viability	How well does your company perform financially?
	Community Development	Does your company have any successful corporate social responsibility programme?
	Product	Is there any concern regarding your product?

3.4.2.2. Secondary Source of Data

Documentation materials are considered a valuable source of secondary data due to their stability and potential for repeated examination and collection (Yin, 2009). In the context of this study, the company's website serves as a primary source of information, offering detailed descriptions of their products and services while providing clarity on assertions and statements regarding these offerings. Additionally, various documents contain information pertaining to the company's operations and customer base. This documentation proved particularly useful in the later stages of the analysis, allowing for the verification of the responses provided by the interviewees.

3.4.3. Data Collection

After consulting the Indonesian Ministry of Industry, 25 companies within the chemical industry were approached, of which 16 responded positively and agreed to participate in the study. The data were collected from several informants via multiple rounds of interviews, conducted between April and October 2021. There were 19 semi-structured interviews conducted online via Zoom and these lasted for approximately 45–60 minutes per interview. All interviews were recorded with the participants' permission and subsequently transcribed for initial analysis. Any references to the organization's name, proprietary product names, interviewee names, names of other individuals, competitors, customers, or any details that could potentially reveal the identity of the organization or the interviewees were redacted from the transcripts.

Table 7. Profiles of the cases

Cases	Chemical Industry	Scope of Business	No of Employees	Interviewee	Roles	Experience (years)
Case Alpha	Multipurpose Plastics	Nationwide	385	P001	Head of Health & Safety Department	16
Case Beta	Petrochemical	Regional	100	P002	Senior Health & Safety Supervisor	9
Case Gamma	Petrochemical	Regional	130	P003	Senior Production Supervisor	12
Case Delta	Pharmacy	Nationwide	4,700	P004	Senior Production Supervisor	10
Case Epsilon	Agrochemical	Nationwide	1,100	P005	Vice Head of Production Department	10
Case Zeta	Petrochemical	Nationwide	10,000	P006	Vice Head of Health & Safety Department	11
Case Eta	Petrochemical	International	500	P007	Senior Health & Safety Supervisor	11
Case Theta	Pharmacy	International	500	P008	Senior Health & Safety Supervisor	8
Case Iota	Pulp and Paper	Nationwide	2,000	P009	Head of Health & Safety Department	10
				P010	Head of Operation Department	12
				P011	Head of Engineering Department	11
Case Kappa	Petrochemical	Nationwide	500	P012	Head of Health & Safety Department	23
Case Lambda	Petrochemical	International	2,000	P013	Head of Marketing Department	16
				P014	Head of Health & Safety Department	14
				P015	Engineer in Production Department	6
				P016	Quality Control Inspector	8
Case Sigma	Petrochemical	International	1,000	P017	Senior Engineer in Production Department	9
Case Upsilon	Petrochemical	Nationwide	8,000	P018	Chief Operating Officer	25
Case Omega	Petrochemical	Nationwide	500	P019	Head of Operation Department	22

The unit of analysis of this study is the individual company participating in this study, whose safety performance and sustainable production performance were investigated. Each company serves as a case, and their safety performance and sustainable production performance were examined. Detailed profiles of each case can be found in Table 7, compiled from information gathered through interviews and the companies' websites. To ensure the research questions were adequately addressed, it was crucial to identify key individuals with specialized knowledge, strategic roles, relevant experience, and a deep understanding of the phenomena being studied. Employing expert interviewing techniques, as suggested by Meuser and Nagel (2009), was deemed essential to enhance the robustness and credibility of the information collected by the researchers.

Prior to the commencement of the interviews, the interviewees were requested to complete a consent form and provided with a research information sheet that outlined the research's objectives, their rights to withdraw from the study, confidentiality and anonymity assurances, as well as the researcher's intent to utilize their responses for research purposes. The consent form sought permission from the interviewees to employ their responses as research data in this study and related research articles, along with a confirmation of their understanding of the contents of the research information sheet. Additionally, consent was sought to record the interviews.

Subsequently, secondary data sources including product and service brochures, websites, news articles, and videos were gathered after the interviews. As explained in the preceding section, these data sources were utilized to cross-verify and validate the interviewees' statements regarding industrial characteristics and the company's safety and sustainability performance.

3.4.4. Data Analysis

After all the participants have been interviewed, the next step is to analyse the data. The first step in carrying out the data analysis was producing the interview transcripts. After that, a priority set of codes was developed. After the codes had been developed, the interview transcripts would be reviewed, and the codes used to mark and identify themes in the interview transcript. The data was then sorted according to the theme and the interview excerpts were put into a spreadsheet.

3.4.4.1. Interview Transcripts

The first step in the data analysis was making the interview transcripts. The recordings from the interviews were uploaded into the website sonix.ai, which then generated the transcripts of the interviews. Since the interviews were conducted in a mixture of English and *Bahasa Indonesia*, the transcripts generated by Sonix still contained errors. Those errors were then reviewed and edited according to the recording. After all errors were found and fixed, the transcript was then imported to Microsoft Word for the next step. Figure 9 shows an example of this process.

Figure 9. Example of making an interview transcript

3.4.4.2. Code Development

The next step in the data analysis was developing an a priori set of codes. Using the theoretical framework that had been developed previously as the context, the researcher set four themes: safety culture, industrial characteristics, safety performance and sustainable production performance. Since the study focused on chemical industry, the term industrial characteristics refers to characteristics in the chemical industry. Figure 10 shows the theoretical framework used.

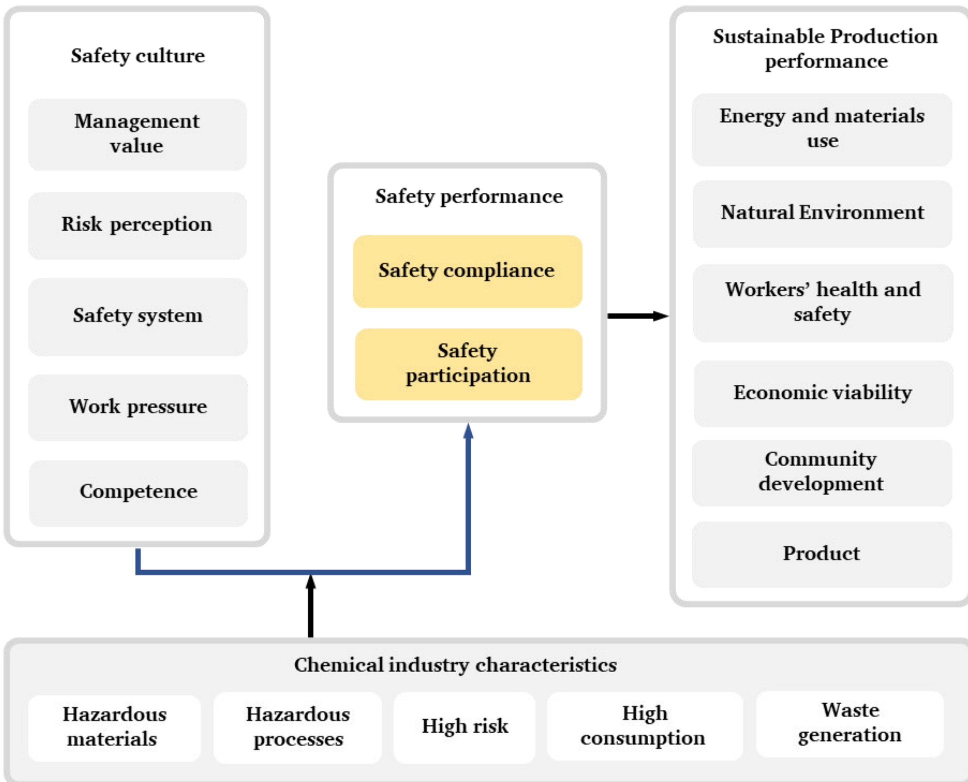


Figure 10. Theoretical framework used in this study.

Those four themes were determined to be code level 0. Subthemes were then developed for each of the four themes. These subthemes were set to be code level 1. In order to capture responses from the interviewees in more detail, level 2 codes were then developed for each subtheme and were then used as the final set of codes. Table 8 shows the complete list of codes.

Table 8. The list of codes used for data analysis.

Level 0	Level 1	Level 2
Industry Characteristics	Hazardous Material	Hazardous raw material
		Hazardous auxiliary material
	Hazardous Process	Complex processes
		High risk processes
	High Consumption	Resources consumption
		Energy consumption
	Waste Generation	Waste volume
		Waste characteristics
	High Risk	Risk for workers
		Risk for the environment
Safety Culture	Management Value	Leadership towards safety
		Resources support
	Risk Perception	Workers' risk awareness
		Work attitude
	Safety System	Workers' H&S assurance
		Emergency response
	Work Pressure	Work system
		Target/deadline
	Competence Level	Education level
		Experience level
Safety Performance	Safety Compliance	Regulation compliance
		Accidents and near misses
	Safety Participation	Safety reporting
		Workers' compliance
Sustainable Production Performance	Resource Use	Renewable resource
		Renewable energy
	Natural Environment	Waste process system
		Environmental impact
	Workers' H&S	Safety issues
		Health issues
	Economic Viability	Business continuity
		Financial performance
	Community Development	Social impact
		Economic impact
	Product	Product issues
		Packaging issues

3.4.4.3. Coding the Transcript

The list of codes given in Table 8 were highlighted. The highlights were given to make the process in the next step easier. After the set of codes had been developed, the next step was to start coding the transcripts. All the interview transcripts were reviewed, and any part of the interview that was relevant to code level 2 was marked with an associated shade of colour. Figure 11 shows an example of an interview transcript that has been coded.

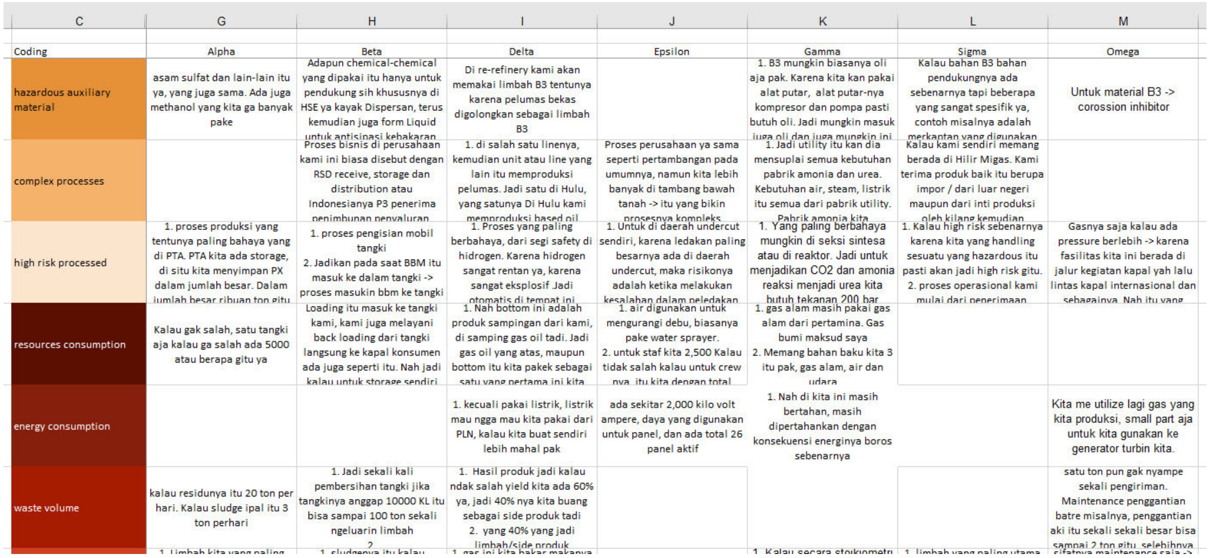
[00:04:34] Kalau tadi bahan baku Amonia sama CO2, kalau untuk bahan penolongnya atau bahan pembantunya, kita urea subsidi itu kan berwarna ya sesuai kebijakan pemerintah. Kalau urea yang non-subsidi memang original-nya urea itu putih dari naturalnya, tapi ya karena kebijakan pemerintah yang subsidi itu harus diberi warna merah muda. Jadi kita pakai bahan penolong pewarna. Pewarnanya sebenarnya sudah food grade sebenarnya aman, tapi tetap saja kalau warna itu kalau ada pencemaran ke air pasti efeknya langsung negatif saja walaupun itu warnanya aman ya. Bahan penolongnya ada pewarna, kemudian ada anti caking. Kalau di urea sepertinya itu aja bahan -bahan bakunya tadi dua CO2 dan amonia dan bahan penolongnya pewarna sama anti craking.

[00:05:36] Itu masih tergolong bahan B3 pak?

[00:05:40] Kalau B3 nggak sih. B3 mungkin biasanya oli aja pak. Karena kita kan pakai alat putar, alat putar-nya kompresor dan pompa pasti butuh oli. Jadi mungkin masuk juga oli dan juga mungkin ini katalis ya. Katalis karena kita ada salah satu apa namanya proses yang membutuhkan katalis tapi dia kan sifatnya digantinya 10 tahunan paling kalau katalis. Kalau oli memang rutin.

Figure 11. Example of the coding process

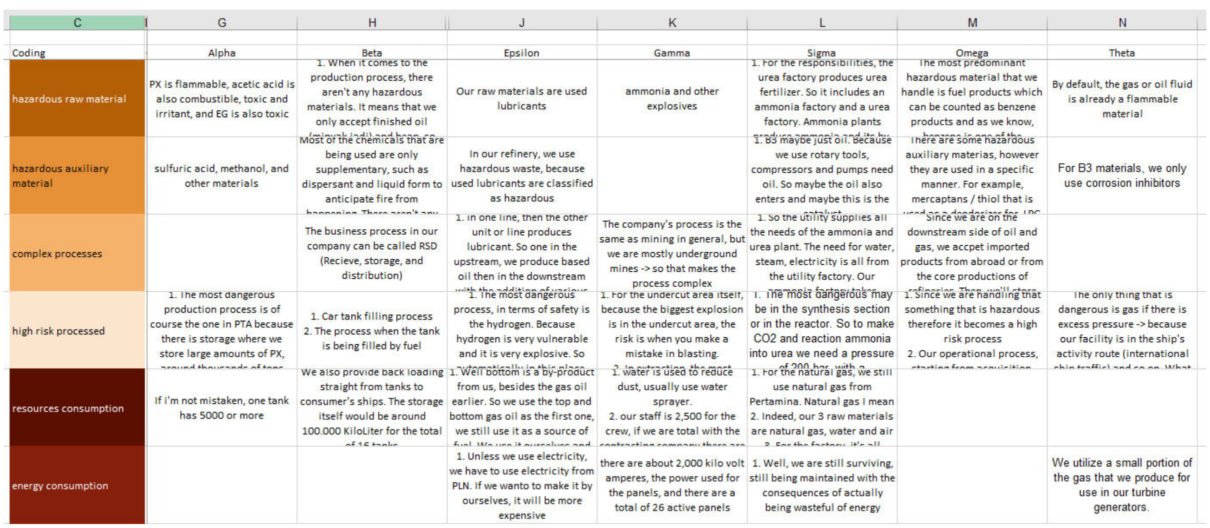
Once all the interview transcripts had been coded, the next process was inputting the relevant interview excerpts into a spreadsheet. This is done to make the data easier to analyse. By only including relevant excerpts, the researcher can focus on relevant data and ignore others that are not relevant. Figure 12 shows how the data are presented after they had been input into a spreadsheet.



C	G	H	I	J	K	L	M
Coding	Alpha	Beta	Delta	Epsilon	Gamma	Sigma	Omega
hazardous auxiliary material	asam sulfat dan lain-lain itu ya, yang juga sama. Ada juga methanol yang kita ga banyak pake	Adapun chemical-chemical yang dipakai itu hanya untuk pendukung sih khususnya di HSE ya kayak Dispersan, terus kemudian juga form Liquid untuk antisipasi kebakaran	Di re-refinery kami akan memakai limbah B3 tentunya karena pelumas bekas digolongkan sebagai limbah B3		1. B3 mungkin biasanya oli aja pak. Karena kita kan pakai alat putar, alat putar-nya kompresor dan pompa pasti butuh oli. Jadi mungkin masuk juga oli dan juga mungkin ini	Kalau bahan B3 bahan pendukungnya ada sebenarnya tapi beberapa yang sangat spesifik ya, contoh misalnya adalah merkaptan yang digunakan	Untuk material B3 -> corossion inhibitor
complex processes		Proses bisnis di perusahaan kami ini biasa disebut dengan RSD receive, storage dan distribution atau Indonesianya P3 penerima penimbunan penyaluran	1. di salah satu linenya, kemudian unit atau line yang lain itu memproduksi pelumas. Jadi satu di Hulu, yang satunya Di Hulu kami memproduksi based oil	Proses perusahaan ya sama seperti pertambangan pada umumnya, namun kita lebih banyak di tambang bawah tanah -> itu yang bikin prosesnya kompleks	1. Jadi utility itu kan dia mensuplai semua kebutuhan pabrik amonia dan urea. Kebutuhan air, steam, listrik itu semua dari pabrik utility. Pabrik amonia kita	Kalau kami sendiri memang berada di Hilir Migas. Kami terima produk baik itu berupa impor / dari luar negeri maupun dari inti produksi oleh kilang kemudian	
high risk processed	1. proses produksi yang tentunya paling bahaya yang di PTA. PTA kita ada storage, di situ kita menyimpan PX dalam jumlah besar. Dalam jumlah besar ribuan ton gitu	1. proses pengisian mobil tangki 2. Jadikan pada saat BBM itu masuk ke dalam tangki -> proses masukin bbm ke tangki	1. Proses yang paling berbahaya, dari segi safety di hidrogen. Karena hidrogen sangat rentan ya, karena sangat eksplosif Jadi otomatis di tempat ini	1. Untuk di daerah undercut sendiri, karena ledakan paling besarnya ada di daerah undercut, maka risikonya adalah ketika melakukan kesalahan dalam peledakan	1. Yang paling berbahaya mungkin di seksi sintesa atau di reaktor. Jadi untuk menjadikan CO2 dan amonia reaksi menjadi urea kita butuh tekanan 200 bar	1. Kalau high risk sebenarnya karena kita yang handling sesuatu yang hazardous itu pasti akan jadi high risk gitu. 2. proses operasional kami mulai dari penerimaan	Gasnya saja kalau ada pressure berlebih -> karena fasilitas kita ini berada di jalur kegiatan kapal yah lalu lintas kapal internasional dan sebagainya. Nah itu yang
resources consumption	Kalau gak salah, satu tangki aja kalau ga salah ada 5000 atau berapa gitu ya	Loading itu masuk ke tangki kami, kami juga melayani back loading dari tangki langsung ke kapal konsumen ada juga seperti itu. Nah jadi kalau untuk storage sendiri	1. Nah bottom ini adalah produk sampingan dari kami, di samping gas oil tadi. Jadi gas oil yang atas, maupun bottom itu kita pakek sebagai satu yang pertama ini kita	1. air digunakan untuk mengurangi debu, biasanya pake water sprayer. 2. untuk staf kita 2,500 Kalau tidak salah kalau untuk crew nya, itu kita dengan total	1. gas alam masih pakai gas alam dari pertamina. Gas bumi maksud saya 2. Memang bahan baku kita 3 itu pak, gas alam, air dan udara		
energy consumption			1. kecuali pakai listrik, listrik mau ngga mau kita pakai dari PLN, kalau kita buat sendiri lebih mahal pak	ada sekitar 2,000 kilo volt ampere, daya yang digunakan untuk panel, dan ada total 26 panel aktif	1. Nah di kita ini masih bertahan, masih dipertahankan dengan konsekuensi energinya boros sebenarnya		Kita me utilize lagi gas yang kita produksi, small part aja untuk kita gunakan ke generator turbin kita.
waste volume	kalau residunya itu 20 ton per hari. Kalau sludge ipal itu 3 ton perhari	1. Jadi sekali kali pembersihan tangki jika tangkinya anggap 10000 KL itu bisa sampai 100 ton sekali ngeluarin limbah 2.	1. Hasil produk jadi kalau ndak salah yield kita ada 60% ya, jadi 40% nya kita buang sebagai side produk tadi 2. yang 40% yang jadi limbah/side produk				satu ton pun gak nyampe sekali pengiriman. Maintenance penggantian batre misalnya, penggantian aki itu sekali sekali besar bisa sampai 2 ton gitu, selebihnya

Figure 12. Inputting the interview excerpts into a spreadsheet

Since the interviews were conducted in a mixture of English and Bahasa, the excerpts collected were still not entirely in English. Before within-case analysis was conducted, the excerpts in the spreadsheet were translated into English. The result of this process is shown in Figure 13.



C	G	H	J	K	L	M	N
Coding	Alpha	Beta	Epsilon	Gamma	Sigma	Omega	Theta
hazardous raw material	PX is flammable, acetic acid is also combustible, toxic and irritant, and EG is also toxic	1. When it comes to the production process, there aren't any hazardous materials. It means that we only accept finished oil	Our raw materials are used lubricants	ammonia and other explosives	1. For the responsibilities, the urea factory produces urea fertilizer. So it includes an ammonia factory and a urea factory. Ammonia plants	The most predominant hazardous material that we handle is fuel products which can be counted as benzene products and as we know,	By default, the gas or oil fluid is already a flammable material
hazardous auxiliary material	sulfuric acid, methanol, and other materials	Most of the chemicals that are being used are only supplementary, such as dispersant and liquid form to anticipate fire from	In our refinery, we use hazardous waste, because used lubricants are classified as hazardous		1. B3 maybe just oil. Because we use rotary tools, compressors and pumps need oil. So maybe the oil also enters and maybe this is the	There are some hazardous auxiliary materias, however they are used in a specific manner. For example, mercaptans / thiol that is	For B3 materials, we only use corrosion inhibitors
complex processes		The business process in our company can be called RSD (Recieve, storage, and distribution)	1. In one line, then the other unit or line produces lubricant. So one in the upstream, we produce based oil then in the downstream	The company's process is the same as mining in general, but we are mostly underground mines -> so that makes the process complex	1. So the utility supplies all the needs of the ammonia and urea plant. The need for water, steam, electricity is all from the utility factory. Our	Since we are on the downstream side of oil and gas, we accpet imported products from abroad or from the core productions of	
high risk processed	1. The most dangerous production process is of course the one in PTA because there is storage where we store large amounts of PX,	1. Car tank filling process 2. The process when the tank is being filled by fuel	1. The most dangerous process, in terms of safety is the hydrogen. Because hydrogen is very vulnerable and it is very explosive. So	1. For the undercut area itself, because the biggest explosion is in the undercut area, the risk is when you make a mistake in blasting.	1. The most dangerous may be in the synthesis section or in the reactor. So to make CO2 and reaction ammonia into urea we need a pressure	1. Since we are handling that something that is hazardous therefore it becomes a high risk process 2. Our operational process,	The only thing that is dangerous is gas if there is excess pressure -> because our facility is in the ship's activity route (international
resources consumption	If i'm not mistaken, one tank has 5000 or more	We also provide back loading straight from tanks to consumer's ships. The storage itself would be around 100.000 KiloLiter for the total	1. Well bottom is a by-product from us, besides the gas oil earlier. So we use the top and bottom gas oil as the first one, we still use it as a source of	1. water is used to reduce dust, usually use water sprayer. 2. our staff is 2,500 for the crew, if we are total with the	1. For the natural gas, we still use natural gas from Pertamina. Natural gas I mean 2. Indeed, our 3 raw materials are natural gas, water and air		
energy consumption			1. Unless we use electricity, we have to use electricity from PLN. If we wanto to make it by ourselves, it will be more expensive	there are about 2,000 kilo volt amperes, the power used for the panels, and there are a total of 26 active panels	1. Well, we are still surviving, still being maintained with the consequences of actually being wasteful of energy		We utilize a small portion of the gas that we produce for use in our turbine generators.

Figure 13. The interview excerpts after translation

3.5 Interim Phase: Instrument Development Phase

The first phase of this study provided in-depth discussions regarding the relationship between safety and sustainable production performance. This phase resulted in confirmation of the factors influencing the relationship as the initial framework suggested and found other factors that had previously not been identified. The next phase of this study is to test this theory using a larger sample in order to evaluate the prevalence of these findings and to advance the theory. This section will address what qualitative findings were used to inform the development of the initial survey instrument. That is, the themes and theoretical categories used to form the questionnaire items and how the constructs were evaluated in the pre-test and pilot phases before finalising the survey. The steps and guidelines used to develop the initial survey for pre-testing and pilot testing are discussed in the following paragraphs.

The eight steps guideline of scale development by DeVellis (2017) was adopted as a rigorous scale process in this phase. Figure 14 depicts the eight steps process, and the activities involved in each step. Step one in this process requires clarity on what needs to be measured. The variables to be measured in this study are the five variables found during the qualitative phase, which are: collective mindfulness, safety culture, safety performance, industrial characteristics, and sustainable production performance.

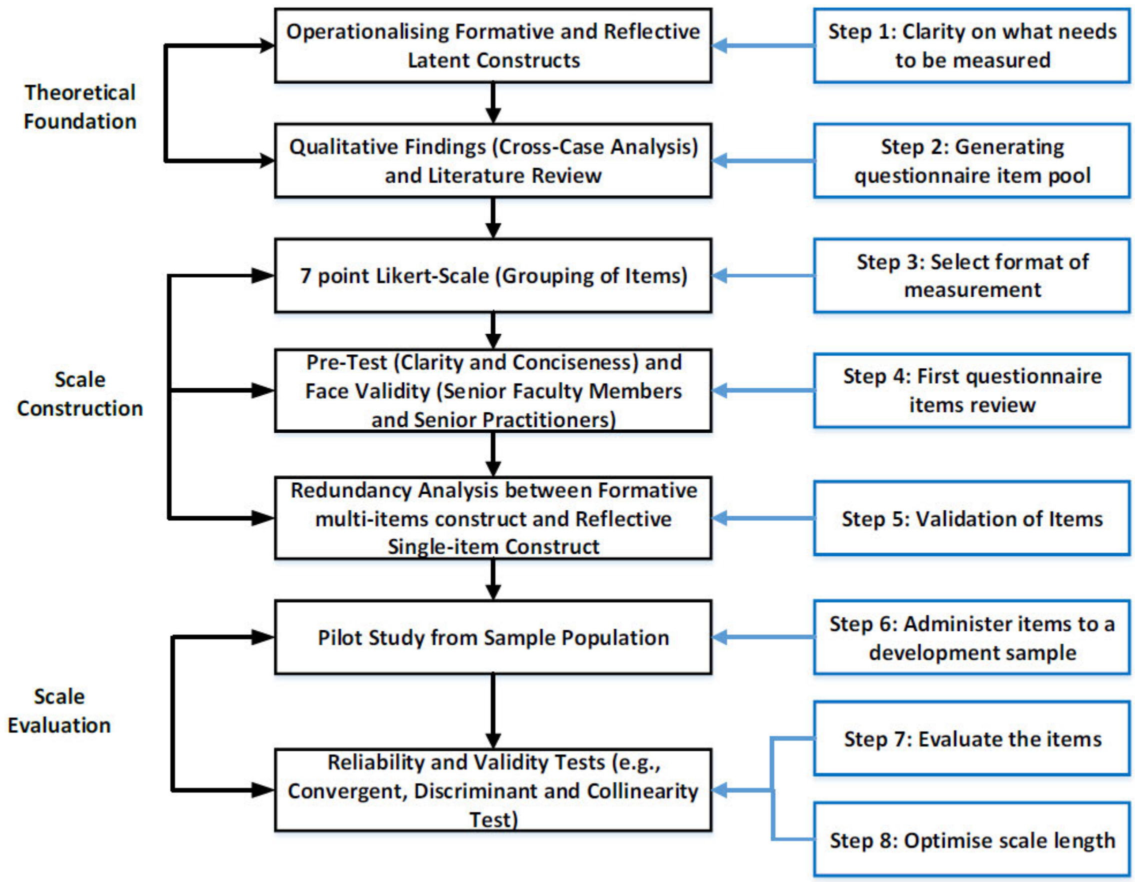


Figure 14. Scale development phase (based on DeVellis (2017)

Step two in the scaling process is to generate an item pool with which to measure the constructs. The qualitative findings reported several different practices in different companies. However, using a cross-case analysis, the highlighted pertinent practices shared in most cases formed the items of the questionnaire. Therefore, only practices evidenced in multiple cases formed the conceptualisation of a construct. The constructs' measurements were based on the emerging qualitative data, which were linked to theoretical categories based on the literature. Step three involved selecting the format for construct measurement. For this phase, the Likert scale was used. The Likert scale presents items as declarative sentences, followed by a range of responses with differing degrees of agreement or disagreement statements (DeVellis, 2017). In this step, all the items corresponding to their constructs are grouped, ready to be assessed using a seven-point Likert scale.

Step four entailed having the first items (questions) reviewed by experts. This process was taken using multiple cycles of revisions as part of the pre-test. Firstly, the questionnaire items were sent to two Indonesians that have credentials in English language (academic background in English literature and experience as a sworn translator). This exercise was to assess the appropriateness of the questions with regard to their order, clarity, wording and more importantly, translation to the Indonesian language. Based on the feedback, changes were made in the wording of some items to improve clarity. Secondly, a face validity test was undertaken regarding the questions surrounding the five variables in the framework. This task was achieved using five academics in safety or sustainability. Each person was asked to evaluate the relevance of each item and its proposed measure of the construct using a seven-point Likert scale (1 = not relevant, 7 = most relevant). Based on this exercise, the questionnaire items were revised, some items were removed, and some were added. The items were then presented to five senior practitioners in the Indonesian chemical industry as a further test of face validity. The practitioners that reviewed the items had little trouble determining which items belong to their constructs.

In step five, single-measure reflective constructs were included as part of the validation items, in order to test the convergent validity of the five factors in the framework. The discussions on the convergent validity test between a formative and reflective measure of the same construct using the redundancy analysis will be discussed in more detail in a later chapter.

Step six involves administering questions to a development sample. To achieve this, a pilot study will be conducted on the sample population to test the survey. In total, 30 responses are expected to be obtained which was deemed appropriate for this exercise.

Steps seven and eight entail upkeeping the reliability and validity of items using different tests. This will be covered in greater depth after the pilot test is conducted.

3.6 Quantitative Study

3.6.1. Sample and Data Collection

The Indonesian Ministry of Industry was consulted to help determine which companies will be invited to participate in the study. Similarly, with the selecting of companies during phase 1, a set of inclusion criteria was set as follows:

- A company that produces physical goods for sale.
- A company in the line of work that is categorised as a chemical industry (petrochemical, agrochemical, pharmacy, polymer, paint, and oleochemical).
- A company that has sustainable production as an important objective.

Additionally, to ensure that the study obtained a good representation of the Indonesian chemical industry, the Ministry's classification for the chemical industry was adopted. The classifications are organic chemical industry (e.g., explosive and textile chemical), inorganic chemical industry (e.g., cement, sulfuric acid, glass), agrochemical industry (e.g., fertilizer, pesticide), rubber and cellulose industry (e.g., pulp, paper, tyres), pharmacy industry (e.g., medicines), and petrochemical industry (e.g., plastics, industrial gas). After ensuring that there are companies from each category with various company sizes, a list of companies was selected and invited to participate in the study.

Each respondent received an email containing the link to the questionnaire while adhering to general data protection rules (GDPR) for consent before taking the survey. A copy of the questionnaire is provided in the Appendix C.

3.6.2. Data Analysis: Structural Equation Modelling

The quantitative data were analysed using structural equation modelling (SEM). SEM is a second-generation statistical technique used to overcome the weaknesses of the first-generation methods (e.g., multiple regression). SEM enables researchers to incorporate unobservable variables measured indirectly by indicator variables (Hair *et al.*, 2019). They also facilitate accounting for measurement error in observed variables. There are two main approaches to estimate the relationships in SEM: Co-variance based SEM (CB-SEM) and variance-based partial least squares SEM (PLS-SEM). The difference between the two relates to how each method analyses the latent variables in the model.

In CB-SEM, the constructs are common factors which explain the co-variation between its corresponding indicators. PLS-SEM considers both common and unique variances (Peng and Lai, 2012), and uses proxies to represent the constructs, which are weighted composites of indicators that represent a construct (Hair et al., 2019). Hence, PLS-SEM takes a composite based approach to SEM and, unlike CB-SEM, lessens the assumptions that a common factor explains all the co-variation between sets of indicators while accounting for measurement error. Consequently, each method is appropriate for different research contexts, and thus, researchers need to understand the differences to apply the correct methods (Hair et al., 2019). In situations where a theory is less developed, the researcher should consider the use of PLS-SEM (Hair et al., 2019) especially when the objective is to predict and explain the target constructs (Rigdon, 2012).

This study adopts the PLS-SEM approach when testing the hypothesised relationships in the conceptual framework. The rationales for using PLS-SEM over CB-SEM are as follows. Firstly, the sample size in this study is planning to be moderate compared to other SEM studies, and the data do not assume a normal distribution (Hair et al., 2019; Peng & Lai, 2012). Secondly, PLS-SEM is more useful when testing the moderation effects analysis between constructs. Thirdly, the structural model is complex, which PLS-SEM can handle better than CB-SEM. Finally, this study seeks to explore new constructs and therefore, takes an exploratory approach. The aim is to predict and evaluate the relationships between these constructs to develop and test the theory (Hair et al., 2019).

The use of PLS-SEM in OM has attracted some critics who have highlighted some methodological problems such as bias in parameter estimates and model measurement errors. Despite such concerns, interest in PLS-SEM is growing (Peng & Lai, 2012). Indeed, the use of different analysis techniques such as PLS-SEM is recommended to address some challenges which limit the applicability of CB-SEM. For example, OM researchers face challenges such as less developed theory, lack of standardised measurement scales, and difficulty in obtaining larger samples when examining phenomena at the organisation level (Peng & Lai, 2012). Such limitations are adequately addressed when using PLS-SEM (Peng & Lai, 2012).

3.6.3. Measures of Construct: Formative and Reflective Constructs

The quantitative phase of this study seeks to analyse the relationships among constructs to test the developed framework regarding the relationship between safety and sustainability; specifically, relationships between safety culture, Collective Mindfulness, safety performance, sustainable production performance, and industrial characteristics. These constructs were obtained from the results of Phase 1, which is discussed in more detail in Chapter 2. These constructs were conceptualised using both formative and reflective measures. In doing so, it avoids measurement model misspecification, inadequate construct conceptualisation, and construct validity issues (MacKenzie, 2003). The accurate specification of the measurement model is critical and must be addressed before meaning can be given to the analysis of the structural model.

In measurement theory, it is critical to note that constructs measured as formative and reflective describe the relationship between an indicator and the latent construct (Mackenzie, 2003). Furthermore, the constructs are not fundamentally formative or reflective and can be modelled as either, depending on a researcher's theoretical expectations regarding how they relate based on conceptual definition or justification of the construct (Mackenzie, 2003). Against this background, the direction of causality between the constructs and their measures were carefully considered to maintain construct validity. According to Peter (1981, p.133) "construct validity is a necessary condition for theory development and testing." Therefore, the constructs representing the five constructs were assessed using formative measurements. That is, the indicators cause the causality, and omitting an indicator is omitting part of the construct. Hence, elimination of formative items must be justified based on theory instead of statistical psychometric properties.

The construct Collective Mindfulness in the framework came from theory developed by (Weick, Sutcliffe and Obstfeld, 1999). The mindfulness practices, as characterised by Weick and Sutcliffe (2008) are: Pre-occupation with failure, Reluctance to simplify, Sensitivity to operations, Commitment to resilience, and Deference to expertise. After establishing these five core practices Weick and Sutcliffe proposed Likert-scaled questionnaires totalling 83 questions designed to be “an audit of mindfulness”. Since then, this Mindfulness Audit has been used widely by various organisations.

The concept of a ‘safety culture’ has largely developed since the 1980s; it was observed that the errors and violations of operating procedures occurring prior to the Chernobyl disaster were evidence of a poor safety culture at the plant and within the former Soviet nuclear industry in general (Pidgeon, 1991). There are five variables in the framework that is used to measure the safety culture: management value, risk perception, safety system, work pressure, and competence level. Management value was operationalised using seven items grounded on the qualitative findings measured on a seven-point Likert scale (1 = strongly disagree, 7 = strongly agree). Similarly, the other four were operationalised using four, seven, five and five items respectively.

Safety performance can be described as the "effectiveness of safety-related tasks." Enhancements in safety performance within an organization have the potential to enhance its resilience and decrease the likelihood of accidents. There are two variables within the framework that is used to measure safety performance: safety compliance and safety participation. Safety compliance was operationalised using seven items grounded on the qualitative findings measured on a seven-point Likert scale (1 = strongly disagree, 7 = strongly agree). safety participation was also measured on a seven-point Likert scale (1 = strongly disagree, 7 = strongly agree) using six items.

Industrial characteristics discussed in this study are related to the usage of hazardous material, the hazardous process involved, risk to both workers and the environment, and waste generated from the production process. These four were measured on a seven-point Likert scale (1 = strongly disagree, 7 = strongly agree) using two items each.

The last construct in the framework is sustainable production performance. Sustainable production refers to the manufacturing of goods using economically viable methods that reduce adverse environmental effects while preserving energy and natural resources. There are five variables in the framework that is used to measured sustainable production performance: the usage of energy and material, impact to the natural environment, workers' health and safety, economic viability, community development and product. The usage of energy and material was operationalised using four items grounded on the qualitative findings measured on a seven-point Likert scale (1 = strongly disagree, 7 = strongly agree). Similarly, the other five were operationalised using four, two, two, three and two items respectively.

Chapter 4: Qualitative Findings

Based on the research methodology, this chapter expands upon the execution of the designed research. The chapter starts with the execution by conducting a pilot study (Section 4.1) using two case organisations, with the intention of verifying the relevance of the interview themes. Next, the chapter explains the data analysis using within-case analysis method (Section 4.2), which involves deep analysis for every case using the framework as a baseline. Every case used throughout this investigation is explained in this section. The chapter then continues by conducting a cross-case analysis (Section 4.3). Finally, the chapter concludes by revising the initial framework, using the results from the qualitative findings.

4.1 Pilot Study

To assess the suitability of the interview design and its ability to gather the necessary qualitative data, a preliminary study was conducted prior to the main data collection phase. Pilot studies are a valuable research practice, as they enable the researcher to evaluate the research design, anticipate interviewee responses, understand the interview process, and identify any potential adjustments needed in the interview design (Creswell et al., 2007).

For the pilot study, two prominent companies in Indonesia, each a leader in its respective industry, were selected. The choice of these companies was based on their significance and the fact that their Heads of Divisions, who hold valuable insights, would be interviewees. This selection ensured that the interview design could effectively capture responses, regardless of how central safety was to the core operations of these companies.

4.1.1. Pilot Study Execution

Before commencing the interviews, the interviewees were provided with a research information sheet and a consent form. The research information sheet outlined the research's objectives and motivations, informed the interviewees of their right to withdraw from the study, assured confidentiality and anonymity, and explained the researcher's intention to utilize the responses for research purposes. The consent form sought the interviewees' permission to use their responses as research data for this study and any associated research articles, along with confirmation of their understanding of the information in the research information sheet. Additionally, the consent form requested permission to record the interview using the Zoom application.

Once the respondents had signed the consent form, the interviews commenced and typically lasted for 45 to 60 minutes. The interviews were recorded using the Zoom application and subsequently transcribed for preliminary analysis. Throughout the interview process, care was taken to avoid any mention of the organization's name, proprietary product names, the respondent's identity, the names of other individuals, competitors, customers, or any other information that could potentially identify the organization or respondent.

4.1.2. Pilot Study Findings

As a result of the pilot study, it was determined that the interview design effectively gathered pertinent data and elicited valuable responses from the interviewees related to the research. It was observed that interviewees occasionally veered off the main interview topics, which is typical in a semi-structured interview format (Miles and Huberman, 1994). To maintain focus on the interview themes and capture comprehensive descriptions, the researcher utilized probing questions.

In summary, the pilot study successfully fulfilled its objective of evaluating the interview design and affirmed its suitability for the study. Additionally, it enhanced the researcher's confidence in conducting interviews and equipped them with the skills to pose probing questions that align with the established interview themes.

4.2 Within-Case Analysis

Within-case analysis provides an in-depth analysis of each case as a stand-alone entity. Based on the interview transcript, each case was then analysed in detail according to the theme in the theoretical framework. Thus, the analysis is structured as follows: a general summary of the company that goes into greater detail on the company's industrial characteristics, the safety culture that is shared by the majority of people within the company, the safety performance of the company that can increase its resistance or robustness and lower the risk of accidents, and finally, the sustainable production performance of the company which is measured by their resource use, the impact on the natural environment, workers' health & safety, economic viability, community development, and product.

4.2.1. Case Alpha

Alpha was established in the 1990s. Alpha has three plants built on a land area of 23 hectares. Currently their production capacity is 700,000 MT per year for Purified Terephthalic Acid (PTA) and 58,000 MT per year for Polyethylene Terephthalate (PET). Seen from their company's vision, "Harmonize for Sustainable Growth", sustainability is an important objective for Alpha. Alpha has been implementing a Responsible Care initiative with efforts made to achieve harmony with the global environment. Alpha claims to have been making efforts to secure environmental preservation, safety of facilities, health and safety of employees, and products' safety by eliminating, reducing and managing the risks. This commitment is described in Alpha's Quality Safety Health and Environment Policy.

Industrial characteristics

Alpha is a company that produces resource for multipurpose plastics. Alpha currently owns two plants. The first plant produces PTA which is then use as material for the second plant, which produces PET. Alpha uses many hazardous materials, either as main or auxiliary materials. Although PTA has very low toxicity and is not a fire hazard, the main resource to produce PTA is Para-Xylene (PX), a chemical substance that is not only flammable, but also can cause headache, fatigue, dizziness, listlessness, confusion, irritability, gastrointestinal disturbances including nausea and loss of appetite, if overexposed to humans. To produce PTA, PX also needs to be processed with acetic acid, which according to P001 is combustible, toxic and an irritant. In the second plant, PTA is not the only main material, Ethylene Glycol (EG) is also needed to produce PET. EG is moderately toxic and has caused several deaths in some countries every year.

Not only does it use hazardous material, but the production of PTA and PET involves processes that are not only complex, but also dangerous. P001 noted how in the first plant they use and store huge amounts of PX and that a small incident can cause fire and even explosion that can be catastrophic. The reactor's plant is the most critical, where a small leak can cause a huge explosion.

In managing huge amounts of hazardous materials, and operating complex and dangerous processes, it can be seen that workers at Alpha are facing high risks every day. As P001 said, Alpha is categorised as a high-risk company by the Indonesian Ministry of Labor.

"There are many materials we use that are hazardous. PX is flammable, acetic acid is also combustible, toxic and irritant, and EG is also toxic. Other than those, we also use hazardous auxiliary materials such as sulfuric acid, methanol, and other materials." (P001)

"The most dangerous production process is of course the one in PTA because there is storage where we store large amounts of PX, around thousands of tons which if burned could have an impact on the plant. The same with acetic acid; if it leaks, the impact can be carried away by the wind and go far into residential areas. In the reactor there is PX which is flammable, acetic acid, and other reactions that are very flammable, so if there is a leak it can cause an explosion." (P001)

Alpha is producing 700,000 MT (PTA) and 58,000 MT PET per year. In producing almost a million metric tonnes per year, Alpha consumes a lot of resources and energy. As P001 put it, "It is only natural". Since the materials used for production come from crude oil, this is not renewable. Alpha also produces a significant amount of waste, 20 tonnes of organic residue and 3 tonnes of sewage sludge per day. Sludge is a thick, semi-solid, or solid residue that is a by-product of their production process. It often contains a mixture of water, solids, and other materials that need to be separated from liquids. P001 said that Alpha used to sell their waste to another company which then use it as a fuel alternative, but they couldn't do that anymore because the Indonesian Ministry of Environment found that it was not good for the environment. Alpha now sends their waste to a third party who processes it so that it no longer harmful for the environment.

"We produce almost a million MT per year, of course we consume a lot of resources and energy." (P001)

"Our biggest waste is organic residue from the PTA factory. In addition there is sludge which comes from waste water treatment or waste treatment plants....we produce organic residue waste at 20 tons/day and sewage sludge 3 tons/day." (P001)

<u>Safety culture</u>

Due to the nature of their operation, Alpha has high risk both for their workers and the environment. According to P001, the management of Alpha are committed to safety. They have regular meeting to discuss safety issues in the company, which involve even the Board of

Directors. P001 also claimed that they have enough resource support from the management. Even though they have yearly budget for safety, if at any time they discover safety issues that have not been budgeted for, the management then increases their budget to deal with those safety issues. As a result, P001 observed that most workers at Alpha have good safety awareness. However, P001 admitted that there are still workers who ignore safety rules, and they still need to improve the safety culture in their company. P001 noted that a bigger problem is not the awareness of their workers, but that of their contractors. In order improve the contractor's awareness, they have developed a contractors' management programme.

"The management's commitment to safety is quite high, so the support is very good… Every month, we also hold Company meetings or committee meetings (which include the Board of Directors), so that up to the highest level, such as the President Director and other Directors." (P001)

"…workers' risk awareness is pretty good, although there are many things we need to improve… Sometimes, there are several people who do not wear safety glasses, only wearing minus glasses. That's the behaviour of people that we need to improve as well." (P001)

"…to minimize this, we actually have a management contractor as well. What happens to everyone who enters must be induction, training, and controlled in the field, must also be patrolled, and so on…. Our budget is unlimited for safety. So even though it's not on a budget, if something is dangerous, it can be immediately followed up for repair. We do indeed have a budget. But if something is dangerous and the budget is finished, the company will give more budget and we can still follow up." (P001)

In general, the competence level of workers in Alpha is not very high. Education-wise, the majority of the workers are high school or vocational high school graduates. For their contractors' workers, the situation is even worse. In daily operation, this is not really an issue because vocational skill is more dominant in their job. But P001 noted that the average education level of workers makes it more challenging for them to raise safety awareness. Every time they find new risk, it requires a long campaign to develop safety awareness regarding the new risk. Another factor that makes it challenging is their work system. The production department of Alpha operates 24 hours a day, 7 days a week. The workers are divided into four groups, and each day there are three groups that work in three shifts. P001 observed that when they are tired, workers tend to cut corners in their job, and are more prone to human error.

"…this is for production shift, it takes 24 hours, right, sir? Yes, 24 hours…for those in production and safety, they work in shifts. There are four groups that work in three shifts, but for those that are working in maintenance, administration and others, are only working in the daytime." (P001)

"…the level of education is varied, from High School to master degree. Most of them are High School or vocational High School." (P001)

Safety performance

Since Alpha is categorised as a high-risk company, there are many regulations that Alpha needs to comply with; however, not all of them can be fully complied with by Alpha. P001 attributed this to the regulations not being reasonably practicable. One of the regulations brought up by P001 was the regulation regarding working in confined spaces. According to this regulation, only workers that have been certified by a licenced third party can enter a confined space. However, due to the nature of their operation, practically everyone in production and maintenance needs to work in confined spaces. Additionally, there are workers from other department, such as the Health & Safety Executive (HSE) department or workers from their contractors, who need to enter confined spaces. As the cost to train and certify a worker is between 5 to 10 million rupiah (around USD $310 to USD $620), the cost to train and certify everyone would be billions of rupiah. The production department alone has around 200 workers. Even if they could obtain a more reasonable cost for the certification, the scheduling for training with a third party can be very challenging. P001 explained that in practice, they only send some of their workers to do the training and get the certification, and then undertake in-house training and have them train other workers in the company. P001 argued that they have followed the regulations as much as possible.

Another problem for Alpha is workers' participation in safety. Despite claiming that most of the workers have good safety awareness, P001 also described how A needs to have frequent Safety Patrols to watch out for workers' attitude towards safety. P001 observed that although there are some workers that always follow the regulations, and even actively remind others to do the same, the majority are not even using their personal protective equipment (PPE) properly. The HSE department also tried to induce workers to participate by developing a programme called Safety Observation. Basically, this programme asks workers to note any unsafe condition, and report it to the HSE department. However, even though there are rewards offered, not many workers participate in the programme.

"…there is one rule regarding certification to work in a confined space. So, the rule states that everyone who enters the confined space must be certified. But in actual practice in the field, almost all of the production and maintenance, everyone goes into the confined space. If we refer to these rules, it means that everyone must be certified. The production employees numbered about 200 people, and the cost per person was at least 5 to 10 million rupiah. So, you can imagine that for production employees alone how many billions are the certification costs. Then contractors too…. yes, that's billions too. Because there are so many people who enter the confined space….And usually, to enter the confined space when there is a maintenance shutdown every year, plus contractor workers which keeps changing and so there will be more costs. Usually we hire the contractor 1, 2, or 3 months beforehand, and certification takes time, sometimes even more than that. Not to mention the time to look for a third party…"(P001)

"…we have Safety observation and Patrol….but there are some workers that should be appreciated because they are quite active in reminding others. So if there is a colleague who breaks the rules, they always remind them, without having to be seen by others without having to be seen by their supervisor…some workers are too lazy to wear PPE properly, for example a helmet must have a chin strap installed; it turns out they don't use it." (P001)

<u>Sustainable production performance</u>

Alpha does not use renewable material as their resource. However, they try to reduce their non-renewable energy source by using renewable energy. In their production process, they also produce methane as a by-product. Alpha uses this methane as a substitute for the hydrocarbon gas that they use. Alpha also uses the heat and steam generated from their processes to power their turbines. The combination of these two has greatly reduced their hydrocarbon gas consumption. In small numbers, A also uses solar panels to power their street lighting.

"…we have a Steam Turbine Generator (STG) which utilizes the heat from the steam generated by the exothermic reaction.." (P001)

"….STG produces electricity using renewable energy…we also utilize methane gas from our water treatment. Our production process includes an anaerobic process. The anaerobic process produces methane gas. Methane gas is used as an addition to the produced gas that we buy from PGN. So it can reduce the resources we buy from PGN….street lighting already uses solar cells.." (P001)

With regard to environmental impact, Alpha does not perform very well. In the past, Alpha sold their waste to another company, which uses it as a substitute for fuel. This was actually an irresponsible act, because later on the Indonesian Ministry of Environment found that the emissions from its combustion was not good for the environment. The government then forbade this practice from continuing, forcing Alpha to find a third party, and pay them to process their waste. Alpha has not learned from the previous case, and currently is trying to sell their waste, not directly as a fuel, but as a resource to generate power.

Alpha performs better in social impact however, helping to educate children in the community by building several libraries and providing teachers for informal free learning sessions. Alpha also helps several communities to increase their economy, training them to be farmers, and educating them in how to run a business. But it is also important to note that Alpha focuses only on communities around their location, and their help does not reach far.

"….we send our waste to PPLI (waste processing centres) in Bogor. It can also be burned, because it still contains calories. A few years ago, we sent the waste to company A, as a substitute for fuel. However, after an audit from KLH, they did not want to receive any more, so we sent all of it to PPLI. In addition, we are also trying to send it to another company, which burns it in an incinerator and uses the heat to generate electricity. It can be done but is still in a trial phase. The majority of the waste is sent to PPLI. Almost 100% to PPLI." (P001)

"…we help many communities to farm goats, mushrooms, mostly vegetable farmers. In addition, there is also something called the Reading House, which functions as small library and to educate the people around us…. the main target is the community around the company location…"(P001)

4.2.2. Case Beta

Beta started its operation in the 2010s. The main products of Beta are gasoline, diesel and kerosene. Mainly, Beta serves customers in one of the provinces in Indonesia, where they are located. Their capacity is around 150,000 kilolitres per month.

Industrial characteristics

Beta refines crude oil into fuel such as gasoline, diesel and kerosene, and distributes it through gas stations which in turn will sell it directly to customers. Beta only has one raw material, but it is highly flammable and combustible. Their finished products also have the same characteristics, with some of those even more combustible than their raw material. As a refinery, Beta operates a complex process, i.e. more than 10 steps, that is also dangerous. Since Beta also distributes their product, they also have to manage the process of storing and delivering hazardous materials. P002 noted how storing and delivering have risks as high as the refinery process. P002 observed that in other similar companies, several major accidents had happened during the storing process. Those accidents happened due to ignorance from the HSE's aspect and underestimating the risks of the storing process.

"…when it comes to the production process, there aren't any hazardous materials. We only use one raw material, so there isn't any other material that is hazardous.…Yes, (the raw material) it is flammable and combustible." (P002)

"…our process is refinery so it is a complex process and high risk…" (P002)

"…extremely dangerous risks happened previously in similar companies, it is mostly due to ignorance from the HSE's aspect.…"(P002)

In their operation, Beta consumes a lot of natural resources and energy. As P002 put it, since it is impossible to achieve 100% efficiency, Beta consumes much more than they produce. Not only do they consume many resources and energy, but Beta also produces a lot of waste. While the refinery process produces various by-products and relatively small amounts of waste, the storing process produces quite a large amount of wastes. Storage tanks need to be cleaned regularly. Beta owns five storage tanks and every time they are cleaned, each tank produces 100 tonnes of waste. Beta also produces a lot of used oil from their maintenance process. Those used oils are classified as class two heavy duty oil, which is hazardous for the environment. The delivery process does not directly produce waste but, according to P002, oil spillage in the ocean is a common occurrence for them.

"…it is impossible to achieve 100% efficiency, so we consume more than we produce." (P002)

"…for tanks with the capacity of 10,000 kl, the cleaning process of the tank would produce 100 tons of waste… used oil from the maintenance process can be classified as class two heavy duty oil.….hazardous and toxic waste that are produced daily are oily cotton waste and oil from the pumps' maintenance process…" (P002)

"…since we have a lot of activity in ports, the environmental issues would be due to the oils that are scattered in the ocean whether in small or large volumes…" (P002)

Safety culture

P002 claimed that Beta has a good safety culture. There are several factors that support the claim. First of all, the management of Beta have been very supportive with regard to safety. Not only in supporting with sufficient resources, the management of Beta also lead by example. They always following the rules and are very strict with everyone who breaks the rules. During the pandemic, the management have shown even more support to the health and safety of the workers. They added to the regular PPE with extra equipment to help in preventing the spread of the virus. Beta has also developed a system in which they don't rely solely on the HSE department for health and safety issues. Each department is asked to actively manage risk, while the HSE department acts as advisor and places workers in each department. Beta also has relatively high standards for recruiting workers. For regular workers, Beta requires them to at least hold a Bachelor degree. Exceptions can be made if the applicant has work experience of five years or more. For their contractors, Beta requires them to be at least high school graduates.

"…our chief officer has always been supportive. He/she has issued a regulation where it is mandatory to wear full on safety gear when workers are in ports. When workers are found not wearing the complete protection gear, they would get a warning. He/she also demonstrates the appropriate actions…" (P002)

"…the management have been very supportive, especially during the pandemic. As each worker is facilitated with their personal protective equipment that is always disinfected. The equipment

often includes hazmat suits…" (P002)

"….in every operational department, there is an HSE worker placed there. However, when it comes to advice or decisions regarding HSE, these should be directed to the department of HSE…" (P002)

"…for operators' levels that are outsourced, they need a high school diploma as a minimum. But, we usually look for someone with a Bachelor degree to handle softwares or computers. That includes those in the administration division, for example those who handle ships' documents. For organic work, the minimum education level is diploma. If it's lower than that, then they need a minimum work experience of five years…" (P002)

Despite good leadership from their management, P002 admitted that the average level of safety awareness in Beta is still mediocre. In a scale from 1 to 10, P002 assessed that general workers' risk awareness is still between 6 and 7. P002 reasoned this situation as being human nature, which he believes makes them tend to work in moderation and expend only as much effort as is needed. Considering the nature of the process, Beta operates a refinery process 24 hours a day but is also forced to operate delivery processes 24 hours a day. This is due to Beta using ships for delivery. For sea routes, deviation from the schedule is a normal occurrence. In order not to waste more time, the workers for loading and unloading process are always ready.

"…in a scale from 1 to 10, workers' risk awareness would be around 6.5…the level of safety culture is still moderate, since not 100% of the workers are aware of the risks…" (P002)

"…it is no secret that most people only work in moderation, therefore justifying moderation in action and efforts…" (P002)

"…there is a fixed schedule that is based on the usual working hours from Monday to Friday. There are also shifts for ships' acquisition, where the schedule still remains tentative….since deviation of the ships sometimes occurs, we operate for 24 hours with four-shifts rotation, consisting of morning shift, afternoon or evening shift, night shift, and day off…" (P002)

<u>Safety performance</u>

Beta claims to comply with every regulation related to the environment, such as waste processing, air emissions, and noise. However, P002 admitted that Beta still have problems complying with regulations related to the working hour of their employees. According to the government regulations, each worker can only work overtime three hours a day, or 14 hours a week. However, due to their recruitment requirement standards, Beta is still short of staff in several areas. In addition, the irregular schedule of shipments forces the workers to work overtime, thus exceeding the limit.

P002 believes that workers' participation levels need to be improved. The HSE department developed a programme that asked workers to report any unsafe acts and conditions that they find, but not many workers have participated. P002 observed that in practice, there are workers that actively remind others and take the initiative in taking care of unsafe conditions. But the problem is that even those workers never bother to make a report. As a consequence, the HSE department does not have a good record of unsafe acts and conditions.

Despite those conditions, Beta has a good accident record rate. The HSE department always manages to achieve the target they are given. P002 highlighted that the worst accident that ever happened only resulted in medical treatment for the workers involved. There has never been a fatality in Beta.

"…the Ministry of Environment implements many regulations, however most of them, such as in the case of waste, air emission, noise, and so on, can be complied with… for overtime regulations, the maximum for a day is three hours and 14 hours for a week. However, in reality it is still often violated…" (P002)

"….the worst accident has been a medical treatment case (MTC), but never fatal…tank leakage has also happened several times…" (P002)

".....the workers' awareness to report an issue is still low. They might see some occurrences and decide to do nothing about it, but there are also some who remind those that did something wrong; however, they might not give a verbal or written report. So, we don't really have a record of unsafe actions or conditions…" (P002)

<u>Sustainable production performance</u>

Since the resource they consume is crude oil, Beta cannot use renewable resources. In order to offset that, Beta is trying to start using renewable sources of energy. Beta has started by using solar panels for lighting. Currently Beta is taking a step forward in using renewable sources of energy. Since their facility is located near the sea, Beta wants to take advantage of their location and is in the process of building a sea water generator.

"…for renewable resources, we're only using solar cell panels for street and motorcycle parking lights, and sometimes for phone charges in the lobby. We are also building a sea water generator…" (P002)

P002 stated that the refinery process in Beta does not have any negative impact on the environment. They carefully process their waste before releasing it into the environment. They also manage to keep their emissions within allowable levels. To support this claim, P002 said that Beta was awarded GOLD, the highest achievement, in PROPER, an environment assessment programme established by Indonesia's Ministry of Environment. Their delivery process on the other hand, often has spillage into the ocean. While they are still struggling to prevent this from happening, Beta has been doing a good job in cleaning up the spillage. Every time they have a spillage, they start cleaning immediately. P002 claimed that their team can clean up even a large spillage in a day.

"Since we do many activities in ports, the environmental issues would be due to the oil that is scattered in the ocean whether in small or large volumes…" (P002)

"….we have a programme at a local beach, which is located in the first ring of our company's location, that is often the location for turtles to hatch their eggs. Turtles used to be eaten and have their eggs taken to be sold by the local people. Because of that, their population decreased significantly. We have created a programme to help in preserving them…along the beaches, there are mangrove plantations where the plant seed can be planted and sold…" (P002)

"….there aren't a lot of complaints from nearby communities that can't be dealt with immediately, so most of the time the issue does not escalate…" (P002)

4.2.3. Case Gamma

Gamma started its operation in the 1990s. Gamma collects used lubricant that still contains impurities such as water, gasoline, additives, asphalt, and heavy metal, and processes it into base oil both for vehicle engines and industrial uses. Gamma owns one of the most technologically advanced plants in Indonesia with a production capacity of 40,000 MT per year. Gamma has two plants built on a land area of 64,150 m^2 and has ISO 9001, ISO 14001 and OHSAS 18001 certification.

Industrial characteristics

Unlike most companies in the petrochemical industry in Indonesia, Gamma does not process crude oil. Gamma specialises in processing used lubricant into base oil both for vehicle engines and industrial uses. Used lubricant is not as dangerous as crude oil but is still classified as hazardous due to its toxic nature. Processes involved in Gamma's operation are also complex. There are several steps in producing base oil, requiring two plants to finish the process. P003 describes the process below, explaining that the end result from the first plant is used as a resource for the second plant. P003 also noted that the processes are not only complex, but also high risk. Among the processes, P003 believes that the process involving hydrogen has the highest risk. The process is sensitive to error and can cause a huge explosion. To mitigate this risk, Gamma located the facility for this process in the corner of their area, and access to this facility is strictly limited. Considering those factors, P003 believes that working at Gamma has very high risks. P003 assessed that even adopting the standards for the oil and gas industry does not change the level of risk in Gamma.

"…in our refinery, we use hazardous waste as material, because used lubricants are classified as hazardous…" (P003)

"….from the stored raw material, we process it in our first unit, which is re-refinery, called re-refining. From the new refinery we produce base oil. Then from base oil, we add some supporting substances or additives, then we pack them as lubricants in our second unit, the blending plant….after the base oil is produced from unit 1, we test whether the base oil we have is still within the standard...then we also need some additives as the designation in this second unit. We just do blend in unit 2. Lastly, we pack it according to the packaging desired by the customer, it could be a bottle, it could be a pail or a drum etc.…" (P003)

"…The most dangerous process, in terms of safety, is the one that involves hydrogen, because hydrogen is very vulnerable and very explosive. So automatically in our company, the access to the area is very limited. We also put it in the far corner, away from everything, and in that place, you have to be extra careful…" (P003)

"…the risk for workers is very high. Despite following standards for the oil and gas industry, the risk is still very high…" (P003)

In order to produce up to their maximum capacity, Gamma consumes a lot of resources. P003 estimated that their production efficiency level is around 60%. This means that to produce 40,000 metric tonnes, Gamma needs to consume almost twice that amount. However, since Gamma is using used lubricant as their main resource, they only consume minimum natural resources in the production process.

"…the result of the finished product, if I'm not mistaken, our yield is 60%, so we throw away 40% of it as a side product… 40% of which is waste/side product…" (P003)

<u>Safety culture</u>

Gamma is trying to develop a good safety culture by adopting the standards for the oil and gas industry. They have developed a system of limiting access to high-risk areas to minimise risk. They also keep educating their workers and even visitors; however, their management does not demonstrate good leadership to support that. P003 noted that the high-level management at Gamma always prioritises business over safety, especially with regard to using the company's resources.

P003 claimed that workers at Gamma have a high awareness of risk. According P003, all workers take their job seriously and always consider risk in doing their job. However, P003 admitted that many workers are not always following rules, which P003 considered as normal due to human nature. P003 also admitted that many contractors who work at their facility break rules frequently. Unfortunately, P003 said they have little control over contractors. This actually could be solved if they had management's full support.

"…So, business is still the first priority. Usually decision makers are like this: the general manager will automatically issue the work order to finish business-related-jobs. Later, the SHE team with GM's knowledge too, will get the next priority…" (P003)

"…(with regard to risk) Very aware, we do not dare to mess around, especially workers doing maintenance jobs or production workers. But because we are also human….we also have a bit of difficulty controlling contractors…" (P003)

"…we use standards for the oil and gas industry in our place. Starting from safety, then for the environment, everything is using (international) standards from the oil and gas industry… So in our plant there are many places with limited access and these require a special permit… then there must be a safety briefing, what can be done and what should not be done there; this also applies to all visitors without exception…" (P003)

Gamma owns two plants, and each has a different work system. The first plant operates 24 hours and has workers working in three shifts. Meanwhile, the second plant only has two shifts and operates 16 hours a day. Another challenge for Gamma is the competence level of their workers. In the past, Gamma did not follow any standards and set the requirement for their recruitment at a low level. As a result, Gamma has many workers with a minimum level of education (elementary school) that still work there. Now Gamma has raised the requirement to be at least at high school graduate level.

"…there are two plants, in unit 1 in refinery, we have three continuous shifts in 24 hours because it is impossible for the operation to be stopped. Then in the second unit in the blending plant, there are two shifts. There are only morning and evening shifts, there is no night shift at our blending plant…" (P003)

"…because we weren't following any standards at that time, we accepted workers with minimum education. Some of them are still working here…nowadays the minimum education level we accept is high school…" (P003)

Safety performance

Gamma does not seem to perform very well with regard to safety. P003 claimed that their company considers complying with regulation is not difficult. However, they have a record of being fined several times by the authorities due to deviation from regulations in practice. P003 said that they do comply with regulations, it was just that they did it using different methods from those that the authorities wanted. But learning what exactly the meaning is of every rule in the regulations is the responsibility of the company. Doing things differently cannot be considered as complying with the regulations.

P003 also admitted that there have been several fatal accidents in Gamma in the last few years. P003 mentioned falling from a height was one of the accidents that had caused a death. P003 did not seem to consider that to be a serious case. As P003 put it, "the worker just slipped". Other than fatal accidents, P003 also noted that accidents involving trucks happen frequently. Despite having identified the risk and noted that it occurs quite often, there is no special action being done by Gamma to mitigate the risk.

"…(complying to regulations) actually it is not difficult, but the problem lies in the method that we use.…there were several cases when we had a misunderstanding with the regulators" (P003)

"…A fatal accident may have happened, for example, falling from a height. Usually the worker slipped…then, accidents involving trucks often happen…" (P003)

<u>Sustainable production performance</u>

With regard to renewable resources, Gamma has performed quite well. Gamma processes used lubricant into new products, effectively reducing the amount of waste. One of the processes in their production also produces hydrocarbon gas, which Gamma uses for their operations. Gamma is not completely self-sufficient however, since they still buy electricity from another company.

"…one of the by-products of our process is hydrocarbon gas, which we use for our own operations…but for electricity we still have to use the supply from a state-owned company…" (P003)

Gamma might not consume a lot of natural resources, but it is not exactly an environmentally friendly company. Gamma produces quite a lot of waste, especially in the first plant. The main wastes produced are asphalt and sulphur. Gamma uses a third party to process their solid waste, e.g. asphalt, but has not undertaken any significant actions regarding their emissions. As P003 admitted, the smell from their emissions is bad, and they often receive complaints from people that live near to their plant.

"…in unit 1, refinery process, there are lots of waste.…asphalt and sulfur are the main wastes…the process also produces hydrocarbon gas, but although technically it is hazardous material, it can be used as an energy supply for our plants..." (P003)

"…the gases from the incinerator… or the gases from the waste products, smell quite bad. So we often received complaints from people living around our plant..." (P003)

Gamma's facilities are not located in a remote area, but in a residential area. This is the reason any impact to the environment from Gamma will directly affect people in the area. Gamma has received many complaints from the local community regarding their waste and emissions. But instead of trying to improve the environmental conditions of the surrounding area, Gamma has chosen to do charity work. Gamma organises blood donors, free mass circumcision and distributes free groceries to people living around their facility. The close proximity of Gamma to the residential area also has had a bad effect on Gamma. Since their location is very close, there were many contacts between their workers and people in the area, resulting in many Covid infected workers. Fortunately Gamma has learned from this incident, and has managed to control the situation better.

"…CSR in our place is more directed towards the environment than the factory. Because we are in the middle of a residential area, when we do things like blood donors, we also include people from around our facility, if they want to participate, they can just come. Then there is something like mass circumcision that is also free. Even for children in orphanages, we pick them up, we do mass circumcision for them. In every holiday, like this Eid, we also distribute groceries..." (P003)

"…There were health issues at the beginning of the pandemic, many people were infected, but now it's much more controlled..." (P003)

4.2.4. Case Delta

Delta first operated in the 1930s. Starting as a small stall with only two workers, Delta was established as a company in the 1970s, and is currently one of the biggest herbal medicine companies in Indonesia. Delta owns a large and modern plant on 30 hectares of land. Despite producing herbal medicines, Delta has received certifications in Good Manufacturing Practice for Traditional Medicines (CPOTB) and Good Manufacturing Practice (CPOB). These certifications provided assurance that their products are manufactured according to pharmaceutical standards.

Industrial characteristics

Delta produces herbal medicines, which use various spices and vegetation as their main raw materials. The nature of their product makes almost all resources used by Delta to be renewable.

Delta also only uses a few hazardous auxiliary materials. P004 noted the only materials that are categorised as hazardous in their company are simple things like industrial batteries and used lubricant oil. Since Delta operates a large and modern plant for their production, the processes involved are complex. However, P004 was reluctant to share more details regarding their process, reasoning that it was a trade secret. P004 was only willing to talk a little regarding their process.

"…Generally we have no hazardous materials for the production's raw materials... the only auxiliary materials that might be called hazardous and toxic wastes are forklift batteries and used lubricant oil…" (P004)

"…At first, the raw materials were formulated. After that, the production process will occur where they would become bulk materials, and then continue to the packing process…" (P004)

Delta produces very little hazardous waste. Their hazardous waste comes from auxiliary material used in their operation, e.g. industrial batteries and used lubricant. The majority of the waste produced by Delta is solid waste that comes from their main raw materials, such as ginger, turmeric, and curcuma. Dealing mainly with vegetation means that the risk is lower. However, P004 highlighted that there is some vegetation that frequently contains bacteria that are potentially harmful for humans.

"…Our solid waste comes from spices like ginger, therefore the waste would be in the form of grounds. The grounds would sometimes drop to the floor as we processed them, and we also consider them as waste. Another example is when we're grinding sugar, the scattered flakes would also count as waste…" (P004)

"….since our raw materials are food and plants, there are some that have bacteria or will possibly ferment into mould or yeast, which is a health risk…" (P004)

<u>Safety culture</u>

The management of Delta seems to show enough support for safety. Delta adopted and got certified in ISO 45001. Delta adopted the QCSDM system, which showed how the management made safety one of their objectives. P004 remarked how the company adopted the system to ensure the safety of workers, and the rules in the company have become stricter after that point.

The management also supplies every worker with complete protective equipment to reduce the risks faced by them. P004 also noted that the company provides all safety equipment that is needed, even insisting on safety belts for jobs that are only one metre above ground. Besides safety, the company also shows concern for workers' health, conducting medical check-ups for everyone once every three months. Considering the management support towards safety, it is no surprise that the average safety awareness among workers is quite high. P004 believes that 80% of the workers have good awareness, and there are only around 20% that still have a tendency to cut corners and break the rules.

"…the support from management is enough, they always supply our PPE needs. For example, if a worker needs to work in higher places, even if only one metre above ground, they provide a safety belt..." (P004)

"…All the workers have been equipped with safety equipment while working. Gloves, customized safety shoes, helmets, masks, earplugs, and so on. We also provide MCU, a medical check-up that is done periodically, every three months..." (P004)

"…We believe some workers already have an understanding or awareness of the risks since we've established rules and we also have campaigns & training regarding those rules, such as on ISO. However, there are some that often break the rules…It can be said that 80% of the workers are already aware of the risks..." (P004)

"…we've acquired the ISO 45001 certification to ensure the safety of our workers… Since the system in our company is QCDSM, safety would also be involved…for those who break the rule, they would first only be given a verbal warning, followed by a warning letter..." (P004)

Delta has a work system that puts more pressure on workers. Due to high demands from the market, Delta operates 24 hours a day, seven days a week. Delta needs to push their production rate in order to keep up with market demand, producing 2,000 tonnes per month, roughly around hundreds of millions of sachets of herbal medicine. The management tries to mitigate the fatigue of workers by regularly rotating the workers' schedules, but the effectiveness of this attempt remains to be seen. P004 expressed concerns about this situation, remarking that when workers are tired, they tend to cut corners and no longer put safety as their first priority. Fortunately, the majority of the workers are high school graduates, and the rest have a Bachelor degree or higher.

The average level of education makes it easier for Delta to educate their workers regarding safety issues.

"…We implement three shifts, from morning until noon, and noon until night and night until morning… Our production runs for 24 hours, but the workers change according to shifts..." (P004)

"…we produce 2000 tonnes per month, roughly around hundreds of millions sachets..." (P004)

"…the general employee's qualification here is a high school graduate..." (P004)

Safety performance

According to P004, Delta has good safety performance. P004 claimed that they comply with every regulation set by the government. P004 even went further and claimed that they have never had any problem with following regulations, and every time there are changes, they will act immediately for every improvement needed. However, P004 admitted that not every worker always follows rules. Despite having high risk awareness, P004 observed that the number of workers that always follow the safety rules is between 60% and 70%. According to P004, those workers are breaking rules not because they don't understand, but simply because they are tired. P004 gave the most frequent incident as an example. Many workers get their foot grazed by forklifts because they walk outside the pedestrian line and too close to the forklift line. They felt tired and wanted to take a shorter route, despite knowing the risk.

"…We are very committed to processing our waste based on the Indonesian Ministry of Environment's regulations…most safety requirements are predetermined by the government. For example, if the lighting is not good enough then it will be improved according to regulations..." (P004)

"…the most frequent incident is people being hit by the forklift. Their foot is often grazed by it..." (P004)

"…on average, the number of workers that always follow the safety rules is between 60% and 70%..." (P004)

Sustainable production performance

Although Delta is mostly using renewable materials as their resources, they are still lacking in the usage of renewable energy. P004 explained that they still have many limitations for moving from fossil fuel. However, Delta has attempted to reduce their negative impact on the environment, by changing from coal and diesel to hydrocarbon gas. The latter produces much cleaner emissions than the former. P004 also claimed that they have no problem with their solid and liquid waste. They used to throw dirty water directly into the environment, but that is no longer the case. Now they process their liquid waste better, and it no longer has any negative impact on the environment. Since most of their solid waste is from food or vegetation, they process it into another product such as fertilizer or fuel briquettes.

"…In the past, we've used coal as energy for the boiler. But now, we've switched to using hydrocarbon gas. We also used diesel previously, but now we've shifted to gas..." (P004)

"…We have our own unit for processing waste, whether for solid or liquid waste... for example, we've processed the sugar flakes to become fertilizers, while spices grounds would become fuel briquettes..." (P004)

"…Back then, the water that we threw out was coloured black. However, that is not the case any more…we also try to reduce waste from our product packaging. We now offer packaging in a pouch, which can be used for around 100 doses, as opposed to packaging in individual doses..." (P004)

Delta also put consideration into their packaging. They have already started providing bigger packaging and reduced their single-dose packaging. Currently they are considering changing the plastic packaging for their powdered products into something more environmentally friendly. P004 also described how Delta has made positive social and economic impacts on various communities. They are educating farmers, or people who are interested in becoming farmers, to do effective and efficient farming. They provide seeds, simple equipment, and even capital to start farming. Delta also buys the yield from those who farm spices or the vegetation needed for their production. This programme has been running for years, and now Delta has partnerships with farmers in various provinces in Indonesia.

"…all of our product is still using plastic packaging. It can't be helped for our liquid products. But some of our products are powder. We could reduce the amount of plastic packaging that we

use...” (P004)

“…We're partnering with farmers. So, we are educating them on how to plant spices and so on, how to cultivate them while using the fertilizer from our waste process system. The yield will then be returned to us again through our purchasing department...” (P004)

4.2.5. Case Epsilon

Epsilon, established during the 1970s, currently stands as one of the largest agrochemical enterprises in Indonesia. The company specializes in the processing of both organic and inorganic materials through chemical procedures, while also engaging in various agriculture-related endeavours. These activities are closely integrated with trade operations and yield products in the form of goods or services, providing enhanced value and benefits. Epsilon operates two expansive facilities spanning 510 hectares each, with a production capacity of 570,000 tons/year of urea and 330,000 tons/year of ammonia per plant. In the production of urea fertilizer, Epsilon primarily employs natural gas, water, and air as raw materials. These components undergo comprehensive processing, ultimately resulting in the creation of ammonia, which is subsequently transformed into urea fertilizer.

<u>Industrial characteristics</u>

Epsilon produces various agrochemicals products, but their main commodity is urea. The main resources to produce urea are ammonia and CO2. Although ammonia does not usually cause problems for humans and other mammals, it is highly toxic to aquatic animals, and for this reason it is classified as dangerous for the environment. Besides being toxic, ammonia is highly combustible in the presence of a catalyst, which is used in the production process of Epsilon. Other than ammonia, Epsilon uses a lot of lubricant oil and catalysts as auxiliary materials that are categorised as hazardous.

Epsilon owns two plants with the same function and capacity. In each plant, the production processes are divided into two stages. In the first stage, natural gas is processed into ammonia and CO2. In the second stage the liquid ammonia and CO2 gas are processed in the reactor to produce urea. The processes are not only complex, but also very dangerous. P005 described that in order to react ammonia and CO2 into urea they need a pressure of 200 bar, with a temperature of around 180-190 C. In the worst case, the reactor can explode. Also in the second stage, the by-product of ammonium carbamate is very corrosive and very toxic. P005 noted that the risk usually increases during the turnaround, because the factory was shut down for repairs and maintenance, and there are vessels or tanks that contain hazardous chemicals.

"…Ammonia plants produce ammonia and its by-product CO2. Ammonia and its CO2 are used for urea production… .Ammonia might be hazardous, because ammonia is toxic, yes, it's toxic..." (P005)

"…hazardous auxiliary material we used, maybe just oil. Because we use rotary tools, compressors and pumps need oil. So we use a lot of oil and we also use catalysts..." (P005)

"…our ammonia factory takes natural gas. The natural gas is then processed into ammonia and CO2. The ammonia and CO2 are the raw materials for our production. The remaining CO2 is in liquid form…We process the liquid ammonia and CO2 gas, then we process it in the reactor to produce urea. Then it is purified and decomposed…later the final product is prilled urea....."(P005)

"…The most dangerous may be in the synthesis section, or in the reactor..." (P005)

Epsilon produces ammonia and CO2 needed by themselves. However, to produce those, Epsilon requires natural gas, which is a finite and non-renewable resource. Epsilon produces more than a million tonnes of urea every year and consumes a lot of natural gas. Although Epsilon consumes a lot of resource, it does not produce many waste products. The main by-product of their process is water. The water produced from their process still has a urea and ammonia content of about 1%. Epsilon then further processes the water to keep the urea and ammonia content to below 2 ppm so that it is safe for the environment.

"…for the natural gas, we still use natural gas from other companies…we use a lot to maintain our production target..." (P005)

"…according to the stoichiometry or chemical reaction, the by-product of the urea plant (ammonia is reacted with CO2) produces urea and water…if we purify urea, the by-product is water, these water vapours still have a urea and ammonia content of about 1%..." (P005)

Safety culture

From the description given by P005, it seems that Epsilon has just developed a proper safety system. A few years ago, Epsilon did not even have a work permit system in their company. P005 remarked that in order to increase the safety culture in their company, Epsilon implemented something called the Safety Golden Rule. Since Epsilon has not been implementing this for very long, there are many things that still need improvement. P005 however noted that in terms of PPE, the management spare no effort to equip every worker. According to P005, everyone on the production floor is equipped with a safety helmet, safety shoes, wear pack and earplugs, and even gas masks. All the equipment supplied is of good quality and passes industrial standards. To discuss safety-related issues, the management hold safety meetings every month. Other notable programmes mentioned by P005 are safety inspections and walk-through management. The former is performed by the Head of Department, and the latter at manager level.

"…For management of safety, I think it's pretty good, there are P2K3 (HSE regular meeting) every month and safety issues are always raised at P2K3 meetings. So there are routine safety inspections and walk-through management..." (P005)

"…In terms of PPE, we can say that it is sufficient. Everyone gets PPE that fits the standard. Safety helmet, safety shoes, wear pack and earplugs, gas masks are also given to everyone..." (P005)

"…to increase our safety culture, we just recently implemented something called Safety Golden Rule. We haven't implemented this for very long, but I think it's been pretty good in the last few years...now we are starting to have a good safety work permit system..." (P005)

P005 assessed that the level of risk awareness in Epsilon is mediocre. There are some workers that are very good, but there are also some that are very bad. P005 thought that on average, the awareness level of regular workers is good enough. Unfortunately, Epsilon also employs many daily workers, which P005 noted are much worse than the regulars. This condition is worsened by the work system. Epsilon has to meet a very high production target, around 500,000 tonnes in a year. Epsilon operates 24 hours, but only has two shifts in a day. This means that a worker has to work 12-hour shifts.

"…for risk awareness, each worker has a different level of awareness…I think it's significantly worse for daily workers…But for regular workers, the awareness level I think it's good enough..." (P005)

"…we work in shifts…we are a factory 24 hours a day. So, we never shut down the production. Saturday and Sunday we are still running…there are shifts and there are regular ones, but if it is holidays, we have to take turns to take care the operation…in the plant, we had a shift change policy... we used to have 8-hour shifts, now we have changed it to 12-hours..." (P005)

"…we have to meet production targets according to the RKAP (yearly production plan). Because we are state-owned, we must also comply with the government programme…the production target is 1,725 tons per day, or around 500,000 tons in a year..." (P005)

Safety performance

P005 remarked that Epsilon had only implemented a proper safety system a few years ago. Before Epsilon did that, accidents occurred quite frequently. Major accidents keep happening every once in a while. P005 mentioned the most memorable accident that happened in 2016. It was during turnaround, when maintenance workers entered one of the storage tanks without checking the oxygen level in the tank. The tank contained hazardous material that caused lost consciousness to the workers. Due to the low level of oxygen in the tank, this accident resulted in fatality for the entire crew in the tank.

Even though P005 claimed that the situation is a lot better now and there have been no fatalities since 2016, accidents and incidents still occur regularly. Minor accidents occur from time to time, and incidents happen on a weekly basis. P005 blamed daily workers, who are unreliable and have a tendency to break rules, for those incidents. Epsilon actually set a rule where daily workers cannot work without supervision; however, due to the high workload, this is often not possible, and usually incidents then occur. Not only safety, but Epsilon also seems to have a problem with the health of their workers. P005 noted that there are common health issues among workers at Epsilon; these include problems related to breathing, coughing, colds, and diarrhoea. Although those health issues are common among workers and occur frequently, there is no special action done by Epsilon to fix this issue.

"…thank God, the last fatal accident was 2016 and so far, there have been no fatalities… there were multiple fatalities during that accident…usually, near incidents occur when there is no regular worker keeping watch, and the daily employees are left alone..." (P005)

"…the most common issues in our company are problems related to breathing, coughing, colds

and diarrhoea…" (P005)

Regarding regulations, P005 noted that there is a new regulation that is challenging to comply with. As per the regulations, Epsilon must keep their emissions to below 125 ppm. In order to monitor their emissions, Epsilon had installed a CEM (continuous emission monitoring) analyser in their chimney. Now, a new regulation requires Epsilon to make their CEM reading accessible by the authorities in real time. So far Epsilon has not managed to make this happen.

"…but we also have a regulation for ammonia, the emission must be below 125 ppm and as per government's policy, we have an online CEM (continuous emission monitoring) analyser, which monitors emissions continuously…but now the government wants to directly monitor emissions online, on their server, which is quite challenging to do..." (P005)

<u>Sustainable production performance</u>

Epsilon uses natural gas, which is non-renewable. To compensate, Epsilon tries to make use of their by-products as much as possible. Apart from CO2 in gas form that is needed for production, the first stage also produces CO2 in liquid form, which Epsilon sells to other companies. Epsilon also keeps the water waste that they produce, processes it to a safe level, and then reuses it for various purposes in their operation. In terms of renewable energy sources, Epsilon do the minimum by using solar panels for street lighting.

"…we used the concentrator water, which was made from 1% ammonia urea, we processed it in BCP (condensation treatment process) so that the ammonia and urea were below 2 ppm, so it was safe and we didn't throw it away either, we returned it to the utility for other uses..." (P005)

"…there is a solar panel in our company, but it is only for street lighting..." (P005)

Epsilon participates in an environmental government programme called PROPER every year. PROPER is an Environmental Management Company Performance Rating Program initiated by the Ministry of Environment in 1995. Its primary aim is to incentivize companies to enhance their environmental management practices. Through the PROPER assessment, companies receive a reputation or image based on their environmental management. This reputation is assessed using colours such as gold, green, blue, red, and black. GOLD is the highest and

BLACK is the lowest category. P005 mentioned that Epsilon always get a GREEN award every year, but the management want to achieve GOLD. However, P005 does not think it is possible without major changes in the company and participation from everybody. P005 actually believes that Epsilon does not pollute the environment. The worst thing that Epsilon disposes of directly into the environment is the ammonia remaining in the pipe. But according to P005, the ammonia content is still below 2 ppm, far below the safe limit of 50 ppm. Unless there is a problem with the reactor, P005 stated it is impossible to reach 50 ppm in their waste. However, to achieve GOLD in PROPER, they need to go beyond that, which P005 thought was not feasible.

P005 also noted another serious problem for Epsilon. P005 expressed concern regarding their business continuity. Unlike their second plant, the first plant is old and no longer economically viable. With support from the second plant, it can still make a small profit; however, if there is no improvement to this situation, Epsilon will have to operate in the red.

"…we participate in an environmental government programme called PROPER. For years we have always been certified GREEN in the programme. This year the management want to achieve GOLD, but we need participation from everybody to achieve this. It is quite difficult..." (P005)

"…we usually dispose of the remaining ammonia in the pipe…but since it is still below 2 ppm it is still safe…I believe the limit is 50 ppm if I'm not mistaken…" (P005)

"…currently the profit is not as good as it used to be. Yes, like I said earlier, because this old factory is getting more and more wasteful, and repairs are getting more frequent…" (P005)

4.2.6. Case Zeta

Zeta was founded in 1960s. Starting as a small company, Zeta later became one of the biggest companies in Indonesia, producing and processing oil and gas from oil fields and taking responsibility for ensuring the availability of fuel and gas across the country. Zeta has seven refineries with a total capacity exceeding one million barrels per year. Zeta has strong commitment to providing energy and developing new and renewable energy in order to sustain the national energy security and self-sufficiency. After several decades of evolution, Zeta has reaffirmed its solid commitment to continue transforming to build a strong foundation to accomplish its vision to be a world-class energy company.

Industrial characteristics

Zeta is a large company with several sites across Indonesia. They produce a wide variety of products including gasoline, diesel, avtur, asphalt, and LPG. P006 stated that they receive products, both imported and from the local core of production, that go through the refinery process and then later they store them in the storage tanks that they have which are spread across many cities in many locations. The distribution process can also be in various modes that include rail modes, pipes, ships, and tankers.

All of those processes are associated with the handling of fuel products. Fuel products that are classified as benzene are known as flammable hazardous material. As a result, each process is critical and has a significant level of risk. P006 shared that he believes the hoarding process poses the greatest risk since the volume of hazardous material being hoarded is quite large. Failure in the process, whether caused by human or technical mistake, will be disastrous. However, according to the records, the distribution process is also very critical, with more accidents occurring in this process.

"…The most predominant hazardous material that we handle is fuel products because they are classified as benzene products and as we know, benzene is one of hazardous materials that is flammable...we also use some hazardous auxiliary materials, which are used in a specific manner. For example, mercaptans/thiol that is used as a deodorizer for LPG and other similar products…" (P006)

"…Our operational process, starting from acquisition, storage, refinery and distribution, is a critical process that has high risk… I believe the process with the most risk is the storage process as the amount of hazardous material that is being hoarded is quite high. Failure in that process will be catastrophic, whether it is caused by human or equipment error…" (P006)

"…our workers face many potential catastrophic accidents, whether it be a fire, explosion, oil spill, and so on…any of those would be very risky to any workers…" (P006)

In one of their operational regions, Zeta distributes around 50,000 kl of fuel a day. As they produce a significant amount of fuel product daily, they also generate high amounts of waste. The majority of its waste is in the form of oil sludge. As for other wastes, such as liquid waste etc., these are mostly domestic waste.

"…the waste with the most significant amount would be the oil sludge itself…we don't really use water raw materials; however, there is a possibility of producing waste in that form…" (P006)

<u>Safety culture</u>

Despite the fact that Zeta is a large corporation, and the process is also a high-risk activity, their safety culture is not well developed. According to P006, one of the factors regarding the lack of a safety culture is the company's structural issues. Every few years the company structure changes. The structure of responsibility or authority changes from one official to another and may even change from one structure to another, and it causes the culture not to be formed properly. As an example, when one person in charge has a safety culture programme that hasn't been executed extensively and has not yet seen what impact it may have, he is then shifted to another structure. Meanwhile, the programme is not continued or even replaced by another. This rapid change in structure also has an impact on employees' lack of safety awareness, due to the lack of awareness training they receive. According to P006, while being agile is important, for companies dealing with hazardous products that pose a high risk, there must also be aspects that must be maintained in order to avoid being too active or too agile.

The company has implemented a number of mitigating measures, including the development of various policies and procedures aimed at improving the safety culture at every level. However, it is still insufficient in terms of raising awareness and developing a safety culture inside the company. The HSE department at the company acts as a consultant and advisor on job risk. HSE only assists in mitigating a risk where the risk itself belongs to the worker. This can only work effectively with a good safety culture and awareness of the workers.

"…The company's safety culture wasn't formed well due to structural issues…when the role models keep on changing, there is no one to give examples of showing how to implement the company's culture. Therefore, the culture does not develop well…due to rapid structure changes, issues regarding the implementation of a safety culture arise…In the end, the safety culture remains at a stagnant point. Even if it improves for the better, it does so at snail-like pace..." (P006)

"…training regarding a division/position is still lacking, therefore the workers' awareness regarding risks and its aspects are also lacking…If we want every involved party to have high

risk awareness, that means it should be emphasized during the training process and for every procedure...” (P006)

“The HSE division is not responsible for the risks; however, we do act as an advisor or consultant when encountering risks…as a form of mitigation, awareness regarding the risks of unsafe conditions can be conveyed to every involved party, such as the authority figures and the teams at the location, and we can also do some simulation drills on emergency situations, what should be done during an emergency, and so on…we also conduct contractor performance evaluation...” (P006)

As a company with high-risk activities, basic safety needs are available at their facilities, although P006 mentioned that there are still many things that need to be improved in terms of infrastructure and facilities. Some of the facilities are quite old and unsafe. In terms of budget, P006 also stated that it is now considered that there will be a decrease due to unfavourable business conditions.

“…when it comes to our facilities and so on, some of our locations have been around for almost 50 years. Therefore, a massive design upgrade is required...” (P006)

At some of its facilities that operate 24 hours, Zeta applies a shift work system. Production and hoarding processes have three working shifts: morning, afternoon and night. Meanwhile, other workers work a standard 8-hour day during daylight. The average competence level of workers at Zeta is a diploma, as higher positions might require higher degrees. There is also a high school level, but these are experienced workers who have worked in the company for decades.

“…Our work system follows the usual standard; we operate for eight hours but it depends on the department. Production and hoarding processes usually work in three shifts: morning, afternoon, and night shift...” (P006)

“…On average, the minimum education level for operators would be a diploma degree. Higher positions might require a higher education level…there are some who are also a high school graduate. But, there is no one with a lower education level than that...” (P006)

<u>Safety performance</u>

Zeta’s safety record shows that they still do not have a good safety performance. There were several major fire accidents that happened in their facility in the last few years. Considering both their material and product are highly flammable, any fire accident can easily escalate and become catastrophic. This is worsened by the fact that Zeta's emergency response equipment is not fully prepared and readily available. P006 noted that when there was a fire in one of their locations, it took days for their team to deal with the fire. Equipment seems to be a major problem for Zeta. According to the regulations, they have to have all lifting equipment inspected and certified by the government. Until now, Zeta has not been able to do this. This is not the fault of Zeta, according to P006, but is because when they published the regulation, the government was not ready to inspect all equipment in every company in Indonesia. But the fact remains that Zeta equipment has not been inspected. There is a possibility that their equipment is not up to standard.

"…Our emergency response equipment is not fully prepared and readily available. So, when there was a fire in one of our locations, the firefighting process took days to deal with the fire..." (P006)

"…Since we are following the international standard, most issues in complying with the regulations would be around training and facilities. Due to the government's regulation, we have to certify lifting equipment in the field. The thing is, when we want to do that, the government is not ready to certify our equipment..." (P006)

The business process of Zeta is full of high-risk activities. Most people would think that the refinery process has the highest risk, but according to their internal risk assessment, the storing process was found to have the highest risk. However, P006 highlighted how their accident record showed that in the distribution process, accidents occur the most. Zeta does not seem to be able to manage their risk well. Accidents happen not only frequently but are also deadly. According to P006, they have been aiming to have zero fatalities for around a decade, but fatal accidents have still happened several times. P006 observed that while it used to happen to their contractors, now it occurs more often to their outsourced workers.

"…If we look at the risk assessment results, it would have shown that the highest risk would be in the hoarding process. However, based on our company's accident record, accidents have happened most frequently in the distribution process…Most of the accidents that happened in our company are mainly due to human error or failure in safety measures regarding the

operation of the distribution process...” (P006)

“…approximately 10 years ago, the company decided on the regulation for zero fatal accidents, meaning there is no fatality in our work location. But until now, it still happens several times…” (P006)

“…In the past, contractors have the most significant fatality numbers. Now, it has shifted to our outsourced workers…” (P006)

<u>Sustainable production performance</u>

Zeta does not use any renewable resources. They use crude oil which is a finite resource. Zeta uses some renewable energy sources, such as solar panels and wind turbines. However, they only use them in miniscule amounts compared to their overall energy consumption. Zeta also does not process their own waste. They only deal with oil spill, both on the land and sea. For all other waste, Zeta sends it to a licenced third party to be processed. P006 also said that during this pandemic time, the company's revenue has been decreasing. As a consequence, the company has tried to make some savings by reducing the available budget. P006 concluded that there will not be any improvements in the near future.

“…We have some solar panels and other sources of renewable energy, such as wind, but the number is not significant...” (P006)

“…When it comes to oil sludge, we follow environmental regulations, therefore our scope is only to manage the oil. After that, we give it to a licenced third party to be processed...” (P006)

“…During these times, the company's revenue has been decreasing, therefore they're trying to make savings by reducing the available budget...” (P006)

Zeta’s business process stops at delivering their product to gas stations. Zeta does not deal with selling directly to fuel users. But since the sales from gas stations will influence their own sales, Zeta supports the gas stations’ owner community in running their business. P006 said that they have support groups where they give people training and production equipment, and also help them improve their marketing process so that they can run their business better. P006 also observed that there are many accidents that happen during the fuel filling process. This is actually outside their scope of work, so it is not their responsibility. Nevertheless, since the fuel filling process is still related to their line of work, Zeta decided to develop a campaign programme. The programme aims to increase people's awareness regarding this issue and prevent accidents from happening.

Although the programmes mentioned by P006 are good for society, Zeta actually has a bigger problem to solve. P006 described that their facility is not located in a remote or industrial area but is close to a residential area. Any major accidents that were to happen in their facility would directly impact the local community. According to P006, Zeta currently already has a bad reputation. This is due several major fire accidents that happened in the last few years, and their failure to deal with them quickly.

"…We have support groups where we give people training, production equipment, and we also help them improve their marketing process so that they can work on their own at the end… We've found that the fuel filling process becomes an unsafe condition due to the modifications that customers have made to their vehicles. We decided to try raising their awareness regarding this..." (P006)

"...most of our work locations are not located in industrial areas, instead we're near to residential areas, thus increases risks for our business. Since an accident in our location could immediately impact the community…In the media, the company's name is bad because we are not good enough in dealing with fire accidents..." (P006)

4.2.7. Case Eta

Eta is a subsidiary of an international company that is based in the Middle East. Its parent company is a leading international, upstream oil and gas exploration and production company. They manage assets and operations spanning ten countries globally, with a primary geographic focus on the Middle East and North Africa, Russia and Southeast Asia. Eta was established in 2012 when its parent company signed a contract with the Indonesian government to operate two natural gas fields in Indonesia. Despite its relatively small size, Eta produces a quite significant amount of hydrocarbon gas which is not only consumed by Indonesia, but also by other countries in the Region.

Industrial characteristics

Eta is a gas exploration and production company that mainly operates offshore in Indonesia.

Eta's working process in general involves extracting gas from wells and then performing a separation procedure based on the physical phase difference between the gas form and the condensed water form. Natural gas and condensed gas are then produced from this process. Despite being a relatively simple process, the raw materials, and products themselves are classified as hazardous materials. Thus, the handling activity of the material already poses a risk. Natural gas has potential hazards include fire, explosion or suffocation. The company also uses corrosion inhibitor chemicals as their auxiliary material, that is not only flammable but also toxic if swallowed, is in contact with skin or if inhaled. It may cause drowsiness or dizziness, allergic skin reaction to severe skin burns, and eye damage.

"…by default, our raw materials, the gas or oil fluid, are already flammable materials...other than that, we also use corrosion inhibitor chemicals…" (P007)

Not only is the material a potential risk, the location of the plant is also at risk. The company mainly operates offshore within ships' activity routes. It also incorporates a pipeline that integrates the offshore facility to the land. P007 stated that their biggest concern is that the facility could be hit by a ship. This could result in an accident such as gas leaking, damaging the facility or even could initiate an explosion and fire. Bad weather in the middle of the sea might further increase this risk. Therefore, Eta's upstream oil and gas offshore facilities are categorised as really high-risk activities as stated by P007.

"The only thing that is dangerous is gas... so if there is excess pressure…" (P007)

"…upstream oil and gas activities like us are really high-risk activities…" (P007)

As a company that is producing gas and condensed gas as an energy source, Eta is also utilising a small portion of their produced gas as their facility's source of energy. P007 noted that on their offshore site, they have two compressors: one for production and the other for turbine generators. The turbine generators are used for converting gas into power for their offshore facility. P007 also claimed that they barely produce any waste from the main process. They only produce waste from the maintenance process in a small amount. These wastes include light bulbs, engine oil and oily cotton waste. On a regular basis Eta only produces waste totalling 200 to 500kg per month. But occasionally they produce up to 2 tonnes of waste due to the big battery replacement.

"…we only produce little waste. Just from the maintenance process. For example, changing the

engine oil earlier, or oily cotton waste…sometimes we change the big battery which can weigh up to two tonnes, but most of time we only produce waste between 200 and 500 kgs…" (P007)

<u>Safety culture</u>

As a company that has a high-risk activity, Eta's commitment to safety is quite strong. P007 noted that the high risk is not only high danger because they are handling combustible materials, but also high expenses and infestations. Thus, they consider safety to be a top priority. Their company not only has a safety policy but also already implements safety and environmental standards. They have already been certified for ISO 14001 and also OHSAS 18001, the latter in 2018 then changed to ISO 45001. The implementation of ISO 45001 shows that safety has been incorporated into the company's management system, in which top management plays a significant role. ISO 45001 also considers both risks and opportunities, which not only eliminates the possibility of future hazards, but also identifies opportunities to improve the overall safety standard. P007 stated that the external auditors have recognised that the safety culture in the company has met these standards.

P007 stated that top management commitments are also shown through the facilities and infrastructure for safety that are fully supported. And not only top management, but also the authorities, put a priority on safety. This has an impact on the budgeting process for safety, which is never an issue. These commitments from top management and authorities, acting as role models, help in strengthening the safety culture among employees in the company. P007 noted that the level of awareness of their workers is actually much higher than the average. The company also has a policy in place that allows any employee to cease any action that they are unclear about or consider may be dangerous. They also may make a request to their supervisor if necessary for a re-briefing, or even replacement tools that they feel would make the activity safer, before continuing with the activity. In addition, the company has a unique routine on its offshore platform; every day at 6 am a briefing related to safety is held and anything found on the previous day is therefore reviewed the next morning.

"…from management, the commitment to safety is quite strong…We have a policy and then we are driven by standards related to environmental safety issues, because we have a fairly good safety culture. We tried implementing it for the last three years with ISO 14001 and also OHSAS 18001. With changes in 2015, in 2018 OHSAS changed to ISO 45001. We are also certified by

external auditors or certifications, recognizing that safety culture in our company has met these standards…in terms of budget, it is very sufficient…" (P007)

As a safety culture has been developed in the company, the HSE is no longer the main implementer in preventing accidents. P007 noted that it is not the HSE department that determines whether a person is safe at work or not, but rather those who have to deal with risks and hazards at work are those who manage it. The HSE here serves as a consultant and advisor to other departments. However, if there is an outstanding safety issue from other departments or a company-level issue arises later, the HSE department will assist in its resolution. The HSE department is also in charge of managing the assurance process, such as reviewing employee medical check-up documents, conducting follow-ups and recommending treatment if needed. Meanwhile, the medical check-up process itself is carried out or registered by the HR department.

"…It is not the HSE department that declares if the person is safe at work or not, but rather those who have risks and hazards at work who manage it…HSE manages the assurance process such as a medical check-up, and the process will be registered by the HR department..." (P007)

On their offshore facilities, Eta operates 24 hours a day, 7 days a week. Although operating 24 hour a day, only two control operator workers are on shift every night, the rest work during the day. P007 stated that at each of their offshore facilities there are about 30-35 employees at the same time and they also have a crew change schedule in a 14-14 days rotation, meaning 14 days at work and 14 days off. The competence levels of workers in Eta are quite varied depending on the level of work. A minimum of high school degree is normally required for cleaning services, but at least diploma degree or higher is required for more technical operators.

"…for those who clean the lodging facilities, we use a third party, and their qualification is high school graduates. But for others (technical staff) at the least it should be diploma level or higher..." (P007)

As they operate non-stop, every Eta facility may have various production targets. Each facility has a specific target, and each day this may be different as well. This is based on the orders placed by the onshore production team. When onshore facilities are shut down, for example, their production targets are reduced. In general, a yearly target is set based on the buyers' requests as well as the state's role as the responsible authority.

"…our units have daily production targets. For each facility/platform, the targets are different, because we have several facilities and according to orders from our sales team on land. Maybe today and tomorrow will be different. When the onshore facility shuts down, we reduce the production again, so it's always different..." (P007)

Safety performance

Eta's safety performance is one of the things that the company is proud of. Since operating in Indonesia, they have maintained an excellent safety record with no Lost Time Incident (LTI) during development and in production. According to P007, they mitigate and control any existing risks, and maintenance activities are also scheduled in such a way as to avoid accidents as much as possible. The company is also committed to complying with all government regulations that are related their business process. P007 noted that they make a list of all the regulations, carry out a review, check the applicability of the regulation and also check the compliance level of the company. In the last 3-4 years, Eta has also received three awards from the authorities: zero accident award, occupational safety award and also GREEN PROPER (environmental management performance appraisal).

"…So we carry out a review, checking all applicable regulations. We list which ones are new, which ones are already in effect, and we check where our compliance level is..." (P007)

Sustainable production performance

Eta does not use renewable material as their resource. They use a small amount of the gas that they produce as their only source of power. On their offshore facilities they have installed a turbine to generate electricity for energy. Regarding the environmental impact, Eta strives to comply with the regulation that includes waste management. They use a third party to process hazardous waste but register it as their own for manifest purposes.

"…we installed a turbine to generate electricity for energy in our production process..." (P007)

"…to manage waste, we collect and segregate it from the facilities; there will be a regular shipment every month, we will send it ashore. Later we will give it to a third party… to process

hazardous waste from the operation of this offshore platform...” (P007)

Regarding the social impact, Eta has a strong track record as well. They provide assistance to the surrounding community, especially the fishermen’s community. P007 claimed that they not only educate them but also invite them to meet with the local administration to discuss their concerns. Eta also offers scholarships at local polytechnics. In addition, graduates from the polytechnic are employed on the platform.

“…in the fishermen's community, we educate them, then we invite the relevant local government where we operate to cooperate. On the other hand, we give scholarships to a polytechnic that is close to our location. Now, we hire graduates from that polytechnic to work at our platform...” (P007)

Eta also adapts really well to existing changes. This is shown by the pandemic issue. They immediately modified the working system, from 14-14 days rotation to 28-28 days rotation. They apply a 5-day quarantine and PCR test before entering the offshore facility for all workers without exception. They make sure that all personnel going into the offshore facility are in good health.

“…due to the pandemic, apart from changing from 14-14 days work system to 28-28 days, we apply quarantine and PCR tests before entering the facility...” (P007)

4.2.8. Case Theta

Founded in 1950s, Theta is a subsidiary of an international company that is based in Europe. Its parent company is a global company which focuses on Life Science related to health and agrochemicals. Theta operates several supply centres in Indonesia, which are part of the production supply chain of its parent company. Theta has a high production capacity and supplies not only the Indonesian market, but also many countries in the world. As does its parent company, Theta aims to improve the quality of life for a growing population by focusing its research and development activities on preventing, alleviating, and treating diseases. Theta regards sustainable development as their core element of corporate strategy and core values.

Industrial characteristics

Theta has three manufacturing facilities. The majority of products from those manufacturing facilities are exported to countries around the world, as well as marketed in Indonesia. P008 believed that the manufacturing process of Theta is classified as high risk. P008 explained that the most dangerous process in the manufacturing facility is the granulation process. First of all, the granulation process uses ethanol as a solvent. Ethanol is highly flammable and can ignite at relatively low temperatures; it also has a relatively low boiling point and turns into vapour relatively easily. The vapour is even more dangerous because it can form explosive mixtures with air. Another dangerous property of ethanol is its toxicity. Ingested in a low quantity, ethanol can cause nausea and vomiting, whilst in a large quantity, ethanol can be life-threatening. Ethanol is also hazardous if it comes into contact with skin or eyes. Prolonged or concentrated contact may cause inflammation to the skin and significant irritation to the eyes.

The second reason the granulation process is described as the most dangerous process by P008 is because it involves an effervescent process. Effervescence is the rapid escape or release of gas from a liquid. Since the liquid involves in the process is ethanol, the danger of fire and explosion to occur is very prominent.

Aside from ethanol, P008 also outlined various chemical reagents that are also classified as dangerous chemicals. However, since those chemical reagents are mostly used in the QC Department, the quantity and area of the usage is limited. Thus, P008 expressed that although they still need to be treated carefully, those reagents are not high on their list of risks. According to P008, Theta is more concerned about machinery safety. They use hundreds of machines in three manufacturing facilities. Without strict regulation and procedures, accidents could happen on a daily basis.

"Well, when it comes to plant safety processes, one of the most hazardous processes is perhaps the granulation process. Because in the granulation process, we need or use ethanol there, sir. So, for the effervescent process as well, as you may know, ethanol is flammable, highly combustible, and so on. So, that's a hazardous process because ethanol is involved. And also, for machinery safety processes, almost all activities that use automatic machines have their machinery safety potential. These machines move and so on, you see." (P008)

"We use quite a few chemicals, sir, but there are some that are categorized as hazardous materials. One of them is perhaps ethanol, but there are also a few others, sir. I might not remember all of them, but we have a quality control laboratory, sir. So, we have many reagents

or chemicals that are used in our QC laboratory.” (P008)

As Theta is producing not only for Indonesia, but also for many countries around the world, it produces a massive amount of product every year. Naturally, Theta consumes a lot of resources and energy. Most of the materials used for production are non-renewable, and a significant portion of these are still imported from other countries. In terms of waste, the biggest percentage of waste produced by Theta is their reject-products. However, since Theta mainly produces medicine, those reject-products are classified as dangerous goods.

“The waste generated from the production process, as I mentioned earlier, the largest quantity of waste is categorized as reject products. That's the highest quantity when the product is rejected or doesn't meet the specifications, so we treat it as hazardous waste. This also includes processes like packaging, which has been contaminated by materials or non-materials, including all its packaging, which becomes waste.” (P008)

Safety culture

According P008, Theta puts developing safety culture as one of their priorities. Theta firmly believes that in order to have a good safety culture they need to have a strong leadership. That is why the first thing they do is ask for commitment from the leaders. Since 2018, Theta has been running a Behaviour-Based Safety (BSS) Program. P008 claimed that BSS Program has been successful in increasing safety culture at Theta.

One of the results of the BSS Program is that employees at Theta have a good risk awareness. After every shift, employees will gather to discuss the risks they faced, and brief the next shift. Theta also has an easy system to report risk in their workplace. Workers do not need to fill in any forms, they just need to take a picture, give a brief description, and send it to a hotline number. H&S Department will then investigate and make a report. The combination of good risk awareness of the workers and a good system developed by the management has resulted in all risks being identified successfully.

“So, first, we hold a commitment from our leadership in our factory, sir. One of our programs is behaviour-based safety (BBS). So, we implement a BBS program in our factory. It starts with providing training to all employees, and then after that, we form a group of colleagues who have received this training or all other employees to identify which behaviours we want to change,

based on their daily risks. Once we've determined which behaviours to change, we then monitor, track, and implement reinforcement. The leadership conducts touch points and coaching to ensure that the behaviours we are targeting or implementing can achieve goals, be sustainable, and continue in the long run." (P008)

"During every shift change in operations, it is mandatory for our colleagues to discuss safety and remind their peers about safety as well. For every shift change, whether it's shift 1, shift 2, or shift 3, safety is always the primary topic of discussion. First, they address whether there are any safety issues, incidents, hazards, and so on." (P008)

<u>Safety performance</u>

P008 believes that Theta has a good safety performance. With regard to regulations, Theta has a dedicated team who review what regulation is relevant to them and inform the related Department to ensure compliance. However, P008 admitted that in practice, sometimes a small allowance is still needed. P008 outlined one of the new regulations applied to them, in which every machine and equipment used must be checked and certified once a year. Considering that Theta owns and operates hundreds of machines, and that the checking and certification can only be done by a licenced third party, it is not feasible practically for Theta to have all their machines certified. When a machine is approaching the expiry date of its certification, Theta will contact a third party to arrange inspection and re-certification. They will then inspect each machine and re-certified machine that pass the inspection. This process takes time, and usually Theta will have a percentage of their machines not inspected until their certification expires. This situation can only be resolved if there are more licenced third parties that can do the inspection. However, the licence can only be issued by the government, so Theta has no control over this issue.

"…there was a new regulation that came out around 2019/2020 regarding compliance with the inspection of production power machinery, where each machine or production power machinery had to undergo inspections. These inspections include the initial one and also periodic ones. Considering the large number of machines or equipment we use, that might be a challenge for us. We are doing it gradually, so we can't do the certification for all of them at once. We refer to it as official certification from the Ministry of Labour, but it's done gradually. This is primarily because of resource constraints, including time and so on, as it takes time, sir, for all of this. Budget-wise, it's not an issue; it's more related to time. Additionally, this regulation

requires periodic reviews of the inspections, sir, once a year, so it's an ongoing process. This is a new regulation that must be complied with." (P008)

P008 also narrated how successful their safety programme is. Theta employs two directional approaches, from the top and from the bottom. From the top, the management are committed to supporting the safety programme. Adequate resources are allocated to ensure the programme can be executed well. They also create a system that is easy to be followed by all workers. Accordingly, from the bottom Theta invests heavily in the BBS Program. Due to excessive campaigning by the BBS Program, the awareness of workers improves, and the participation rate is very high. P008 disclosed that of the 500 workers who were targeted by the BBS Program, all of them have willingly participated in every safety programme. In the risk reporting programme for example, each worker has reported at least one risk per year.

"So, we've also developed a system, an easy-to-use system, for everyone to report hazards. We set targets, sir, at the beginning of the year, for example. We have a total of 500 employees, and our target is to have 500 hazard reports in a year, and all 500 of them should be mitigated. This also helps create awareness among employees. It makes them aware of the workplace hazards. Alhamdulillah (thankfully), until now, we're still on track and it's still going well; our colleagues are still reporting." (P008)

Sustainable production performance

Theta is a subsidiary of a global company. As a result, they have awareness about sustainability issues earlier than other local companies. Theta states that they support the Sustainable Development Goals (SDGs) of the United Nations. They aim to achieve these by 2030. Currently, their main concern is greenhouse gas (GHG), and they are trying to reduce their contribution to it. Theta also currently planning to install solar panels on a big scale. However, this is still in the planning phase, and has yet to be implemented.

Theta also has a good safety record. There has not been any major accident in the last few decades, and there is no minor accident in the last few years. There are near miss reports from time to time, but these are always followed by an investigation. After the investigation is concluded, the H&S Department then issues corrective and preventive action to avoid the same incident happening again. Theta is also actively developing the community around their location.

Since the majority of their product is medicines, Theta puts a lot of effort into improving the health level of the local community. P008 described how they sponsored many small clinics to have sufficient human resources and medicine supplies. They also did a lot of coaching and training for healthcare workers so that they have adequate skills and experience.

"…On a global scale, we are actually committed to sustainability. If you are familiar, it's related to the SDGs, which stands for Sustainable Development Goals, consisting of 17 goals outlined by the United Nations. Well, one of them is also part of our company's agenda for 2030." (P008)

"…the most significant usage is electricity, in our location when it comes to energy. Well, maybe in the future, we are planning for solar panels. But this is still in the planning stage, so it's for the future…" (P008)

"*Alhamdulillah (thankfully), throughout this year, we haven't had any accidents. There have been a few near misses, but these near misses were somewhat related to our operational or production processes and occurred outside our facility." (P008)*

"We have a CSR (Corporate Social Responsibility) program, as far as I know. It might not be just one; there are several, but the one I'm most familiar with is community empowerment, particularly related to the Posyandu (Integrated Health Post). It's more focused on healthcare. So, we engage with the mothers and encourage them to visit the Posyandu, and so on. We provide whatever is needed. So, we are involved, not just in terms of budget allocation but also actively involved in the program. For instance, we provide health-related education, maybe related to pharmaceuticals, and then we also provide midwives or doctors at the Posyandu." (P008)

4.2.9. Case Iota

Iota is a prominent pulp and paper manufacturing company that specialises in delivering dependable and top-class paper products. Iota has declared their dedication to environmental sustainability by predominantly using recycled fibres in their products and holding certifications for FSC® and ISO 14000, underscoring their eco-friendly practices.

Iota was founded in 1970s on a 5-hectare site in Indonesia and rolled out their very first jumbo roll paper in 1970s, using a paper machine with the capacity to produce up to 6,000 tons annually. In response to the increasing demand for paper in Indonesia, they embarked on their first expansion programme in the 1980s. This involved adding three additional paper machines, which raised their total production capacity to 36,000 tons per year. They made further investments in the 1990s by incorporating two more paper machines, bringing the total capacity to 78,000 tons per year.

Iota established their own 27 MWh power plant unit in the 1990s. This power plant unit ensures a consistent and reliable supply of electrical energy required for production, enabling them to maintain product quality and fulfil customer requests promptly.

By 2015, Iota manufacturing operations had expanded to cover a 28-hectare area, equipped with eight paper machine units with a combined capacity of up to 230,000 tons per year. Their production encompasses a diverse range of industrial papers, fine papers, and tissues. These products are then distributed to both domestic and international markets.

Industrial characteristics

Iota produces a large number of products every year. Naturally, Iota consumes a significant number of materials and energy. Being a pulp and paper manufacturer, the main raw material for their production is wood. However, Iota does not cultivate their own trees, but procures the wood from several suppliers.

The three informants from Iota, P009, P010 and P011 all believe that their work environment is high risk. P009 was concerned about the usage of chemicals in their manufacturing process, which is large both in quantity and variety. P010 noted that they had many incidents and accidents involving machinery. In contrast to common perception, small machineries cause more accidents, due to their moving parts and reachability. On the other hand, P011 does not have many experiences with minor accidents, but had experienced several major accidents involving the production of pulp.

"We use quite a few chemicals. The most dangerous one is chlorine because it's toxic. We also use other chemicals that are quite hazardous, like sodium sulphide or sulphuric acid. But the most dangerous one is chlorine." (P009)

"The most dangerous, especially the ones that often cause workplace accidents, are in the machine areas, specifically the parts of the machines that rotate. I've observed that the machines causing accidents most frequently are often not very large and don't operate at very high speeds.

These tend to lead to accidents. It might be because people perceive them as slower, so they are less cautious." (P010)

"Those with a high risk, perhaps the first part in processing the paper pulp, there have been incidents where people have been seriously injured. It has happened several times." (P011)

Theta also manages their waste quite efficiently. Considering that their main material is wood, most of their waste from production processes is usable by another industry. Taking advantage of the situation, Theta sells a significant portion of their waste to other companies through third parties. The most common usage of their waste is as fuel.

"We collaborate with a cement industry plant. As far as I know, they can use it for their needs as well. It's used as a substitute for raw materials in their next production process, if I'm not mistaken. The third party we contract with will collect our waste, and then they will send it to another company. They calculate it as a purchase from us. They say it's used as raw material by them. Mostly, from what I know, it's used for fuel." (P011)

Safety culture

P009 claimed that the management is very supportive of safety. They allocate resources for their H&S Department. Iota also puts safety as a primary objective for their workers. When the production quota is achieved, but an accident has happened, the managers and supervisors are assessed as failing in their responsibility. However, what they mean by an accident in this evaluation seems to be only a major accident. According to P010, only less than 1% of workers in Iota has ever been involved in an accident. Iota has aimed to achieve a zero-accident rate since a few years ago but has not managed to achieve it until now. Iota actually has procedures for all of their activities, but P010 claimed that there are workers who like to take short cuts, breaching the procedures, and this results in an accident. It can be seen that there is a small percentage of workers who still do not have a good risk awareness.

Iota has tried to increase the risk awareness of their workers. They kept campaigning about their target: to achieve zero accidents. They assign and deploy a risk officer to patrol and remind workers about safety procedures. They also put an accident record at the gate, to remind everyone that accidents do happen, and everybody needs to careful. However, so far Iota has not managed to achieve its zero target. This might be due to the average level of education of their workers being relatively low, and that most workers have only received basic safety training. Only a handful managers and supervisors received regular safety training.

"As for workplace accidents, they still occur. In reality, the existing risks are well managed. There are risks, but they are under control. Regarding what we call accidents, if everything goes according to the system, workplace accidents should not occur. It's because sometimes operators want things to be done quickly. So, it depends on each operator. On average, maybe 9 or 8 out of 10 will follow the procedures, while the rest will deviate and experience accidents." (P010)

"There's a lot of support from management, and when it comes to safety, it can be considered good. Maybe it's related to the budget or human resources; those aspects are in good shape. Management also places safety in a high position. So, even if production targets are met, as long as there's an accident, it becomes an issue. Supervisors and managers are seen as failing in such cases, which is what usually happens here. And even if the output decreases but there are no accidents, we might choose that. So, what's emphasized is indeed "safety first." (P009)

"What we've been striving for up to now is that in every department, there is a safety officer. They emphasize procedures. We have security personnel who continuously monitor because accidents still occur. So, when we arrive, at the entrance, there's a monitor. The monitor doesn't display production output but instead shows how many workplace accidents have occurred up to today. It's to demonstrate that our target is Zero accidents. If an accident does happen, what it would be like, approximately. There are also photos of previous workplace accidents. They serve as reminders for employees not to let such incidents occur. So, these photos of our colleagues who have experienced accidents are displayed near the entrance. So, while waiting in line to enter, we can see them and check the table that counts how many workplace accidents have occurred each day up to today." (P009)

<u>Safety performance</u>

In general, Iota always complies with every regulation that is relevant to them. However, P010 admitted that they are not always adapting quickly when there is a new regulation issued by the government. One example described by P010 is regulation regarding live monitoring of their waste release. The government requires them to measure pollutant levels in their waste. This measurement has to be done in real time, every time they release waste to the environment. The result must also be sent to the government in real time as well. To comply with this regulation, Iota needs to buy and install the necessary equipment, which can only be imported from abroad. They encountered several problems in acquiring the equipment, causing them to be unable to meet the deadline by the government. Furthermore, they still have problems with installation of the equipment, and are still unable to do measurements and reporting in real time.

"Regulations for live wastewater quality monitoring. In Indonesia, these regulations are new, and we are still having difficulty complying with them. It involves sending water quality information to the government online, 24 hours a day. The challenge is that this is still a new system, and errors can occur with the equipment and internet connectivity, which may pose difficulties for us. The water quality can vary. In our location, it is manually measured and found to be good. However, when the equipment sends data to the government, the data sent does not match the manual measurements. The accuracy of this is still not reliable." (P010)

Another problem faced by Iota regarding regulation compliance is about the inconsistencies of different government bodies. P009 claimed that there are several regulations from different government bodies that contradict each other. P009 however admitted that they usually just read the regulations themselves, and occasionally attend to the socialisation of the regulation. They do not have a dedicated team to review regulations, which leads to a situation in which they can often misunderstand the regulation.

"Safety regulations are quite extensive, but sometimes they overlap. Regulation A says A, but Regulation B says B. For example, concerning hazardous waste (B3 waste), the regulations from the Ministry of Manpower and the Ministry of Environment are different for the same item. It seems like they need to be simplified so that industry players can easily comply with the regulations. Also, when it comes to our relationship with the government, it involves reading regulations or participating in awareness campaigns. But sometimes, we can't fully understand the regulations. So, when we're audited, we sometimes learn things anew. "Oh, it should be like this or like that"." (P009).

<u>Sustainable production performance</u>

Considering the scale of their production, Iota has been included in a programme called

PROPER by the government. In the last few years, Iota has always been awarded blue by the government. Being awarded PROPER Blue signifies that Iota has made efforts in environmental management as required by applicable regulations or rules but also means that Iota is barely complying with the regulations.

Iota has received FSC certification since 2012. The certification for FSC forest management verifies that the forest is being overseen in a manner that safeguards biodiversity, enhances the well-being of local communities and workers, and maintains its economic sustainability. FSC-certified forests adhere to rigorous standards in terms of environmental, social, and economic management.

"So far, we have always received a Blue PROPER rating from the government. We have consistently received the Blue rating for several years." (P009)

"We have obtained FSC certification since 2012. It's typically somewhat challenging to obtain this in Indonesia. So, in broad terms, the concept is that the raw materials we purchase come from forests. Now, our suppliers, when they harvest the forest, have an obligation to replant an equivalent amount to what they've cut. So, being FSC certified means that the traceability and responsibility of the producer can be accounted for. In Indonesia, there might be only one or two companies that are FSC certified." (P009)

4.2.10. Case Kappa

Kappa started their operation in the 1970s and has earned recognition as a prominent leader within their field. In anticipation of the growing demand for their plastic packaging, Kappa offers an extensive array of services to its clientele, including 8-colour printing, various laminating options (PE, PP, SP), bag manufacturing, shrink labelling, and the filling of products such as sugar, pepper, and salt. To meet the increasing requirements for packaging materials, the company established its second factory in the 1990s. Supported by a workforce of 500 highly skilled and factory-trained employees, as well as a sophisticated range of equipment, Kappa is firmly dedicated to consistently producing high-quality products.

<u>Industrial characteristics</u>

Kappa's main product is flexible packaging. At maximum capacity, Kappa is able to produce 17 million metres of flexible packaging in a month. Kappa consumes a large number of raw materials and energy in their manufacturing process. P012 considers production activity at Kappa to be high risk. In manufacturing their product, Kappa uses a lot of chemicals in their process, some of which are categorised as dangerous chemicals. For example, Kappa uses ethyl acetate as a solvent agent in their process. Ethyl acetate poses a significant fire risk and can be harmful when ingested or inhaled. Prolonged or repeated exposure to this chemical can result in severe damage to internal organs. Additionally, ethyl acetate can lead to irritation if it contacts the eyes or skin. During their manufacturing process, the temperature in their machine can be as high as 330 degrees Celsius. This environment causes many chemicals to be vaporised, creating more risk to workers.

Other than the chemicals, P012 outlined another type of risk: risk of being hit by mechanical movements from the machines. The manufacturing process at Kappa is not an automatic process. All of their machines need to be operated manually, and still involve a lot of human intervention. This results in high interaction between workers and machines, creating many risks during operation.

"In one month, if all three production lines are operational, the total product we produce amounts to around 17 million meters." (P012)

"We use quite a lot of hazardous materials (B3 substances). Most of them are used as solvents. One of the most dangerous ones is ethyl acetate. If ingested, it can lead to death. Its vapour is also harmful to the lungs. In our location, the temperature can reach up to 330 degrees Celsius. Many chemicals become vapour at that temperature, and inhaling those vapours can also be dangerous." (P012)

"All those machines are dangerous. They're all made of metal, move at high speeds, and most of them need to be manually controlled, so they're really hazardous. There's a machine where the operator has to feed in sheet-shaped materials, and the machine will clamp them. Even a slight lapse in attention, and the operator's fingers or even hand could get caught. Then there's another machine that cuts materials, and the operator has to catch the cut pieces to feed into another machine. If they're not careful, they could get their hand cut." (P012)

Safety culture

Kappa is still building their safety culture. Currently, their biggest concern is their workers' risk awareness. Due to the type of product that they manufacture, Kappa uses many chemicals. But according to P012, Kappa does not have any problems with managing the chemicals. It might be that because perception about chemicals is dangerous, P012 finds workers are very careful when they are dealing with them. In contrast, many workers seem to be underestimating the risk of their machineries. Despite many procedures being issued for working with machinery, many workers often ignore them.

P012 said that management at Kappa is committed to safety. This claim was based on what the management has provided to improve safety. Each worker is supplied with safety equipment. Firefighting equipment is also supplied. Kappa also collaborates with firefighters to mitigate fire risk at the company. Upon more detailed enquiries however, it seems that support given by the management at Kappa is just the minimum requirement to comply with the regulations. There are also health and safety programmes that are no longer running due to limited budget.

The average level of education at Kappa is also quite low, with the highest education level for operators being only high school graduates. Even for management positions, these are not always filled by university graduates. Safety competence levels also seemed to be low. Kappa has around 200 workers, but only has one dedicated worker for safety. The only safety related training given to workers is firefighting training, which is conducted once a year. Considering that Kappa's manufacturing process is running 24 hours a day, one dedicated safety worker does not seem to be adequate.

"Management supports efforts to enhance the safety culture in our workplace. This is evident through the support provided in terms of facilities and budget. Every worker is provided with safety helmets and shoes, and there is an abundant supply of firefighting equipment. Collaboration with the fire department is also established. In the past, milk was also provided to workers because it was beneficial for those who were frequently exposed to chemical vapours. However, perhaps due to budget constraints, this practice is no longer being carried out." (P012)

"We have a total of around 200 employees. The operators have various educational backgrounds, but the highest educational level is typically a high school diploma. For managerial positions, a bachelor's degree is usually required. Although there are some employees with lower educational levels, their experience can qualify them for managerial

roles." (P012)

"We have one employee specifically responsible for safety. They oversee safety training conducted here. Typically, fire extinguisher training is held once a year." (P012)

Safety performance

Kappa does not seem to perform very well regarding regulation compliance. To reduce pollution, the city government prohibits the usage of coal to power manufacturing facilities. However, Kappa does not want to use other sources of energy, since the cost will be much higher. So, they are still using coal, but have upgraded the chimney that they use. The chimney has a good filtering system and is equipped with water spray to "catch" the ash so that it won't be released into the air. Kappa might think that they are preventing pollution, just as wanted by the city government. However, they are still deviating from the regulation, and this might get them into trouble later on.

"In our industrial area, the use of coal as a raw material is currently prohibited by regulations. However, due to cost-saving measures desired by the big boss, who wants something more economical, we still use coal. But we take precautions by using a high-quality chimney. Apart from having a filtering system, inside the chimney, there is also the use of water spray to prevent coal ash from dispersing into the sky and polluting the air." (P012)

P012 also admitted that there have been several major accidents in Kappa in the last few years. P012 mentioned there was a worker who lost a limb due to being clumped by a machine. P012 did not seem to consider that to be a serious case. As P012 put it, "there has not been any death in our company". P012 also mentioned that accidents with machinery trucks happen frequently. Despite having identified the risk and noted that it occurs quite often, there is no special action being undertaken by Kappa to mitigate the risk.

"Operators still tend to be careless when working with machines. They should ideally stay focused and always follow procedures, but because many of them have bad habits, accidents still occur. There have been incidents where someone's hand got caught in a machine, leading to amputation. There have also been cases where someone's hand got severed by a machine. We

have reminded them repeatedly, but these incidents still occur." (P012)

Sustainable production performance

Kappa manages their waste quite efficiently. The majority of their waste comes in the form of solid waste which is usually excess or reject product that cannot be delivered to their client. Since their product is mainly plastic, their solid waste has economical value. Kappa always collects their solid waste and sells it to other companies. Usually, the buyer will process it into plastic resin first, and then use it for other purposes. Their non-plastic solid waste is also in demand. There are several companies that are willing to buy it and use it for alternative material to produce bricks. Similarly, their liquid waste is also always bought by other companies. The majority of their liquid waste is excess ink from production. They collect it in a specific container, leave it until it has solidified, and then transport it to their buyer.

In contrast, Kappa seems to be neglecting their air pollution. When asked about their impact on the air, P012 simply stated that they do not know it because they never measure their pollutant level.

"When it comes to our solid waste, many are willing to purchase it. Most of our solid waste consists of plastic. It's usually excess production or items that don't pass quality control. Many other companies are interested in buying these to process them into plastic resins. They can be used for various purposes, either resold or used in production again. Besides plastic, there are also those who want to purchase it. I'm not sure about the details, but they say it's bought as raw material for making bricks." (P012)

"As for our liquid waste, many are interested in buying it as well. Our liquid waste usually contains ink. We collect it first, leave it outside, and it eventually solidifies. Afterward, it's transported for sale." (P012)

"Well, when it comes to air pollution, we don't really know because we've never measured it." (P012)

With regard to the source of energy, Kappa currently uses coal to fuel their manufacturing facilities. They also buy electricity from a state-owned company, but this is limited to office usage. Kappa is content with what they have now and does not have any plan to change it. Renewable energy sources are considered to be a luxury and will not be utilised for the time being.

"We use coal as the factory's energy source. We also use electricity from the national grid (PLN), but that's only for the office. Renewable energy sources like solar panels seem quite luxurious. Currently, we have no plans to adopt them." (P012)

4.2.11. Case Lambda

Established in the 1980s, Lambda holds the distinction of being Indonesia's pioneer in flexible packaging manufacturing and ranks as a prominent producer of flexible packaging films in Southeast Asia. Their annual capacity reaches nearly 131,000 tons, enabling the production of a diverse range of packaging film products for both industrial applications and consumer goods.

Lambda's scope of activities revolves around the manufacturing and marketing of plastic goods. Currently, Lambda's primary activities include the production and marketing of flexible packaging materials, specifically Biaxially Oriented Poly Propylene (BOPP) film, Biaxially Oriented Polyethylene Terephthalate (BOPET), also known as Polyester (PET) film. These films are used for various applications, including food packaging, cigarette packaging, paper lamination, labels, and general packaging purposes.

Industrial characteristics

Lambda produces flexible packaging, supplying their product to 60 different countries in five continents. On average, Lambda produces 131,000 tons of product every year. As shown in their production output, Lambda consumes a large number of raw materials and energy in their manufacturing process. P013, P014, P015 and P016 all said that the risk faced by workers at Lambda is high.

P015 and P016 narrated the manufacturing process at Lambda and described the hazardous materials and process involved. The process that concerns P016 the most is the winding process. This is due to the nature of the process, in which the machine rotates with high power and speed and has to be manually operated by operators. A simple mistake from the operators can cause major injuries. Another process that concerns P016 is the MDO process, which includes four phases: heating, stretching, annealing and cooling. Just like the winding process, the machines involved in the MDO process all need to be operated manually by operators.

P015 also added that in addition to mechanical risk, there are several chemicals used in the process that raise health and safety issues. Mainly, those chemicals are used as a solvent agent, such as acetone or methyl ethyl ketone (MEK). These substances can be extremely hazardous if inhaled or come into direct contact with the skin.

"In my opinion, one of the most dangerous aspects of our production process is related to the winder process. This is because it involves the winding process, where a machine with significant power rotates. The winder machine also requires an operator to manually feed materials, leading to interaction between the operator and the machine while it is in operation." (P016).

"Apart from the winder process, another similarly hazardous process is the MDO (Machine Direction Orientation) process. This is because the machines used for the MDO process also require manual operation by operators." (P016)

"In our production process, there are several chemicals classified as B3 that we use. These are typically used as solvents, such as acetone or methyl ethyl ketone (MEK). These substances can be extremely hazardous if inhaled or come into direct contact with the skin." (P015)

<u>Safety culture</u>

The management of Lambda has shown their commitment to improving the safety culture in their work environment. P016 narrated how since first joining company, the management has consistently improved safety every year. All improvement regarding safety has always been approved by the management. Although P016 admitted that sometimes their budget is not enough to do the improvement, the proposal never got rejected. Instead, the management asked them to do the improvement in several steps, so that it can be fully implemented in one or two years. Management also provided facilities for the safety of their workers. This is not only limited to the facilities needed during working, such as PPE, but they also provide shuttle cars, to ensure their workers can arrive home safely.

"Our management is highly committed to safety development. While not all safety developments can be immediately implemented, there are programs with substantial budgets or funds, leading

to significant investments that management must allocate. They have simply advised to proceed gradually. The work is carried out incrementally but continuously, without compromising the value of the intended development." (P016)

In general, workers at Lambda have a good risk awareness. This is due to continuous training that is mandatory for every worker. Every time a worker is assigned to a department, even if it is not a new worker, the worker must undertake a safety induction training. To ensure the risk awareness remains high, the worker must also undertake safety training twice a year. This policy is applied to every worker at Lambda.

"Every time an employee is assigned to a particular department, they are required to undergo safety induction training, even if they are not new employees. So, even existing employees, if they are being placed in that department for the first time, they must attend the training. Furthermore, to ensure that their risk awareness remains intact, they are obliged to attend training periodically, if I'm not mistaken, it's twice a year." (P016)

<u>Safety performance</u>

According to P016, Lambda has good safety performance. P016 claimed that they comply with every regulation set by the government. P013 claimed that Lambda even already fully comply with a regulation that many other companies find hard to do. P013 referred to this regulation, which asks companies to register their liquid waste treatment facility. The facility must be registered, have its coordinates listed, and can be monitored online in real time. To ensure their compliance, Lambda has a dedicated team that reviews all the relevant regulations and makes changes or improvements when it is necessary.

"For liquid waste, we already have a treatment facility in place. This facility is registered with the Ministry of Environment and Forestry (KLH), complete with detailed data, coordinates, and processes that are monitored by both the central and regional KLH offices. The results of the waste treatment are also measurable and continuously monitored by them, and this can be done online in real-time." (P013)

Lambda is still lacking with regard to the participation of their workers. Lambda has a dedicated team to assess and review their current safety state. Accordingly, the team will also find what needs to be improved and create safety programmes to achieve it. Although workers always follow every mandatory programme, when their participation is voluntary, there is only a small number of workers who usually participate. They have made several innovations to increase the voluntary participation of workers but have not been successful so far.

"We are honestly puzzled by the participation of our employees. When it comes to mandatory programs, it doesn't require much effort as most of them will surely participate. It's rare to find employees who are stubborn and unwilling to join mandatory programs. However, when we create non-mandatory programs, hardly anyone participates. It's usually the same group of people who attend. We've tried offering incentives, but the situation remains the same." (P014)

Sustainable production performance

Currently Lambda is still lacking a facility or plan to use renewable energy. However, Lambda is already aware of their impact on the environment. They have not started to implement renewable sources of energy yet because the investment cost for now is still too high for them to be justified, so Lambda focuses on energy alternatives that are friendlier to the environment. Lambda previously used coal to fuel their energy generator. However, they have successfully converted to natural gas since last year. Natural gas has a less negative impact on the environment.

"Currently, we do not have the facilities or plans to use renewable energy sources. However, this is not because we are not concerned about environmental issues. On the contrary, we are very aware of the impact of the industry on the environment. We have not yet adopted renewable energy sources because, at the moment, the costs are still too high for us. Therefore, for now, we are more focused on using environmentally friendly energy sources." (P014)

Lambda manages their waste very well. As already discussed, Lambda processes their liquid waste in a water treatment facility and can be monitored online by the government. Lambda also has a contract with a government-licenced third party, to collect, take, and process their domestic waste and hazardous waste. Regarding their excess production and scrap, Lambda sells it to several companies that need the material for other purposes. Lambda also takes this as an opportunity to do community development for the local neighbourhood. A part of their scrap is not sold but is given to the community. Education and training are also given to the community so that they can use and process the scrap to have more economical value.

"There are used cardboard packaging materials that are managed by a third party for collection. We are also doing collaborating with the Karang Taruna group that wishes to utilize and work together to benefit from this process." (P014)

4.2.12. Case Sigma

Sigma is an integrated global energy producer and provider. Sigma has successfully become a leading multinational oil and gas company, as well as the world's largest solar energy operator. As of now, Sigma employs a workforce around a thousand individuals, all committed to delivering safer, cleaner, more efficient, and innovative energy accessible to more people. With a strong sense of responsibility, Sigma dedicates their full attention to ensuring that their operations in over 130 countries consistently provide socio-economic and environmental benefits.

Sigma's presence extends to 23 countries in the Asia-Pacific and Middle East regions, including Indonesia. Sigma is committed to generating innovation and growth, which they then offer to consumers in various forms, including retail networks, lubricants, LPG, specialty fluids, aviation fuels, and other transportation-related products and services.

Sigma was established in the 1960s. Their operation covers an area of 3,266.44 square kilometres in a delta swamp region, extending to the offshore waters, in one of the provinces in Indonesia. Sigma operates seven oil and gas fields in this area, and recently, Sigma's average production was 24.7 thousand barrels of oil per day (MBOPD) and 523.5 million standard cubic feet of gas per day (MMSCFD).

<u>Industrial characteristics</u>

Sigma is an oil and gas exploration and production firm with an area of operation covering both onshore and offshore in Indonesia. Their general workflow involves extracting oil and gas from wells and then conducting a separation process based on the physical distinction between the gaseous and condensed water forms. This process yields crude oil, natural gas and condensed gas. Although the procedure is relatively straightforward, both the raw materials and resulting products are considered hazardous substances. Consequently, handling these materials inherently carries risks. Both crude oil and natural gas present potential hazards such as fire, explosions, or suffocation. The different properties of crude oil and natural gas also make the process become more complicated. Additionally, the company employs corrosion inhibitor chemicals as auxiliary materials, which are not only flammable but also toxic if ingested, come into contact with the skin, or are inhaled. Exposure can lead to drowsiness, dizziness, allergic skin reactions, severe skin burns, and eye damage. As P017 put it, "*not many companies have a higher risk than us*".

Furthermore, aside from the hazardous nature of the materials, the facility's location poses risks as well. Sigma operates several offshore facilities along shipping routes and utilises a pipeline connecting the offshore facility to the mainland. One significant concern, as noted by P017, is the possibility of a ship colliding with the facility. This scenario could result in accidents such as leaks of crude oil and/or natural gas, damage to the facility, or even trigger explosions and fires. The presence of adverse weather conditions in the open sea might exacerbate these risks. Consequently, Sigma's upstream oil and gas offshore facilities are categorised as activities with very high inherent risks, as indicated by P017.

"Our company has a vast operational area, managing 7 oil and gas fields both onshore and offshore. The complexity level of our operations is extremely high. Furthermore, both our raw materials and products are hazardous materials, highly prone to combustion and explosions." (P017)

"Offshore operations are even more complex than onshore ones. There are weather factors that can greatly hinder employees from working when conditions are extreme. There is also the isolation factor, which can make employees feel bored and, of course, affect their focus on work. If not managed properly, this can make them more prone to making mistakes. There is also the factor of ship routes near our offshore facilities, which, if not monitored closely, could lead to ships colliding with our facilities." (P017)

<u>Safety culture</u>

P017 believed that among companies in Indonesia, the safety culture in Sigma is one of the best. They were the pioneer of the slogan "Safety First" in Indonesia, demonstrating the high commitment of the management towards safety. P017 said that the management of Sigma really gives high importance to safety, not just in the slogan, but really puts it into practice. According to P017, the commitment can be felt by everyone in Sigma. The management provides safety equipment of the best quality. Safety is always discussed first in every meeting. A harsh penalty is always given to everyone for breaking safety procedures. Sigma also gives safety training beyond the standard. For example, the standard requires there is safety officer who is trained in basic firefighting and basic first aid. But in Sigma, both those trainings are mandatory for everyone. A higher level of safety training is then given to the safety officer.

"Our management has a policy that safety is number one. And it is clear that safety is truly a priority for management. This can be felt by everyone, that it is not just a slogan." (P017)

"For safety, our management aims to go above the standard. For example, if the standard requires having safety equipment of quality A, our management purchases equipment of A-plus quality." (P017)

"In other places, basic fire and first aid training are usually given to safety officers. But in our place, it is mandatory training for everyone. Everyone must be able to operate a fire extinguisher. Our safety officers receive more advanced training." (P017)

Due to the seriousness of the management regarding safety, everybody at Sigma has a high-risk awareness. Since everyone receives safety assessment training, anyone can do an assessment every time they notice a risk in their workplace. As opposed to the safety officer reminding everyone about risk in their workplace, workers notice risk and ask the safety officer to do a follow up. It can also be seen that Sigma has developed a good safety system, where everyone can participate in mitigating the risks. If someone encounters a hazard, he or she already knows what to do, i.e. what is the first thing to do, who to notify, and how to minimise the risk.

"Everyone has received Job Safety Analysis (JSA) training. Everyone knows how to assess risks in their workplace." (P017)

"If someone encounters a dangerous situation, everyone already knows what to do. What should be done first, who should be reported to, and how to prevent the danger from escalating." (P017)

Sigma recognises that everyone has different strengths and weaknesses. Sigma has designed the safety team to consist of different people from different departments. Someone from the supply chain department knows better regarding ship movement, but others from the production department know better regarding the production process, and the risk involved. With this design, the safety team is expected to know every detail of a process, what the risks are, and how to mitigate the risk.

"Our management ensures that the safety team is always composed of individuals from different departments. This way, everyone can bring their respective expertise, allowing safety issues to be analysed in a detailed and holistic manner." (P017)

<u>Safety performance</u>

Sigma does not have a zero-accident record. From time to time, accidents do happen in Sigma. However, P017 still considers Sigma to have an excellent safety performance. There are two reasons for this confidence. First, Sigma has a very high risk. Their production runs 24 hours a day and 7 days a week. They have massive production facilities, and more than a thousand workers. Considering the size and complexity of their production, it is extremely difficult to be able to achieve zero accidents. Second, even though accidents are happening, most of the time these do not result in injury to workers. Facility or equipment damages are the most common outcomes of the accident. While injury does happen, it is always minor and major injury never occurs. P017 recalled that for as long as he has worked at Sigma, the heaviest injury that he knows of is a twisted ankle.

"We have never achieved zero accidents, but I believe it's understandable because we are a high-risk company with extensive operations. Our activities are complex, and we have more than 1000 employees. Achieving zero accidents is almost impossible. However, even when accidents occur, there have been no serious injuries. As far as I know, the most severe injury that has ever occurred here was just a twisted ankle." (P017)

P017 is also very proud of their compliance with regulations. First of all, Sigma has a dedicated team to review all the regulations. The team will analyse the content of regulations and determine the implications. They will then invite representatives from related departments to discuss the implications of those regulations. The meeting will conclude whether they have fully complied with the regulations or not. If they have not, then the related department will be responsible for doing the follow up, ensuring that the regulations will be followed as soon as possible. Secondly, P017 described again how the management usually always go above the standard. For every requirement in a regulation, Sigma will go one level above it. Thus, every time there is an inspection from the officials, Sigma always pass with flying colours.

"We have a team whose sole responsibility is to study regulations related to our operations. If, for example, a new regulation is introduced, this team will immediately study it, assess its implications for us, and then invite relevant departments for discussion on whether we are in compliance or not. If we are in compliance, that's great, and it means we are ready to implement it. If not, the relevant departments are responsible for taking the necessary actions to ensure compliance with the regulation." (P017)

According to P017, the participation rate of the workers at Sigma is also very high. Due to continuous training given to everyone, and the high commitment to safety demonstrated by the management, everyone has a good understanding of risk and the importance of safety. Thus, it is always easy to ask for participation from the workers. For example, the system at Sigma determines that the safety officer will come to every department to conduct Job Safety Assessments (JSA) together with representatives from the department. This activity is conducted regularly, to ensure that every risk has been identified and assessed properly. In practice, when safety officers come to a department, usually risk identification has been done, and the representatives only need to consult the safety officers about how to treat or mitigate the risk. The risk identification and assessment process has become a habit for many workers, and they continually perform it without waiting for the meeting with safety officers.

"Our employees here are very enthusiastic about participating in safety activities. For example, in the case of Job Safety Assessment (JSA), typically, each department should wait for the safety officer to arrive at their department to conduct JSA together. However, in practice, they often initiate it themselves. When the safety officer arrives, they mainly only need to engage in discussions on how to address the identified risks and issues." (P017)

Sustainable production performance

Considering that Sigma's main activities are extracting and processing crude oil and natural gas, it is clear that none of the raw materials used in their production process are renewable materials. As for their energy source, Sigma already has solar panels installed to supply their energy. This is only limited to their office building however, as their energy consumption for production facilities is too massive to be supplied by solar panels. Sigma owns a power plant as their main energy source. To reduce their impact on the environment, Sigma chose to use gas as their fuel for this power plant. As they also produce gas, this choice makes it simpler as they do not need to acquire their need from somewhere else.

"As for our energy source, we have our own power plant that runs on gas. We use gas because it's more environmentally friendly, and it's convenient for us since we also produce gas. We have also implemented solar panels, primarily for our office space. However, it's not sufficient to cover our production facilities." (P017)

Sigma manages their waste quite well. The largest waste they produce is sludge. Sigma hires a reputable company to do the treatment for their sludge waste. Sigma wants to preserve the water reserves in the area, so they have instructed the third party to extract as much water as possible from the sludge and release it back into the earth. Sigma only releases water that has been treated to a safe level into the environment. The same cannot be said for their air pollution however, as they release a lot of smoke into the air. P017 stressed that this cannot be helped, as the nature of their production causes combustion to happen very frequently, and it is very difficult to control everything.

"The waste we generate is mostly in the form of sludge. We have a contract with a reputable company to process our sludge waste. We have asked them to separate water from the sludge as much as possible so that it can be returned to the earth, ensuring the water reserves in our area are preserved." (P017)

"As for air pollution, we must admit that there is indeed a significant amount. Since we process crude oil and gas, it is highly flammable, and this cannot be prevented. Therefore, all we can do is control the combustion process." (P017)

4.2.13. Case Upsilon

Upsilon was founded in the 1970s. Starting exclusively as an acetylene manufacturer, Upsilon kept growing and started to be involved in the chemical industry, serving clients such as pulp and paper companies, textile industries (in the bleaching process), and others in the 1990s. Today, Upsilon has become one of the largest players in the industrial gas sector in Indonesia; both their gas products and gas-related services have been widely used in various industries such as healthcare, construction, oil and gas, metallurgy, petrochemicals, electronics, automotive, and many more. Over the years, Upsilon has become recognised as a leading industrial gas company in Indonesia.

<u>Industrial characteristics</u>

Upsilon produces various gases for industrial needs, including air gases (oxygen, nitrogen, and argon), synthetic gases, fuel gases, rare gases, sterilization gases, refrigerant gases, and electronic gases. Upsilon also provides specialty and medical gases, along with equipment and free installation. Some industrial gases they produce are harmless both to humans and the environment. However, the largest portion of their products are categorised as dangerous goods. Fuel gas, which is highly flammable and explosive, is the most dangerous product of Upsilon. Higher levels of exposure to argon gases can cause feelings of nausea, vomiting, loss of consciousness, entering into a coma, and even result in fatality. Being exposed to extremely high concentrations of pure nitrogen can induce dizziness and a sensation of light-headedness. Moreover, it displaces oxygen in the air, leading to a loss of consciousness and potentially fatal consequences. One of the most significant dangers linked to nitrogen and other inert gases, such as argon, carbon dioxide, and helium, is the risk of asphyxiation.

"We produce various types of gases for industrial purposes. While some of our products are not hazardous to both humans and the environment, the majority of our products fall under the category of hazardous materials (B3)." (P018)

Upsilon not only produces the gases, but also offers a distribution service for their products. They have a pipe installation to send the gases from their manufacturing facilities directly to their major clients' facilities, but the majority of their products are "packed" and distributed in gas bottles and cylinders. Upsilon distributes their products to various islands in Indonesia. Their products are not only used by big industries, but also small or even home industries. Considering that their products are dangerous goods, distributing them to all over Indonesia creates many risks. Other than the manufacturing process, Upsilon also needs to manage their distribution process well to minimise or even eliminate the risks.

"In addition to production, we also distribute industrial gases. For larger-scale distribution, we establish pipeline networks, enabling direct delivery to our clients after production. However, the majority of our distribution is done in the form of gas bottles and cylinders. We have to

distribute these products throughout Indonesia, even though they are categorized as hazardous materials (B3), making the distribution process quite complex." (P018)

Safety culture

Although Upsilon is a sizable corporation, and their process carries a high level of risk, their safety culture remains underdeveloped. One of the reasons might be due to their management's attitude towards safety. The management does not seem to give safety a high priority. Although commitment to health and safety is listed as one of the company's missions, it is not reflected in everyday practices. The management seems to give the highest attention to the distribution process. As mentioned before, Upsilon distributes their product all over Indonesia which has proved to be challenging for them. First, Indonesia is an archipelago. To send their product, Upsilon transports it via land, air and sea, which calls for strict planning and coordination. Second, transportation infrastructures in Indonesia are very varied. They are very developed on the main island, but largely underdeveloped in other areas. This forces Upsilon to have more hubs than necessary, to be able to change the type of transport they use. Third, their product is listed as very strategic for industry. Consequently, the government regulates the maximum price for their product. This limits their budget, as they cannot increase their price, no matter how high their expenses.

"Our product distribution is extremely challenging. We have to deliver to all corners of Indonesia. However, conditions vary in each region. In many places, we have to switch from large trucks to smaller ones, and then to vans because the roads cannot accommodate large vehicles." (P018)

"The prices of our products are regulated by the government. We can't increase the prices as we wish. As a result, we have to be very cautious about managing our expenses." (P018)

Upsilon does not provide much safety training for their workers, just what is mandatory in the regulations. As a result, the majority of their workers do not have good risk perception. They don't seem to be aware that they are handling dangerous goods. As P018 said, even for wearing safety equipment, they need to be constantly reminded by the safety officer. Furthermore, only workers in the main island have a good education level. The majority of their workers in other areas are only high school graduates or even lower.

"Many employees tend to be disobedient. It's even difficult for them to use Personal Protective Equipment (PPE). Our safety officers have to conduct regular patrols to supervise and remind people." (P018)

"It's also challenging to find qualified employees in other areas because, on average, the level of education in the region is lower. Getting high school graduates is already considered good." (P018)

<u>Safety performance</u>

Upsilon's safety track record indicates that their safety performance is still lacking. In recent years, there have been several significant fire incidents at their facility. Given the highly flammable nature of both their materials and products, any fire incident has the potential to quickly escalate and become extremely severe. P018 listed several major fire incidents that happened in the past. Those fire incidents even caused fatalities, with victims not only their workers, but also local residents in the area. Additionally, they also suffered sizeable damage to their facilities. P018 also mentioned that during the transportation process, minor accidents happen quite frequently. But as long as there is no major injury or lost time, P018 considered it to be acceptable.

"We experienced a major accident at our facility. There was an explosion in the acetylene production plant followed by a large fire. There were fatalities, and the economic losses were also significant." (P018)

"Accidents on the road happen quite frequently, but they are usually minor. For example, our transport vehicles may occasionally brush against other vehicles on the road. These incidents rarely result in severe injuries. It's often due to the pressure of meeting schedules, causing drivers to hurry and be less cautious." (P018)

P018 claimed that Upsilon comply with all regulations; however, it seems that they only do the bare minimum required. There are many things that they do just for the sake of following the regulations. Some safety trainings are only done when it is nearing the time for audit and inspection from the officials. After the audit, safety will be neglected again. The schedule for training is often deferred.

"We do follow all the regulations in place. However, due to budget constraints, sometimes certain activities, such as safety training, may be postponed and rescheduled. Typically, we catch up on these tasks as the audit approaches to ensure everything is completed by the time of the audit." (P018)

As consequence of Upsilon's workers' low risk awareness, the participation level of the workers is also low. Most workers seem reluctant to do even the mandatory training. Finding workers to join the safety team is not easy. Most workers will find many excuses to avoid being in the safety team. Most members of the safety team are there because they were assigned, as opposed to being there because they wanted to.

"It's really difficult to find volunteers for the safety team. When we ask, they usually decline with various reasons. So, we have to appoint them before they agree to join." (P018)

<u>Sustainable production performance</u>

Upsilon produces a large number of air gases (oxygen, nitrogen, and argon). Those gases only need to be taken and separated from the air. Thus, most of the material needed by Upsilon is 100% renewable. Upsilon has also installed and operated solar panels for their energy supply. The usage of the solar panels is not limited to office uses but is also for their manufacturing facility. The solar panels only supply 25-30% of production energy needs, as the energy consumption is very high. The rest of their energy needs are supplied by the government electricity company.

"…Most of our raw materials are free because we simply extract them from the air…" (P018)

"However, even though our raw materials are free, our electricity consumption is very high. We have a significant number of solar panels, but they still cannot meet all of our electricity needs at the factory. So, we purchase electricity from the state-owned company." (P018)

Upsilon does not produce waste from their product. Most of Upsilon's industrial gases are distributed in gas bottles and cylinders. After the customers use the gas, they will return the bottles or cylinders to Upsilon. Those bottles and cylinders will be used again to distribute the gases in the next batch. Upsilon also does not pollute the air much, because argon, nitrogen and oxygen are safe for the environment.

"Our products are delivered in bottles or gas cylinders. These bottles and cylinders can be reused multiple times. So, after the customers have finished using them, the cylinders are returned to us, and we reuse them for the next batch." (P018)

"There is no need for special treatment for oxygen, argon, and nitrogen gases, as they can be released directly into the atmosphere." (P018)

Upsilon does not do much community development. P018 explained that unfortunately, they do not have enough budget to do it. But P018 believed that Upsilon still contributes a lot to local communities. Upsilon has distribution centres all around Indonesia, thus it has created many job opportunities, most notably in remote areas where there are not many opportunities for local people.

"We don't engage in extensive community development because our budget is limited, so we can't do much in that regard. However, our contribution to the community remains significant because we provide a lot of job opportunities, especially in remote areas." (P018)

4.2.14. Case Omega

Omega is an entirely Indonesian-owned company that was founded in the 1970s. It had modest beginnings, when it only produced Metal Coatings and Metal Printing Inks. Recognising that there is a greater demand for its products in other areas, the company moved its manufacturing facilities to its current location in the 1980s. This relocation allowed Omega to better serve its customers' needs. This move aligned with the company's goals for the next decade, which included expanding its manufacturing operations and internationalization. The new facility included modern Research & Development laboratories and the development of new product lines.

Omega takes pride in being the market leader in Metal Coating products for over 35 years. The company expanded its product line to include Industrial Coatings, Water-Based Flexographic Inks, Rotogravure Inks, Offset Inks, and Screen Inks. In the early 90s, Omega established another division to meet the growing needs of various industries. Omega started to provide Chemicals Adhesives & Specialty Chemicals for the Flexible Packaging Industry and also sealing compounds.

In the mid-90s, Omega further improved its Coil Coatings and Wood Finishing Systems products due to increased local market demand. Also in the 90s, Omega entered the market for Industrial Coatings for plastics, targeting consumer electronic appliances, mobile phones, and the automotive market segments.

Omega's management is committed to enhancing its Research & Development capabilities, developing new products, and ensuring the availability of quality products for customers. Omega has also positioned itself for the export market and continues to invest in its workforce to meet the industry's increasing need for flexibility.

Industrial characteristics

P019 narrated that there are three main materials for Omega's production process: resin, pigment, and solvent agents. In solid form, resin is unlikely to cause any harm to the workers. However, due to the production process, it will change into vapours. Continuous exposure to these vapours can cause irritation to the lungs. Asthma can be triggered in certain individuals due to exposure to curing agents. Asthma manifests with symptoms such as a sensation of tightness in the chest, difficulty breathing, wheezing, and coughing. These symptoms can manifest either after work hours or during the nighttime. Workers at Omega work extensively with resin, so they are very susceptible to exposure.

"Our production process typically involves three types of materials: resin, pigments, and solvent agents. Among these three, the one that has the most extensive interaction with employees is resin. In its solid form, it may not be hazardous. However, during the production process, a significant amount of it evaporates. This becomes highly dangerous because continuous inhalation can damage the lungs." (P019)

Solvent agents are not as extensive as resin in Omega. However, they pose more risk than resin. Most solvent agents are toxic. Any form of exposure, whether contact with skin, inhaled, or ingested, can cause serious harm to humans. Furthermore, they are highly flammable. Just a slight friction can cause them to combust instantly. They also have a relatively low boiling point, which causes them to be present in vapour form. In that form, a small spark of electricity can cause combustion or even explosion.

"Solvent agents are even more hazardous. They tend to be highly toxic, and any contact with the skin, inhalation, or especially ingestion can pose serious risks to workers. What makes them

even more dangerous is their extreme flammability. They can easily catch fire with just a slight spark or friction. Considering the production process typically involves high temperatures, their tendency to evaporate quickly is a major concern. If there's a short circuit and they come into contact with an electrical spark, it can result in immediate ignition and, in some cases, even lead to explosions." (P019)

Safety culture

P019 claimed that Omega has a good safety culture. The management consider safety to be an important issue, and support safety management with many resources. Since the highest risk at Omega is fire, the management spare no effort in mitigating fire risk. In each facility, there are many firefighting equipment. Hand-held fire extinguishers are abundant and can be easily accessed by everyone. Every building is also equipped with more than one fire hose. Regular firefighting training is also conducted for the workers. Most workers at Omega are proficient in using firefighting equipment.

Omega also provides first aid facilities for exposure to solvent agents. Although PPE is provided, minor exposure still happens on a weekly basis. To mitigate the impact, there are many waters taps and showers provided to wash the body part being exposed. First aid medicines are also provided and can be accessed freely by workers.

"The management is highly committed to addressing the fire hazards. They provide comprehensive and abundant firefighting equipment. Lightweight fire extinguishers are positioned every few meters, and in every building, there are multiple fire hoses. Regular training sessions are also conducted for using this equipment. Our goal is that if a fire occurs, it should be extinguished in under 3 minutes." (P019)

"Despite the provision of Personal Protective Equipment (PPE), incidents of exposure to hazardous substances on the skin still occur frequently. Therefore, there are numerous facilities available for washing, such as sinks and showers. Additionally, there is an abundance of first aid supplies provided, which employees are free to use as needed." (P019)

Due to high concern from the management, everyone at Omega has a good risk perception regarding fire risk. Everyone is very careful, because they know that a slight mishap can cause a catastrophic accident. However, this seems to be limited only to fire risk. Most workers do not seem to show the same concern for other risks. Exposure to chemicals is an example. It happens on weekly basis and most workers consider it to be "normal" and "unavoidable". When it happens, they just wash the exposed area with water, apply the medicine, and move on.

"All our employees are well aware of the dangers of fire and exercise extreme caution. They understand that their livelihoods depend on this awareness. In the event of a major fire, the company's operations could come to a halt, potentially leading to job losses for everyone." (P019)

"It seems like the employees are quite relaxed when it comes to dealing with chemicals. If there's skin contact, they might think that washing and applying first aid can easily resolve the situation." (P019)

Safety performance

P019 believed that Omega has a good safety performance. They comply with all the regulations that are relevant to them. Omega even goes beyond the regulations. Regarding regulations for fire safety for example, P019 said what they do is actually doubling the regulation requirement. They also have a department to oversee government regulation, ensuring that they always comply with it.

"I'm very confident that we have complied with all the regulations. There's a department responsible for ensuring this. They closely monitor the existing rules and make sure we don't violate any of them. In fact, sometimes we go above and beyond the regulations. For instance, when it comes to fire safety, our equipment exceeds the required standards by up to twice the specified amount." (P019)

Although Omega is very keen to ensure their compliance with the regulations, their direction of policy seem to be leaning towards reactive action. Instead of preventive measures, they are more focused on how to treat a risk after it has happened. Taking fire as an example, Omega invests a lot in firefighting equipment and training and considers fire incidents as "unavoidable". Fire happens quite frequently at Omega, several times in a year. Although they always manage to extinguish it in under 3 minutes, as their standard determines, it keeps happening in regular basis.

"Fires typically occur 2-3 times a year. However, due to the training and equipment we have in place, we consistently manage to extinguish them within 3 minutes, as per our target. We have become proficient in handling fires." (P019)

Since everyone is very concerned about fire, it is easy to ask for participation from workers regarding fire safety. Everyone is always willing to join training or simulations to combat fire. This is only limited to fire safety however, as they are more reluctant to be involved in other kinds of training. Even though it is always open to everyone, usually other training is only attended by the health and safety department.

"When it comes to fire safety, everyone is highly motivated to participate. Whenever there's fire safety training or a fire drill, everyone is eager to take part. However, for other types of training, it can be a bit more challenging. Typically, it's mainly the Health, Safety, and Environment (HSE) department that actively participates in those." (P019)

<u>Sustainable production performance</u>

Omega does not use renewable material as their resource. They also do not use renewable sources of energy for their facilities. P019 said that they do not have any solar panels for example, nor do they have any plans to use them in the foreseeable future. According to P019, they do not consume energy as much as many other companies in the chemical industry. Thus, they are less concerned about energy supply.

"We currently rely entirely on the national power grid (PLN) as our energy source. As for renewable energy sources like solar panels, we haven't adopted them yet, and there are no immediate plans to do so. This is because our energy consumption isn't particularly high, so we haven't been too concerned about exploring alternative sources at this time." (P019)

The good point about Omega is that they manage their waste quite well. According to P019, one of the reasons is that they do not use too many dangerous goods, and their production process is relatively simple. Their liquid waste is mostly water, which is handled by a licenced third party. The process mainly is separating the water from other pollutants. The water will be released back into the environment, while the pollutant will be destroyed by the third party.

"We don't have any waste issues at all. Perhaps this is because we don't use hazardous materials

(B3) extensively, and our production process is relatively straightforward. Most of our liquid waste is primarily water, and it is managed by a third-party company that has obtained government licenses. Their process involves separating water from other impurities. The water is then returned to the earth, while the remaining impurities are properly disposed of." (P019)

4.2.15. Summary of Within-Case Analysis

The 14 cases with 19 informants that were compiled are described by the nature of their industrial characteristics, safety culture, safety performance, and sustainable production performance. These cases were analysed using the theoretical framework developed previously and based on the within-case analysis conducted, the state of each key construct in every case can be determined. There are four levels of state assigned using: very poor, poor, good, and very good, depending on the context of each key construct. The only exception is Figure 15, where the levels of state assigned are very low, lo, high, and very high. Figure 15 – Figure 25 illustrates the summary of each state being assigned to every case.

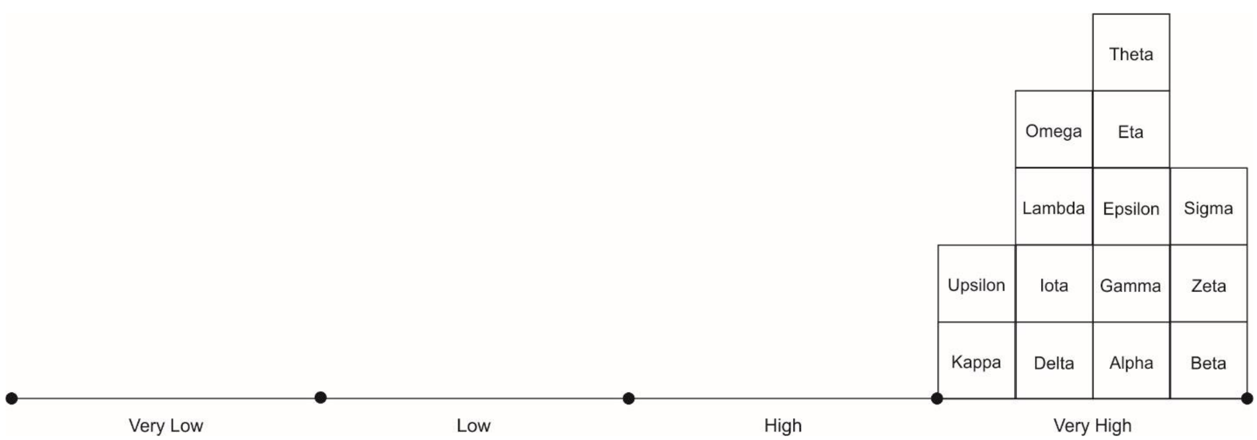


Figure 15. The state of each case for industrial characteristics

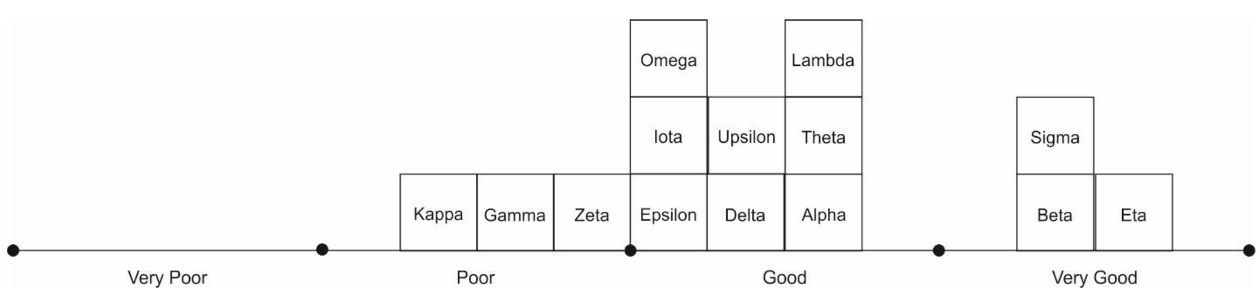


Figure 16. The state of each case for management value

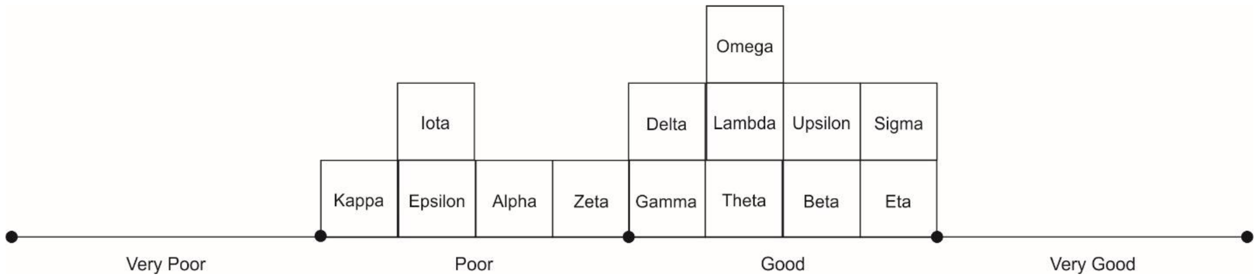


Figure 17. The state of each case for risk perception

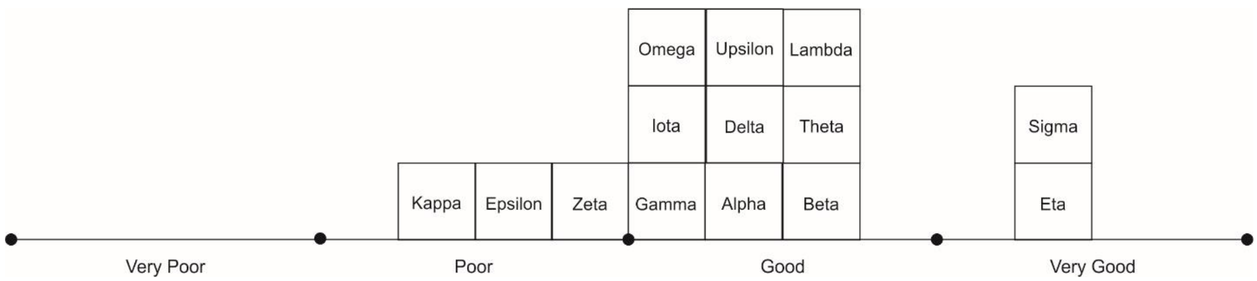


Figure 18. The state of each case for safety system

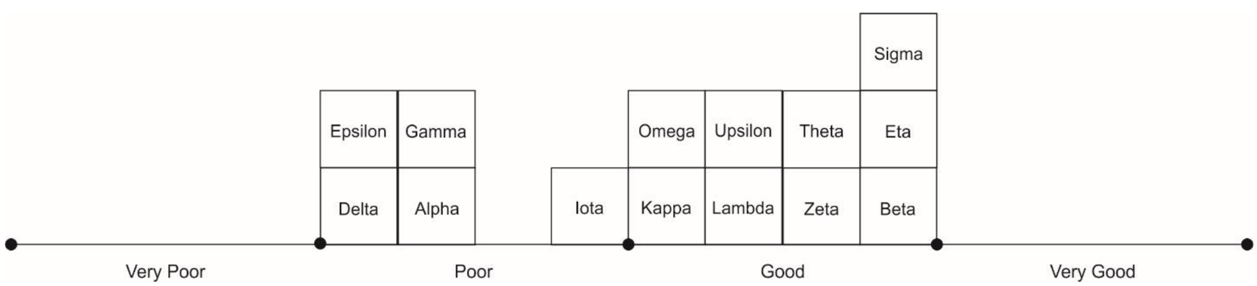


Figure 19. The state of each case for work pressure

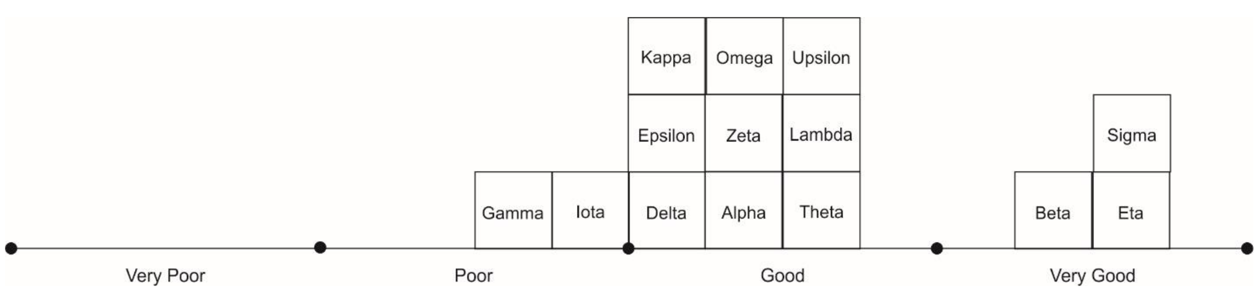


Figure 20. The state of each case for competence

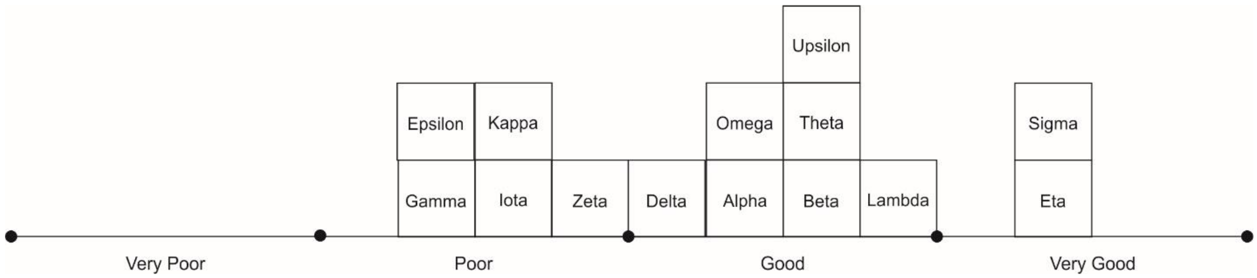


Figure 21. The state of each case for safety culture

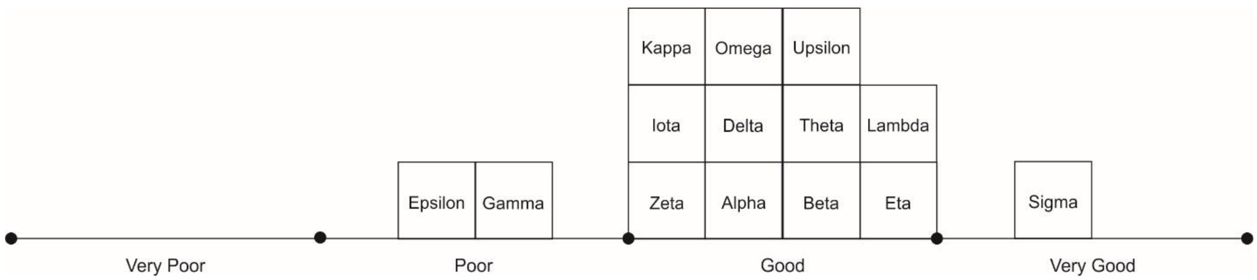


Figure 22. The state of each case for safety compliance

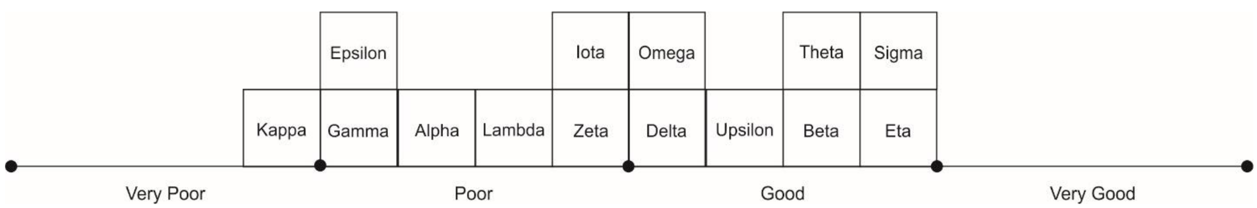


Figure 23. The state of each case for safety participation

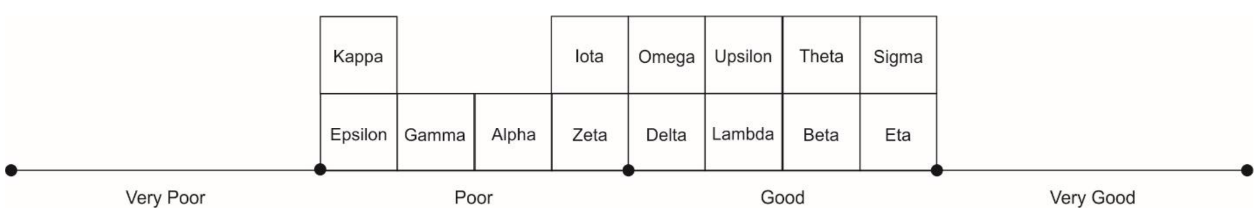


Figure 24. The state of each case for safety performance

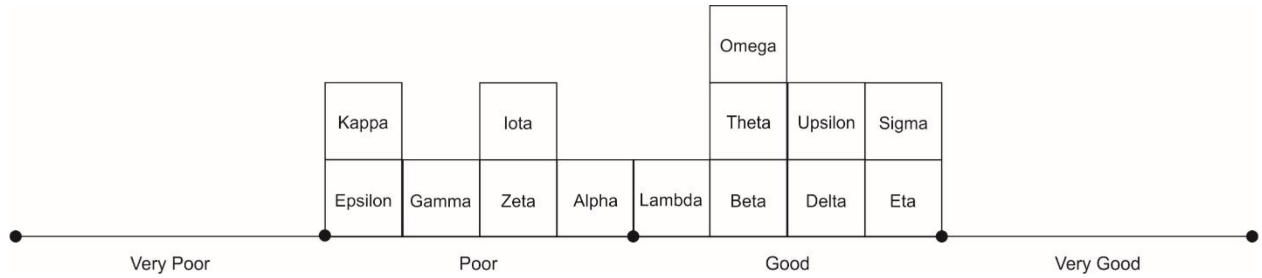


Figure 25. The state of each case for sustainable production performance

4.3 Cross-Case Analysis

Following the within-case analysis, the subsequent stage involves juxtaposing the cases, seeking out trends that elucidate the research phenomenon (Meredith, 1998). An uncomplicated yet efficient analytical method entails selecting a central group, category, or concept relevant to the research query and identifying shared attributes of that concept among the cases (Voss et al., 2002). Since the theoretical framework that has been developed is used as the basis for this study, a cross-case analysis was performed in accordance to propositions from the framework. Using the result from the within-case analysis, the pattern across all the cases is then analysed.

4.3.1. Relationship between safety culture and safety performance

The initial framework suggests that safety culture is the antecedent of safety performance. As the antecedent, the presence of a safety culture is required to have a good safety performance. This proposition also postulates that the higher the safety culture, the higher the safety performance will be. In order to investigate this proposition, the four possible state-pairings of safety culture and safety performance are listed: good safety culture and good safety performance; good safety culture and poor safety performance; poor safety culture and good safety performance; and poor safety culture and poor safety performance. Using data presented in Figure 21 and 24, these pairings are then checked across all the cases. Figure 26 illustrates the comparison between cases in the context of the relationship between safety culture and safety performance.

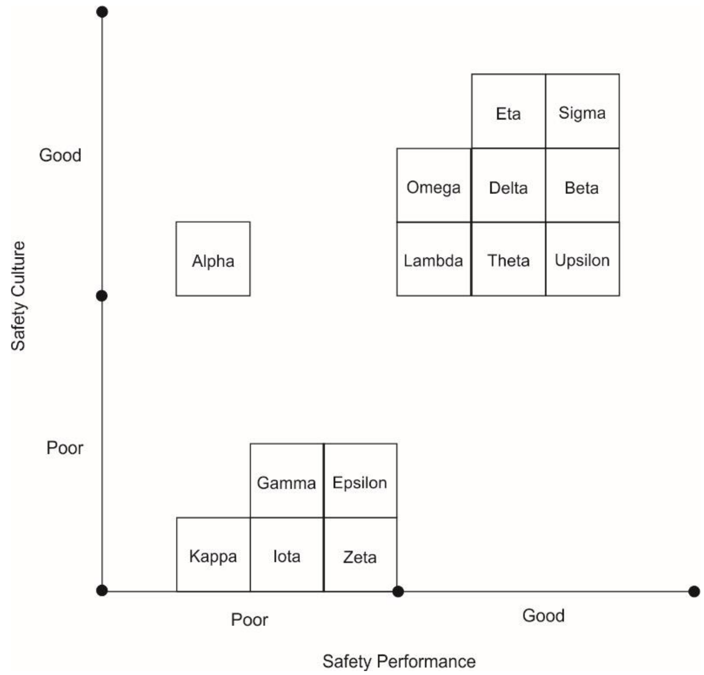


Figure 26. Cross-case analysis to investigate the relationship between safety culture and safety performance.

From Figure 26, it can be seen that the findings are consistent with the initial framework. Across the 14 cases, there is no case where a company has a good safety performance without the presence of a good safety culture.

Proposition 4 in the initial framework suggests that management value, risk perception, and safety systems are the antecedents of safety compliance. This implies that good safety compliance cannot be achieved without good management value, risk perception, and safety systems. In order to substantiate the initial framework, the states of management value, risk perception, and safety systems (i.e., the constructs herein) of each case were compared to the state of safety compliance in the respective case. Fig. 27 illustrates this comparison by showing the four possibilities how close our initial framework is to industrial practice. The possibilities are: 1) Good safety compliance with no constructs being in a good state; 2) Good safety compliance with only one construct being in a good state; 3) Good safety compliance with two constructs being in a good state; and 4) Good safety compliance with all constructs being in a good state.

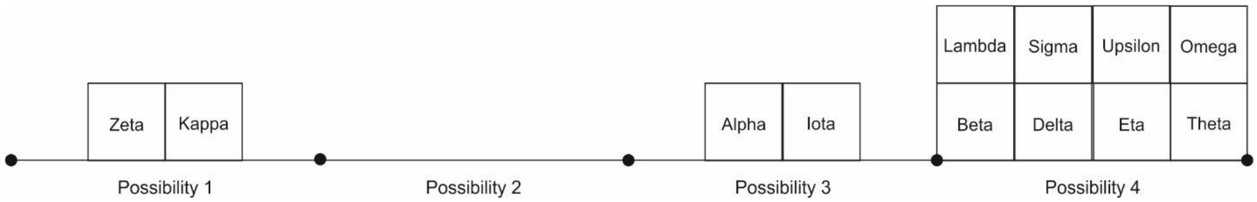


Figure 27. Cross-case analysis to investigate the antecedent of safety compliance.

Figure 27 shows that only some of the cases were consistent with the initial framework. There were eight out of 14 cases that showed good safety compliance, with all constructs being in a good state. Cases Zeta and Kappa were the ones where they had good safety compliance without any constructs being in a good state. Cases Alpha and Iota both had good management values and a good safety system but poor risk perception. However, both cases (Alpha and Iota) still had good safety compliance, indicating that not all three constructs were the antecedents for good safety compliance. Cases Gamma and Epsilon did not have good safety compliance and thus could not be used to validate this proposition.

Proposition 5 in the initial framework suggests that work pressure and competence are the antecedents of safety participation. This implies that good safety participation cannot be achieved without good work pressure and good competence. In order to validate the initial framework, the states of work pressure and competence (i.e., the constructs herein) of all cases were compared to the state of safety participation in respective case. Figure 28 shows three different possibilities for how close our initial framework is to industrial practice. The possibilities are: 1) Good safety participation with no constructs being in a good state; 2) Good safety participation with only one construct being in a good state; 3) Good safety participation with all constructs being in a good state.

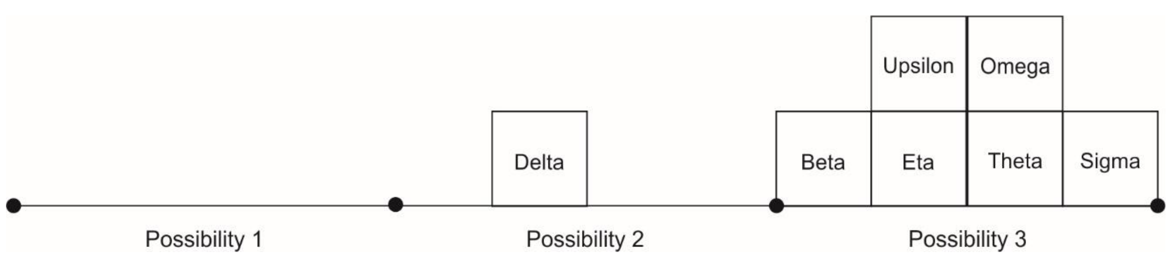


Figure 28. Cross-case analysis to investigate the antecedent of safety participation.

Figure 28 shows that across all cases, there were only seven cases with good safety participation and thus can be used to validate Proposition 5. Among those cases, six out of seven were consistent with Proposition 5. Case Delta has good safety compliance despite having poor work pressure. This indicates the possibility of good competence being the only antecedent for good safety participation. However, the number of cases is too small to ascertain this.

4.3.2. The roles of chemical industry characteristics

The initial framework suggests that the chemical industry characteristics moderate the relationship between safety culture and safety performance. The harsher the characteristics of the chemical industry, the weaker the influence of safety culture on safety performance will be. In order to investigate the initial framework, the two possible impacts of industrial characteristics towards safety culture's influence on safety performance are listed: Industrial characteristics affect safety culture influence on safety performance and Industrial characteristics do not affect safety culture influence on safety performance. Using data presented in Figure 15 and 24, the two possible impacts are then checked across all the cases. Figure 29 illustrates the comparison between cases in the context of proposition 2 in two possible outcomes: 1. Industrial characteristics do not affect safety performance, and 2. Industrial characteristics affect safety performance.

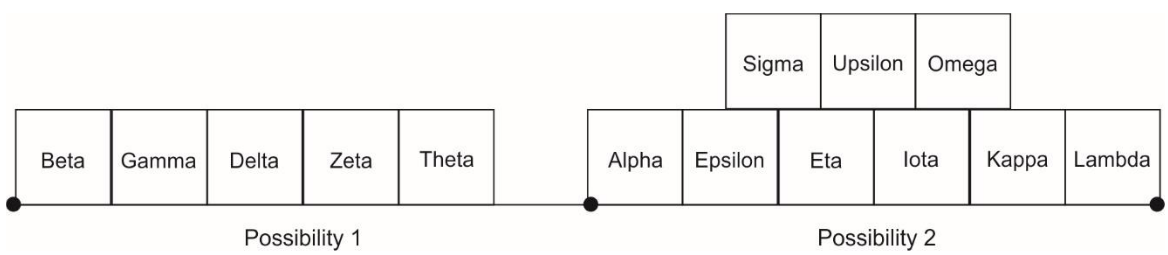


Figure 29. Cross-case analysis to investigate the role of chemical industry characteristics.

The findings presented in Figure 29 show that the real situation in the industry is fairly consistent with the initial framework. Except for five cases, the industrial characteristics of case Alpha through to case Omega show indications of affecting the influence of safety culture on safety performance. Cases Beta, Gamma, Delta, Zeta, and Theta are the cases that show a contrasting result.

4.3.3. Relationships between safety performance and sustainable production performance

The initial framework suggests that safety performance directly influences sustainable production performance, and the higher the safety performance, the higher the sustainable production performance will be. In order to investigate the initial framework, the four possible state-pairings of safety performance and sustainable production performance are listed: good safety performance and good sustainable production performance; good safety performance and poor sustainable production performance; poor safety performance and good sustainable production performance; and poor safety performance and poor sustainable production performance. Using data presented in Figure 24 and 25, these pairings are then checked across all the cases. Figure 30 shows the comparison between cases in the context of the relationship between safety performance and sustainable production performance.

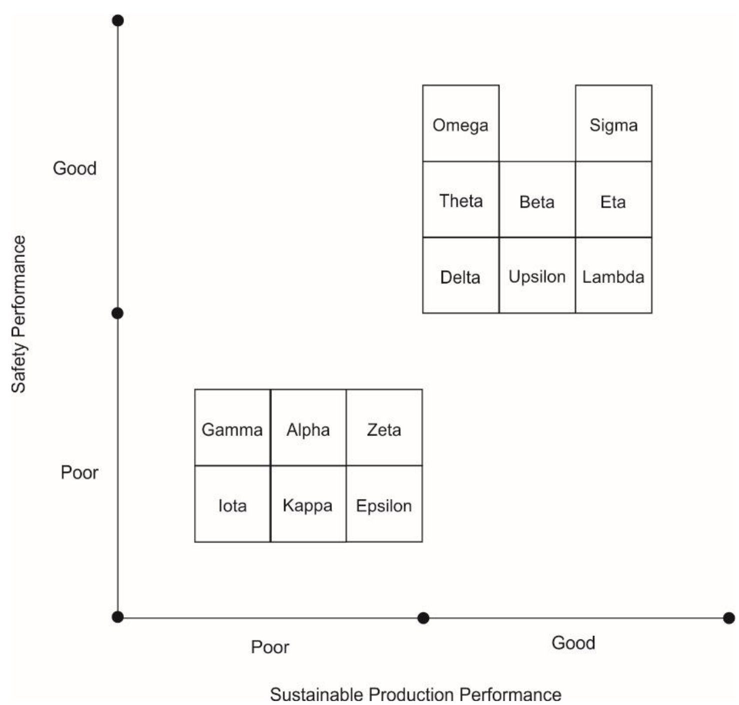


Figure 30. Cross-case analysis to investigate the relationship between safety performance and sustainable production performance.

From Figure 30, it can be seen that the findings are consistent with the initial framework. In every case, safety performance is seen as directly influencing sustainable production performance. In cases Beta, Delta, Eta, Theta, Lambda, Sigma, Upsilon and Omega which have good safety performance, their sustainable production performance is also good. In contrast, Alpha, Gamma, Epsilon, Zeta, Iota and Kappa have a poor safety performance. In those companies, their sustainable production performance is also poor.

4.4 Qualitative Study Analysis

Previous sections have discussed the understanding of how safety performance influences sustainable production performance. In this section, findings regarding safety culture, safety performance, sustainable production performance and the role of industrial characteristics are analysed. Afterwards, several inconsistencies between the initial framework and the industrial framework are analysed and possible explanations are discussed. Lastly, based on the results from the qualitative study, the revised framework is mapped and constructed.

4.4.1. Relationships between safety culture, safety performance, sustainable production performance and the role of industrial characteristics

As described in the previous section, findings from the cross-case analysis show some consistency between the initial framework and industrial practice. Regarding the role of industrial characteristics, across the 14 cases, the only contrasting result is case Delta, where their industrial characteristics did not show any influence towards safety performance. The findings also showed a complete match from all the cases regarding the relationship between safety culture, safety performance, and sustainable production performance.

The safety culture of an organisation is viewed as the values and beliefs held collectively by members within an organization, pertaining to what is considered significant and how organizational processes function, interact with work units, organizational structures, and systems. This collective dynamic shapes the behavioural norms within the organization, fostering a safety-oriented culture (Singer *et al.*, 2009). Research from various fields has stressed the importance of a safety culture. Many believe that having a strong safety culture will bring benefits for the organisation (Griffin and Neal, 2000; Guldenmund, 2000; Hajmohammad and Vachon, 2014). Supporting the findings from this study, other industries have noted the relationship between safety culture and safety performance. In medical practice, a better safety climate in a hospital was associated with a relatively lower incident of patient safety (Singer et al., 2009). Similar results were found from the construction industry (Molenaar, Park and

Washington, 2009), manufacturing organisations (Cheyne *et al.*, 1998), nuclear plants (Morrow, Kenneth Koves and Barnes, 2014), and the Food & Beverages industry (Otitolaiye *et al.*, 2021).

Regarding the role of industrial characteristics, much research that study high risk industry seems to agree that the characteristics of the industry influence their safety culture. Grote & Künzler (2000) noted that an understanding of safety culture has deeply rooted assumptions about the interplay of people, technology, and the organisation in their relation to safety. The chemical industry has its own unique characteristics, where the situation for people, technology and the organisation are complex. Several descriptions given for the chemical industry are high-risk industry (Song et al., 2019), uses high technology (Marhavilas et al., 2020), involves complex processes (Brzezińska et al., 2019) and is capital-intensive (Teh et al., 2019). Additionally, it also has very strong connections to virtually every other sector of the economy. These characteristics require a highly trained workforce for the industry's operation (Lee et al., 2015). In addition, (Çakıt *et al.*, 2019) assessed the perceived safety culture among five petrochemical production companies in Japan. Their study found that in Japan, personnel awareness in the petrochemical industry regarding safety culture is sufficient to influence error behaviours. This is due to the characteristics of the petrochemical industry that has very high risk. Their results revealed the need for management to reduce unsafe personnel conduct by improving safety procedures in daily routines. Their findings also highlighted the need to examine safety management systems and ascertain organisational characteristics that directly or indirectly affect unsafe performance at work.

Findings from the case studies show how safety performance directly influences sustainable production performance. Similar results are also found from other fields. In the process industry, companies with better suppliers and contractors' health and safety performance were found to also have improvement in sustainability performance (Husgafvel et al., 2015). From the energy sector, it was found that the safety performance of energy systems can have important implications for the environmental, economic, and social dimensions of sustainability as well as the availability, acceptability and accessibility aspects of energy security (Burgherr and Hirschberg, 2014).

4.4.2. Modifications for the proposed framework

Based on the findings and discussion in the previous sections, the initial framework does not seem to perfectly match with industrial practice. There are some modifications that need to be done. This section will discuss suggested modifications for the framework.

4.4.2.1. Antecedents of safety performance

As discussed in the previous section, every case that has a good safety performance also has a good safety culture, indicating that safety culture is indeed an antecedent for safety performance. However, there are several cases, case Alpha for example, where they have a good safety culture, but a poor safety performance. This finding suggests the possibility of safety culture not being the only antecedent for safety performance, but that there is another antecedent.

If we take a closer look at the cases that have a good safety culture, and also have a good safety performance, they must have something that was not found in other cases. Case Sigma has an excellent safety culture and a good safety performance. One thing that is distinctly noticeable in case Sigma, is that they have rigorous safety procedures, and they always follow them.

"…we have many procedures regarding safety, to the point of some people considered redundant. But we believe that those procedures are really important. We always follow every procedure and never cut corners…" (P017).

Like case Sigma, case Eta also has an excellent safety culture, followed by good safety performance. P007 revealed how precautious they are when they are facing risks.

"…Regarding Covid 19, we are really careful. We do not want the disease to spread in our base, so we take every preventive and mitigation step that we can think of…" (P007).

In case Sigma, they have so many procedures that following all of them produces a high amount of paperwork. Even though they admit that they might have more procedures than necessary, they do not want to reduce them. This practice came from their awareness that their operation is complex and high risk. They are afraid that if they try to simplify their operation, they might miss something that could lead to an accident.

Meanwhile, the practice in case Eta shows their understanding that failure is a possibility. There is no method that is 'failproof'. For risks that they are not willing to accept, they consider what failures might happen, and how to mitigate those failures from occurring. Hence, they applied multiple layers of protection. If one layer failed, they still have other protections in place.

The practice in cases Eta and Sigma are strikingly similar with the core theoretical principles of Collective Mindfulness (CM). There are five core principles of CM: Preoccupied with Failure, Reluctant to Simplify, Sensitivity to Operations, Commitment to Resilience, and Deference to Expertise (Weick & Sutcliffe, 2008). Collective mindfulness, denoted as CM, extends beyond the mere aggregation of individual mindfulness. It represents the tangible expression of consciously coordinated actions executed by the organization's collective members, rather than being a reflection of the inner mental processes of each individual within the organization. These five principles facilitate the thoughtful examination of failures, the capacity for recovery, and pertinent past encounters, allowing for the establishment of a framework in which current operations acquire significance or can be reconfigured to achieve meaning.

Many studies have argued the importance of CM for safety performance. In this study, evidence has been found that indicates the practice of two of CM’s principles, the first and the second, but not the other three. Further study is needed to examine the practice of CM in the chemical industry. Nonetheless, this study’s findings suggest that CM is important for safety performance. Therefore, the first and second propositions are put forward, stating that:

Proposition 1: In the context of the chemical industry, safety culture is the antecedent of safety performance. The higher the safety culture, the higher the safety performance will be.

Proposition 2: In the context of the chemical industry, Collective Mindfulness (CM) is the antecedent of safety performance. The higher the implementation of CM, the higher the safety performance will be.

4.4.2.2. Industrial Characteristics

In the previous section, it has been discussed how industrial characteristics have an impact on the relationship between safety culture and safety performance. Across the 14 cases, there are only five that did not seem to be affected by their industrial characteristics (cases Beta, Gamma, Delta, Zeta and Theta). The state of their safety performance seems to be the same as their state of their safety culture, despite having high risk. In all other nine cases, there is a change to the state of their safety performance from the state of their safety culture. This might be an indication that the industrial characteristics indeed have an impact on the relationship between safety culture and safety performance. However, there are also other indications that suggest differently.

First of all, although the state of their safety performance is indeed changing, there is no obvious pattern to the changes. As can be seen in Figure 15, in some cases their safety performance is better than their safety culture (e.g., case Iota), in some cases their safety performance is slightly worse (e.g., case Epsilon) and, in some cases their safety performance is much worse (e.g., case Alpha). In all cases, their industrial characteristics are categorised as high risk. According to this study's initial framework, the impact of the relationship between safety culture and safety performance should be the same. However, the findings show a different result. There are two possible explanations for this: there are differences in their industrial characteristics that have not been recognised yet, or industrial characteristics are not the reason for changes to the state of their safety performance from the state of their safety culture.

Secondly, in the previous section, the possibility of another antecedent for safety performance has been discussed. The changes that were found in the state of their safety performance from the state of their safety culture might be caused by this antecedent, as opposed to industrial characteristics as the initial framework suggested. However, at present there is still no conclusive evidence. Since this study is focused on exploring its initial framework, and CM as an antecedent of safety performance has not been confirmed yet, a more detailed study is needed to confirm this indication.

Thirdly, some informants suggested that industrial characteristics have an impact on the relationship between safety performance and sustainable production performance, and not the relationship between safety culture and safety performance.

"…our plant has really high risk, with fire as the highest risk. Both our materials and products are highly combustible, so we have to allocate a lot of resource for prevention and mitigation. This allocation "eats" our budget and we have to postpone a lot of plans. We really want to install solar panels in our plant but had to postpone it due to upgrading of firefighting facility…" (P019).

"…we are often requested by our customer to help in disposing of our product. Many customers are not aware that our product needs special treatment in storing it. If they do it wrongly, they cannot use it anymore. Meanwhile some of our products are classified as dangerous goods, so they need our help to dispose of them. This situation makes our dangerous waste higher than it actually is…" (P013).

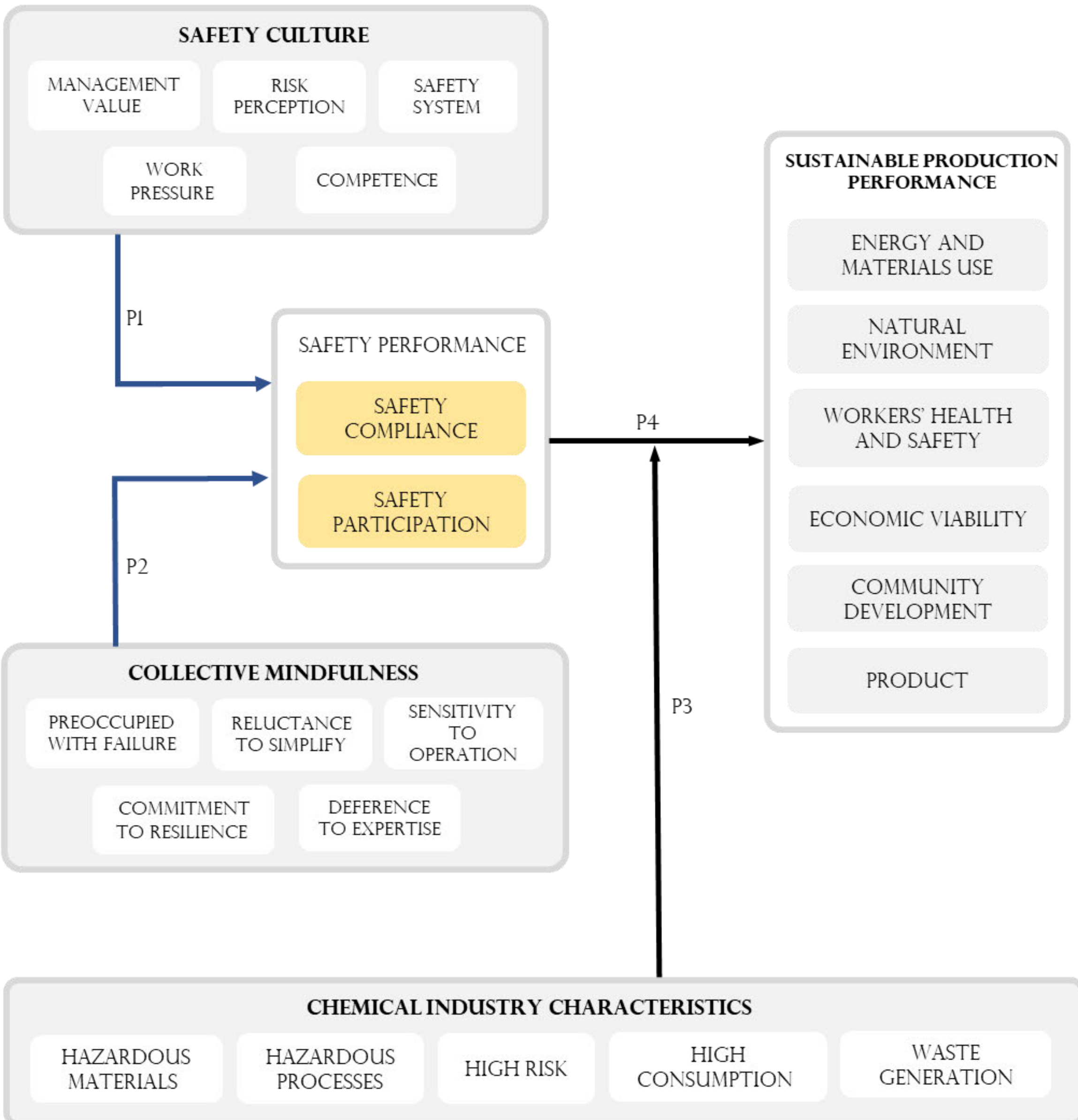
Regarding industrial characteristics, this study has not found conclusive evidence. Although there are indications that industrial characteristics are indeed influencing the relationship between safety culture and safety performance, as per the initial framework, there is also an indication that they are not. Also, there are indications that they are influencing the relationship between safety performance and sustainable production performance, and not the relationship between safety culture and safety performance. Unlike the previous proposition regarding industrial characteristics, these indications seem more promising to be investigated further in the next phase of the study. Thus, proposition 3 is formulated as follow:

Proposition 3: Chemical industry characteristics moderate the relationship between safety performance and sustainable production performance. The harsher the characteristics of the chemical industry, the weaker the influence of safety performance on sustainable production performance will be.

4.4.2.3. Revised framework

The previous sections have discussed modifications that need to be done to the framework, resulting in propositions 1, 2, and 3. Results from cross-case analysis have also shown that the initial proposed framework is consistent with industrial practice, with regard to the relationship between safety performance and sustainable production performance. Thus, proposition 4 is postulated, and a revised framework is proposed as follows:

Proposition 4: Safety performance directly influences sustainable production performance. The higher the safety performance, the higher the sustainable production performance will be.



P1 – P4: PROPOSITION 1 - PROPOSITION 4

Figure 31. Revised Framework for the relationship between safety performance and sustainable production performance based on qualitative study.

The diagram presented in Figure 31 above illustrates the updated framework depicting the relationship between safety performance and sustainable production performance within the chemical industry. In contrast to the initial theoretical framework introduced in Chapter 2, this revised framework is not solely based on existing literature but has been expanded to incorporate empirical data. Nevertheless, it's important to note that the qualitative study did not yield definitive answers for both RQ1 and RQ2. While the qualitative investigation suggested the inclusion of CM (Collective Mindfulness), supported by strong indications, it has yet to be substantiated by empirical evidence. Furthermore, the role played by industrial characteristics remains unclear, leaving RQ2 unresolved. Thus, in order to shed light on the precise role of industrial characteristics, and to obtain findings that are more valid and reliable, there is a need to collect empirical data in larger sample.

Chapter 5: Quantitative Findings

This chapter is structured as follows. Section 5.1 described the model and hypothesis used in this phase. Section 5.2 provides a descriptive analysis of the sample characteristics, while Section 5.3 offers a brief overview of the measurement theory of reflective and formative measured constructs. Section 5.4 focuses on reflective measurement models by analysing internal consistency reliability, convergent validity, and discriminant validity. Section 5.5 examines the formative measurement models by assessing the convergent validity, collinearity issues, significance, and relevance of the formative indicators. Section 5.6 provides the structural model results by evaluating collinearity issues and path coefficients of the structural model. It also presents hypotheses testing results, coefficient of determination, effect size and predictive relevance. Finally, Section 5.6 summarises the salient points of the chapter.

5.1 Model and Hypothesis

The findings in Chapter 4 have resulted in the modification of the theoretical framework proposed in Chapter 2. In order to generate statistically valid and reliable findings that can be generalised to a larger population, the quantitative study is conducted. Based on the revised framework in Chapter 4 (Figure 31), the model used in this study is constructed as follows:

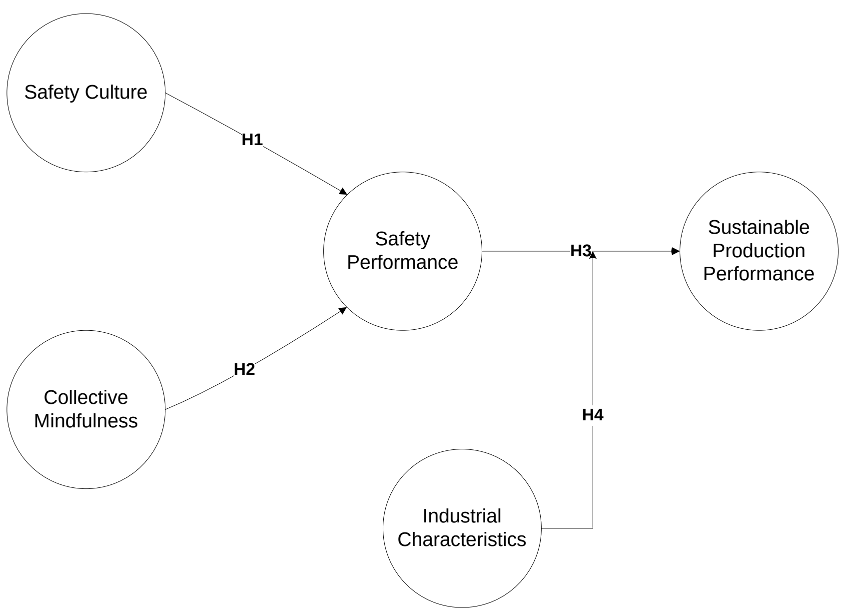


Figure 32. The model for quantitative study.

Based on the above model (Figure 32), a set of research hypotheses were developed for this study. These hypotheses were then empirically tested to answer the two research questions. The set of hypotheses is given as follows:

H1a: *The higher a firm's management value safety, the higher the safety performance of that firm.*

H1b: *The higher a firm's risk perception, the higher the safety performance of that firm.*

H1c: *The higher a firm's safety system, the higher the safety performance of that firm.*

H1d: *The higher a firm manages work pressure, the higher the safety performance of that firm.*

H1e: *The higher a firm's level of competence, the higher the safety performance of that firm.*

H2a: *The higher a firm is preoccupied with failure, the higher the safety performance of that firm.*

H2b: *The higher a firm's reluctance to simplify, the higher the safety performance of that firm.*

H2c: *The higher a firm's sensitivity to operation, the higher the safety performance of that firm.*

H2d: *The higher a firm's commitment to resilience, the higher the safety performance of that firm.*

H2e: *The higher a firm's deference to expertise, the higher the safety performance of that firm.*

H3: *A firm's safety performance positively impacts their sustainable production performance.*

H4: *A firm's industrial characteristics negatively impact the relationship between safety performance and sustainable production performance.*

5.2 Descriptive Analysis

This section provides a descriptive analysis of the sample population. As shown in Table 9, more than half of the respondents work in petrochemical, agrochemical, and organic compound industries. The petrochemical industry has the highest percentage with 21.7%, in contrast to the inorganic compound industry which only contributes 9% to the total. A small percentage of the respondents (5.4%) work in other industries that still involve chemical processes and/or processes such as manufacturing and mining.

Table 9. Respondents Distribution (Type of Industry)

	No. of Respondents	Percentages
Organic Compound Industry	41	18.6%
Inorganic Compound Industry	20	9.0%
Agrochemical Industry	42	19.0%
Cellulose and Rubber Industry	27	12.3%
Petrochemical Industry	48	21.7%
Pharmacy	31	14.0%
Other	12	5.4%
	221	100.0%

Table 10 shows the distribution of the respondents, in terms of their work responsibility. Health and Safety made up more than a third (33.4%), while 52 respondents work around environment issues (23.5%) and 48 work in production (21.7%). Compliance and Corporate Social Responsibility (CSR) only contribute less than 10% each (7.2% and 8.1% respectively) and other types of responsibility made up the last 5% of the respondents.

Table 10. Respondents Distribution (Type of Responsibility)

	No. of Respondents	Percentages
Health and Safety	76	34.4%
Environment	52	23.5%
Production	48	21.7%
Compliance	16	7.2%
Corporate Social Responsibility (CSR)	18	8.2%
Other	11	5.0%
	221	100.0%

In terms of company size, the majority of the respondents work in medium-sized and large companies (more than half work in companies with 251-500 employees and 501-1000 employees with 22.2% and 30.8% respectively) and only 13 (5.9%) respondents work in small companies that have between 1 and 50 employees. There are 28 respondents that work in companies with more than 1000 employees, and they made up 12.7% of the respondents.

Table 11. Respondents Distribution (Size of the Company)

	No. of Respondents	Percentages
1-50 employees	13	5.9%
51-100 employees	27	12.2%
101-250 employees	36	16.3%
251-500 employees	49	22.3%
501-1000 employees	68	30.8%
More than 1000 employees	28	12.7%
	221	100.0%

As shown in Table 12, the majority of the respondents have sufficient work experience in their field, with a huge 65.6% having worked in their field between 3 and 6 years. There are 35 people (15.8%) that have only worked between 1 and 3 years, followed closely by people with more than 10 years' experience with 14.5% (32 people). Only a small number of the respondents have worked for less than a year (9 people).

Table 12. Respondents Distribution (Work Experience)

	No of Respondents	Percentages
Less than a year	9	4.1%
More than 1 year but no more than 3 years	35	15.8%
More than 3 years but no more than 6 years	78	35.3%
More than 6 years but no more than 10 years	67	30.3%
More than 10 years	32	14.5%
	221	100.0%

5.3 Assessment of Measurement Models

In this section, the analysis of both reflective and formative measurement models is examined, which explains how the constructs in the conceptual framework are related. These measurement models establish the connections between the indicators and the constructs. By comparing the theoretically driven measurements with the sample data, empirical measures allow us to assess how well the proposed theory fits the data and evaluate the predictive capabilities of the model. The PLS-SEM approach follows a systematic process to maximise the explained variance (R^2 value) of the endogenous variables (DRC) in the path model. The assessment of the measurement and structural models in PLS-SEM focuses on metrics that determine the model's quality and predictive abilities (Hair et al., 2019).

However, reflective and formative measurement models are based on different measurement theories and require different evaluation measures. Reflective measurement models are evaluated based on internal consistency, reliability, and validity, including convergent validity and discriminant validity. These evaluation measures are not applicable to formative measurement models. Formative models, on the other hand, are assessed based on content validity, convergent validity, the significance and relevance of indicator weights, and the presence of collinearity among indicators (Diamantopoulos, Riefler and Zeugner-Roth, 2008; Hair *et al.*, 2019). The following sections will analyse these metrics, starting with reflective measurement models, then formative measurement models, and finally, the assessment of the structural model.

5.4 Reflective Measurement Model

The evaluation of reflective measurement models involves several tests: composite reliability (CR), reliability of individual indicators, average variance extracted (AVE), and discriminant validity. Each of these assessment tests will be explained in the following sub-sections.

5.3.1. Internal Consistency Reliability: Cronbach's Alpha and Composite Reliability

The reliability of the model's internal consistency was evaluated using Cronbach's alpha (CA), which estimates reliability based on the intercorrelations among the indicator variables. A CA value above 0.70 is considered acceptable (Hair et al., 2017). However, CA has certain limitations when applied to PLS-SEM. It assumes that all indicators have equal outer loadings within a construct and is sensitive to the number of items in the scale, often underestimating internal consistency reliability (Hair et al., 2017). To overcome these limitations, a CR test was conducted. CR is an alternative measure of internal consistency reliability that takes into account the varying outer loadings of the indicator variables. CR ranges from 0 to 1, with higher values indicating higher levels of reliability. Therefore, it is recommended to report both CA and CR as the absolute reliability lies between these two measures (Hair et al., 2017). Previous research suggests that a CR level of 0.6 or higher is satisfactory for exploratory studies, but it should not exceed 0.95 (Hair et al., 2017). As shown in Table 13, both CA and CR values are within the recommended range. This indicates that the four reflective constructs have a high level of internal consistency reliability.

5.3.2. Convergent Validity: Indicator Reliability and Average Variance Extracted

Convergent validity refers to the degree to which a measure demonstrates positive correlations with other measures of the same construct. In the case of reflective constructs, it is expected that the indicators converge or share a significant amount of variance (Hair et al., 2019). Convergent validity of a reflective construct is assessed through outer loadings and the AVE. A higher outer loading, which represents the reliability of the indicator, indicates that the associated indicators have a substantial amount in common, with a recommended value of 0.70 or higher. However, it is important that all indicators have statistically significant outer loadings, even if some loadings are relatively lower (Hair et al., 2019). AVE, on the other hand, evaluates the convergent validity at the construct level. It is calculated as the average of the squared loadings of the indicators related to a particular construct. A desirable AVE value is 0.50 or higher, indicating that, on average, the construct explains more than half of the variance in its indicators. As demonstrated in Table 13, both the indicator reliability (loadings) and the AVE values exceed the minimum required thresholds of 0.7 and 0.5, respectively. Therefore, the four reflective constructs exhibit a strong level of convergent validity.

Table 13. Results Summary for Reflective Measurement Models

Construct	Item	Convergent Validity		Internal Consistency Reliability		
		Loading	AVE	CA	CR	Rho_A
Management Value	MV1	0.733	0.63	0.852	0.9	0.852
	MV2	0.818				
	MV3	0.847				
	MV4	0.772				
	MV5	0.793				
Risk Perception	RP1	0.85	0.66	0.871	0.91	0.874
	RP2	0.805				
	RP3	0.804				
	RP4	0.815				
	RP5	0.788				
Safety System	SS1	0.838	0.687	0.848	0.9	0.858
	SS2	0.878				
	SS3	0.823				
	SS4	0.772				
Work Pressure	WP1	0.829	0.655	0.869	0.9	0.88
	WP2	0.842				
	WP3	0.809				
	WP4	0.878				
	WP5	0.788				
Competence Level	CL1	0.793	0.687	0.846	0.9	0.867
	CL2	0.788				
	CL3	0.772				
	CL4	0.733				

5.3.3. Discriminant validity

Discriminant validity refers to the degree to which a construct is distinct from other constructs. It is established when a construct captures unique phenomena that are not represented by other constructs in the model. Two commonly used measures of discriminant validity are cross-loadings and the Fornell-Larcker criterion (Fornell and Larcker, 1981). The cross-loadings test examines the outer loading of an indicator on its respective construct and compares it to its cross-loadings on other constructs. The outer loading should be higher than any of its cross-loadings on other constructs to demonstrate discriminant validity. The Fornell-Larcker criterion, on the other hand, compares the square root of the AVE for each construct to its highest correlation with any other construct. The rationale is that a construct should share more variance with its own indicators than with any other construct (Hair et al., 2019). As depicted in Table 14, the square roots of the AVEs (highlighted in bold and italics) are all greater than the correlations between the constructs (columns and rows). This indicates that all four reflective constructs effectively measure distinct concepts and demonstrate discriminant validity.

Table 14. Fornell-Larcker Discriminant Validity Test

	Management Value	Risk Perception	Safety System	Work Pressure	Competence Level
Management Value	**0.794**				
Risk Perception	0.745	**0.829**			
Safety System	0.781	0.783	**0.813**		
Work Pressure	0.762	0.763	0.786	**0.834**	
Competence Level	0.544	0.673	0.677	0.685	**0.825**

However, recent studies have raised concerns about the suitability of cross-loadings and the Fornell-Larcker criterion as exclusive assessments of discriminant validity. These approaches do not indicate a lack of discriminant validity even when two constructs are perfectly correlated (Voorhees *et al.*, 2016). In response, Henseler et al. (2015) propose an alternative method called the heterotrait-monotrait (HTMT) ratio of correlations. The HTMT ratio estimates the actual correlation between two constructs if they are reliable (Hair et al., 2019). A correlation value close to 1 suggests a lack of discriminant validity between the constructs. Henseler et al. (2015) recommend a threshold value of 0.85 for conceptually distinct constructs in the path model and a value of 0.90 for conceptually similar constructs. In Table 15, the HTMT values for all pairs of constructs are presented in a matrix format. All HTMT values are below 0.85, which is slightly above the threshold for conceptually distinct constructs, but within the acceptable range of 0.90 for conceptually similar constructs. Therefore, both analyses confirm the presence of discriminant validity among the reflective constructs in the model.

Table 15. HTMT Discriminant Validity Test.

	Management Value	Risk Perception	Safety System	Work Pressure	Competence Level
Management Value	1				
Risk Perception	0.633	1			
Safety System	0.524	0.786	1		
Work Pressure	0.448	0.635	0.723	1	
Competence Level	0.233	0.359	0.359	0.29	1

5.5 Formative Measurement Model

The application and validation of formative measurement models have been the subject of significant debate and disagreement (Hardin *et al.*, 2010). Moreover, previous studies reviewing the use of partial least squares structural equation modelling (PLS-SEM) in marketing and strategic management have highlighted researchers' tendency to inappropriately apply criteria for evaluating reflective measurement models to assess the quality of formative measures (Hair et al., 2019. The statistical techniques used for evaluating reflective measurement scales cannot be directly applied to formative measurement models. This is because formative indicators represent the independent causes of the construct and may not exhibit high correlations. Formative indicators are assumed to be error-free, making the concept of internal consistency reliability irrelevant. Additionally, assessing convergent and discriminant validity using methods designed for reflective measurement models lacks meaningful interpretation in the context of formative measures. Therefore, researchers are advised to prioritise content validity by ensuring that indicators capture the essential aspects of the construct before empirically evaluating formative constructs (Hair et al., 2019).

Content validity for formative measures can be established through rigorous qualitative studies, comprehensive literature reviews, and a solid theoretical foundation to ensure the inclusion of relevant indicators. As discussed in previous chapters, these procedures were employed prior to the empirical examination of the formative constructs. In this section, the analysis will focus on assessing convergent validity, addressing collinearity issues, and evaluating the significance and relevance of the formative indicators for the five constructs in the model, following the guidelines proposed by Hair et al. (2019). Each of these assessments will be discussed in the subsequent sub-sections.

5.4.1. Assessing Convergent Validity

Convergent validity in a formative measurement model is evaluated by comparing a formative measured construct with a reflective measure of the same construct to determine their level of correlation. This analysis is known as redundancy analysis. Redundancy analysis examines the shared information between the formative and reflective constructs within the model. In this analysis, the formative construct serves as an exogenous variable that predicts the reflective construct, which can be represented by one or more reflective indicators (Hair et al., 2019). In this study, a single item was used for the reflective construct as part of the redundancy analysis, which was included in the questionnaire. The decision to use a single item for the reflective construct was made to keep the survey length manageable, as longer surveys can lead to decreased response rates and an increased number of missing values.

The strength of the relationship between the formative and reflective constructs indicates the validity of the formative indicators in measuring the construct. A recommended threshold for demonstrating convergent validity between the same formative and reflective construct is a path coefficient value of 0.70 or higher (Hair et al., 2019).

Table 16. Redundancy Analysis for Convergent Validity Test

	Preoccupied with Failure	Reluctant to Simplify	Sensitivity to Operation	Commitment to Resilience	Deference to Expertise
Preoccupied with Failure	0.741				
Reluctant to Simplify		0.782			
Sensitivity to Operation			0.711		
Commitment to Resilience				0.739	
Deference to Expertise					0.744

5.4.2. Assessing Collinearity Issues

Formative indicators differ from reflective indicators in those high correlations between formative indicators, known as collinearity, which can affect the estimation of weights and their statistical significance (Hair et al., 2019). When multiple indicators are involved, this is referred to as multicollinearity. To assess multicollinearity among formative constructs, the variance influence factor (VIF) is calculated. The VIF measures the extent to which the standard error increases due to collinearity. A VIF value of 5 or higher indicates a potential collinearity problem, suggesting that 80% of the indicator variance is explained by other formative indicators within the same construct. As indicated in Table 16, the VIF values for each indicator associated with the formative construct are below 5. Therefore, there are no concerns regarding multicollinearity in the measurement model.

5.4.3. Assessing the Significance and Relevance of the Formative Indicators

The significance and relevance of formative indicators can be evaluated through their outer weights, which are obtained through multiple regressions using the construct scores as the dependent variable and the formative indicators as the independent variables (Hair et al., 2019).

The outer weights are standardised values that indicate the relative contribution or importance of each indicator in constructing the construct. A bootstrapping procedure is employed to assess the significance of the formative indicators in establishing the construct in PLS-SEM. This procedure tests whether the outer weights are significantly different from zero (Hair et al., 2019).

However, it is important to note that when a single formative construct is measured using a larger number of indicators, it is more likely to yield one or more insignificant outer weights. Formative measurement with a limited number of indicators may still have statistically significant weights. Therefore, non-significant indicator weights should not be immediately dismissed as indicators of low measurement model quality. Instead, they should be retained for further analysis and considered in terms of their absolute contribution or importance to the construct.

Hair et al. (2019) provides guidelines for handling non-significant indicator weights. They suggest considering the absolute contribution of a formative indicator, which is indicated by its outer loading in PLS-SEM. The outer loadings are obtained through simple regressions of each indicator on its corresponding construct. If an indicator has a non-significant outer weight but an outer loading above 0.5, it should be interpreted for its absolute importance and retained in the measurement model. However, if an indicator has a non-significant outer weight, a lower outer loading below 0.5, and lacks conceptual or theoretical relevance, it should be removed from the measurement model (Cenfetelli and Bassellier, 2009).

In Table 16, all formative indicators are shown to be statistically significant ($p < 0.05$). These indicators were retained despite not being statistically significant due to their conceptual and theoretical relevance to the constructs. Additionally, the outer loadings for each indicator are above 0.5, indicating their absolute importance (Hair et al., 2019). Table 17 presents the results of the bootstrapping procedure (5000 sub-samples) for the bias-corrected confidence interval (BCCI) of the outer weights. The BCCI values indicate the range within which the outer weight of an indicator lies, with a 95% probability.

5.6 Assessing the Structural Model Results and Model Fit

Sections 5.3 and 5.4 examined the reflective and formative measurement models to ensure the reliability and validity of the constructs in the model. In this section, the analysis is taken further by evaluating the structural path model, which represents the underlying theoretical framework and relationships between constructs. By testing hypotheses, the assessment of the structural model demonstrates the model's predictive capabilities and the interrelationships between constructs. In PLS-SEM, parameters are estimated to maximise the explained variance of the endogenous latent variables, such as DRC, which differs from the approach of CB-SEM. Unlike CB-SEM, which aims to minimise differences between sample covariances and those predicted by the conceptual model, PLS-SEM focuses on maximising explained variance (Hair et al., 2019).

Therefore, the concept of "model fit" used to evaluate how well a model matches the empirical data and identifies model misspecifications is not fully applicable to PLS-SEM. These two techniques pursue different statistical objectives when estimating model parameters (Henseler et al., 2015). As a result, goodness-of-fit measures such as chi-square (χ^2) or other fit indices associated with CB-SEM do not apply to the PLS-SEM technique.

However, the usefulness of goodness-of-fit in estimating PLS-SEM parameters has faced empirical and conceptual challenges as it fails to distinguish between valid and invalid models, and it is not applicable to formative measurement models (Henseler, Ringle and Sarstedt, 2015). As a result, researchers employing PLS-SEM propose alternative measures for assessing model fit. For example, Henseler et al. (2015) respond to the critique by Rönkkö & Evermann (2013) by suggesting the use of the CB-SEM test of standardised root mean square residual (SRMR) as a valid measure of model fit in the context of PLS-SEM. SRMR is defined as the root mean square difference between observed correlations and model-implied correlations (Hair et al., 2019). In CB-SEM, an SRMR value of 0.08 is considered indicative of a good fit. Another model fit measure for PLS-SEM is the root mean square residual covariance (RMS theta), which follows a similar rationale as SRMR but relies on covariances. RMS theta values below 0.12 suggest a well-fitting model, while higher values indicate a lack of fit. The structural model in this study yielded SRMR and RMS theta values of 0.07 and 0.11, respectively, which are below the recommended thresholds. Therefore, these measures can help identify any model misspecifications in the hypothesised structural model.

The evaluation of the structural model's results follows the five-step guideline outlined by Hair et al. (2019). These steps include: 1. Assessing collinearity issues in the structural model, 2.

Examining the significance of path coefficients, 3. Evaluating the R^2 values, 4. Calculating the f^2 effect size, and 5. Determining the predictive relevance Q2. The subsequent sub-section will discuss each of these tests in detail.

5.5.1. Collinearity Issues at the Structural Model

When evaluating collinearity in the structural model, the same criteria as those used for assessing formative measurement models at the indicator level are applied. A VIF value exceeding 5 indicates significant collinearity (Hair et al., 2019). However, to examine collinearity at the structural level, the VIF values of all sets of predictor constructs in the model are considered. Table 17 displays the VIF values for various combinations of endogenous constructs (columns) and their related exogenous (i.e., predictor) constructs (rows). For instance, the ability to anticipate, adapt, respond, recover, and learn as predictors of a firm's DRC. As depicted in Table 17, all VIF values are below 5. Consequently, collinearity among the predictor constructs does not pose a significant concern in the structural model.

5.5.2. Structural Model Path Coefficients

The subsequent stage in analysing the structural model involves assessing the significance level of the proposed relationships, represented by the path coefficients, between the constructs. Path coefficients that approach positive one indicates strong relationships that are statistically significant.

The bootstrapping procedure was employed, utilising 5000 sub-samples, to calculate the standard errors of the estimates and determine the significance of the path coefficients using t-values and p-values (Hair et al., 2019). A significance level of 95% and a two-tailed critical value of 1.96 were set to test the significance of all the structural path coefficients.

This model is based on the conceptual framework derived from the qualitative study. It explores the connections between five principles of high reliability organisations (HRO) and safety culture as an antecedent of safety performance. Additionally, it examines the relationship between safety performance and sustainable production performance in the outcome constructs, considering the influence of industrial characteristics on this relationship. The following paragraphs provide an analysis of the significance of all the hypothesis relationships within the model.

5.5.3. Hypotheses Testing Results

To answer the question, *how does safety culture influence safety performance?* Five sub-questions were formulated to examine each aspect of that question. Each of these sub-questions, in turn, are expressed as a set of hypotheses that are given below.

H1a: The higher a firm's management value safety, the higher the safety performance of that firm.

H1b: The higher a firm's risk perception, the higher the safety performance of that firm.

H1c: The higher a firm's safety system, the higher the safety performance of that firm.

H1d: The higher a firm manages work pressure, the higher the safety performance of that firm.

H1e: The higher a firm's level of competence, the higher the safety performance of that firm.

The findings regarding the hypotheses are summarised in Table 17. The table indicates that the relationships between a company's safety culture and safety performance are statistically significant ($p < 0.001$) in the expected direction. Hypothesis H1a reports the highest path coefficient ($\beta = 0.620$), which is also significant ($t = 11.996$, $p < 0.001$). Based on the data, it can be concluded that the hypotheses suggesting that safety culture influences the level of safety performance in a firm are supported.

Table 17. Hypotheses Results of Safety Culture as Antecedents to Safety Performance

Hypothesis	Relationships	Sample Mean (Std Beta)	Standard Deviation (STDEV)	T Statistics	P Values	Result
H1a	MV ==> SP	0.62	0.052	11.996	0	Supported
H1b	RP ==> SP	0.322	0.096	3.312	0.001	Supported
H1c	SS ==> SP	0.284	0.062	4.649	0	Supported
H1d	WP ==> SP	0.362	0.074	4.953	0	Supported
H1e	CL ==> SP	0.36	0.056	6.378	0	Supported

To answer the question, *how do HRO principles influence safety performance?* five sub-questions were formulated to examine each aspect of that question. Each of these sub-questions, in turn, are expressed as a set of hypotheses that are given below.

H2a: The higher a firm is preoccupied with failure, the higher the safety performance of that firm.

H2b: The higher a firm's reluctance to simplify, the higher the safety performance of that firm.

H2c: The higher a firm's sensitivity to operation, the higher the safety performance of that firm.

H2d: The higher a firm's commitment to resilience, the higher the safety performance of that firm.

H2e: The higher a firm's deference to expertise, the higher the safety performance of that firm.

The findings for these hypotheses are presented in Table 18. According to the table, the relationships between a company's safety culture and the five resilience capabilities are statistically significant ($p < 0.001$) in the expected direction. Hypothesis H2c reports the highest path coefficient ($\beta = 0.620$), and it is also statistically significant ($p < 0.001$). Based on the data, it can be concluded that the hypotheses suggesting that safety culture influences the level of safety performance in a firm are supported.

Table 18. Hypotheses Results of Collective Mindfulness as Antecedents to Safety Performance

Hypothesis	**Relationships**	**Sample Mean (Std Beta)**	**Standard Deviation (STDEV)**	**T Statistics**	**P Values**	**Result**
H2a	PF ==> SP	0.62	0.052	6.428	0	Supported
H2b	RS ==> SP	0.362	0.096	3.312	0	Supported
H2c	SO ==> SP	0.412	0.062	4.649	0	Supported
H2d	CR ==> SP	0.348	0.074	4.953	0	Supported
H2e	DE ==> SP	0.284	0.056	6.378	0.001	Supported

Continuing the framework, there are two more questions that need to be explored: *How does safety performance influence sustainable production performance?* and *how do industrial characteristics influence the relationship between safety performance and sustainable production performance?* Therefore, the following hypotheses were put forth to be tested.

H3: A firm's safety performance positively impacts their sustainable production performance.

The relationship between a company's safety performance and sustainable production performance was found to be supported by the data. The coefficient of association ($\beta = 0.276$) was statistically significant ($p < 0.001$) in the expected direction. These findings provide evidence to support the hypothesis that a firm's safety performance has a positive impact on their sustainable production performance.

H4: A firm’s industrial characteristics negatively impact the relationship between safety performance and sustainable production performance.

The analysis revealed a negative correlation between the firm's industrial characteristics and the relationship between safety performance and sustainable production performance. The coefficient of association ($\beta = 0.393$) was found to be statistically significant ($p < 0.001$) in the expected direction. These findings provide support for the hypothesis that a firm's industrial characteristics have a negative influence on how their safety performance impacts sustainable production performance.

5.5.4. Coefficient of Determination (R^2 Value) and Effect Size (f^2)

The subsequent stages of the analysis involve examining the coefficient of determination, denoted as R^2, and the effect size, f^2, within the structural model. The R^2 coefficient assesses the model's predictive capability by quantifying the squared correlation between the actual and predicted values of a specific endogenous construct. It serves as an indicator of the model's predictive strength within the sample (Henseler, Ringle and Sarstedt, 2015). R^2 values range from 0 to 1, with higher values indicating greater accuracy and model fit. Recommended thresholds for R^2 values of endogenous variables are 0.75 (substantial), 0.50 (moderate), or 0.25 (weak) (Henseler et al., 2015; Hair et al., 2019. However, relying solely on R^2 values to evaluate predictive power can be misleading. R^2 is susceptible to bias when the number of non-significant exogenous constructs increases or when the relationship between exogenous and endogenous constructs is only slight (Hair et al., 2019). To address this issue, an adjusted coefficient of determination (R^2adj) can be used to mitigate potential bias. This measure takes into account the varying number of exogenous variables and sample size (Sarstedt, Wilczynski and Melewar, 2013). According to Table 19, the R^2adj values for the five principles of HRO can be classified as substantial, while the values for safety performance and sustainable production performance are categorised as moderate. On the other hand, the R^2adj values for work pressure and competence level are considered to be weak.

Table 19. R^2 and Adjusted R^2 Values

Constructs	R Squared	R Squared Adjusted
MV	0.553	0.549
RP	0.385	0.383
SS	0.738	0.735
WP	0.714	0.711
CL	0.699	0.696
PF	0.628	0.62
RS	0.335	0.33
SO	0.036	0.033
CR	0.738	0.735
DE	0.714	0.711

In addition to assessing R^2 values, the effect size (f^2) determines any changes in R^2 value for endogenous construct while omitting exogenous construct in the model. The change in the R^2 value is calculated by estimating the PLS path model twice. Firstly, with the exogenous variable included and secondly, with the variable excluded (Hair et al., 2019). The rule of thumb for assessing the effect size values are 0.02, 0.15, and 0.35. These represent small, medium, and large effects, of the exogenous variable, respectively (Cohen, 1988). Effect size below a value of 0.02 indicates that there is no effect from the exogenous to the endogenous construct. For instance, results show that preoccupation with failure and sensitivity to operation have a medium effect on the safety culture, with values of 0.229 and 0.116, respectively. However, both of these capabilities do not affect industrial characteristics.

5.5.5. Predictive Relevance Q^2

The next step in the analysis involved assessing the predictive relevance of the path model using Stone-Geisser's Q^2 value (Geisser, 1974; Stone, 1974). The Q^2 value is obtained in PLS-SEM by employing a blindfolding procedure that involves omitting and predicting specific data points of the endogenous construct indicators. This procedure compares the original values with the predicted values (Tenenhaus *et al.*, 2005). A Q^2 value greater than zero for a reflective endogenous latent variable indicates the predictive relevance of the path model for that particular dependent construct (Hair et al., 2019). All three reflective endogenous constructs have Q^2 values above zero. Notably, safety performance exhibits the highest Q^2 value (0.361), followed by sustainable production performance (0.213), and finally, management value (0.021). These results demonstrate support for the model's predictive relevance regarding the reflective endogenous constructs. In other words, the exogenous constructs (e.g., safety performance) have predictive relevance for the endogenous construct (e.g., sustainable production performance) within the model.

Chapter 6: Discussion

This chapter is structured as follows. Section 6.1 focuses on the analysis of safety culture as the antecedent of safety performance. Section 6.2 carefully examines another antecedent for safety performance: Collective Mindfulness with its five principles. Section 6.3 presents a discussion about industrial characteristics as the moderator of safety performance and sustainable production performance. Section 6.4 thoroughly analyses the main topic of this study, the impact of safety performance on sustainable production performance. Section 6.5 focuses on answering the research questions of the study. Section 6.6 carefully examines the contribution of this study to knowledge, while Section 6.7 thoughtfully discusses the practical contribution.

6.1. Safety Culture as an Antecedent of Safety Performance

The study findings highlight the crucial role of safety culture in determining safety performance, as it serves as a direct precursor to the latter. This point was consistently evident and supported by both phases of the study. The qualitative investigation revealed strong indications that effective safety performance is unattainable without a strong safety culture. Each component of safety culture, namely management value, risk perception, safety system, competence level, and work pressure, demonstrated positive correlations with safety performance. These findings were further validated in the quantitative study, where hypotheses H1a, H1b, H1c, H1d, and H1e received robust support and showed statistical significance, with medium to large effect sizes. Consequently, these results reinforce the notion that the quality of a firm's safety culture directly impacts its safety performance. Notably, the path from management value to safety performance exhibited the highest positive relationship ($\beta = 0.620$, $t = 11.996$), followed by risk perception to safety performance ($\beta = 0.360$, $t = 6.378$), and competence level to safety performance ($\beta = 0.362$, $t = 4.953$).

This result further supports the results from the systematic literature review (SLR). During the SLR, it was found that as a primary dimension, safety performance is driven by other constructs including a safety system and management commitment as its antecedents. A good safety system in an organisation can improve safety culture and, therefore, safety performance, thus increasing the value of safety performance. Low levels of management commitment decrease the safety culture and, therefore, safety performance (Wilding and Lewis, 2007). This argument implies that once a safety culture is established, safety performance will then occur (Syaifullah *et al.*, 2022).

In short, safety culture has been determined as the antecedent of safety performance in the literature. Champion et al. (2017) argued that the key to success for the Dow Chemical Company in reducing its accident rate between 2013 and 2015 was built on a strong foundation of safety culture and leadership. A strong management system and constant devotion to process safety at all levels of the organisation are necessary to drive the reduction of process safety incidents. Athar et al. (2019a) found that managerial aspects are considered to be key contributors to accidents. Similarly, McQuaid (2000) argued that the emphasis placed on senior management involvement may result in the ownership of health and safety being removed from the shop floor.

The qualitative study also produced similar results. The findings are consistent with the initial framework. Across the 14 cases, every company that has a good safety performance always has a good safety culture.

The result from this study shows similarities with studies in other industry. For example, the characteristics of construction workers at the group or organisational level often encompass elements such as safety culture, safety climate, interpersonal relationships among workers, and their respective roles in ensuring construction safety (Zhou, Goh and Li, 2015). Safety culture, as defined by most definitions, encompasses shared beliefs, values, and attitudes within a group. It is widely acknowledged that safety culture plays a crucial role in ensuring the safety of workers on construction sites (Choudhry, Fang and Mohamed, 2007). Comparisons of safety culture can be made across different levels of construction management, including top management, supervisory staff, and frontline workers (Fung *et al.*, 2005). Choudhry et al. (2007) conducted a comprehensive review of existing literature on safety culture, offering clarifications in terms of definitions, empirical evidence, and theoretical advancements. Various measures have been explored and proposed to further enhance safety culture on construction sites (Chinda and Mohamed, 2008; Molenaar, Park and Washington, 2009).

A comprehensive behavioural safety system and its intervention programme were implemented and executed at specific construction sites (Choudhry, 2014). After conducting safety behaviour measurements for a few weeks, the project management team implemented the planned intervention and conducted subsequent measurements. Notably, there was a clear improvement in safety performance across all categories, including PPE, housekeeping, access to heights, plant and equipment, and scaffolding. The research findings demonstrate that the safety performance scores at one project increased from 86% (at the end of the 3rd week) to 92.9% by the 9th week. The intervention yielded significant reductions in unsafe behaviours and substantial increases in safe behaviours. This case study provides evidence that an approach involving goal setting, feedback, and effective measurement of safety behaviour, when implemented by dedicated management, can significantly enhance safety performance in construction site environments. Importantly, the results indicate that the behavioural-based safety (BBS) management technique can be applied across different cultural contexts, making it both a valuable approach for improving the safety of frontline workers and applicable to ongoing construction projects industry-wide.

Another research study has explored the connections between specific managerial involvement and its impact on quality and safety (Parand *et al.*, 2014). It provides a summary of the overall role's significance and influence. Out of the articles reviewed that examined either the outcomes of management involvement in quality or its perceived importance, six articles indicated that managerial involvement had a positive effect on quality and safety performance. Senior management support and engagement were identified as primary factors associated with favourable quality outcomes across the entire hospital and the success of quality improvement programmes. Conversely, six articles suggested that managerial involvement (from the Board, middle, and frontline) had minimal, no, or even negative influence on quality and safety.

The review specifically examined the role of managers in upholding and promoting safe and high-quality care. The existing studies shed light on the time dedicated, activities undertaken, and engagement levels of hospital managers and Boards, all of which have the potential to positively impact quality and safety performance. However, the review also revealed a lack of such involvement and the absence of certain conditions that could facilitate their work.

The expected positive correlation between safety competence and compliance was validated in all four time periods (Kvalheim and Dahl, 2016). On average, the inclusion of safety competence in the regression model accounted for approximately 8% of the variance in safety compliance across the measurement periods. This suggests that prioritising knowledge of health, safety, and environmental (HSE) procedures, as well as providing adequate training on safety and working conditions, plays a crucial role in promoting compliant work practices. These findings align with previous research conducted in the context of passenger ferries, where an association between competence improvement and compliance was identified (Lu *et al.*, 2011).

Procedures and guidelines form essential components of a safety system and are intended to be utilised by workers prior to and during the execution of their tasks in high-hazard industries. The findings of this thesis indicate that a well-structured safety system, characterised by easily accessible procedures and readily available relevant guidelines, facilitates safety compliance. This finding is consistent with studies conducted in offshore supply bases (Antonsen, 2009) and offshore service vessels (Dahl and Kongsvik, 2018). On average, the inclusion of the safety system in the regression model accounted for approximately 4% of the explained variance in safety compliance across the four periods.

Including safety supervision in the regression model resulted in an additional explained variance of approximately 4% on average across the four measurement periods. The significant and positive contribution of supervisors to enhancing safety compliance stems from their ability to involve workers in safety-related discussions and value their input on safety matters. This finding aligns with previous research conducted by Dahl (2018) and Lu and Yang (2011), as well as with the assumption that workers are inclined to adopt behaviours that are expected, rewarded, and supported within the organisation, as suggested by (Zohar, 2010). The findings from this study further highlight the importance of supervisor involvement in daily safety work, which is consistent with previous observations in the offshore petroleum industry (O'Dea and Flin, 2001).

Including work pressure in the regression model increased the explained variance by approximately 9% on average across the four time periods. According to the standardised regression coefficients, work pressure emerged as the most influential factor in this study's model for predicting safety compliance. The balance between safety and production has been a recurring topic within the realm of safety sciences, and the findings of this thesis affirm that imbalanced priorities, favouring production over safety, have an adverse effect on safety compliance. This further supports Zohar's (2010) assertion that workers tend to adopt behaviours that are expected, supported, and rewarded, indicating that climates that prioritise production at the expense of safety will negatively influence safety behaviour.

The research findings highlight the critical significance of emergency management, start-up and shut-down systems, and documentation in ensuring safety performance in offshore operations (Tang *et al.*, 2017). Neglecting these key indicators increases the likelihood of incidents or errors. This study provides valuable insights into identifying and refining the most relevant health and safety indicators for offshore oil and gas facilities. Future research can explore the relationship between these indicators and the actual safety performance of offshore oil and gas plants, further enhancing our understanding in this area.

The findings from the minutes of the Health Safety Committee (HSC) meetings indicate a more effective HSC that successfully addressed safety issues (Nielsen, 2014). This aligns with previous research by (Morse *et al.*, 2009), which showed that successful HSCs review a greater number of complaints and suggestions. In the follow-up interviews, this improvement was largely attributed to the inclusion of supervisors and the health and safety advisor in the HSC, as well as the increased frequency of meetings. Initially, the HSC lacked the knowledge to resolve identified safety issues, but after the inclusion, the health and safety advisor was able to provide recommendations for solutions, prompting the HSC to take action. Additionally, the presence of supervisors in the HSC facilitated problem-solving, as they were responsible for practical implementation and follow-through. The questionnaire data on perceived HSC performance further supports this interpretation, as significant improvements were observed across all areas. These findings are consistent with international evidence suggesting that changes in the size, composition, process, and activities of HSCs lead to improved safety performance.

Safety culture is a concept that gains significance when considered in the context of hazards and risks. Risk, in this context, encompasses hazards arising from human activities as well as those stemming from natural factors. Therefore, safety involves the capacity to diminish or eradicate the chances of perilous incidents taking place. This is particularly crucial in high-risk environments like the chemical industry, where the potential hazards pose significant threats to both human beings and the environment.

McQuaid (2000) noted that making a company safe is all about order, control and good behaviour. That is not only a plus point for safety. Employees recoup the costs doubly because the company becomes more productive. So safeguarding employees safeguards the future of the company. In recent years, many researchers have shared the same concern as McQuaid. Casson Moreno and Cozzani (2015) analysed a database of accidents related to bioenergy production; this database was obtained from many different sources of literature including accidents that happened in the production of biofuels, biomass and biogas. Then the accident data results were analysed, and the results of conventional fuel production and processing accidents were compared to that analysis. It is shown that in recent years the number of accidents has increased significantly. In particular, the number of events increased from five times in the 2005-2007 period to ten times the number of events in the 2008-2011 period. This finding highlights the importance of safety, where if the situation is not managed well, the loss will be heavy. The consequences of the absence of safety not only impact on humans but also the environment. Sikorova et al. (2017) noted that aside from the impact on human health, the consequences of most major accidents were also shown to have a significant impact on the environment, social well-being and also on the biotic components of the environment. In certain cases, surface water and groundwater pollution occur, which could pollute drinking water supplies in the affected area. There is also regular soil contamination where hazardous contaminants penetrate deeply and remediation on the site is needed by removing a substantial amount of polluted soil. The results of water and soil pollution may endanger not only humans but also plants and wildlife.

Not only in “established” fields, but some researchers also argued the importance of safety in a relatively new field such as nanotechnology. Iavicoli et al. (2017) argued that from an occupational health perspective in the field of nanotechnology, safety seems an even more urgent issue. They pointed out that the increasing use of nanotechnology in agriculture may become a potential occupational hazard. The use of not fully explored xenobiotics in agriculture may become a risk for agricultural workers who may be exposed to the substance while performing their routine tasks. The question is raised regarding the potential hazard of being exposed to these substances and also how to specifically identify, communicate, and handle the certain risk for regulatory purposes.

The human factor is an essential issue for safety. As Sikorova et al. (2017) nicely summarised, the majority of accidents involving runaway reactions in the process industry are associated with the failure of controls and safeguards, or with human error. Many researchers share similar concerns and have given greater attention to managing human error in the chemical industry.

Akyuz and Celik (2015) studied how to minimise human error in LPG storage and handling processes. The operation of LPG cargo transport and handling (loading or unloading) often presents significant potential hazards, including risk to the environment, risk of injury or even risk of death to crews on board ships and at terminals. In this context, every crew member that works on board an LPG tanker should be able to perform the necessary operational functions under various conditions without conflict. Human reliability plays an important role in sustainable maritime transport at this level, with the highest degree of sensitivity to safety and loss prevention. Chidambaram (2016) highlighted how significant human and organisational factors are involved in accidents in all sectors of industry. An accident study in the Greek petrochemical industry from 1997 to 2003 showed that 73% of the accident causes were related to human factors (46%) and organisational factors (37%). Close study of incidents in Korea between 1988 and 1997 showed that most accidents (46%) occurred mainly due to operational failures, which were rooted in human factors including lack of maintenance and lack of a culture in safety-consciousness. In another study case, a review of 118 investigative findings on the losses incurred in containment incidents at Dutch Seveso Sites from 2006 to 2010 found that over half of the operating barrier task failures were largely due to rule-based and knowledge-based errors. These statistics illustrate how significant the human safety factor is.

Although many researchers have stressed the importance of safety in the chemical industry, occupational health and environmental impacts are typically considered at the later/final stages. However, the cost of process improvement and operational risks can be significantly reduced if these aspects are considered at the preliminary stage compared to the later stage. Thus, the safety aspect should be reviewed at the earlier stage as also stated within articles in the literature (Teh et al., 2019). Brzezińska et al. (2019) shared the same concern, noting that although fire can result from a growing range of threats, many fire strategies still do not include proper hazard analysis at the early stages of the project. Chidambaram (2016) also noted that the inclusion of design errors and the contribution of process defects would produce a similar degree of contribution, as found in the incident review of the Greek petrochemical industry. Athar et al. (2019) also argued that industrial disaster can be avoided through sustainable process designing at the design stage.

There is a problem however in tackling safety issues in the early stages. Fernandez-Dacosta et al. (2019) argued that the research effort to analyse and improve the existing methods is imbalanced compared to developing a new one. The assessment of the applicability and accuracy of the existing evaluation methods can be carried out only by comparing their findings with those of a complete evaluation. Their study noted that little has been reported on such an evaluation, especially for bio-based chemicals. Fernandez-Dacosta et al. (2019) concluded that the current assessment methods for the early-stage development of bio-based chemicals are not necessarily applicable and the outcomes to ensure safety and sustainability by design are not adequate. Similar to Dacosta et al. (2019), Phan et al. (2012) stated that there is lack of a reliable sustainable assessment tool for green motions in the chemical industry. A challenge arises when attempting to implement only a subset of the 12 principles outlined in the green metric, as this approach can backfire and result in illogical outcomes. Employing a limited, short-term strategy of this kind has the potential to harm not only the reputation of the company employing it but also erode trust among customers and the general public in the entire industry. Furthermore, certain principles within the set may conflict with each other, making it challenging to determine the most appropriate course of action to achieve the best overall results.

In summary, it is desirable to eliminate or minimise hazards at source by good design, avoiding the need for expensive and complex safeguards or procedures to manage the risks. Despite its obvious benefits, it is a fact that inherent safety is not well-grounded in the consciousness of management and designers. There are constraints which inhibit this, and which need to be and are being addressed by HSE in various ways. These constraints include: the rapidity of technological advance can result in health, safety and environmental issues having to be taken up as an afterthought; the development of inherently safer solutions is long-term and extends beyond the time window for investment decisions; and the fact that inherent safety is undoubtedly demanding on people's thinking time. It is so much easier to keep bolting on extras; and assume that decision-makers are well informed, in particular, they know about the cost of accidents and ill-health and the cost of preventive measures. However, much of the cost of poor health and safety performance is hidden because it is difficult to observe or estimate or because it is borne by a party other than the risk creator. This can make the inherently safer solution look expensive (McQuaid, 2000).

A prime illustration of these principles in action is seen in the case of Eta. Over time, Eta has cultivated a robust safety culture, echoing the findings of Choudhry (2014). This case exemplifies how the adoption of safety behavioural programs has enhanced their safety performance. At Eta, virtually every employee takes responsibility for managing risks in their respective workplaces, ensuring that safety is paramount in all their tasks. This collective behaviour is reinforced by supportive managers who consistently prioritise and advocate for safe and high-quality practices.

6.2. Collective Mindfulness as Antecedent of Safety Performance

The qualitative study revealed evidence indicating the presence of another factor influencing safety performance in addition to safety culture. The study proposed that the five principles of Collective Mindfulness - being preoccupied with failure, reluctance to simplify, sensitivity to operation, commitment to resilience, and deference to expertise - would have a positive impact on safety performance (H2a, H2b, H2c, H2d, and H2e). The results strongly supported these relationships, indicating that Collective Mindfulness does serve as an antecedent to safety performance (Syaifullah *et al.*, 2021). Among these relationships, the association between being preoccupied with failure and safety performance demonstrated the highest coefficient of association and significance ($\beta = 0.550$, $t = 8.056$), followed by reluctance to simplify and safety performance ($\beta = 0.500$, $t = 4.933$), and commitment to resilience and safety performance ($\beta = 0.317$, $t = 4.578$).

This result is further supporting the result from the qualitative study. As discussed in the previous section, every case that has good safety performance also has a good safety culture, revealing that safety culture is indeed an antecedent of safety performance. However, there are several cases, case Alpha being an example, where they have a good safety culture, but poor safety performance. This finding suggests the possibility of a safety culture not being the sole antecedent of safety performance.

In cases Sigma and Omega, they have so many procedures, which consequently produces a large amount of paperwork. Even though they admitted that they might have more procedures than necessary, they did not intend to reduce the paperwork. This practice stemmed from their consciousness of their complex and high-risk operations. Simplifying the paperwork might jeopardise their safety.

Meanwhile, the practices in cases Eta, Lambda and Upsilon showed their acceptance that failure remains a possibility. There does not seem to be a single method that is fail-proof. For risks that they are not willing to accept, they carefully consider the failures that might happen, and how to mitigate those failures. For instance, by building a redundancy of protection, if one layer of protection fails, they are still protected by the other layers.

While the qualitative study found indication for the first two principles of Collective Mindfulness, the result from the quantitative study confirms the other three. In other word, it is confirmed that Collective Mindfulness is an antecedent for safety culture.

One thing that makes an HRO different is that it is always preoccupied with failure (Weick and Sutcliffe, 2008). HRO never underestimates a symptom that appears and always considers it as a sign that the system might have a failure, which if left might have dire consequences later. A preoccupation with failure serves as a continuous reminder that encourages proactive and preventive examination of potential weaknesses. It treats any instance of failure or near-miss as a signal of potentially more significant underlying issues (Sutcliffe, 2011). Preoccupation with failure means that everybody in HRO is always attempting to identify how to do things right, what failure could happen, how failure could happen and what failure has happened. It does not mean that people in HRO are worrying too much about failure. More precisely, it means that people in HRO always try to find any signals or symptoms that indicate there is a chance of unexpected events occurring. One reason to develop this mindset is to avoid being overconfident or over optimist. Being preoccupied with failure also assists learning and acknowledges that any problem that seems to be minor at first, might be a symptom or signal of a bigger problem. Small or minor failures that occur, can be used to learn how another failure could happen again in the system. While many other organisations address failure by trying to ensure it will not happen again, HRO is the opposite. It addresses failure by trying to recreate the failure, to have a better understanding about the organisation, how the system works and what failure can disrupt continuity.

In short, preoccupation with failure suggests that to prevent failure an organisation must preoccupy itself with discovering potential failures and their causes (Hales and Chakravorty, 2016). There are several ways to do this, namely: collectively increase alertness, never be satisfied with the "status quo", always try to find better alternatives, recognise and acknowledge errors, and keep improving current processes to prevent failure or error.

The findings are in line with the first principle of HRO. As discussed in a previous chapter, failure and error were determined to be the cause of accidents in many cases in various industries. For example, Sikorova et al. (2017) summarised in their study that the majority of accidents involving runaway reactions in the process industry are associated with the failure of controls and safeguards or with human error. Chidambaram (2016) also noted how significant human and organisational factors are in accidents in all sectors of industries. An accident study in the Greek Petrochemical Industry from 1997 to 2003 showed that 73% of accident causes were related to human factors (46%) and organisational factors (37%). A close study of incidents in Korea between 1988 and 1997 showed that most accidents (46%) occurred mainly due to operational failure, which was rooted in human factors including lack of maintenance and lack of a culture in safety-consciousness. Those statistics highlight how essential the human factor is in safety.

Supporting the first principle, the second principle is also managing the unexpected by being unwilling to make things simpler (Weick & Sutcliffe, 2008). While it is important to be able to focus on several important issues and main objectives, people need to keep avoiding overcomplication, as keeping things simple will help to understand more details. The second principle encourages reluctancy to simplify in order to have a more holistic understanding about what problem might appear and what they can do when it does. The second principle also takes into account the nature of the world, which is complex, unstable, unknowable and unpredictable, and takes this approach to make people understand as much as possible. People in HROs prefer experience from various backgrounds, which is critical to new knowledge, and always attempt to facilitate different opinions that derive from the diversity of experience, without eliminating any unique perspective brought by that diversity.

Always trying to find alternative perspectives is critical to new knowledge, finding unseen potential problems and recognising a shift in demand are indicators of a reluctance to simplify. In most cases, people usually try to make things simple when they are faced with complicated tasks, according to how they understand the situation. Unfortunately, simplification can create difficulty in the form of overconfidence and fool them into believing that they have a complete understanding of the situation. Moreover, simplification can also create less caution and unnecessarily limit imagination for any unexpected events that might result from their action. Most HROs deal with a complicated environment with high levels of risk. The second principle helps people in HROs to have a holistic understanding regarding complex situations that they face. To recompense for the lack of simplification, HROs welcome different expertise and backgrounds to reduce assumptions and also to have more nuance in seeing issues and making decisions. It's not that people in HROs know everything, but they have complete understanding about what they do not know. They expect the unexpected and are ready to be surprised and always stay alert. Since HROs deal with a complex environment, the idea is that their sensory system should be as complex as the environment in order to comprehend it. Perspective from just one person can only do so much, while a complex technical system will be able to comprehend more. That is the reason why HROs welcome diverse experience: to create a team with varied experience and perspectives. They will have more variety than a team that consists of people with similar experience.

The second principle of HRO encourages processes that are insightful and driven by data, and always notice special characteristics of a problem before deciding on a solution to address the problem. It believes that every problem has its own uniqueness and rejects similar generic "best practice" to address every problem (Hales & Chakravorty, 2016).

The third principle is concerned with the operation of an organisation. HROs pay extra attention to operation, where most of the actual work is done (Weick & Sutcliffe, 2008). The "big picture" for HROs is less strategic and more situational than is true of most other organisations. When there is a well-developed situational awareness, continuous adjustments can be made that prevent errors from accumulating and enlarging. Irregularities are easier to identify and isolate when they are still within control and can be managed immediately. HROs understand the importance of sensitivity to operations and its relation to sensitivity in relationships. When there is inadequate knowledge of the system to work effectively, there can be hesitancy in voicing their thoughts because of fear of undermining the system. It is common knowledge in HROs that if information about its operations is withheld, people will not be able to have a holistic view of those operations. Whatever the reason for withholding the operation (be it fear, unawareness or simply indifference), it does not make any difference.

Developing and preserving a holistic view of present situations by giving consideration to up-to-date information indicates a sensitivity to operations (Sutcliffe, 2011). There is an image that is similar to the concept of situational awareness, and is unique to HROs, called "having the bubble". The idea in this concept is that if a person in an organisation is completely aware of the situation that is currently happening, that person can foresee the occurrence of small problems and anticipate those problems with the necessary small modifications. These small modifications are critical to prevent a series of failures from occurring and creating major problems. As illustrated by the famous Swiss cheese model, many major problems started from small failures that then line up. The awareness of the situation that is currently happening can help address those small failures before they create bigger problems.

Sensitivity to operations recognises that a solution to one problem may create another and therefore process-wide measurement is essential (Hales & Chakravorty, 2016). The concept of sensitivity to operations shares a similarity with the notion of "having the bubble" that is used in the Navy. This notion refers to how the crew of a ship is aware of the present ship's situation and condition. This can be achieved by communicating with each other face to face, to keep sharing the latest information and leaving the problem to its respective experts.

HROs understand that there is no system that is perfect. That is the reason, despite taking so many precautionary actions, that HROs complement themselves with the fourth principle: commitment to resilience. "The core of resilience lies in the inherent capability of an organization (or system) to sustain or recover a dynamically stable condition, enabling it to persevere in its operations even in the aftermath of a significant incident or under continuous stress." HROs understand that despite all the efforts made, errors and failures will continue to happen and complement themselves with the ability to recover from those errors and failures. The distinctive characteristic of HROs is not that they are free from error and failure, but that they can always recover from them.

A commitment to resilience means that an organisation has the ability to "bounce back" when unexpected events occur. The ability to do that involves the need to be able to improvise, learn, the capability to multitask and be adaptive to change. The first three principles have made people in HROs able to foresee and anticipate any potential failure. Despite that, they understand that unexpected events cannot be eliminated completely. That is the reason why the fourth principle prepares people in HROs to deal with unexpected events as they occur, and to quickly adapt as needed by the situation.

Commitment to resilience welcomes initiatives and creativity from every member of the organisation, in order to keep making improvements to the process. This principle also encourages people to take action to prevent failures from happening and relies on the expertise of employees in the operations to anticipate risk and address as many threats as possible when they appear. A commitment to resilience means that an organisation has the ability to "bounce back" when unexpected events happen. Thus, it can be argued that how responsive an organisation is in facing unexpected events can be a parameter of how committed that organisation is with regard to resilience.

Brzezińska et al. (2019) highlight the importance of flexibility in the implementation of fire safety and protection with sustainability consideration, and incorporate economics, environment and the social aspect. They argued that even a fire incident that is fairly minor within an environment such as the chemical industry can possibly cause a fire propagation that is uncontrolled and results in a domino effect, which can then lead to huge loss of property and process continuity and potentially also damage the nearby environment. The more complicated the involved process is, the higher the requirement for the strategy to be flexible. Fujii and Managi (2012) also consider flexibility as important: noting that there are differences in toxic chemical substance management by industry type in the U.S. manufacturing sector. Therefore, the environment policies for chemical substances management need to consider the differences of industrial characteristics, which are a function of intermediate use and available technology for emission reduction. Welch & Hartman (2003) discussed a case study in Chevron Texaco and suggested that a key to any long-term initiative is the level of ongoing support it receives. Thus, management must be involved in the audit process and can respond accordingly to the result of the audit. On 29 April 1994 in Malaysia, the Chemical Industries Council launched the Responsible Care Programme (RCP). This programme was voluntarily adopted by a wide range of chemical companies and used to promote good chemical management. The RCP also contributed to increasing Environment Health and Safety (EHS) performance continuously, both in the context of their products and operations. Considering public concerns, the RCP operates in a responsible and sensitive manner (Lee et al., 2015). The RCP adopted cooperation and initiatives voluntarily with the government and other main stakeholders in the industry. By meeting and going beyond legislative and regulatory compliance, the RCP has managed to accomplish their objectives.

Contrasting with that, case Beta also showcases a firm dedication to resilience. Despite being relatively new in the industry, Beta is actively developing its safety culture. With a strong management team that places a high value on safety and is committed to learning from mistakes, Beta has made significant strides. In their early days, minor fire incidents occurred several times. However, the management treated each incident with great seriousness, implementing improvements afterward. This willingness to acknowledge errors and the capacity to learn from them has been instrumental in Beta's achievement of a fire-free record over the past decade.

The last unique characteristic of HROs is that they defer to expertise (Weick & Sutcliffe, 2008). As mentioned in the previous chapter, HROs welcome diverse experience and expertise, not only because this will provide greater perspective to identify potential problems in their complex environment, but also because it will increase their capability to deal with those identified potential problems. Organisations that have an inflexible hierarchy tend to be especially susceptible to failure. Failure at a higher stage in the hierarchy creates problems that are bigger and more difficult to handle because they accumulate all the failures at lower stages. To prevent this situation from happening, HROs do not do all the decision-making at the higher stage in the hierarchy but distribute it at the lower level. An HRO encourages people on the front line to make decisions with regard to the expertise of personnel instead of their rank.

HROs are inclined to push down decision-making from a higher level to their experts when unexpected events occur (Sutcliffe, 2011). When unexpected events start to appear, HROs shift the authority to make decisions to those who have the most expertise in relation to the unexpected event. By being flexible with their hierarchy during unexpected events, HROs manage to deal with unavoidable unexpected events and insufficient knowledge.

Similar to the fifth principle of an HRO, this study also finds that good management practice and compliance with related regulations will minimise risk in the chemical industry and increase its performance. As has been discussed in a previous chapter, the literature suggested who should be the executor of their recommendations. Those suggested are engineers, researchers/scholars, operators, top management and regulators. In other words, the findings suggested that those recommendations can be executed by the related expert in the field, and not necessarily the top management.

6.3 Industrial Characteristics as Moderator of Safety Performance and Sustainable Production Performance

This study has reasoned that the five industrial characteristics derived from the literature, hazardous material, hazardous process, high risk, high consumption and waste generation, are the moderators to the relationship between safety culture and safety performance. The qualitative study explored this idea in depth and in doing so, found indications that the industrial characteristics are more likely to be moderating safety performance and sustainable production performance. Those indications were brought into the framework and modified the initial relationship. This theory was then tested in the quantitative phase by answering hypothesis H4. The results supported the results from the qualitative study and confirmed the role of industrial characteristics as a moderator for safety performance and sustainable production performance. The path coefficient and significance for this hypothesis was reported as follow: $\beta = 0.337$, $t = 3.354$.

This result supported the result from the qualitative study. In the previous section, it has been discussed how industrial characteristics have an impact on the relationship between safety culture and safety performance. Across the 14 cases, only five did not seem to be affected by their industrial characteristics (cases Beta, Gamma, Delta, Zeta and Theta). The state of their safety performance seems to be the same as the state of their safety culture, despite the high-risk environment. In all other nine cases, there is a clear indication that industrial characteristics do moderate the relationship between safety culture and safety performance. However, there are also other indications that suggest differently.

First of all, although the state of their safety performance is indeed changing, there is no obvious pattern to the changes. As can be seen in Figure 26, in some cases their safety performance is better than their safety culture (e.g., case Iota), in other cases, it is slightly worse (e.g., case Epsilon) or much worse (e.g., case Alpha). In all cases, their industrial characteristics are categorised as high risk. According to this study's initial framework, the impact on the relationship between safety culture and safety performance should be same; however, the findings did not concur. There are two possible explanations for this: 1) there are differences in their industrial characteristics that have not yet been properly understood, or 2) industrial characteristics are not the only trigger that may change the state of their safety performance as a result of the change of state in their safety culture.

Second, in the previous section, the possibility of another antecedent for safety performance has been discussed. It is suspected that the changes in the state of their safety performance from their state of safety culture might be influenced by this antecedent, as opposed to the chemical industry characteristics, as this study's initial framework suggests.

Third, some informants suggested that industrial characteristics have an impact on the relationship between safety performance and sustainable production performance, and not the relationship between safety culture and safety performance.

The findings from the quantitative study confirm that industrial characteristics are moderating the relationship between safety performance and sustainable production performance.

The chemical industry has its own unique characteristics, compared to other industries. Several researchers have described these characteristics in their studies. Lee et al. (2015) described the chemical industry as an industry that uses high technology and is capital-intensive. Additionally, it also has very strong connections to virtually every other sector of the economy. These characteristics require highly trained and skilled talent for its operation. Research and development to produce new value-added products are required in this industry as well. The chemical industry is likely to become more and more relevant, so there is a need to be well prepared in order to appeal to more investments. This is also in line with the plans of the Indonesian government to further consolidate and increase the strength of the attractiveness of the manufacturing sector. In general, the more complex the processing, as in the chemical industry, the more likely it will be to cause more incidents or accidents, with major consequences. The only notable exception to this is the dust explosions, which unlike any other major accident can happen only from process operations that are very simple, such as in the case of biomass (Casson Moreno & Cozzani, 2015). Reniers and Amyotte (2012) observed that if the first few decades of the preceding century are examined, the number of plants that handle hazardous chemicals in the world has increased significantly. This is a direct result of the variety of chemical products and processes that keep increasing. At the same time, due to increasing densities of population, those plants have to be located closer to each other and consequently, closer to highly populated neighbourhoods, while the chemical sector comprises a variety of facilities and risks. Champion et al. (2017) highlighted that while major accidents in chemical manufacturing are rare, their repercussions can be highly serious. Notable incidents like the Deepwater Horizon oil rig explosion and oil spill in April 2010, the Imperial Sugar Refinery dust explosion in October 2009, and the BP Texas City Refinery vapour cloud explosion in March 2005 serve as illustrations of significant accidents within the chemical industry. These occurrences had a profound effect on both human lives and the environment and garnered extensive media attention. Liew et al. (2014) added that the chemical industry mostly includes the extraction process of raw materials such as gas, minerals, and crude oil. This process is highly energy intensive and thus considered to be high risk. The chemical industry also deals with handling chemicals that are toxic, flammable, and hazardous in large volumes. Different characteristics of sustainability are highlighted in different areas within the chemical process industry.

Due to its own unique characteristics, the chemical industry has faced several challenges. Choy et al. (2016) argued that consumer products that are chemical based, for example detergents, cosmetics, soap, and shampoo, need to be more multi-functional, micro-structured, and engineered better than previously in order to fulfil the requirements of the consumer. This situation has created new challenges for the chemical industry to both remain profitable and achieve sustainable growth at the same time. In addition to Choy et al. (2016), Fernandez-Dacosta et al. (2019) pointed out that presently the chemical industry relies mainly on the usage of fossil resources that are finite. This has resulted in consumption of non-renewable resources that are unsustainable and increase the emission of greenhouse gases (GHGs). To remedy that situation, changing to an economy that is bio-based has been argued as an alternative to support sustainable development. Hansen et al. (2007) emphasized that the exposure to tens of thousands of unexamined and unregulated chemicals available in the European market could be seen as a significant threat to human well-being and the environment. In recent times, there has been a noticeable increase in public awareness regarding potential dangers associated with the usage and consumption of chemicals. Chemicals like PCBs and DDT serve as prominent examples of the significant shift that our society has undergone, both in terms of acknowledging public health and environmental issues and in perceiving these problems. Some of these issues have transitioned from being visibly evident and indisputable local concerns to becoming concealed, uncertain, and long-lasting global risks.

Brzezińska et al. (2019) believe that chemical industry plants are confronted by a variety of critical safety issues, with the consequences of a fire being one of them. Even a fire incident that is fairly minor, within the environment of the chemical industry, can possibly cause a fire propagation that is uncontrolled and a resulting domino effect, which can then lead to huge loss of property and process continuity, and potentially also damage the nearby environment. Those are not the only harmful consequences, as fire is also a threat to the health and lives of humans. Therefore, in infrastructures such as chemical industrial plants, it is essential to have appropriate levels of fire safety and protection. In the chemical industry, fire accidents occur regularly, mostly with major consequences to human life, property damage, business continuity, and the well-being of the environment. Due to the major consequences, industrial engineers, consultants, and scientists attempt continuously to improve the safety performance of the chemical industry. Unfortunately, industrial chemical plants have high levels of complexity and variation, which makes it difficult to implement fire protection rules or regulations that are generic. In addition to that Akyuz and Celik (2015) described the operations of LPG tankers as highly sensitive and hazardous. Thus, there is a need to effectively implement the control measures on board ships. If there are failures during the operation of critical processes (i.e. cargo loading), the most likely outcome is that they would lead to disastrous accidents such as a massive explosion.

In the agriculture industry, Raksanam et al. (2012) outlined how farmers encounter various occupational health risks, including health issues stemming from exposure to agrochemicals (specifically, pesticides), musculoskeletal ailments, and physical injuries. Pesticide exposure poses a notably high occupational hazard for farmers in Thailand, and these chemicals are extensively utilized worldwide to safeguard or enhance the productivity of industrial agricultural products. Pesticides not only eradicate pests but can also harm the surrounding ecosystem and other essential organisms responsible for maintaining ecological equilibrium. While some attribute this situation to a lack of risk perception, Remoundou et al. (2015) contended that there is insufficient empirical evidence linking the risk perceptions and attitudes of European laborers and operators to their adoption of protective practices, and even less is known about residents and bystanders in this context. Inadequate literacy skills may lead to difficulties in comprehending labels on pesticide containers or written risk communications outlining how to mitigate exposure. Research suggests that low literacy levels serve as a significant obstacle to the adoption of self-protective measures, particularly among agricultural workers in developing regions.

During the case studies, Lambda provided examples of how industrial characteristics can influence the relationship between safety performance and sustainable production performance. Although Lambda demonstrates good safety performance, which would typically correlate with sustainable production performance, the nature of their industry poses challenges. Operating in a high-risk sector, their sustainable production performance isn't as robust as expected. Many customers are unaware of the specialised storage requirements for Lambda's products, leading to potential disposal issues if mishandled. Given that a significant portion of their products is classified as hazardous, customers rely on Lambda for proper disposal, contributing to the perception of higher hazardous waste than their actual waste.

Despite those challenges, the effort to overcome it will be rewarding. Iavicoli et al. (2017) support this belief. They argued that nanotechnology can deliver the desired development of “high-tech” agricultural fields, which are equipped with a variety of intelligent nanotools that make the precise management and control of inputs possible. The above “high-tech” agricultural fields would be very helpful both to implement delivery systems for agrochemicals, improving plant propagation, and to create new products that are nano-bio-industrial, which is important for detecting environmental pollutants and clearing them. The development of nanotechnology potentially can decrease the negative impact of modern agriculture on the environment and economy, while still allowing the improvement in yields’ quality and quantity.

6.4. Impact of Safety Performance on Sustainable Production Performance

The qualitative findings highlighted several operational performances which are supporting this argument. Sustainable production performances are grouped into the six categories of: energy and material use, natural environment, workers’ health and safety, economic viability, community development, and product, as based on the literature. Overall, participants articulated that their firm’s safety performance had positive impacts on their sustainable production performance. Similarly, the quantitative finding (i.e., H3) confirms that a firm’s safety performance positively impacts their sustainable production performance ($\beta = 0.505$, $t = 8.667$). Therefore, the results from both phases of this study indicate the value of investing in a firm’s safety performance.

This result support previous findings. During the SLR, it was found that many have argued that safety performance is the primary dimension in influencing safety production performance. Choy et al. (2016) argued that safety is a critical issue for sustainable consumption and production. Casson Moreno and Cozzani (2015) carried out a survey of major accidents related to the production of bioenergy (intended as biomass, bioliquids/biofuels and biogas) based on past accident reports available in the open literature and in specific databases and built a data repository. Data analysis shows that major accidents have increased in recent years and their number keeps on growing, resulting in relevant human, environmental and economic losses. Kim et al. (2017) particularly noted that proper assessment and management of hydrogen fluoride is essential for a safe and sustainable chemical industry.

Griffin and Neal (2000) described safety compliance and safety participation as indicators for safety performance. González-Moreno et al. (2013) described how a more efficient and responsible use of natural resources, including energy, is an important factor in increasing sustainable production performance. Their study involved a sample of 544 companies in the Spanish chemical industry and concluded that safety compliance and participation are needed to achieve their goals.

The qualitative study also supported this. The result, to a considerable extent, demonstrates the consistency of the findings with the initial framework. In all the cases, safety performance directly influences sustainable production performance. In cases Beta, Delta, Eta, Theta, Lambda, Sigma, Upsilon and Omega, which have good safety performance, their sustainable production performance is also good. In contrast, cases Alpha, Gamma, Epsilon, Zeta, Iota and Kappa have exhibited both poor safety performance and sustainable production performance.

Findings from the case studies show how safety performance directly influences sustainable production performance. This is in line with other studies, for instance in the process industry, demonstrating that companies with a good suppliers’ and contractors’ health and safety performance were found to have a good sustainability performance too (Husgafvel et al., 2015). A study on the energy sector showed the safety performance of energy systems holds significant ramifications for the environmental, economic, and social facets of sustainability, along with the elements of energy security related to availability, acceptability, and accessibility (Burgherr

& Hirschberg, 2014). Another study also found that human factor and organisation environment are crucial components in striving for product sustainability (Petersen, 2021).

With the lack of effective environmental policies, industrial practices would result in the production of vast amounts of waste, the misuse of natural resources and unnecessary energy use. This entails designing and implementing sustainability policies in the manufacturing sector (Abdul-Rashid et al., 2017). One of the main environmental measures is sustainable industrial practices (Abdul Rashid et al., 2017). Implementing sustainable manufacturing is generally perceived as improving environmental performance as the industrial performance metrics today move from economic-centric success measures to sustainability measures. The term "sustainability" is defined as the expansion of the corporate perspective, which considers environmental, social and economic aspects. Hence, to assess the performance of sustainable production, it is important to assess all three aspects instead of just economics.

As summarised by Kallenberg (2009), There are several cases that have widely highlighted the issue of how chemicals in products are potentially hazardous, some of those cases are: brominated flame retardants (BFRs) in several products such as electronics and textiles (Kallenberg, 2009), China-produced plastic toys that contain lead at dangerous levels (Smitt 2007), dioxin in animal feed and benzene in Perrier (Wiener, 2006), phthalates in plastics (Renn & Schweizer 2008; Wiener & Rogers 2002), and various products including cosmetics that contain nano particles (e.g. Ennart, 2007; Hertel & Zimmer, 2008). Those cases and also many others unspecified, which have been covered extensively by the media, and have been the topic for discussion in many forums, both formal and informal, have become the reason for the growing interest from the EU, the EU Member States and also the public. In Sweden, there has been a lot of concern from the Swedish government, the Swedish Chemicals Agency and numerous 'green' advocacy groups regarding the issue of potentially dangerous chemicals in consumer goods (notably so the BFRs).

Those cases summarised by Kallenberg (2009) highlighted how the chemical industry is still facing challenges in terms of sustainability from an environmental aspect. Hansen et al. (2007) also added that a wide range of dangerous persistent organic pollutants (POPs) have been found in the Arctic regions where such chemicals have never been produced or used, as an indication of the existence of invisible global chemicals threats, making this problem even more severe.

Other than the environmental aspect, sustainable production performance also has challenges from a social aspect. Trasande et al. (2011) noted that as chemicals have become widespread in the environment in industrialised countries, the prevalence and incidences of chronic health conditions have increased. These conditions encompass asthma, specific birth defects, leukaemia, and brain and testicular cancer. One out of every six children in the United States are presently obese, with 2-8% affected by developmental disabilities. While scientific evidence directly linking the rising chemical exposures to obesity is currently insufficient, it's worth noting that the National Research Council approximates that around 28% of developmental disabilities may be attributed, at least partially, to environmental factors. Furthermore, outdoor air pollutants have been proven to worsen childhood asthma, and benzene, certain pesticides, and 1,3-butadiene, an industrial chemical, have all been linked to childhood malignancies. Casson Moreno and Cozzani (2015) also reported several accidents, resulting in human, environmental and economic loss. Their study also analysed some incidents in the production of biodiesel and linked them to limited experience of the companies' operators in handling the complex industrial chemical processes.

Several studies have been conducted to improve sustainability production performance. Fiorini & Vasile (2011) described how Fast Reactors have a unique capability as a sustainable energy source, which can potentially replace fossil fuel as an energy source. The closed fuel cycle allows the use of natural resources to be significantly improved and the volume of a high-level waste and heat load reduced. The sodium-cooled rapid reactor has the most extensive technical foundation among the fast reactor systems owing to the experience gained internationally from the operation of experimental, prototype and commercial-sized reactors. In food production, Holt et al. (2016) pointed out that ensuring food security through agricultural production is becoming increasingly difficult due to the depletion of natural resources. As the global population continues to grow, the need to meet food demand while minimizing environmental harm becomes a pressing challenge. Holt et al. (2016) also noted that the lack of effective pesticides may result in a reduction in the percentage of wheat production in the UK. In terms of adopting additional risk mitigation measures to achieve the anticipated levels of protection, not all of these measures have been put into practice in the UK.

Despite well-intentioned efforts, incidents still occur, and similar incidents continue to be repeated. To tackle this problem, Liew et al. (2014) suggested greater contributions from companies. Companies can contribute to sustainability in many ways and the agendas should cover the social, environmental and economic aspects – the triple sustainability bottom line. These include reducing operations' energy and water consumption, reducing pollution and waste, increasing the morale and productivity of workers, complying with regulations, and reducing operational risk. Building stronger relationships with communities, NGOs, governments, and peers in the industry are other actions of measurement that can be initiated by companies.

Among the investigated cases, Theta exemplified how strong safety performance can positively impact sustainable production performance. Theta's management demonstrated a deep commitment to worker well-being, effectively managing risks to prevent major accidents over the last few decades. While minor incidents like trips, slips, and falls still occurred, they were limited in scope. Workers attested to the significance of Theta's safety measures in enhancing sustainable production performance. Notably, Theta excelled in community development, actively participating in the establishment of numerous small clinics across Indonesia. Beyond supplying medication, Theta also deployed healthcare professionals and offered free health education to these clinics.

6.5. Answering the Research Questions

In this study, RQ1 aims to comprehend the extent to which safety influences sustainable production performance within the chemical industry. Moreover, RQ1 seeks to unravel the mechanisms that underlie this relationship. To address RQ1 comprehensively, this research started with a systematic literature review (SLR). Drawing valuable insights from the existing literature, the study subsequently progressed to gather empirical data via a qualitative case study. Despite acquiring significant insights from the qualitative study, certain aspects of RQ1 remained unclear. As a result, a quantitative study was conducted to acquire empirical data from a more extensive sample size. The findings from the quantitative study succeeded in providing a clear understanding of this issue.

RQ1 poses the question: "*To what extent does safety influence the performance of sustainable production in the chemical industry, and what are the underlying mechanisms*?" The investigation has revealed that within the chemical industry, characterised by high risks to both human life and the environment, safety assumes a pivotal role. The absence of safety measures brings in critical consequences, impacting not only the well-being of workers but also exerting significant consequences on the environment and the economy. This study has further constructed a framework, rigorously tested through empirical quantitative data. This framework explains the mechanisms governing the relationship between safety and sustainable production performance. It identifies safety culture and collective mindfulness as the antecedents to safety performance, while emphasizing that safety performance directly influences sustainable production performance.

Complementing RQ1, RQ2 aims to understand the role of the chemical industry's characteristics in the relationship between safety and sustainable production performance. The specific traits associated with the chemical industry, including its high-risk nature, utilization of advanced technology, capital-intensive operations, and extensive interconnections with various economic sectors, have been extensively discussed in prior research.

RQ2 poses the question: " *To what extent do the chemical industry's characteristics affect the relationship between safety and sustainable production performance*?" While the findings from the systematic literature review (SLR) hinted at industrial characteristics influencing the relationship between safety culture and safety performance, this suggestion was not corroborated by the qualitative case study. However, the subsequent quantitative study confirmed that industrial characteristics do indeed impact the relationship between safety performance and sustainable production performance. The framework derived from this study provides a comprehensive explanation of the role and extent of the influence exerted by industrial characteristics.

6.6. Contribution to Knowledge

The outcomes of this research have made significant contributions to various areas of knowledge, particularly those aligned with current discussions on sustainability, safety, Collective Mindfulness (CM), and mixed-methods research. By doing so, it has effectively tackled the research inquiries outlined in Section 1.3 of the introductory chapter. First, this study has investigated the extent of safety impacting the performance of sustainable production in the chemical industry. Furthermore, it also explores the underlying mechanism of the relationship between safety performance and sustainability performance. Second, this study analyses the extent of industrial characteristics affecting the relationship between safety performance and sustainability performance. Third, by building on the previous two points, it provides a conceptual framework to assess the antecedents, dimensions, and outcomes of improving an organisation's safety performance. Finally, this study was grounded in two rigorous data collections and with robust analysis phases for each. These ascertained the value in improving an organisation's safety performance, and thereby developing and advancing the topic. In light of this, the study promotes the adoption of mixed-methods research, as a suitable approach for inquiries of this nature.

Several studies have explored the connection between safety and sustainability, yet there remain gaps warranting further investigation. Nawaz et al. (2019) conducted a systematic literature review addressing the relationship between safety and sustainability and how this understanding can enhance the practical implementation of sustainable development. Their research affirmed the close association between safety and sustainability, emphasizing that incorporating safety considerations during the design phase is pivotal for sustainable development. Nawaz et al. (2019) underscored the significance of viewing safety as an integral component of sustainability and advocated for their concurrent consideration to attain sustainable development. However, despite presenting compelling arguments concerning the linkage between safety and sustainability, Nawaz et al. (2019) did not delve into the specific mechanisms governing this relationship. How exactly safety can affect sustainability, and what are other factors influencing the relationship, remained unexplored in their study. Furthermore, the study was only limited to literature study, without collecting any empirical data.

In contrast to Nawaz et al. (2019), Severo et al. (2015) conducted a study that involved the collection of empirical data. Their research focused on the examination of the interplay among cleaner production, environmental sustainability, and organizational performance within 298 companies in the Brazilian metal-mechanic industry. The study's findings suggested that the adoption of cleaner production practices and the promotion of environmental sustainability can yield positive outcomes for both the environment and an organization's performance. Specifically, the research indicated that implementing cleaner production methodologies can lead to increased production capacity, enhanced flexibility, and improvements in health and safety aspects. It's worth noting that this study primarily focused on the influence of sustainability on organizational performance, including aspects related to health and safety, rather than the reverse perspective. Similar to Nawaz et al. (2019), this study also did not delve into the specific mechanisms that underlie the observed relationship.

Sovacool et al. (2016) provided compelling evidence of the connection between safety and sustainability. Their research focused on assessing the risk of energy-related accidents within a range of low-carbon energy systems. These accidents were analysed in terms of their frequency over time, severity (measured by fatalities), and extent of property damage. Drawing from an original historical database spanning from 1950 to 2014, they conducted a comparative evaluation of energy accident risks across various energy sources, including biofuels, biomass, geothermal, hydroelectricity, hydrogen, nuclear power, solar energy, and wind energy. The results of their study revealed that these energy systems collectively experienced 686 accidents, resulting in 182,794 human fatalities and $265.1 billion in property damages. Across the entire sample, the average property damage amounted to $388.8 million per incident, accompanied by an average of 267.2 fatalities per accident. This study effectively demonstrated the close interconnection between safety and sustainability. It emphasized that any efforts to enhance sustainability, when safety considerations are neglected, can lead to detrimental consequences. Furthermore, the research implied that the absence of safety measures not only poses risks to human lives but also inflicts significant harm on both the environment and the economy. However, similar to Nawaz et al. (2019) and Severo et al. (2015), Sovacool et al. (2016) also did not delve into the specific mechanisms that explain the relationship between safety and sustainability.

Nawaz et al. (2019) conducted a systematic literature review and put forth a compelling argument highlighting the strong connection between safety and sustainability. Severo et al. (2015), on the other hand, undertook an empirical investigation by gathering data from 298 companies, ultimately affirming the close relationship between sustainability and safety. Meanwhile, Sovacool et al. (2016) delved into an analysis of a historical accidents database, subtly suggesting that the absence of sustainability measures can have repercussions that extend beyond human impact, adversely affecting the environment and the economy. Building upon the foundations laid by these previous studies, this study investigated the issue further. In the initial phase, a systematic literature review was conducted, revealing that safety performance significantly influences all aspects of sustainable production performance. Subsequently, a theoretical framework elucidating the mechanisms underlying this relationship was proposed. In the second phase of the study, some of these findings were validated through qualitative empirical data. While the precise role of industrial characteristics remained somewhat unclear, there were indications pointing towards the concept of collective mindfulness. Finally, in the third phase, all the findings were confirmed through quantitative empirical data. This study contributes further advancements beyond prior research, notably in the extent to which safety impacts sustainable production performance and the development of a framework that elucidates the mechanisms governing this relationship (Syaifullah et al., 2023).

The findings from this study contribute to the sustainability literature. In sustainability, there is a concept called the three pillars of sustainability; these are social, economic, and environmental (Purvis, Mao and Robinson, 2019). These pillars are considered equally important for sustainable development. The social pillar focuses on social cohesion, equity, and safety. The economic pillar involves technology, innovation, laws, governance, and financial incentives. The environmental pillar emphasizes the preservation and protection of the natural environment. These three pillars work together to create a framework for sustainable development. It is important to consider all three pillars in order to achieve long-term sustainability.

Within the concept of the three pillars of sustainability, safety is limited to just being part of the social pillar. Although the three pillars are supposed to be considered equally important, the economic and environmental pillars of sustainability have received more attention (Ruiz-Mercado et al., 2012). To make it worse, public opinion suggests that health and education are crucial elements of the social pillar, while security, culture, and the arts are considered to be less important (Ballet, Bazin and Mahieu, 2020). This situation has made the role of safety in sustainability to be miniscule. However, the findings from this thesis show that safety plays a crucial role in sustainability. Ignoring safety can have adverse consequences for sustainable development. The absence of safety not only will impact the social pillar, but also the economic and environmental pillars.

The findings of this study also contribute greatly to the safety literature. Initially, safety in the industrial context was primarily seen as a means to protect workers while they were on the job.

In simpler terms, it was initially regarded as solely focused on safeguarding the interests of employees. However, this perspective evolved as numerous studies demonstrated that upholding safety in the workplace also offers advantages to the company itself. Some of these advantages include cost reduction (for instance, fewer accidents result in decreased medical expenses, fewer workers' compensation claims, and lower insurance premiums; additionally, avoiding fines and penalties for non-compliance with safety regulations also contributes to lowering costs), the mitigation of property damage (industrial mishaps can lead to costly harm to equipment, structures, and the environment, but adhering to proper safety protocols can reduce the risk of such incidents), the enhancement of productivity (a secure work environment often leads to increased efficiency, as employees are more focused on their tasks and less preoccupied with concerns about their safety), and the enhancement of reputation (businesses that prioritise safety tend to enjoy more favourable reputations, making them more attractive to customers, investors, and partners who value the well-being of employees and the public).

This perspective has evolved to an even higher level now, as the findings from this study validate a strong connection between safety and sustainability. Despite numerous studies and evidence highlighting the advantages of enhancing safety for both employees and companies, safety initiatives still encounter various barriers. Among these, one of the most substantial barriers is the perception that implementing safety measures is expensive. Companies may hesitate to invest in safety equipment, training, and protocols due to concerns about escalating operational costs. Nonetheless, when considering the additional benefit of fostering safety, specifically in terms of advancing sustainability goals, the perceived cost of implementing safety measures can be viewed as more manageable. Furthermore, companies can encounter fewer conflicting priorities since the implementation of safety measures can serve multiple objectives.

Another area to which this study contributes is the Collective Mindfulness (CM) literature. Initially, CM was observed primarily in high-consequence industries, such as nuclear power plants, aviation, and the military, where the implications of errors or failures are severe. However, over time, there has been a growing body of evidence demonstrating the applicability of CM in various industries. One notable domain is healthcare, where hospitals and healthcare organisations can leverage CM to cultivate a culture of patient safety, reduce medical errors, and enhance overall care quality. This approach can also facilitate better communication among healthcare providers, ultimately leading to improved patient outcomes. Additionally, the construction industry has also shown significant interest in adopting CM principles. Construction companies and engineering firms can utilise CM to bolster safety protocols at construction sites, enhance project management practices, and proactively prevent accidents.

This study has demonstrated that CM plays a crucial role in achieving superior safety performance. In its absence, safety performance may not reach its full potential. Furthermore, this high level of safety performance has a direct correlation with achieving sustainable production excellence in the chemical industry. These findings expand the body of knowledge related to CM by introducing a new domain of study: the chemical industry. Given the inherent characteristics of the chemical industry, characterised by high-risk factors with potentially catastrophic consequences in the event of errors or failures, the significance of the CM concept in this context becomes evident. There is a compelling rationale for further research to delve into the practical applications of these findings at the operational level.

6.7. Contribution to Practice

Recent events such as the dam collapse in Brazil (2019), the oil spill in Siberia, Russia (2019), and the chemical plant explosion in Tarragona, Spain (2020), serve as illustrations of how major accidents can have catastrophic consequences and give rise to sustainability challenges.

In the case of the Brumadinho dam in Brazil, there was a devastating structural failure in 2019, resulting in the release of a significant volume of mining waste and sludge. Beyond the tragic loss of lives, the discharged mining waste polluted rivers and aquatic environments, causing harm to ecosystems and the contamination of water sources. Furthermore, the aftermath of the disaster had enduring impacts on the local environment, including deforestation, soil degradation, and the depletion of biodiversity.

In 2020, a thermal power plant in Norilsk, Siberia, Russia, experienced a catastrophic collapse, leading to the discharge of approximately 21,000 tons (equivalent to roughly 150,000 barrels) of diesel fuel into the surrounding environment. This spill was one of the largest of its kind in the Arctic region, resulting in severe consequences for the nearby ecosystem and communities. The Arctic region is particularly susceptible to environmental harm due to its delicate and distinct ecosystems, and this spill posed a significant threat to vulnerable habitats and wildlife.

Furthermore, in January 2020, a massive explosion rocked a chemical plant situated in Tarragona, Spain, sparking a fire and subsequent releases of hazardous chemicals. The force of the explosion was considerable, causing extensive damage to the facility and the surrounding vicinity. This explosion led to the emission of toxic substances, including ethylene oxide and propylene oxide, raising concerns regarding the potential environmental impacts, air quality, and the potential contamination of nearby ecosystems.

These incidents and their devastating consequences strongly align with the conclusions of this research. The absence of proper safety protocols in those three instances led to not just loss of lives and substantial economic damage but also extensive harm to the environment on land, in the sea, and in the air. This setback poses a significant obstacle to the pursuit of sustainability.

Chapter 7: Conclusions

7.1 General Conclusion of the Study

This study offers a valuable contribution by showing the research gaps for further study in order to understand the relationship between safety and sustainable production performance in the chemical industry. There is a need to refine the relationship between those two, and there are two specific gaps that are identified in the literature. The first remains unclear on how precisely safety can influence the sustainable production performance in the chemical industry. The second is that there is inconsistency in the positioning of safety in supporting sustainable production performance in the chemical industry.

Another valuable contribution from this research is that it shows the relationship between safety and sustainable production performance in the chemical industry and uncovers the link between the two. The framework and proposition produced from this research will help in opening new possible paths for safety research. Other than the obvious benefits of safety, keeping humans and the environment safe, improving safety can also result in other advantages, with improving sustainability being one of them.

Although the framework was developed using the context of the chemical industry, it is open to customisation for other industry sectors with similar characteristics, with some adjustments to the components of sustainable production performance. In this researcher's opinion, the framework could be deployed into a practical workbook consisting of self-assessment procedures, so that practitioners can further explore their capabilities, allowing a fuller understanding of how to increase their sustainable production performance, relevant to the specific application of this framework (possibly) beyond the chemical industry sector.

7.2 Limitations and Recommendations for Further Research

It is clear that this work could generate different interpretations and opinions simply because of the way the framework is formulated. Nonetheless, it is hoped that this study can stimulate a healthy discourse on the practical realities of sustainability performance in the chemical industry where safety, until now, remains a topical research concern.

There are several limitations to this study. First, it is based on an SLR to unravel the relationships between safety and sustainable production performance, particularly in the chemical industry. Second, the initial framework was developed from an amalgamation of multiple theories, mainly from the perspectives of safety. As a further work, an empirical study will be conducted in the context of the chemical industry to validate the proposed framework.

7.3 Concluding Remark

This study can induce a healthy discussion on the practical implementation of how safety can be best employed in improving sustainable production performance. The framework, which was originally created within the context of the chemical industry, can be adapted to other industries that share similar traits, with some adjustments to the components of sustainable production performance.

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Appendices

Appendix A: Informed Consent Form

INFORMED CONSENT FORM:
[The Impacts of Safety on Sustainable Production Performance in the Chemical Industry]

You are invited to take part in this research study for the purpose of collecting **professional experience** on investigating the impacts of safety on sustainable production performance in the chemical industry.

Before you decide to take part, you must **read the accompanying Participant Information Sheet.**

Please do not hesitate to ask questions if anything is unclear or if you would like more information about any aspect of this research. It is important that you feel able to take the necessary time to decide whether or not you wish to take part.

If you are happy to participate, please confirm your consent by circling YES against each of the below statements and then signing and dating the form as participant.

1	**I confirm that I have read and understood the Participant Information Sheet for the above study and have had the opportunity to ask questions.**	**YES**	**NO**
2	**I understand my participation is voluntary and that I am free to withdraw my data, without giving a reason, by contacting the lead researcher at any time until the date specified in the Participant Information Sheet.**	**YES**	**NO**
3	**I have noted down my participant number (top left of this Consent Form) which may be required by the lead researcher if I wish to withdraw from the study.**	**YES**	**NO**
4	**I agree for the interview to be audio and video recorded.**	**YES**	**NO**
5	**I understand that all the information I provide will be held securely and treated confidentially.**	**YES**	**NO**
6	**I understand that the purpose of the recording is for use in research and supervision. This will allow the lead researcher to consult his assigned supervisor(s), who may listen to the video and audio recording in an individual or group supervision format.**	**YES**	**NO**
7	**I understand that the researcher will translates the transcription of this video and audio recording into English and use it for the purpose of research.**	**YES**	**NO**
8	**I am happy for the information I provide to be used (anonymously) in academic papers and other formal research outputs**	**YES**	**NO**
9	**I agree to take part in the above study**	**YES**	**NO**

Thank you for your participation in this study. Your help is very much appreciated.

Appendix B: Gatekeeper Permission Letter

Dear [whom it may concern],

I am a PhD student within the Centre of Business in Society (CBiS) at Coventry University. My study focuses on investigating the impacts of safety on sustainable production performance in the chemical industry. I am writing to ask for a) permission to contact staff for participant recruitment; b) permission to conduct an interview to one staff that is qualify the requirements (please see section below) who is willing to take part in my research.

What is the purpose of the research?
The purpose of the study is to investigate how safety can influence sustainable production performance in chemical industry. The study also wants to investigate the role of chemical industry characteristics in the relationship between safety and sustainable production performance. Understanding of the relation between safety and sustainability performance can helps improving the latter. A new framework that can integrate safety and sustainability is the expected output of this study.

What will happen if your company takes part?
In total, from your company, I wish to recruit 1 (one) staff that works in either Production, Health & Safety or Environment Department in your company, and has been working for 10 years or more in his/her field for an interview. The interview will be conducted online, lasting at most 1 hour, where I will ask the staff a number of questions regarding his/her professional experience generally, the characteristics of your company, safety culture, safety performance and sustainable production performance in your company. The interview will be conducted using Zoom or other similar application and will be recorded using the application used. Taking part is entirely voluntary, the staff that participate will be able to withdraw at any time.

Please be reassured that as part of Coventry University's rigorous ethics process, all aspects of this study has been approved by the Research Centre for Business in Society (CBiS) ethics committee and all individuals who take part will be fully informed and debriefed.

Data Protection and Confidentiality
Your data (your staff and your company) will be processed in accordance with the General Data Protection Regulation 2016 (GDPR) and the Data Protection Act 2018. All information collected about your staff or your company will be kept strictly confidential. Unless they are fully anonymised in our records, your data will be referred to by a unique participant number rather than by name. Your data will only be viewed by the researcher/research team. All electronic data will be stored on a password-protected folder on Coventry University's one drive. All paper records will be stored in a locked filing cabinet Coventry University. The lead researcher will take responsibility for data destruction and all collected data will be destroyed on or before 30th August 2026.

Data Protection Rights

Coventry University is a Data Controller for the information you provide. You have the right to access information held about you. Your right of access can be exercised in accordance with the General Data Protection Regulation and the Data Protection Act 2018. You also have other rights including rights of correction, erasure, objection, and data portability. For more details, including the right to lodge a complaint with the Information Commissioner's Office, please visit www.ico.org.uk. Questions, comments and requests about your personal data can also be sent to the University Data Protection Officer - enquiry.ipu@coventry.ac.uk

What happens now?

If you are willing to take part, please email to confirm this. Also, if you have any queries, please get in touch. My e-mail address is syaifullad@uni.coventry.ac.uk.

Yours sincerely,

Danu Hadi Syaifullah
Research Student
Coventry University
Coventry CV1 5FB

Appendix C: Questionnaire Sample

The Impacts of Safety on Sustainable Production Performance in the Chemical Industry

You are being invited to take part in research on investigating the impacts of safety on sustainable production performance in the chemical industry. Danu Hadi Syaifullah, research student at Coventry University, is leading this research. The purpose of the study is to investigate how safety can influence sustainable production performance in chemical industry. The study also wants to investigate the role of chemical industry characteristics in the relationship between safety and sustainable production performance. Understanding of the relation between safety and sustainability performance can helps improving the latter. A new framework that can integrate safety and sustainability is the expected output of this study.

You are invited to participate in this survey to share your knowledge and expertise with us. We would be grateful if you could spare 20-25 minutes as your contribution is critical to this study. Your participation is voluntary, and if you complete the survey, we will provide a summary of the findings. The results of this study will be used strictly for academic purpose, and your answers will be anonymous and analysed in combination with other participants' responses. This study has been reviewed and approved through Coventry University's formal research ethics procedure. If you have any question, or are unhappy with any aspect of this research, please first contact the lead researcher, Danu Hadi Syaifullah, syaifullad@uni.coventry.ac.uk.

To complete the survey, please consent by selecting the "agree" button below. We appreciate your input and many thanks in advance for your contribution! Clicking on the "agree" button below indicates that:

- You have read the above information
- You voluntarily agree to participate
- You are at least 18 years of age

Part 1: Introduction

Q1. Which of the following best describes your company?

a) Organic chemicals industry
b) Inorganic chemicals industry
c) Agrochemical industry
d) Cellulose and rubber industry
e) Pharmacy industry
f) Petrochemicals industry
g) Other (please specify)

Q2. Which of the following best describes your responsibility at your company?

a) Health and Safety
b) Environment
c) Production
d) Compliance
e) Corporate Social Responsibility
f) Other (please specify)

Q3. How many employees does your company employ?

a) 1-50 people
b) 51-100 people
c) 101-250 people
d) 251-500 people
e) 501-1000 people
f) >1000 people

Q4. How long have you been working in your field (not limited to your current company)?
a) Less than a year
b) More than a year but not more than 3 years
c) More than 3 years but not more than 6 years
d) More than 6 years but not more than 10 years
e) More than 10 years

Part 2: Collective Mindfulness

In this section, we are seeking to understand your company's state of collective mindfulness. Collective mindfulness is defined as a team's capacity to develop a rich awareness of discriminatory details about internal and external processes and to regulate team behaviours accordingly. There are 5 questions in this part, each question consists of several statements. For each statement, please indicate the extent to which you agree or disagree with the statement as applicable to your company's condition. (1 = Strongly Disagree, 7 = Strongly Agree)

Q5. How preoccupied your company with failure?

PF1. We actively look for failures of all sizes and try to understand them.
PF2. When something unexpected occurs, we always try to figure out why our expectations were not met.
PF3. We regard near misses as failures that reveal potential dangers rather than as successes that show our capability to avoid disaster.
PF4. We often update our procedures after experiencing a near miss.
PF5. People report significant mistakes even if others do not notice that a mistake is made.
PF6. Managers actively seek out bad news.
PF7. People feel free to talk to superiors about problems.
PF8. People are rewarded if they spot potential trouble spots.

Q6. How reluctant your company to simplify?

RS1. People around here take nothing for granted.
RS2. Questioning is encouraged.
RS3. People feel free to bring up problems and tough issues.
RS4. People generally deepen their analyses to better grasp the nature of the problems that arise.
RS5. People listen carefully, and it is rare that someone's view goes unheard.
RS6. People are not attacked when they report information that could interrupt operations.
RS7. When something unexpected happens, people spend more time analysing than advocating for their view.
RS8. People trust each other.

Q7. How sensitive your company to operations?

SO1. On a day-to-day basis, there is always someone who is paying attention to what is happening.
SO2. Should problems occur, someone with the authority to act is always accessible to people on the front lines.
SO3. Supervisors readily pitch in whenever necessary.

SO4. People have discretion to resolve unexpected problems as they arise.
SO5. During an average day, people interact often enough to build a clear picture of the current situation.
SO6. People are always looking for feedback about things that aren't going right.
SO7. People are familiar with operations beyond their own job.
SO8. We have access to a variety of resources whenever unexpected surprises crop up.
SO9. Managers constantly monitor workloads and reduce them when they become excessive.

Q8. How committed your company to resilience?
CR1. Resources are continually devoted to training and retraining people to operate the technical system.
CR2. This organization is actively concerned with developing people's skills and knowledge.
CR3. This organization encourages challenging "stretch" assignments.
CR4. There is a concern with building people's competence and response repertoires.
CR5. People have a number of informal contacts that they sometimes use to solve problems.
CR6. People learn from their mistakes.
CR7. People rely on one another.
CR8. Most people have the skills to act on the unexpected problems that arise.

Q9. How differed your company to expertise?
DE1. People are committed to doing their job well.
DE2. People respect the nature of one another's job activities.
DE3. If something out of the ordinary happens, people know who has the expertise to respond.
DE4. People in this organization value expertise and experience over hierarchical rank.
DE5. In this organization, the people most qualified to make decisions make them.
DE6. It is generally easy to obtain expert assistance when something comes up that we don't know how to handle.

Part 3: Safety Culture

In this section, we are seeking to understand your company's safety culture. The safety culture of an organisation is the product of individual and group values, attitudes, perceptions, competencies, and patterns of behaviour that determine the commitment to, and the style and proficiency of, an organisation's health and safety management. There are 5 questions in this part, each question consists of several statements. For each statement, please indicate the extent to which you agree or disagree with the statement as applicable to your company's condition. (1 = Strongly Disagree, 7 = Strongly Agree)

Q10. How much value your management put on safety?
MV1. Management acts decisively when a safety concern is raised.
MV2. Management acts only after accidents have occurred.
MV3. Corrective action is always taken when management is told about unsafe practices.
MV4. In my workplace management acts quickly to correct safety problems.

Q11. How is risk perceived in your company?
RP1. I am rarely worried about being injured on the job.
RP2. In my workplace the chances of being involved in an accident are quite large.
RP3. I am sure it is only a matter of time before I am involved in an accident.
RP4. I am clear about what my responsibilities are for health and safety.

Q12. How is safety system in your company?
SS1. I cannot always get the equipment I need to do the job safely.
SS3. Sometimes conditions here hinder my ability to work safely.

SS4. Sometimes I am not given enough time to get the job done safely.
SS6. This is a safer place to work than other companies I have worked for.
SS7. There is a procedure for every possible situation.

Q13. How is work pressure in your company?
WP1. I am satisfied with my level of control and involvement in my job.
WP2. The number of meetings that I have to attend hinder my work.
WP3. My company have enough workers to fulfil our target.
WP4. I have personal target that is difficult to achieve.

Q14. How is competence level in your company?
CL1. Managers ensure the competence of all people in health and safety matters.
CL2. Health and safety training is appropriate for my job.
CL3. I feel competent in health and safety issues that affect my work areas.
CL4. I know what to do in case of emergency.
CL5. I am qualified to do my job.

Part 4: Sustainable Production Performance

In this section, we are seeking to understand your company's sustainable production performance. Sustainable production is the creation of manufactured products through economically sound processes that minimize negative environmental impacts while conserving energy and natural resources. There are 6 questions in this part, each question consists of several statements. For each statement, please indicate the extent to which you agree or disagree with the statement as applicable to your company's condition. (1 = Strongly Disagree, 7 = Strongly Agree)

Q15. How is the energy and material used in your company?
EM1. Our production process requires a massive amount of fresh water.
EM2. We consume a big number of raw materials to produce our product.
EM3. Our company use a lot of electricity for production process.
EM4. Only a small number (if any) of our energy needs supplied from renewable sources.

Q16. What is the impact from your company to the environment?
NE1. Our company produce a lot of waste.
NE2. We do not contribute to global warming.
NE3. There are a lot of toxic chemicals used in our production process.
NE4. We process all dangerous waste before releasing to the environment.

Q17. What is the state of workers' health and safety in your company?
HS1. We spend a lot of money to ensure compliance to EHS (environment, health and safety) regulation.
HS2. We have a low number of lost workday injury and illness (someone being unable to work due to injury or illness).

Q18. How is the economic viability of your company?
EV1. I believe that our business is financially profitable.
EV2. I cannot imagine how our product can become obsolete.

Q19. How is your company's contribution to community?
CD1. The existence of our company is very beneficial for communities around us.

CD2. I consider our company as labour intensive.
CD3. The number of turnover rates in our company is low.

Q20. How environmentally friendly is your product?
CP1. Our product can easily be disassembled, reused, or recycled.
CP2. Our product use biodegradable packaging.

Part 5: Safety Performance

In this section, we are seeking to understand your company's safety performance. Safety performance is defined as "the quality of safety-related work". Safety performance improvements in an organization can increase its resistance or robustness and lower the risk of accidents. There are 2 questions in this part, each question consists of several statements. For each statement, please indicate the extent to which you agree or disagree with the statement as applicable to your company's condition. (1 = Strongly Disagree, 7 = Strongly Agree)

Q20. How is safety compliance in your company?
SC1. I use the correct personal protective equipment for the task I am doing.
SC2. Everyone receives the necessary workplace health and safety training when starting a job, changing jobs, or using new techniques.
SC3. There is regular communication between employees and management about safety issues.
SC4. Systems are in place to identify, prevent and deal with hazards at work.
SC5. There is an active and effective health and safety committee and/or worker health and safety representative.
SC6. Incidents and accidents are investigated quickly in order to improve workplace health and safety.
SC7. Communication about workplace health and safety procedures is done in a way that I can understand.

Q21. How is safety participation in your company?
SP1. I often take part in development of the safety requirements for my job.
SP2. I feel free to voice concerns or make suggestions about workplace health and safety at my job.
SP3. If I notice a workplace hazard, I will point it out to management.
SP4. I know that I can stop work if I think something is unsafe and management will not give me a hard time.

Part 6: Industrial characteristics

In this section, we are seeking to understand your company's characteristics. Characteristics discussed in this study are related to the usage of hazardous material, hazardous process involved, risk to both workers and environment, and waste generated from production process. There are 4 questions in this part, each question consists of several statements. For each statement, please indicate the extent to which you agree or disagree with the statement as applicable to your company's condition. (1 = Strongly Disagree, 7 = Strongly Agree)

Q22. Is there any hazardous material used in your company?
HM1. Our main material for our product is combustible and/or toxic.
HM2. Our production process involves materials that can be considered as dangerous goods.

Q23. Is there any hazardous process involved in your company?
HP1. Our production processes are complex and/or using high technology.
HP2. A small mistake in production process can cause fatal accident.

Q24. How high is the risk in your company?

HR1. I believe that our company has high risk to the environment.
HR2. Our production activities generate many risks to our workers.

Q25. How many wastes generated in your company?
WG1. Only a small portion of our materials are used in our product.
WG2. It is dangerous to directly release our waste to the environment.

Appendix D: List of Publications

1. Syaifullah, Danu Hadi, Tjahjono, B., McIlhatton, D., & Zagloel, T. Y. M. (2022). The impacts of safety on sustainable production performance in the chemical industry: A systematic review of literature and conceptual framework. *Journal of Cleaner Production*, 366(May 2021), 132876. https://doi.org/10.1016/j.jclepro.2022.132876
2. Syaifullah, D. H., Tjahjono, B., McIlhatton, D., & Zagloel, T. Y. M. (2021). An Empirical Study to Scrutinize the Interplay between Safety and Sustainable Production Performance in the Context of Chemical Industry. *2021 IEEE International Conference on Industrial Engineering and Engineering Management*, IEEM 2021, 1152–1156. https://doi.org/10.1109/IEEM50564.2021.9673038
3. Syaifullah, D., Tjahjono, B., McIlhatton, D., Zagloel, T. Y. M., Baskoro, M.L., Beltran, M. (2023). How Does Safety Affect Sustainability? an Empirical Study in the Chemical Industry. In: *Silva, F.J.G., Ferreira, L.P., Sá, J.C., Pereira, M.T., Pinto, C.M.A. (eds) Flexible Automation and Intelligent Manufacturing: Establishing Bridges for More Sustainable Manufacturing Systems*. FAIM 2023. Lecture Notes in Mechanical Engineering. Springer, Cham. https://doi.org/10.1007/978-3-031-38165-2_103