

From Gameplay to Risk Reduction: A Mixed-
Methods Evaluation of Serious
Games to Improve Stakeholders' Awareness and
Communication about Natech Risk

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ゲームから減災へ：Natech リスクに関する利害関係
者の意識とコミュニケーション向上を目的としたシリア
スゲームの多面的評価

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Abstract

This research explores the effectiveness of serious game workshops as a tool for supporting Natech risk management, integrating findings from three interconnected studies. The first chapter presents the introduction to the research topic, from the general concepts of Natechs, risk management, and presents the problem statement, motivation to conduct this research and set the background., and the second chapter conducts a literature review about Natech and Natech related management in previous research. It presents Natechs' previous examples, their potential for more severe and more spread consequences than other hazards, how Natech risk differs from other risks. It presents the complex nature of Natechs, requiring a more participatory approach to manage them, presenting the need for participation from multiple stakeholders, and to explore the ways to raise risk awareness levels and promote communication among them.

The third chapter presents a study establishing the context by examining the trends, impacts and involved stakeholders in Natech accidents in Colombia. Using data from the National Agency for Environmental Licenses, supplemented by public sources like news and industry reports, the researchers compiled a database of Natech accidents between 2000-2022². The study focuses on oil and gas infrastructure, and its vulnerability to natural hazards, particularly in mountainous regions. The study identified 245 Natech events affecting different facilities during this period. Landslides and flooding emerged as the most frequent triggers. After a deeper look on some events, the study pointed out at the lack of Natech risk awareness among many actors, and underscores the need the need for improved risk assessment and mitigation strategies, considering the specific Natech hazards prevalent in the region. The study's findings contribute to a better understanding of Natech risks, needed for informed decision-making for enhancing facilities safety in hazard-prone areas. The research also underscores the importance of reporting past events and its analysis for characterizing Natech events and developing effective prevention and response measures.

Building upon this foundation, the fourth chapter of the study investigates the immediate impact of serious game workshops on Natech risk awareness and communication among diverse stakeholders in Colombia and Japan. Employing a pre- and post-workshop surveys, and serious game sessions, the study assessed the impacts in risk perception, awareness, and communication behaviors. Participants

represented various stakeholders, including government, industry, first responders, communities, and academia. The anonymous surveys evaluated participants' understanding of Natech risks, their perceived preparedness, awareness levels and their communication practices related to such hazards. The serious game, a participatory approach provided an interactive platform for multiple stakeholders to experience simulated Natech scenarios and explore collaborative risk management strategies. Participants reported increased awareness of Natech risks, improved risk perception, and enhanced communication behaviors. The study highlights the potential of serious games as a valuable tool for raising awareness, changing risk perception, and promoting dialogue among diverse stakeholders. The interactive and engaging nature of serious games facilitated a deeper understanding of Natech hazards and encouraged collaborative problem-solving.

Finally, the study extends this analysis by examining the mid- to long-term impacts of the serious game workshops. The changes in Natech risk perceptions, awareness, and risk communication processes, and, crucially, the implementation of risk reduction actions resulting from the workshops are examined, approximately one year later. The research employs a mixed-methods approach, combining a follow-up survey aiming to all workshop participants with semi-structured interviews conducted with a subset of participants. This combination allows for both data collection and in-depth exploration of individual experiences and perspectives. Key findings indicate that serious gaming workshops can positively influence Natech risk awareness, communication practices, and mitigation actions across multiple stakeholder groups in the mid-long term. The research highlights the potential of serious gaming as a valuable tool for fostering sustained engagement with Natech risk management and promoting tangible risk reduction efforts. The study also underscores the importance of longitudinal evaluation to understand the long-term effectiveness of such interventions. Further research is recommended to explore the specific mechanisms through which serious gaming achieves these positive outcomes and to investigate the contextual factors that may influence their sustainability.

Collectively, these studies provide compelling evidence for the effectiveness of serious game workshops in enhancing Natech risk management. The first study establishes the need for improved risk awareness levels and risk communication strategies, while the second and third studies demonstrate the potential of serious games to address this need, both immediately and over time. The research highlights the value of serious games as a tool for raising awareness, improving risk

perception, fostering communication, and promoting the implementation of risk reduction actions. Further research is recommended to explore the specific mechanisms through which serious gaming achieves these positive outcomes and to investigate the contextual factors that may influence their long-term sustainability.

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1. Introduction

1.1. Background

Natural hazard-triggered technological events with the consequent release of hazardous materials are known as Natech. These events have the potential to cause severe and extensive impacts in large areas, leading to huge economic and environmental damages (Cruz 2003). In addition, rapid population growth and economic development have led to having industrial facilities in hazard-prone areas resulting in the increased potential for multiple hazards, possibly leading to damage and disruption of critical infrastructure and societal activities (Yue Li et.al.,2011). Natechs pose significant challenges to communities, industries and governments, often resulting in cascading effects that exacerbate the impacts (Cruz and Suarez-Paba 2019). Natechs have become a growing concern, particularly in the field of disaster management worldwide, because they have the potential to cause severe and extensive impacts in large areas often in communities with little awareness of these hazards and hence little preparedness (Cruz, 2003). One example were the many Natech events triggered by Hurricanes Katrina and Rita in 2005 in the US that damaged oil and gas facilities leading to oil spills, chemical releases, and power outages as it has been reported by Cruz and Krausmann, (2009). The study concludes that a significant number of releases occurred primarily from platforms with natural gas releases being more common from pipelines. The authors emphasize the need for improved reporting and recording of hazmat incidents and recommend further investigation into the higher number of natural gas releases from pipelines.

Prior studies have identified increasing trends in Natech reports over the past few decades. For instance, Luo et al. (2020) examined the trends and characteristics of Natechs reported to the National Response Center database in the United States. They found that 3.98% of the total analyzed reports correspond to Natech events (1990-2017). They also identified a rising trend since 2004, and 98.24% of these being related to meteorological phenomena, which could increase due to climate change. Similarly, Girgin & Krausmann (2014) studied Natech risk in pipelines in the US and the European Union and also identified an increasing trend in the number of Natech events. For the US, they used the PHMSA (Pipeline and Hazardous Materials Safety Administration) database showing an increasing trend in reported pipeline Natechs from 1993 to 2012. This increase may be partly due to

improved reporting practices. For the European pipelines, the authors analyzed Natechs in the EGIG (European Gas Pipeline Incident Data Group) also showing an overall increasing trend between 1970 to 2009. These authors suggest caution when reporting the findings directly, since they might be affected by variations in reporting criteria and data collection methods across the different areas, and these differences should always be present when developing conclusions.

Past Natech accidents have also demonstrated a lack of awareness concerning these types of events, and limited if no risk communication between involved stakeholders. For example, in 2011, the Great East Japan earthquake and tsunami caused severe damage to the Fukushima Daiichi nuclear power plant, leading to a nuclear disaster with long-lasting environmental and health consequences (Kinoshita 2014). Most importantly, the author noted a lack of clear information and risk communication on behalf of the Japanese government following the accident, which led to public confusion and distrust.

Another case that exemplified the lack of risk communication among different stakeholders occurred in Colombia in the same year. After a heavy rainfall period, a transmission pipeline failed and leaked gasoline, leading to a delayed fire and an explosion in Dosquebradas (El Tiempo 2012; LTDA. 2011; Semana 2011). This incident resulted in the deaths of 33 individuals and damaged several households in the surrounding neighborhood. According to reports, the lack of communication among the various stakeholders following the incident led to a loss of trust within the affected communities. This lack of communication affected residents, but also caused significant damage to the industry's reputation and resulted in economic losses due to the required compensations. The lack of risk communication before the accident, led to changes in the national regulation on disaster risk management, incorporating requirements for risk assessment, provision of information to communities regarding the risks, and the concept of shared responsibilities in a territory emphasizing transparency between stakeholders.

Finally, to illustrate a more recent event, in July 2018, Soja City in Japan was affected by heavy rains that caused an aluminum factory to get flooded, leading to a subsequent vapor explosion. The explosion caused the destruction of the facility and extensive damage to several neighboring facilities (Araki et al. 2021a). In addition, one hundred and twenty households were damaged, and some people were injured. Araki et al. (2021) reported a widespread lack of awareness among the residents, the

fire department, and even city officials regarding the potential consequences of this type of accident. They concluded that in the case of Natechs, effective risk communication mechanisms need to be established to ensure all stakeholders are better prepared.

These examples indicate that Natech events can have catastrophic consequences and highlight the importance of implementing comprehensive risk management strategies that integrate natural hazard and technological risk assessment, as well as effective risk communication among all stakeholders. In all the mentioned events and the related studies, the lack of risk awareness and risk communication mechanisms caused negative impacts, such as imprecise information about evacuation orders, the lack of credibility regarding the information shared by the industries, and the damages to their reputation, and finally the lack of trust among them. Considering these events and highlighting the conclusions of the mentioned studies, the need for improved Natech risk management, including enhanced risk awareness and risk communication and collaboration among different stakeholders has become increasingly evident, as an important factor for effective risk reduction.

Previous Natech studies in Colombia are scarce. One study by Suarez-Paba et al. (2020) investigated Natech risk management and risk perception of government organizations in Colombia identifying gaps for improved risk management. Furthermore, the study found the need to promote Natech related training and specially cooperation among different stakeholders. In another study, Suarez-Paba (2019) identified and analyzed Natech risk awareness and risk management practices among industrial facilities in Colombia when dealing with Natech scenarios based on a questionnaire survey. The study found that although there is awareness of the natural hazards that can impact the industrial facilities surveyed, there is lack of knowledge regarding Natech scenarios and their impacts on business continuity. Nevertheless, the authors also found that there was willingness among industrial facility managers to learn about Natechs and their risk management.

Studies regarding Natech risk awareness, communication and risk management in other parts of the world have found similar problems, as will be discussed later section 2 of this thesis. Overall, gaps in current approaches to Natech risk management, awareness and communication point to the need for further research to better identify the main challenges and opportunities in order to develop more effective strategies, particularly in regions like Colombia that face multiple natural hazards and have a growing industrial/infrastructure base.

A previous study by Gaillard & Mercer (2013) pointed out the need to better understand the communication between local and regional actors and their dynamics, and who are the key actors that need to be involved and how to foster effective cooperation and collaboration around risk management. In the context of risk communication and risk awareness, Gaillard & Mercer (2012) highlighted the need to bridge the gap between public understanding and scientific knowledge, as well as the importance of combining technical and scientific knowledge with local and traditional knowledge to improve risk awareness and communication among all stakeholders, emphasizing the value of a participatory approach.

In the risk management context, the need for multi-stakeholder approaches has been highlighted. Particularly for Natechs, since they constitute a complex problem for risk management and risk governance with high uncertainty, it is important to bring together involved stakeholders to take part in the process (Aven and Renn 2010). Samaddar et al. (2016) have pointed out that however, this remains to be done effectively. The authors stressed the importance of employing participatory approaches over the more traditional top-down and bottom-up approaches.

Different kinds of approaches were available in the literature, from top-down, to bottom-up, however participatory approaches seemed to be the most suitable, since they have been used in different contexts, including risk management, and they have been proved to be a tool that could foster the discussion and the exchange of pertinent information among the relevant stakeholders, which is crucial to enhance coordination and trust for improved Natech preparedness and response. For knowledge transfer only, top-down and bottom-up approaches can achieve the goal. Top-down (e.g. lectures, webinars, exhibitions , or bottom-up approaches (e.g. get knowledge from communities) are not enough to bring stakeholders together (Charrière et al. 2017). Nowadays it is well accepted that risk management and risk reductions strategies need to have discussion and more participation. Participatory approaches such as focus groups or serious gaming (Fleming et al. 2020; Solinska-Nowak et al. 2018) can be helpful for raising risk awareness and also to bring the actors together and therefore providing a space to build trust. Serious games have been proved as effective tools for risk communication and awareness of Natech risks, with positive experiences (Tzioutzios 2022).

According to Nakano & Yamori (2021) and Nakano et al. (2020), there is a need to evaluate interventions to determine how they might lead to improved risk communication, awareness, and ultimately implemented actions. They acknowledge the importance of shifting from knowledge-based evaluations of disaster risk to more action-oriented approaches. Additionally, they suggest evaluating long-term impacts rather than just immediate potential effects, to capture the changes promoted by risk awareness and communication strategies. In summary, current research on Natech risk management consistently emphasizes the critical need to address deficiencies in risk awareness, risk communication, and collaboration among different stakeholders for effective risk reduction.

1.2. Problem statement and research motivation

As mentioned above, the lack of stakeholders' awareness of Natech risk, and the lack of risk communication have been observed and reported in these past events (Cruz, A.M, Krausmann, E. 2009; Araki et al. 2021a; Kinoshita 2014; Semana 2011). The governments of many countries worldwide, such as the cases of the United States of America, the European Union and Colombia (Krausmann, Cruz, and Salzano 2017) have taken proactive measures to improve their disaster risk management policies to include Natech events and make all the stakeholders in a territory to communicate, and to share the related responsibilities, the lesson from more recent events, still call for a more comprehensive approach to Natech risk management and Natech risk governance practices, particularly those related with Natech risk awareness and Natech risk communication.

Through my previous work experiences in Colombia's oil, gas, and chemical industries, as well as my role as part of engineering consultant teams and in assisting the development of disaster risk management-related regulations from a technical standpoint, I have faced various challenges posed by Natech events in the country. These experiences have helped me understand that there are differing perceptions of these issues among various stakeholders and that there is a lack of a coordinated approach to Natech risk management in Colombia. This has motivated me to undertake research in this area. From my experiences, I have observed the lack of trust among stakeholders, the absence of a shared understanding of the problem, and the lack of clear communication channels and protocols to ensure coordinated actions during Natech events as the main gaps that need to be addressed.

This was a motivation when I decided to start my PhD studies in Kyoto University. I particularly

remember one the mentioned Natech occurred in 2011, while I was a master student, studying about process safety back in Colombia. The event in Dosquebradas in December 23th 2011, marked the beginning of changes in the regulation, as I started my master program, and therefore it became an important topic on my process safety related lectures and my research back then. This included a change in Colombia from emergency and disaster preparedness to a disaster risk management paradigm. Since then, a few related decrees have been implemented, including requirements for companies and other entities to carry out risk assessments, including not only industrial scenarios, but natural and conjoint scenarios (Natech) (UNGRD 2017b). The requirements also sets rules regarding major accidents (Ministerio de Salud y Protección Social et al. 2021), requiring industry that handles hazardous materials to developed management programs for chemical accidents including Natechs. One of the new concepts that was introduced, is the co-responsibility, meaning all the actors in a territory need to participate in these risk management activities, according to their capabilities. Before coming to Japan for my PhD studies, there was still a lack of clarity and room for improvement on how to implement these regulations and policies at the local level and regional level, and how to ensure the proper coordination and cooperation among the different stakeholders.

Given the above, and the fact that Colombia is prone to various natural hazards such as floods, landslides, and earthquakes, and has numerous industrial facilities and infrastructure vulnerable to technological accidents, and considering the limited research on Natech risk management in developing countries like Colombia, the following research questions remain to be addressed:

- What is the situation in Colombia regarding Natech accident trends and impacts?
- How can we support the implementation of Natech risk management regulations and policies at the local level and regional level?
- How can we promote coordination and cooperation among the different stakeholders?

1.3. Research aim and objectives

Considering all the above, the research aim of this doctoral thesis is to support the implementation of Natech risk management policies by clarifying the roles and responsibilities of diverse stakeholders regarding Natech risk and promoting stakeholder awareness and risk communication. Furthermore, the thesis the thesis applies and evaluates the use of a serious gaming approach to increased risk awareness levels and promote risk communication concerning Natech risks among multiple and

diverse stakeholders and evaluate the effects in the short term and the mid-long term and the potential to foster the implementation of actions. To achieve this, the following research objectives have been defined:

- To understand the incidence and impacts of Natechs in Colombia, and to identify lessons regarding stakeholders' roles and responsibilities through the development of a Natech database.
- To apply and evaluate a serious game, to raise Natech risk awareness and promote risk communication among different stakeholders in a real-world setting.
- To investigate the impact of the gaming workshops on risk awareness, risk communication, and protective actions regarding Natech risk reduction in the mid-to-long term.

To achieve the first objective, the study surveyed accident reports and publicly available information sources to identify trends, affected infrastructure, and consequences of these Natech events. This involved analyzing the types of natural hazards that triggered Natech accidents involving hazardous materials, the specific infrastructure types most frequently affected, and the resulting impacts on the environment and surrounding communities. Ultimately, the study aims to contribute to a better understanding of Natech risks in Colombia, leading to the identification of potential improvements in the Natech risk assessment process, highlighting the need for stakeholder involvement and addressing the lack of communication and trust among them.

To accomplish the second research objective, a serious game previously developed was utilized. This aimed to promote communication among diverse stakeholders, identify their perceptions about Natechs, and assess the effectiveness of serious gaming interventions in enhancing risk awareness, communication, and multi-stakeholder trust.

The third research objective was to be achieved by analyzing changes in stakeholders' reported awareness levels, communication practices, and implemented risk reduction actions in the mid to long term. This was carried out using a survey and conducting semi-structured interviews with some participants to obtain feedback on the workshop outcomes.

1.4. Dissertation outline

The first step of this dissertation contains the introductions to the research topic. The second chapter conducts a literature review about Natech, Natech previous trends, and Natech Risk Management practices and risk governance policies worldwide to have a sounder theoretical background to support the research.

Chapter 3 approaches one of the identified main gaps and challenges related to Natech risk management. It refers to the lack of standardized reports and data collection on Natech events, which constrains the understanding of Natech incidence and risk. The second step towards the research aim was to analyze the historical record of events. Through a comprehensive analysis of available historical data and case studies, I investigated the incidence of these events, their direct impacts and some other indirect impacts that were only evident after complementing the information from different sources (Chapter 3). The related stakeholders were also identified alongside their responsibilities, existing risk management practices and some of the challenges they faced. After this, it was determined that the events were happening and frequently reported, but the information was not shared to raise awareness about this topic. Furthermore, in some cases the stakeholders were not even aware of the presence of others in the territories, their roles and responsibilities. It was also evidenced that this caused delays when responding to events, highlighting the importance of Natech Risk Awareness and Communication among them.

The third step was then to search for available tools to bring the stakeholders together to raise their awareness about their own responsibilities, as well as those of the others and about the Natech events affecting the national territories. As it's been mentioned, a participatory approach, particularly a serious game was to be used (Chapter 4). The implementation of the game in real-world setting, with actual stakeholders aimed to raise Natech risk awareness but also to know more about the risk communication process at the local and national levels, aiming to improve collaboration for Natech preparedness and response. We studied the Natech risk awareness and Natech risk communication elements, using a serious game during some multi stakeholder's workshops in different cities in Colombia, and a survey that allowed us to evaluate the effects of implementing these tools. This part of the research was designed with a combined approach involving both qualitative and quantitative

elements, to have a comprehensive and holistic understanding of the problem Natechs pose on different stakeholders in a territory.

One of the identified limitations of the previous study was that it only evaluated the immediate effects of the conducted workshops on awareness, but it could not evaluate the effect of the workshops in the medium to long term. Therefore, the fourth step was to evaluate the impacts of the workshops in the medium and long term to understand the effectiveness of the approach to achieve the goal of raising awareness and improving risk communication (Chapter 5). In this phase, we conducted interviews and surveys with the participants almost one year after the workshops. This aimed to identify whether or not the stakeholders' implemented actions, communication plans, and other initiatives as a result of their participation in the workshops. The data collected provided valuable insights on the effectiveness of the proposed approach, as well as identifying some remaining challenges that need to be addressed in future research and risk governance initiatives.

Finally, the last step was to integrate all the findings and present the potential of serious gaming to enhance Natech risk management (Chapter 6), that can be replicated in other contexts. The research indicates that raising Natech risk awareness and improving Natech risk communication are crucial steps to enhance the coordination and collaboration among stakeholders for better Natech preparedness and response, and can benefit from serious gaming, immediately after the activities, but can also sustained in the mid to long term.

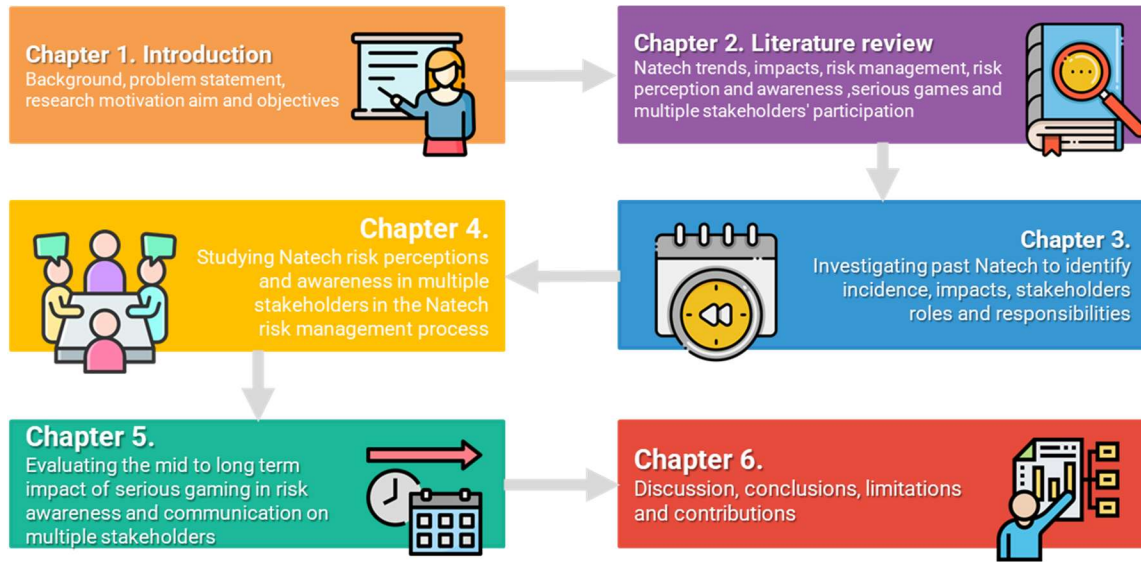


Figure 1. 1. Research methodological steps

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2. Literature review

2.1. Introduction

Natechs' impact on industrial facilities handling hazardous materials have resulted in accidents such as oil spills, explosions or fires leading to casualties, major impacts to the environment, and long periods of service disruption, as it was described above. Natech risk differs from technological or natural risk in that its multi-hazard nature requires an integrated approach to manage them (Cozzani et al. 2010). Both technological risks and Natech risks are complex, and thus they require detailed risk assessments and management processes. Earthquakes, tsunamis, floods and landslides, among other hazards, have affected industrial facilities around the world, causing loss of containment events, such as fires, explosions, and oil spills resulting in huge economic and environmental damage. The intricate interactions between these natural hazards and industrial facilities handling hazardous materials, have contributed largely to exacerbate accidental impacts on communities and the environment, particularly in urban areas.

The scientific community has recognized the need to further study Natech risks, investigate past events, understand the underlying causal factors, and develop effective prevention and mitigation strategies. Researchers have been increasingly focused on Natech risk assessment, modeling, and risk management frameworks to reduce the impacts of these events (Ricci, Casson Moreno, and Cozzani 2021; Salzano et al. 2013). Furthermore, lessons from past Natech events have served to identify the unique challenges in managing the interacting natural and technological risks.

The role of different stakeholders, including industry, local authorities, emergency responders, and the public, has been identified as critical in strengthening Natech risk governance and implementing comprehensive disaster risk reduction strategies. One key aspect that has emerged is the need for improved risk communication governance and stakeholder engagement in the risk management process.

This review examines the current state of research on Natechs, disaster risk management, risk communication governance, stakeholders in the risk management process, the study of past Natechs, lessons from previous Natechs, serious gaming and participatory approaches, risk perceptions, risk awareness and disaster risk reduction action on the long term.

2.2. Studies on past Natechs

The occurrence of natural disasters triggering technological accidents, or "Natech" events, has become increasingly recognized as a significant risk in recent years. These events can have severe consequences, have contributed largely to exacerbating accidental impacts on communities and the environment, particularly in urban areas. The frequency of these conjoint natural and technological hazards (known as Natech) is about 3-7% annually in chemical accident databases in the United States, Europe and Japan (Luo et al. 2020).

Efforts in developing approaches to integrated natural and technological risk assessment are impeded by the lack of accessible databases with reliable information on Natech accidents and incidents. According to the survey on Natech risk assessment and management practices conducted by OECD, few countries have established specific guidelines on Natech risk reduction so far (Girgin, Necci, and Krausmann 2019; Krausmann et al. 2017; Ricci et al. 2021).

A comprehensive analysis of the occurrence of Natech events in the process industry provided insights on the trends, geographical distribution, technological scenarios, and consequences in terms of human losses and asset damages (Ricci et al., 2021). The study found that meteorological events, such as storms, extreme temperatures and lightning were the main triggers of Natech scenarios, and an increasing number of Natech events was observed over time, with specific increases corresponding to the occurrence of severe natural disasters.

Past Natech events have provided valuable lessons for improving risk management approaches. For the case of Natechs, given their nature, they are low probability and high consequence events. Some examples show the devastating impacts of Natechs and demonstrated the need for integrated risk assessment and management approaches that account for multi-hazard scenarios. Some studies have investigated the chain of events and impacts of Natechs in the past, providing some lessons for

the risk management and risk governance.

- The Hurricane Katrina in the US, that led to chemical spills and fires from damaged industrial facilities, highlighted the need for better emergency planning and preparedness for Natech risks (A.M. Cruz* 2009). These Natech events also underscored the need for strengthening infrastructure resilience, and community preparedness (Girgin et al. 2019).
- The Fukushima Daiichi nuclear disaster in Japan, triggered by the 2011 Tohoku earthquake and tsunami, also revealed the insufficient consideration of multi-hazard scenarios in risk assessment and management, and highlighted the importance of considering multi-hazard scenarios in risk assessment and emergency planning (Kinoshita 2014).
- The pipeline failure and leak, followed by a fire and an explosion in Dosquebradas (El Tiempo 2012; LTDA. 2011), Colombia after a heavy rainfall period in 2011, was another example showcasing the cascading effects of natural hazards on industrial facilities. After the event, the lack of risk communication among the different stakeholders involved was identified as a key issue that hindered effective emergency response and recovery.

Other studies have delved deeper into the identified reporting trends in different regions of the world. One example is the study carried out by (Luo et al. 2020). These authors developed a semi-intelligent framework to identify Natech incidents from the National Response Center database, which serves as the point of contact in the United States for reporting all hazardous substance releases, oil spills, chemical spills, radiological releases, and maritime security incidents. The NRC operates a 24/7 hotline and receives reports from the public, industry, and other government agencies. Their results showed that natural hazards such as storms, floods, and seismic events are the most common triggers for Natech incidents. From the total reports they gathered from 1990 to 2017, 3.98% corresponded to Natech reports. They identified an increasing trend in Natech reports over time, starting in the year 2004. Of all the Natechs, 98.24% were related to meteorological phenomena. The authors mention that this trend could further increase due to climate change.

Girgin & Krausmann (2014) analyzed the trends in the US and Europe, specifically for pipelines. In the US, they used the PHMSA database, which showed an increasing trend in reported pipeline

Natechs from 1993 to 2012. The authors attributed this increase in part to improved reporting practices. Likewise, in Europe, the authors examined the European Gas Pipeline Incident Data Group database. EGIG is a group of European natural gas transmission pipeline operators who collaborate to collect and analyze incident data to improve pipeline safety. The analysis of this data also indicates an overall increasing trend. (Girgin and Krausmann 2014a) noted that these variations in reporting criteria and data collection methods across regions may also be affected by changing reporting practices over time.

While in Europe and North America, Natech events are widely reported and analyzed, in other parts of the world, such as Latin America, data availability and analysis of these events is still limited.

2.3. Natech Risk Assessment and Management

The risk assessment process has been implemented in the last decades in oil and gas industries and, more recently in some countries, Natech specific regulations for risk assessment are being put into effect. However, there is still a lot to be done in terms of raising awareness and including Natech scenarios on these assessments (El Hajj et al. 2015). Traditional risk assessment approaches have been focused on single hazards and lacked integration with wider societal and economic systems.

The assessment of Natech risks presents several challenges compared to traditional technological risk assessment (Ahmadi et al. 2020; Cozzani, Antonioni, and Spadoni 2006). Besides the need to evaluate the impact of natural hazards on industrial systems, there is also a need to account for the interaction and cascade effects between different types of hazards. Existing approaches for Natech risk assessment rely on the use of complex tools and models that often require detailed data on both the industrial facility and the natural hazards, which can be a significant challenge in many cases. To overcome these challenges, there have been efforts to develop more holistic and comprehensive frameworks for Natech risk assessment and management.

In the last decades, some works aimed at the development of risk analysis and assessment methodologies, considering fixed facilities as critical equipment and the impacts of natural events such as earthquakes (Antonioni et al. 2015; Campedel, M et al. 2008), flooding (Landucci, G. et al. 2016) and lately even for some other natural events like lightning have been proposed (Misuri, Antonioni, and Cozzani 2020). These include the analysis of both direct Natech scenarios, related to

the damage of equipment, and indirect Natech scenarios, related to the failure of supporting systems like utilities.

As mentioned in OECD previous workshops (OECD 2012), developing specific guidelines is still due to achieve Natech risk reduction. When it comes to Natech, the uncertainty is high for both, the natural and the technological event occurrence and intensity. One way to deal with this difficulty on the assessment process, is to build well-defined scenarios. One approach that has been used by a few studies is studying past events, to understand the chain of events and identify key elements for the scenario definition (Ricci et al. 2021).

Another study that provided a panorama about the available approaches regarding Natechs was developed by (Mesa-Gómez, Casal, and Muñoz 2020). The main contributions are the comprehensive Review of Natech Risk Analysis, providing a systematic review of existing methodologies for Natech risk analysis, categorizing them based on the type of hazard considered (single, sequential, or cascading), the type of analysis (qualitative, semi-quantitative, or quantitative), and the specific techniques employed (e.g., fault tree analysis, event tree analysis, Bayesian networks). The study also focused on multi-hazard approaches, considering the combined effects of multiple natural hazards on technological systems, analyzing the trends and challenges in this area, highlighting the need for more integrated and comprehensive risk assessment frameworks. Finally, the study highlighted the key gaps in current Natech risk analysis methodologies, such as the limited consideration of cascading effects and the lack of standardized approaches for integrating different types of hazards. This study provided a guide for the future research and development in this critical area.

2.4. Natech Risk awareness and Risk Communication

Natechs have the potential to cause severe and extensive impacts in large areas, often affecting communities with limited awareness and inadequate preparedness for these hazards (Araki et al. 2021a; Cruz 2003; Nobuhito Ohtsu et al. 2023). The lack of stakeholder awareness regarding Natech risks, as well as the insufficient risk communication among them, can hinder effective evacuation and emergency management decision-making. Moreover, enhancing risk awareness and promoting risk communication are essential steps that can enable the implementation of effective risk management practices.

The need for improving risk communication, stakeholder engagement, and long-term resilience building are critical lessons that have emerged from past Natech disasters. Effective communication is critical to promoting risk awareness, disaster preparedness and resilience among the various stakeholders involved in Natech risk management (Krausmann et al. 2017). However, the low visibility of Natech events in risk communication systems has been highlighted by recent studies (Lestari et al. 2021). Improving the quality and accessibility of Natech-related information for the public, industry, and policymakers is essential (Tzioutzios 2022).

Risk communication is an interactive process of exchanging information and opinions among individuals, groups, and institutions. It involves multiple messages about the nature of risk and other non-risk-specific messages that express concerns, opinions, or reactions to risk messages or to legal and institutional arrangements for risk management (Aven and Renn 2010). The ultimate goal of risk communication is to assist stakeholders and the public in understanding the rationale behind risk-based information and to arrive at balanced judgments that reflect the factual evidence about the matter at hand in relation to their own interests and values. In other words, good practices in risk communication are meant to help all affected parties make informed choices about matters of concern to them.

At the same time, the purpose of risk communication should not be seen as an attempt to convince people (Aven and Renn 2010), such as the consumers of a risk-bearing product, that the communicator, which could be a government agency, has done the right thing. Rather, the purpose is to provide people with all the information they need to make decisions or judgments that reflect the available knowledge and their own preferences. Some of the main challenges that risk communication needs to address include explaining the concept of probabilities, coping with different time scales (such as mid-term or long-term effects), providing credibility of the agencies and institutions that provide risk information, dealing with the diversity of stakeholders involved in the risk management phase, and addressing intercultural differences within heterogeneous societies.

In a previous study, some participants expressed strong concerns about the potential consequences of Natech events since they participated in the workshops while others expressed their perceptions have not changed since they have been exposed previously to the Natech possibilities (Logan et al.,

2008). The researchers believe the outcomes of the study provides insights that can inform the design of more inclusive and effective Natech risk management strategies in Colombia and potentially other countries facing similar challenges.

The literature indicates that raising risk awareness and improving risk communication among diverse stakeholders are critical for developing and implementing effective disaster risk reduction measures.

2.5. Stakeholders' roles and responsibilities

Risk governance refers to a collaborative decision-making process that engages both governmental entities and non-governmental stakeholders. Governing choices in modern societies is seen as an interplay between governmental institutions, economic forces and civil society actors (such as NGOs). In this perspective, risk governance should consider both the technical risk assessment and the societal aspects of risk, such as perception, concerns, and acceptability (Ortwin Renn 2008). Good risk governance relies on the engagement and cooperation of different stakeholder groups, including public authorities, industry, civil society organizations and the general public.

Natechs can be defined as complex and highly uncertain problems for disaster risk management (DRM) and disaster risk governance (DRG), requiring the participation of some main stakeholders (Aven and Renn 2010). They are complex because they involve multiple hazards and cascading effects, and they are uncertain since they require consideration of the probabilities and outcomes of two sets of events (the natural event and the technological event). They are uncertain because the probabilities and outcomes of the natural hazard and the technological hazard must be considered together, and both of them are not certainties.

Therefore, as it has been established by (Aven and Renn 2010) the main stakeholders include:

- Government agencies are responsible for disaster/emergency management, environmental protection, and industrial safety regulation.
- Industrial facility operators of hazardous installations.
- First responders (fire, police, emergency medical services).
- Local communities and the general public.

Some previous studies have also stated that effective Natech risk management necessitates the coordinated efforts and participation of various stakeholders (Cruz and Suarez-Paba 2019). Other studies have emphasized that risk management processes can benefit through the co-production of knowledge, where risk analysts, decision-makers, and other stakeholders collaboratively develop policies through an iterative process of dialogue, suggesting for the need of more participatory approaches (David R. Johnson 2019).

2.6. Participatory approaches and serious gaming approaches

As previous research has shown, implementing disaster risk reduction strategies can face challenges, such as difficulties in bringing diverse stakeholders together and building trust. Additionally, enhancing risk awareness and effective risk communication among the involved parties remains an ongoing issue that requires attention (Gaillard and Mercer 2013). Participatory approaches can help improve risk awareness and foster collaboration among different stakeholders in Natech risk management.

Participatory approaches, such as serious gaming and simulation exercises, can engage stakeholders, enhance risk awareness, and promote shared understanding of the complex Natech risk landscape (Tzioutzios 2022).

(Solinska-Nowak et al. 2018) (Solińska-Nowak et al., 2018) describes serious games as valuable tools for disaster risk management education and engagement. The authors highlight their potential to reach diverse audiences, including affected communities, policymakers, and other stakeholders. They emphasize the capacity of serious games to simulate disaster scenarios realistically, promoting experiential learning and improved understanding of DRM challenges. The study also notes the potential of serious games to raise disaster risk awareness, facilitate hazard identification, encourage preventive actions, and foster empathy and perspective-taking among players. However, the authors also acknowledge limitations, including the scarcity of rigorous research on the effectiveness of serious games in DRM and the need for more user-tailored game design and robust evaluation methodologies.

Overall, the literature suggests that participatory approaches, such as serious gaming, can be valuable in enhancing stakeholder engagement, risk awareness, and collaborative disaster risk reduction efforts, particularly for complex Natech risk management.

2.7. Action based-evaluation and long term studies

The existing literature on Natech risk education (Iwahori et al. 2017; Nakano et al. 2020) suggests the need for more long-term, action-based evaluations to understand the lasting impacts of participatory approaches and risk communication strategies. However, the existing literature on long-term, action-based evaluations of risk management strategies was found limited.

A literature review highlights the importance of long-term, action-oriented evaluation to truly understand the effectiveness of disaster education programs for children. Iwahori et al. (2017) noted that current research on disaster risk reduction education tends to rely on a knowledge transfer paradigm, which manifests in two ways. First, the evaluation methodology often involves pre- and post-intervention questionnaire surveys to assess the reduction in the knowledge gap between experts and the public. Second, DRR education interventions in schools and communities are typically evaluated over a very short timeframe. The authors argue that this short-term knowledge transfer model fails to capture the deeper and more enduring impacts on attitudes, behaviors, and ultimately, disaster preparedness actions.

Nakano et al. (2020) emphasized that long-term, action-oriented evaluation is crucial to comprehending the true effectiveness of disaster risk reduction education. They critique the prevalent short-term, knowledge-transfer approach, which primarily focuses on immediate knowledge gains rather than sustained behavioral changes and actual disaster preparedness actions. The authors highlight how long-term evaluation can reveal the development of proactive attitudes, the impact of DRR education on long-term community engagement, and the effectiveness of risk reduction efforts during actual disasters. The study showcases the benefits of this approach through a case study of a DRR education program in Nepal, demonstrating how long-term evaluation revealed the sustained impact of the program on students' attitudes and actions, even years after their initial participation. The authors conclude that long-term evaluation is essential for gaining a comprehensive understanding of the effectiveness and sustainability of DRR education initiatives.

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3. Investigating past Natechs to identify incidence, impacts, stakeholders' roles and responsibilities

Abstract

Considering the current challenges for implementing Natech risk management and the research gaps identified in the introduction (Chapter 1), and the state of the art shown by the literature review (Chapter 2), this chapter aims to understand the incidence and impacts of these Natechs in Colombia, and to identify lessons regarding stakeholder roles and responsibilities through the development of a Natech database.

The oil and gas industry in Colombia has been identified as a sector with high potential for Natech accidents due to its vulnerability to natural hazards like earthquakes, floods, and landslides. However, as presented, few studies have investigated the implementation of national policies related to these events, or the incidence and impacts of Natech events in the industry. In this context, it is valuable to analyze the available information on historical Natech events that have occurred in the oil and gas industry in Colombia, their impacts, and how these events have been addressed by the different stakeholders involved.

To this end, a Natech database was developed to compile available information on historical Natech events in the Colombian oil and gas sector. This was achieved through a survey of chemical accident reports in Colombia to determine the type of infrastructure most frequently affected, and the consequences of the Natech accidents in the territory. Data for the study was obtained from the National Agency for Environmental Licenses in Colombia. Following data aggregation and cleaning, a non-exhaustive keyword-based search was carried out to identify Natech accident reports. The Natech accident data collected was complemented by surveying publicly available information sources, such as news, industry, and government reports to consolidate a Natech database. The study results show 245 Natech events were reported between 2000-2022. Natechs events have been more frequently reported in the last decade. Flooding and landslides were found to be the most common natural hazards causing damage. Of these 245 events, 106 affected oil and gas transmission pipelines. These events were studied in depth, since these pipelines pass through natural hazard prone areas, where different stakeholders were identified. Some pipeline segments were involved in several

Natech accidents, pointing to the importance of reviewing risk management measures in place. A detailed analysis based on complimentary sources points to a lack of dialogue among involved stakeholders, their roles and responsibilities, and problems regarding risk information and communication processes. This work also helped to identify direct and (often ignored) indirect impacts, providing some insights, could be useful for the industry and the government entities to implement risk reduction measures and improve risk management policies.

3.1. Introduction

The interactions between natural hazards and industrial infrastructure handling hazardous materials have often led to chemical accidents that impact communities and the environment. These natural hazard-triggered chemical accidents are known as Natechs (Suarez-Paba et al. 2019). Colombia is prone to natural hazards (i.e., floods, landslides, earthquakes) (World Bank n.d.-a) and they have affected industrial facilities and infrastructure, causing events where hazardous materials were spilled, leading to outcomes such as fires, explosions, and oil spills, resulting in substantial economic and environmental damage in the past (El Tiempo 2012; LTDA. 2011; Semana 2011).

This situation is particularly complex in urban areas worldwide, where these facilities are more common, due to society's energy requirements (Ramírez-Camacho et al. 2019). In Colombia, there is a high number of chemical industries, including oil and gas, that are vulnerable to natural hazards (World Bank n.d.-a). When considering the oil and gas sector only, over 8000 km of oil and gas transmission pipelines owned by ECOPETROL, the main oil and gas company in the country, are spread all over the territory (Bayona Lina 2017). Since these pipelines often traverse regions prone to natural hazards, they are at high risk of being affected in the event of a Natech. Evidence of some Natechs in Colombia like the explosion in Dosquebradas in 2011, has been presented, however no previous studies regarding their incidence, impacts and stakeholders' responsibilities were found.

When natural hazards affect pipelines, the impacts tend to be higher and last longer, than those affected by other causes, such as corrosion or third-party damage (E. M. Lee, et al. 2016). These events have been registered in Colombia, a mountainous country with extensive pipelines due to oil production in several parts of the country, a few oil refineries, and other oil and gas infrastructure. Oil and gas transmission pipelines are vulnerable to extreme natural hazard events, particularly heavy

rains, flooding, and rain-induced landslides that could become more frequent and more intense due to climate change (Suarez-Paba et al., 2019). Given the widespread distribution of Colombia's pipelines, they frequently pass through natural hazard-prone areas, exposing them to potential landslides and flooding, among other hazards. Landslide impacts on pipelines often result in significant leaks leading to casualties, major environmental impacts, and long periods of service disruption, causing extensive damage every year (Luo et al. 2020). However, Colombia has limited information regarding Natech event frequency, accident trends and dynamics, and their direct and indirect impacts. The present work seeks to identify and analyze accident reports in Colombia to fill this gap.

Although progress has been made on reducing industrial accidents in Colombia, the implementation of Natech risk management strategies remains limited. In this context, the compilation of historical Natech events and the identification of commonalities in terms of natural triggers, affected industrial infrastructure, and consequences, may provide valuable insights into the challenges faced by stakeholders.

3.2. Literature review

A few studies have investigated past events to better understand Natech trends and dynamics. Cozzani et al. (Cozzani et al. 2010) analyzed several accident databases in Europe and the United States (U.S.). They identified 272 accidents caused by flooding on different industrial fixed facilities and highlighted the importance of considering flood triggered scenarios. The authors also developed event trees for quantitative assessment of such accidents. Another study by Sengul *et al.* (Sengul et al. 2012) in 2012 examined trends in the NRC (National Response Center) database for the U.S., identifying a large number of hazardous materials releases due to natural hazards between 1990 and 2008. This study concluded that large releases occurred most frequently due to major natural hazards and noted an increase in the number of reported Natechs over time.

Given the importance of learning from past events, Luo et al. (2020) proposed and used a data mining methodology to identify and extract Natech events from the NRC (National Response Center) database between 1990 and 2017. The authors found that the majority of the retrieved Natechs in the study period were related to meteorological phenomena, with hurricanes, heavy rains, and storms as

the main hazards.

Girgin and Krausmann (2014b), at the Joint Research Centre in Europe, investigated Natech accidents involving pipelines in Europe and the United States. Their results highlighted the importance of landslides as a threat to this infrastructure. Finally, Paltrinieri and Khan (2016) gathered information on two major events and found that materialized scenarios were not considered in the safety reports or the municipalities' disaster risk management plans. Their study demonstrated that even after previous accidents, stakeholder organizations regarded these events as unavoidable because the initial cause was a natural event. In the cases examined, there were early warnings or similar previous events, but the available analysis methodologies failed to identify these types of scenarios as Natechs.

Some authors conducted accident analyses for industrial facilities, considering only technological events in pipelines. Ramírez-Camacho et al. (2019) examined a group of accidents caused by the explosion of natural gas pipelines, leading to crater formation, and also affecting parallel pipelines sharing the pipelines' ROW (Right of way). Other previous works analyzing the influence of several factors on the accident rate are related to occupational health, traffic, and other industries, such as in the mining industry (Xie Xuecai et al. 2022). Yet other studies have conducted statistical analyses on chemical industry accidents, particularly related to ammonium nitrate storage (Yue Yue, et al., 2023). C.Y. Lam and A. M. Cruz (2019), using complex network theory to carry out probabilistic risk modeling, identified risk factors for events on gas distribution pipelines in Japanese cities.

The above studies can support risk assessments, which have been implemented in the last decades in oil and gas industries and, more recently some countries have adopted regulations that specifically call for Natech specific considerations in the risk assessment process (Anon n.d.; Ministerio de Salud y Protección Social et al. 2021; Parlamento Europeo n.d.; UNGRD 2017a). In recent decades, some works aimed at the study of assessment methodologies, considering fixed facilities as critical equipment and the impacts of natural events such as earthquakes Giacomo Antonioni et al. (2007), flooding (Landucci, G. et al. 2016) and lately even lightning (Misuri et al. 2020), have been proposed. Nevertheless, studies considering transmission pipelines and landslides are still scarce.

Guidelines (OECD 2015), have been developed worldwide to support the inclusion of Natech

scenarios in risk assessment processes for industrial facilities. However, there is still a lot to be done in terms of including Natech scenarios in these assessments. As mentioned in OECD's previous workshops (OECD 2012), developing specific guidelines is still needed to achieve Natech risk reduction. With Natech, the uncertainty is high for both the natural and the technological event occurrence and intensity. One way to deal with this difficulty in the assessment process is to study past events, to help define the scenarios. The present work investigates accident reports in Colombia to identify and analyze past Natech events providing insights on potential accident scenarios that are much needed for future risk assessments.

As mentioned above, even though Natechs can cause severe impacts, they are still considered low frequency, making related information scarce. Additionally, Natech related studies are complicated to carry out, as they consider the natural hazards on the one hand, and the technological events on the other hand, and also, they need to consider the facility type and the possible final events, given the presence of different hazardous materials and operating conditions. Thus, it is difficult to find reports of past events to study their trends and dynamics. This makes the study of reported Natechs relevant, as there is still room to learn from previous events, thereby allowing to improve the Natech risk assessment process.

The present study holds significant value as it aims to identify and analyze past Natech accidents reported in a database established by the Colombian national authorities in the period 2000 to 2022. The analysis seeks to understand not only Natech accident trends, but also the direct and indirect impacts, including impacts on communities. Furthermore, it identifies important lessons for industry operators and government entities, providing safety recommendations for improved risk management and safer territories.

3.3. Methodology

The methodological steps for this study are presented in the following figure.

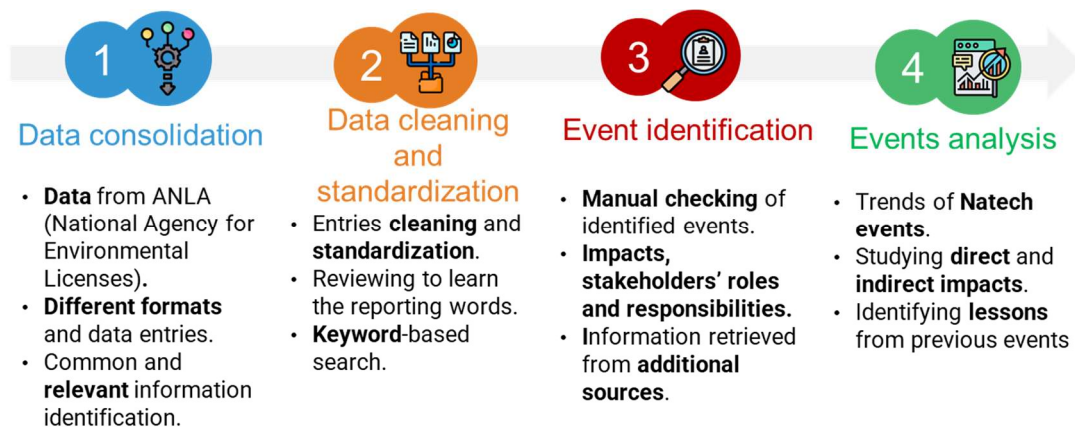


Figure 3. 1. Methodology to establish a Natech database

3.3.1. ANLA Database consolidation

The analysis of past accidents was carried out using a database from the National Agency for Environmental Licenses (ANLA). The ANLA database was chosen because it is the national accident database related to the country's oil and gas, mining, and energy sectors. It also includes accident reports on oil and gas transmission pipelines. The database contains a total of 10,322 entries from 2000 to 2022, where any 'loss of containment' (LOC) event is to be registered according to national regulations. This database has been evolving since it was created in response to the requirements of the regulations in place. This has resulted in different reporting formats with different information collected, possibly influencing the number of related reports and the information included.

The ANLA database comprises a set of files, each with different formats that have changed over the years. The first challenge for the current project was consolidating the data in those files into a unique file. Consequently, it was necessary to define some common information fields (e.g., date, location, reported cause, if available, responsible company, released hazardous material, pipeline system name, and event description, among others) that were relevant for the accident analysis to be conducted. A consolidated database based on the ANLA files was created and used for the analysis.

3.3.2. Data cleaning and standardization

After preparing the consolidated database, data cleaning and standardization were the next steps.

The first step was to eliminate duplicated entries. A total of 35 duplicated events were identified and deleted. The second step was language standardization. For example, we checked for possible typos, plural or singular words used for the same term, and so on. Then, we standardized the names given to the substances.

In this study, we are interested in identifying Natech events in the oil and gas transmission pipelines. In order to eliminate entries in other sectors, it was necessary to identify those other sectors. Data after 2016, contains a “sector” field that includes “mining”, “electricity” and “oil and gas”. However, this field is missing in data prior to 2016. Using a keyword search, entries related to mining and the electricity sectors were identified and excluded from the analysis. A total of 10,207 (98.9 % of the total) events related to the oil and gas sector were identified. The next step involved identifying events related to oil and gas transmission pipelines. Entries from 2020 contain a “subsector” field that includes fixed facilities oil and gas transmission pipelines. However, entries before 2020 do not. Thus, it was necessary to conduct another keyword search and manual search by reading through the event descriptions to categorize entries based on their subsector (e.g., pipelines, production units, transportation trucks).

3.3.3.Event description

The goal here was to identify Natech events which occurred on oil and gas transmission pipelines. Initially, the identification process used a database column called “Cause category”, filtering those entries categorized as “Natural event”. This step considered all the reported natural events, including landslides, flooding, lightning, wildfires, and hurricanes, among others defined by the Colombian government regulation (UNGRD 2017b). Those database entries provided relevant keywords for different natural events including how they are named based on local knowledge, and organizational knowledge from the reporting companies. This step was particularly time-consuming, since the people in charge of reporting have very different cultural and academic backgrounds, and consequently a similar event could be reported differently. This search used all the columns related to causes, substances, pipeline systems and event description, and consequences. A list of possible names for the natural hazards in Spanish (the original language of the database) from different regions was established using additional information sources and the previous experiences of the authors to perform a more comprehensive search. The following list was developed considering the national

terminology developed by the UNGRD (The Colombian National Unit for Disaster Risk Management), as shown on Table 3. 1. This list was used for a keyword-based search to identify Natech events in oil and gas transmission pipelines (from now on referred to as pipeline-Natechs).

Table 3. 1. Considered natural hazards. Adapted from (UNGRD 2017b)

Natural hazard	Possible keywords (Spanish)
Earthquake	temblor, temblor de tierra, terremoto, sismo, movimiento telúrico.
Strong winds Tropical cyclone	Vendaval, fuertes vientos, vientos fuertes, huracán, tormenta tropical, ventisca, ráfaga, ventarrón, temporal, borrasca y tromba.
Wildfire	Incendios forestales, incendios de suelos, incendio de hojarasca, incendio de la cobertura vegetal.
Landslide	Remoción de masa, deslizamiento, remoción de tierra, reptamiento de suelos, reptamiento, derrumbe, talud, tierra, pendientes, suelos, alud de tierra, avalanchas, volcamientos, desprendimientos de tierra, corrimientos de tierra, movimiento de tierras, caídas de tierra, hundimientos de la tierra, rompimiento de montañas, escurrimiento de la tierra, resbalamiento de la tierra.

For some events, the information was not complete, and publicly available information on the accidents was consulted. These additional information sources include:

- The UNGRD national database, collects reports on emergencies including natural hazard events affecting communities in Colombia. After identifying natural events that triggered pipeline-Natechs, this database provided valuable information to complement the consequences of the events on communities.
- News from international, national, regional, and local media. Articles, reports, tweets, photos, and videos including social media.
- Governmental sources: Local and regional government disaster risk management plans where the events occurred complemented the information about the impacts on communities and the environment. Some regulations concerning the environmental licenses given by ANLA were also gathered. These public documents provided information regarding the operations, conditions and approximate location of some pipeline-Natechs.

- Industry reports: Publicly available reports regarding operation and maintenance practices, service disruption, pipeline location and operational conditions helped to identify affected facilities and details about the chain of events.

Finally, potential pipeline-Natechs were identified through the keyword search, while also considering the pipelines information provided in the entries, particularly the column called “Event description”. After identifying Natech events using the keyword search, each Natech event was checked manually to confirm that the event was triggered by or resulted as a consequence of a natural hazard event.

Some categorized values were assigned to the database fields, defining standard values for the analysis according to the following categories:

- Occurrence date: Month and year.
- Occurrence Location: Municipality and region.
- Hazardous materials: natural gas, crude oil, gasoline, LPG, diesel or biodiesel, Jet A1.
- Pipeline system involved: the names may not have matched publicly available information because reporters sometimes used names for subsystems. Using regulation information provided by ANLA, they were grouped as systems.
- Pipeline properties: diameter, year of construction, age when the accident occurred.
- Consequences and final event classification: fires, explosions, spillages, air pollution, water and soil contamination, service disruption.
- Environmental factors: Oceanic Niño Index (ONI). This information was completed using Colombian government entities information and the data from the United States National Oceanic and Atmospheric Administration (NOOA).
- Impacts on communities, environment, and infrastructure. Using the additional sources, it was possible to determine details about what happened and how it affected the mentioned targets.
- General description of the Impacts on communities, environment and infrastructure. For these columns, the information was extracted from the original columns called “Observations, Notes and impacts”, containing a general description of the event and the additional information sources mentioned above.

The next step in the analysis was to identify impacts on communities and the environment considering

area-wide impacts, pipeline properties (e.g., operation conditions, age, diameter,), and hazardous materials.

3.4. Results

3.4.1. Event identification

From the original 10,322 events in the consolidated database, 10,207 events (99 %) are related to the oil and gas sector (see Figure 3. 2.a). Of these, 6,181 events (61%) occurred in fixed facilities and 3,406 events (33 %) on oil and gas transmission pipelines (see Figure 3. 2b).

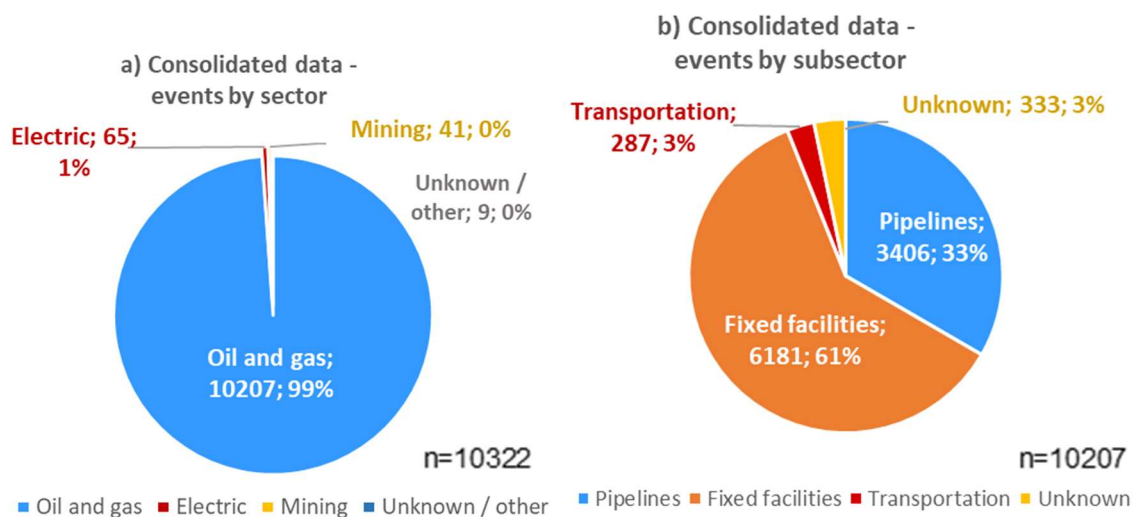


Figure 3. 2. Consolidated data 2a) Events by sector, 2b) Events by subsector.

Out of the original 10,322 events, 245 (2.4 %) events were identified as Natech accidents triggered by different natural hazard events such as landslides, flooding, wildfires, lightning, and hurricanes, affecting all types of sectors and facilities (See Figure 3. 3). 549 events (5.31 %) were categorized as unknown, because it was not possible to determine if a Natech occurred or not with the available information. All of the identified Natech by natural event are presented in the Table 3. 2

Table 3. 2. Identified Natech by natural event

Natural hazard	# Total Natech	# Pipeline Natech	# Fixed facilities Natech	# Hazmat Transportation Natech
Landslides	98	91	7	No identified Natech
Flooding / heavy rainfall	114	14	100	
Hurricane / Tropical storm	6	1	5	
Wildfires	21	0	21	
Ligthning	6	0	6	
Total natural events	245	106	139	

A total of 230 out of 245 Natechs occurred in oil and gas facilities (Figure 3. 3).

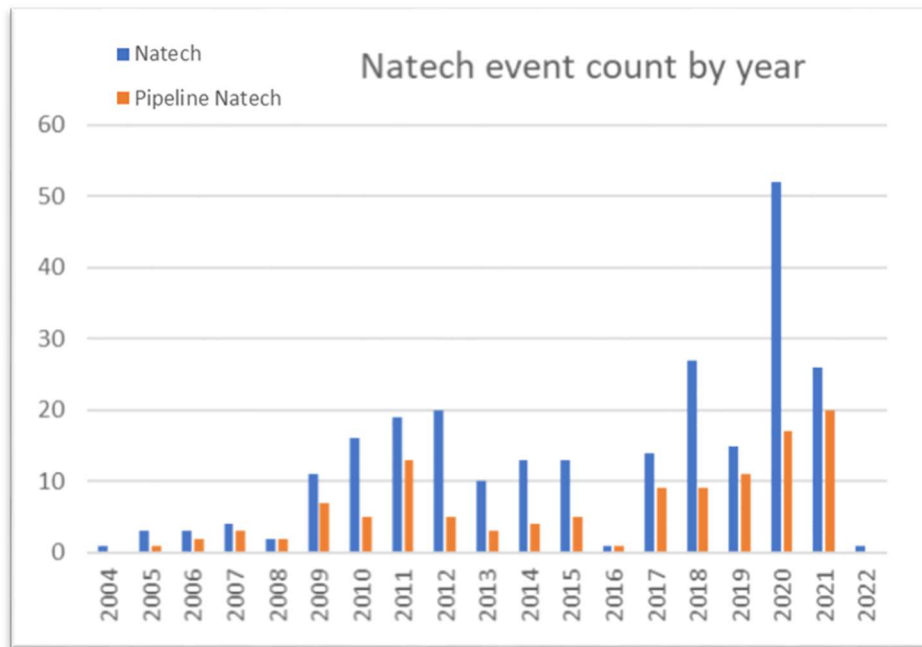


Figure 3. 3. Trends of Natechs during the studied period in all the facilities and pipelines.

After identifying 245 total Natechs and given the focus on roles and responsibilities of the stakeholders in the territory, a deeper analysis was performed on the Natechs that affected pipeline

facilities. Since these transmission pipelines pass through shared territories and potentially impact communities, required coordination from the local and regional, and possibly national governments, the study focused on analyzing those 110 pipeline-Natech events.

Over 110 events were identified as possible pipeline Natechs, and after the manual confirmation, a total of 106 events were confirmed as transmission pipeline-related Natech (herewith referred to as pipeline-Natechs) reports during the study period from 2000 to 2022.

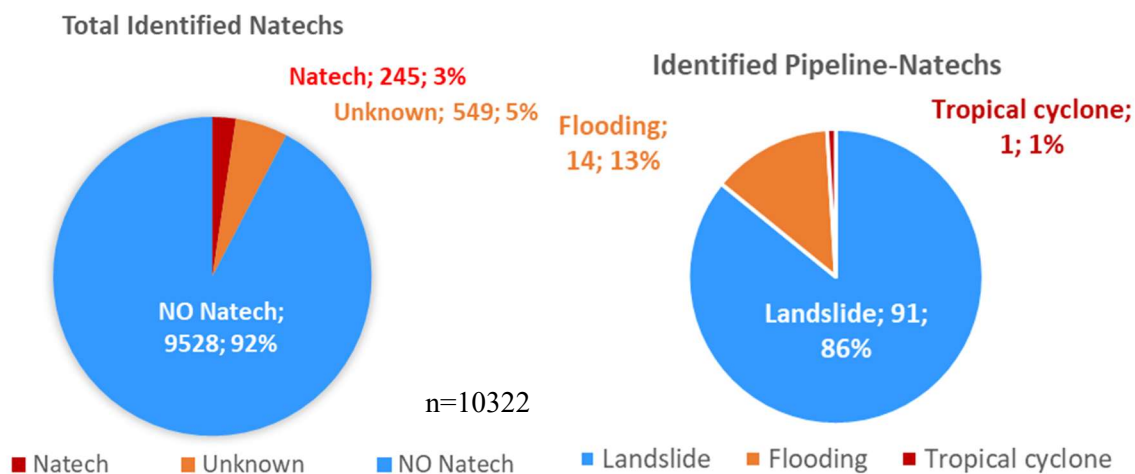


Figure 3. 4. Identified Natechs. 2a) Total Natechs 2b) Total pipeline Natechs by natural event.

Landslides were the main natural hazard triggering Natechs on transmission pipelines (91 events), followed by flooding (14 events), and finally, one event caused by a tropical cyclone. It is important to note that all the landslides were caused by heavy rainfall. No events triggered by earthquakes were identified in the database.

3.4.2. Pipeline-Natech accident analysis

As mentioned in the previous section, 106 pipeline-Natech events were identified and analyzed. An increasing trend in the reported events can be seen in Figure 3. 5. It is important to consider that the reporting requirements significantly changed in 2016. An abnormality can be observed during 2016 because ANLA could not share the information with us for that period. Figure 3. 5 indicates that there is an increasing trend both for the total number of pipeline-accident reports (left) and the

pipeline-Natech reports (right), which is related to changes in regulation, requiring LOC's to be reported to ANLA. The trend is observed both for the total number of events, and specially accentuated for pipeline-Natech events (Figure 3. 5a), corresponding to changes in rainfall patterns. Some peaks can be observed in the 2011-2012 and 2017, 2020 periods. These periods also coincide with La Niña phenomenon being declared for those years. Consequently, the rainfall patterns increased.

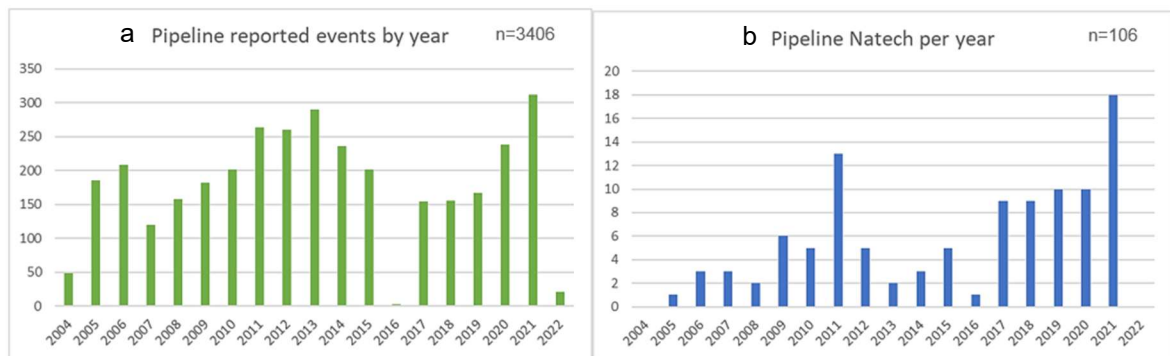


Figure 3. 5. Total identified pipeline reports (a), and pipeline-related Natech reports (b), between 2000-2022 in the ANLA database.

3.4.3. Direct and indirect impacts

For 71 out of the 106 identified Natech events it was possible to obtain information regarding impacts on the surrounding communities and the environment. These were classified as direct, such as injuries, deaths or health problems and environmental contamination caused by the release of energy or substance involved in the Natech event. Indirect and wide-area impacts, on the other hand, include water and gas supply disruption and psychological effects (reported for one municipality in the Disaster Risk Management local plan) that were not caused by the direct effect of the Natech event (See Figure 3. 6). During the study period, direct impacts included 31 reported deaths, at least 86 injured and 650 neighboring homes affected. 4 events caused direct impacts of the events triggered fires and explosions. Only 41 events (47%) reported direct environmental effects, such as air pollution, soil and water contamination (Figure 3. 6). Indirect impacts included the interruption of natural gas service in several municipalities (in some cases, for periods of more than 3 months) and fuel availability.

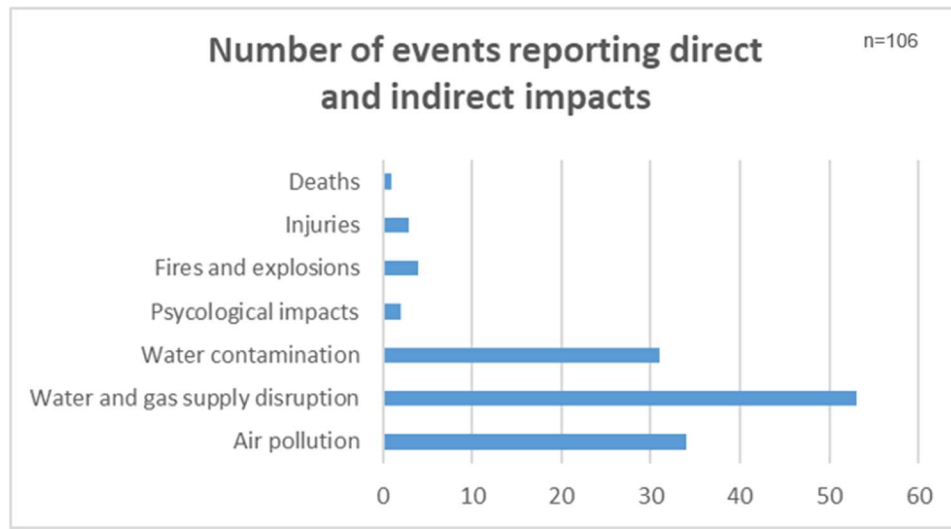


Figure 3. 6. Analysis of past events impacts on people and the environment.

3.4.4.Type of substances

The most frequently reported hazardous material releases were natural gas (63% of the total identified pipeline-Natechs), a highly flammable substance that could lead to fires and explosions and induce suffocation in people exposed (See Figure 3. 7a). After natural gas, we found that crude oil was present in 20% of the events. Crude oil can cause important impacts on the environment, contaminating both soil and water and affecting flora and fauna in the area.

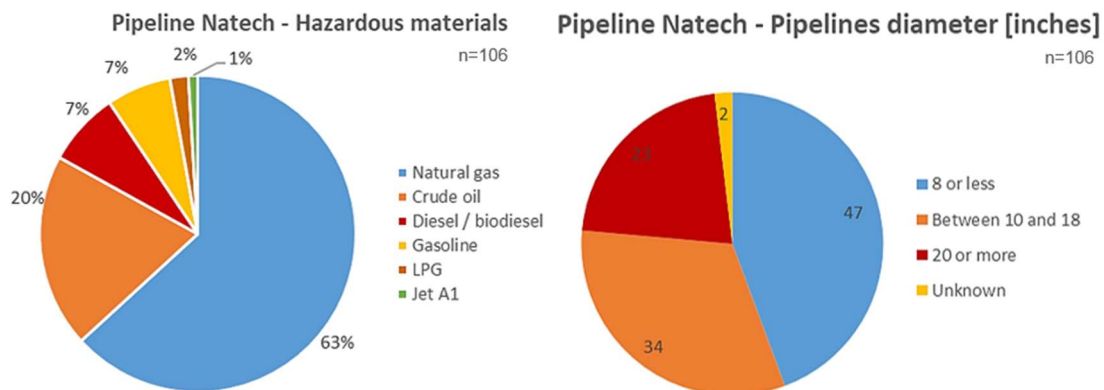


Figure 3. 7. Hazardous materials and pipeline diameter incidence.

3.4.5. Pipeline characteristics

The analysis showed that accident frequency varied with pipeline diameter. See Figure 3. 8b. Natural gas is usually transported in small-diameter pipelines, while crude oil pipelines generally have larger diameters. Smaller diameter pipelines, of 8 in or less, were more frequently (47 reports) associated with Natech accident reports, followed by pipelines of 10-18 in in diameter (34 reports).

The incidence of Natechs on pipelines varied with the age of the pipeline when failing (See Figure 3. 8a). The incidence of events is higher in newer pipelines (i.e., less than 20 years old when failing). After a deeper analysis, it was also found that the newer pipelines are gas pipelines with smaller diameters, which can make them more vulnerable to failure when exposed to natural hazard loads (Figure 3. 8b). Furthermore, it was identified that they pass through areas that are highly susceptible to landslides. This stresses the importance to adhere to building codes, pipeline location and maintenance practices for this type of infrastructure. Some pipelines have been operating for over 50 years, 6 of these events corresponded to pipelines still operating after 51 years.

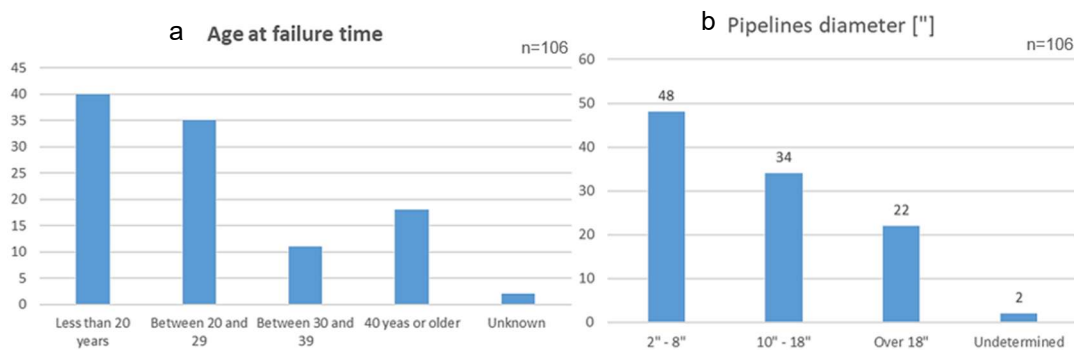


Figure 3. 8 a) Pipeline age when failing, b) pipeline diameter.

3.4.6. Pipeline's location

There are 32 departments in Colombia, and oil and gas transmission pipelines traverse about more

than half of them in the country. Pipeline-Natechs occurred in 16 departments. See Figure 3. 9 a. The regions with the higher number of pipeline-Natechs are Santander (34 events corresponding to around 32% of the total), followed by Norte de Santander (17 pipeline-Natechs or 16 %), both located on Los Andes mountains (Cordillera de los Andes, in Spanish. Around 50% of the events occurred in areas defined by the Colombian government agency SGC (Colombian Geological Service) as “high” in terms of susceptibility to landslides, almost 19% in areas defined as “very high”, and 30% in areas identified as “medium”. Figure 3. 9 a shows the location of the events in Colombia’s main pipelines distribution map (Ecopetrol n.d.) on the left, and in the location on the landslide susceptibility map on the right (Servicio Geológico Colombiano 2023).

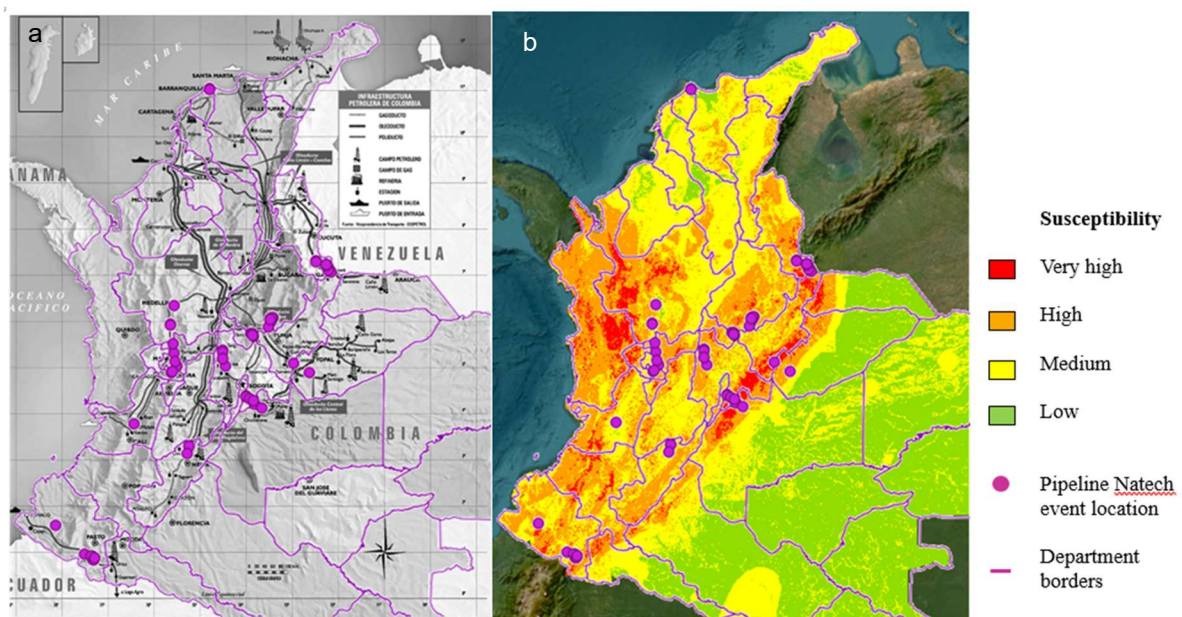


Figure 3. 9. Pipeline-Natechs according to pipeline location (a), and landslide susceptibility (b)
Adapted from:(Ecopetrol n.d.; Servicio Geológico Colombiano 2023)

3.4.7.Relationship with climate variability and climate change

Finally, since climate change might cause hydrometeorological events to become more frequent and more severe (Krausmann et al. 2017; Luo et al. 2020), and given that the most common natural

hazards reported in the database are heavy rainfall-induced landslides and flooding, it became essential to check climate variability. El Niño and La Niña are two climate phenomena that occur in the Pacific Ocean and have significant impacts on weather patterns around the world. El Niño refers to a period of warmer-than-normal sea surface temperatures in the equatorial eastern Pacific Ocean (Vinh Hoa Dang et al. 2020). This warming of the ocean surface leads to changes in atmospheric circulation, resulting in altered weather patterns globally. La Niña, on the other hand, is characterized by cooler-than-normal sea surface temperatures in the same region. During La Niña, the atmosphere cools, leading to reduced water evaporation. The changes in weather patterns are linked to temperature and rainfall patterns occurring worldwide due to El Niño (warm period) and La Niña (cold period) (NOOA n.d.). During these phenomena, the temperature in the Pacific Ocean changes, affecting the rainfall patterns in South America and, therefore Colombia. The average trimester temperature change is publicly available (NOOA n.d.). For each Natech event, we used the average trimester temperature change that includes the month of the Natech event as follows: e.g., pipeline-Natech event date: September 2020, corresponding average trimester temperature change: value for August-September–October 2020. Figure 3. 10 was developed including 91 months, where at least one Natech was registered. As figure 7 shows, a higher number of Natechs occurred during the cold period which corresponds to La Nina. From all the months during at least one Natech occurred, 62% correspond to the cold period, and 38% to the warm period. During cold periods, the rainfall is increased (iMMAP 2023), leading to more frequent flooding and landslides that can trigger pipeline-Natechs.

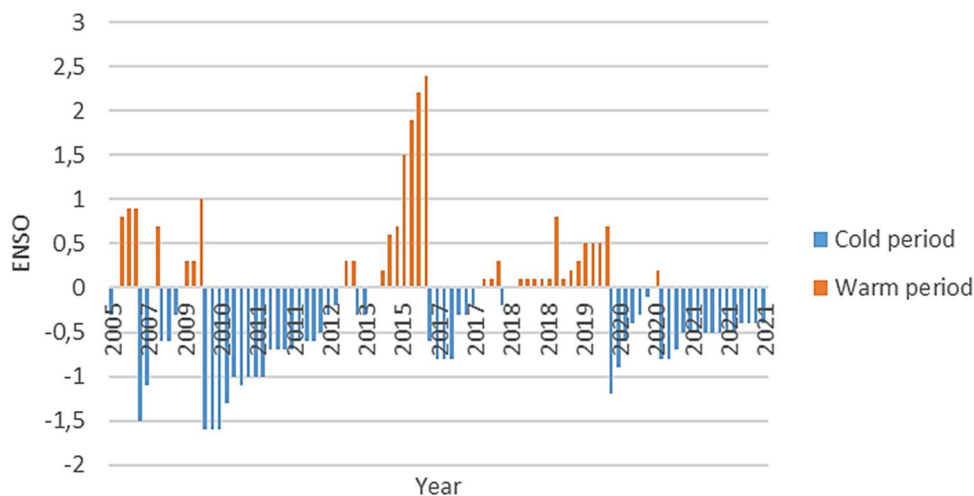


Figure 3. 10. ONI index when Natech occurred.

3.4.1. Identified stakeholders' roles and responsibilities

After a deeper analysis of the pipeline-Natechs database, the roles and responsibilities of stakeholders were identified for 66 events. The results showed that the reports were initially provided by industrial operators, but in some cases, the event reports were also completed by local and national governments, especially in cases involving large-scale impacts and injured people. However, the industry's responsibility to check the pipeline's condition and clean up hazardous materials was clearly stated for only 37 out of 106 events.

The analysis revealed that 14 events had clearly stated impacts on communities, including crop contamination, water supply interruption, and natural gas service disruption. This indicates the need to improve interagency coordination and communication to properly identify roles and responsibilities, as well as strengthen emergency response capabilities to handle these types of events. Surprisingly, the coordination committees established by national regulation reported participating in only one of these events, where 33 people were reported dead. This suggests a lack of awareness about other stakeholders present in the territory and the absence of coordinated protocols for responding to such events.

In one case, the local community living near a transmission pipeline repeatedly informed the local authorities about the poor condition of the infrastructure and their concerns, but no measures were taken by the operators. This underscores the importance of robust monitoring of pipeline structural integrity and better community engagement to minimize future Natech accidents.

Finally, another event, while not resulting in fatalities, showed that the interruption of natural gas service directly affected around 17,000 people. In this instance, 3 people were injured, and the situation received media attention, allowing for a more in-depth analysis. This analysis revealed that the natural gas service was interrupted for 3 months, leading to a rise in the price of gas service nationwide.

The findings of this study indicate that Natech events involving pipeline incidents are a serious issue in Colombia, with significant impacts in terms of human losses, contamination, and disruption of critical services.

3.5. Discussion and conclusions

The present work identified events triggered by different natural hazards in Colombia. National official and publicly available information was gathered, and the study resulted in the consolidation of an archive of accidental events. The results of the data analysis showed that natural hazards have affected the industrial sector resulting in 245 Natech events over the period of study of almost 23 years. According to our analysis, natural hazards triggered 2.4% of the total chemical accidents reported (245 out of 10322). This is consistent with the results reported by Luo et al. (Luo et al. 2020). They found that Natechs represented between 2.3 % and 7.3 % annually of all chemical accidents reported to the National Response Center database in the United States in the period 1990-2017. Natech events are becoming more frequent, possibly related to heavy rainfall pattern changes due to climate variability and climate change. La Niña phenomenon is expected to become more frequent and more severe due to climate change (Tao Geng et al. 2023). However, we also acknowledge that one factor affecting reporting trends is the change in relevant regulations and their impact on reporting practices by industrial operators.

When analysing only those events related to oil and gas transmission pipelines (3406 out of 10322), we determined that pipeline-Natechs represent 3.1 % of them (106 events). Our analysis also determined that events triggered by landslides represent 2.6 % of the total (i.e. 84 % of all pipeline-Natechs were triggered by landslides). Our finding is consistent with Girgin and Krausmann (2014b) study that investigated pipeline-Natechs in the European Union and the USA. On the one hand, regarding European pipelines, 7.5 % of the total entries correspond to ground movement as a cause, and from this, 57 % were categorized as being caused by landslides (around 4.2 % of the total events). On the other hand, they determined that from the total entries in the Pipeline and Hazardous Materials Safety Administration (PHMSA) database in the USA, 37 % of the total onshore pipeline event entries, correspond to geohazards, and from this the most common cause was landslides (46% from geohazards). Due to their extensive length, pipelines may be located in areas more exposed to natural hazards, requiring special attention from industry risk managers and government authorities, particularly at the regional and local levels.

The analysis of past events helped to identify impacts on the environment and surrounding

communities, as well as the trends regarding transported materials and pipeline properties. The most frequently involved hazardous material in the identified events (63% of the pipeline-Natechs) is natural gas, followed by crude oil (20%). Girgin and Krausmann (2014b) also reported that natural gas was the most common hazardous material involved in pipeline event. They reported that 55% of the pipeline-Natechs were related with natural gas, followed by crude oil.

In terms of the types of chemical accidents, only 2.4% of the pipeline-Natech events involved fires and explosions. In the work by Girgin and Krausmann (2014b), the authors identified 278 incidents involving ignition and fire in the USA (around 15% of their identified onshore pipeline-Natechs). This difference may be due to stricter reporting requirements, capturing even small releases. Furthermore, the PHMSA database in the USA is a well-constituted database compared to the consolidated database we built for this study, using different sources.

We identified 31 reported deaths, at least 86 people injured, and 650 neighboring homes affected in our study. From this, 100% of the deaths and 81 of the injuries were caused by a single event, due to a gasoline pipeline full-bore rupture, caused by a heavy rain induced landslide in December 23, 2011 in Dosquebradas, Colombia. In the report by Girgin and Krausmann (2014b), the natural gas incidents present a significantly higher number of injured people, and for 24 natural gas related incidents there was an injury (2.3-2.6%). We agree that their finding is to be expected, however our data differ, because of the single mentioned Dosquebradas event, where gasoline was spilled. Coming back to our results, 37% of the events generated environmental contamination affecting soil and water bodies and sometimes even affecting the availability of drinking water in affected communities). The results of the data analysis show the importance of landslides and flooding as a threat to hydrocarbon transmission pipelines

After getting information from additional sources, some wide-area effects were identified. Sixty percent of the events led to interruption of natural gas service in the affected municipalities (once for 135 days, affecting more than 1 million people) and fuel availability, leading to an increase in the price of natural gas. In some cases, reputational damage to the companies was such that local communities were opposed to granting industry personnel to access the area to repair the pipelines. In addition, psychological effects were reported to local authorities in the surrounding communities, but no evidence was found that this information reached the national government. This points to the

importance of risk communication among all stakeholders, including industry, local, regional, and national government entities, communities in the vicinity, as well as communities potentially affected in wider areas.

One crucial finding was the incidence of events being higher among the newest pipelines (i.e., less than 20 years old when failing), which led to the study of pipeline diameters. This finding is consistent with Girgin and Krausmann (2014b) work that indicated that smaller diameter pipelines are more vulnerable to ground movement than larger diameter pipelines. It was also found that smaller diameters corresponded to these newer pipelines, stressing the importance of reviewing the pipeline system design, the pipeline location and the natural hazards in the area, and maintenance practices for this infrastructure. Some pipelines were initially built over 50 years ago, 6 of the identified Natechs occurred in these older pipelines. It is not feasible to determine the exact age of the pipeline segment that failed, but according to general industry practices, 50 years old is over the expected operating life of the infrastructure.

The importance of documenting the events and, therefore, the possible lessons to be learned from past events was highlighted. It was noted that despite similar past events in the same areas, some accidents came as a surprise, and no lessons were gathered and implemented. Besides, the lack of information flows from industry to government and communities was evidenced by looking at differences in government reports and industry reports regarding the same events. Thus, the importance of risk communication between stakeholders in the territory, in accordance with the guiding principles (like shared responsibility) of the disaster risk management act (Anon n.d.) in the country is also emphasized.

Another lesson points to the Natech scenarios being disregarded. As mentioned before, one of our additional sources were the local disaster risk management plans, for some of the municipalities where the events happened. When looking at these plans, we noticed there are no Natech identified scenarios, only natural and technological events as separate scenarios. However, the possibility of landslides or flooding triggering pipeline accidents was identified in these plans but not addressed (A couple of examples of these plans can be found in (CMGRD Güepsa 2016; CMGRD Toledo 2012)). Some pipelines were affected on more than one occasion by Natech events during the study period, so they can be considered as “unknown known” events, which points to the importance of reviewing

the risk management measures currently implemented.

After reviewing the news and other publicly available information, we recognized that there is a publicly held belief that nothing can be done to mitigate situations in which natural events trigger technological accidents (Natech). Pipeline operators' performance reports and public statements after the events have occurred, despite the severity of the accident, focus on how natural events such as landslides and floods cannot be prevented (El Tiempo 2012). There is a definite need to improve Natech risk awareness, given the lack of measures to manage this particular kind of risk. We must identify, and document lessons learned and develop Natech scenarios in pipelines to support the formulation of measures to prevent and mitigate these events. Local authorities must improve their capabilities for disaster risk management and increase their awareness of Natech. We identified efforts to increase awareness about Natechs in the national level, such as the development of related risk management regulations (Anon n.d.; Ministerio de Minas y Energía de Colombia 2021; Ministerio de Salud y Protección Social et al. 2021; UNGRD 2017a). However, there is still a gap between national and local government capabilities, as it was evidenced by the mentioned local risk plans, where the Natech scenarios are still not considered. Finally, risk information disclosure is still a topic to be addressed considering all stakeholders: industry, government, and communities.

This work demonstrated the importance of reporting practices. It is difficult to gather information about past events without standardized reporting practices or a widespread reporting culture among industries. Thirty-four percent of the identified Natechs were not initially reported as related to natural causes, highlighting the need to review practices and culture around incident reporting. Current reporting practices still need improvements for technological accidents, especially for Natech, considering the potential to impact wide areas. Reporting practices focus particularly on direct impacts, some attention is given to emergency response, but little is reported regarding root causes or the chain of events, unless there are injured people or fatalities that receive attention in the news and media. The indirect or wide area impacts are not currently registered, and it is still a challenge to study Natech by checking only accident database entries. We observed that it is common to report initial events but locating completed events from the beginning to the end is still tricky. Another critical issue is how events are reported, possibly related to the knowledge of the people in charge of reporting, since the lack of basic information and the vocabulary used sometimes constitute a challenge to study past events.

All of the above constitutes an important point that requires more study to understand better the roles and responsibilities of different stakeholders and how they allocate and prioritize resources. Furthermore, a deeper understanding on how the different stakeholders communicate and how aware they are about each other's roles, and specially how they perceive the Natech risks in their territories, is still lacking. The results of this investigation suggest that Natech events represent a significant problem in Colombia, with substantial consequences in terms of human casualties, environmental pollution, and disruption to essential infrastructure.

3.6. Future work

The limitations of the keyword-based search are acknowledged, and also the limited number of reports used for this study. There is a need to further study the statistical significance and possible relationships among the studied parameters. Furthermore, the need to develop tools to support risk management and risk communication processes was identified, and therefore decision making for operators and government was noted and requires some further development. Currently available information does not provide enough details for analysis, and existing analysis tools focus on technological events only and fail to consider Natech scenarios more comprehensively. A logical next step is to study regional stakeholders and their communication process to support decision-making. Such a study will contribute to developing risk reduction measures and risk management policies to support industrial operators and government entities in their decision-making processes, involving all stakeholders (communities, industrial facilities responsible, and government). On the other hand, risk communication channels are still to be established, leaving a gap to be studied in the risk communication process among the stakeholders to better understand local and regional dynamics and how different environmental and cultural traits can affect the outcomes.

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4. Studying changes in risk awareness and communication in multiple stakeholders using a serious game

Abstract

The previous part of the thesis identified some lessons after studying previous Natechs (Chapter 3). A lack of Natech Risk management involved stakeholders' awareness, and communication among them was one of the key identified lessons. By looking at previous examples, the problems given by this recurrent situation were identified to be serious, presenting problems managing risks. The aim of this study is to support raising Natech risk awareness and risk communication among different stakeholders by applying and evaluating a serious game in a real-world setting. To address this gap, we conducted a thorough examination of risk awareness and the communication process and available approaches by conducting a literature review.

The first set objective was to address this gap by further test and prepare a serious game, EGNARIA (Educational Game for Natech Risk Awareness) previously developed by (Tzioutzios 2022) to raise Natech risk awareness and communication among different stakeholders. The second objective was to apply the serious game in real-world settings with a range of stakeholders in different locations, to measure its effectiveness in accomplishing such goals. Representatives from different stakeholders in Colombia were invited and participated in serious gaming workshops (national, regional and local government, industry, first responders, communities and academia). Pre-workshop and post-workshop surveys were adapted to the Colombian context to be used with the participants to evaluate the impacts of the serious gaming workshops on stakeholders' risk awareness and risk communication

The serious game approach showed some changes in most of the evaluated variables and promises to be a good approach to raise awareness and change risk perception, promoting the dialogue among different stakeholders, and showing the importance of information sharing. The findings from this study suggest that the serious game approach was effective in improving Natech risk awareness among the diverse group of stakeholders and enhancing communication and collaboration among the stakeholders.

4.1. Introduction

Natural hazard-triggered chemical incidents present substantial challenges to communities, industries and governments. In the last decade, Natech accidents have surfaced as a new threat to the countries and their economies across the world and raised questions of preparedness against large-scale impacts in the future (Chakraborty, Ibrahim, and Cruz 2018). The lack of stakeholders' awareness about Natech risk, and the lack of risk communication among them, can be a difficulty for an effective evacuation and emergency management decisions as has been established in Chapter 1 and Chapter 2.

Previous studies have highlighted the importance of stakeholder involvement in risk management and the need for a more participatory approach, as it can increase awareness and understanding of the risks (Solinska-Nowak et al. 2018). The examples from previous Natechs shown in Chapter 1, helped to demonstrate the importance to raise awareness of Natech risks and promote communication and trust among diverse stakeholders. The first example occurred in Colombia in 2011 due to a rainfall-induced landslide that caused a gasoline pipeline to rupture, leak on a river, and explode near the town of Dosquebradas, Colombia, on December 23, 2011 (El Tiempo 2012; LTDA. 2011; Semana 2011), caused 33 reported deaths, at least 86 people injured, and around 650 neighboring homes affected, demonstrating there was a lack of transparency and communication among the different stakeholders involved. The pipeline operator did not share information with the local government and the surrounding community, and their statements changed, causing more distress and confusion about the mitigation measures to be taken. Similar findings regarding risk awareness and communication have been found by other authors studying previous Natechs. After the event in Soja city in 2018, Araki et al. (2021) reported a total lack of awareness about the potential consequences for this type of accident among local residents, the fire department, and city officials. According to these authors, when it comes to Natechs, there is a need for risk communication mechanisms to be in place so all the stakeholders are better prepared. In the two mentioned events, the lack of risk awareness and risk communication mechanisms caused negative impacts, such as imprecise information about impact mitigation and or delays in evacuation orders. Even though Japan is considered a leader in terms of disaster risk management worldwide (World Bank n.d.-b), there is still a need to raise Natech disaster risk awareness and improve or strengthen risk communication processes among multiple stakeholders.

Considering the above, the governments of some countries, including Colombia have taken

proactive measures to align their disaster management policies and frameworks with the guidelines and priorities outlined in the Sendai framework for disaster risk reduction 2015-2030, seeking disaster risk reduction. By integrating the concepts of the Sendai Framework, these countries have attempted to develop a more comprehensive approach to addressing complex disaster-related risks, such as Natechs. In Colombia, after the accident in Dosquebradas in 2011, the national government has implemented new policies (Anon n.d.; Ministerio de Salud y Protección Social et al. 2021; UNGRD 2017a) considered a range of measures to strengthen its preparedness and response capabilities to mitigate the impacts of such Natech events in the future. In particular, the mentioned regulation introduced the concepts of shared responsibility from all the stakeholders about risk management in a territory, including government, industry and communities and the need for a risk communication process. However, despite these advancements, the challenge remains in ensuring that all stakeholders, from government agencies to local communities, are aware of the Natech risks and are actively engaged in the risk communication process. As mentioned above, effective risk communication and stakeholder awareness are crucial for mitigating Natech risks. The country has been changing the regulation over the last decade, but after studying the statistics we realized risk information is not flowing among stakeholders, making it difficult for them to assume their responsibilities, even though this is an explicit requirement in the regulation.

Natechs have also been recognized as complex, severe, and uncertain events. Given the above, it is important that all the main stakeholders have the ability to deal with disasters at the local, regional, and national levels (Aven and Renn 2010). As such, addressing the challenges of Natech risk awareness and communication pose significant challenges to communities and governments, often resulting in cascading effects that exacerbate their impacts (Cruz and Suarez-Paba 2019; Krausmann et al. 2017). Analogous to other disaster risks, effective risk communication and stakeholder awareness are vital for mitigating the consequences of Natechs. Therefore, enhancing Natech risk awareness and communication among stakeholders should be a high priority for policymakers, communities, industry managers, and first responders.

Nowadays there are some innovative approaches to enhance disaster risk management DRM and achieve disaster risk reduction DRR. Currently, it is well accepted that DRM and DRR strategies need to have discussion and participation from all the actors. Participatory approaches such as focus groups or serious gaming (Solinska-Nowak et al. 2018; Fleming et al. 2020) can be helpful for raising risk

awareness and also to bring the actors together and therefore providing a space to build trust. If there is no trust among the actors, no effective communication channels can be built, consequently, there's no discussion. Recent studies have also highlighted the potential of serious gaming as a tool to raise awareness about Natech risks, improve stakeholder engagement, and enhance communication and collaboration between different actors. The serious game, proposed by Tzioutzios (2022), named EGNARIA, promotes dialogue among stakeholders and their participation in decision-making processes concerning natural and Natech disasters under high uncertainty and often incomplete information. The findings from Tzioutzios (2022) suggest that the serious game approach effectively enhanced Natech risk awareness among the diverse group of stakeholders.

Therefore, the aim of the study is to test a serious game approach to support raising Natech risk awareness and risk communication among different stakeholders by applying the game and evaluating it in a real-world setting. To achieve this aim, the following activities were set: further testing and preparing a serious game developed to raise Natech risk awareness and improve communication among different stakeholders; applying the serious game in real-world settings with multiple stakeholders; and evaluating the impact of the serious gaming workshops on stakeholders' risk awareness and risk communication.

4.2. Literature review

4.2.1. Natech risk perception, Natech risk awareness and Natech risk communication

Disaster risk awareness (DRA) and disaster risk communication (DRC) are paramount for achieving disaster risk reduction (DRR) and mitigating Natech Risks. Disaster Risk Awareness can be defined as the extent of common knowledge about disaster risks (UNISDR 2009), and to (UNISDR 2009). To raise risk awareness, it is also necessary to take risk perception into account (Charrière et al. 2017). Perceived risk has been defined as various kinds of attitudes and judgments about a risk; it can be quantified and predicted (Mohammad 2019). Raising risk awareness and communication among stakeholders, particularly local communities, has been identified as a critical issue that must be addressed to develop and implement effective DRR measures (OECD 2015). On the other hand, the Risk Communication process can be used to raise risk awareness among the stakeholders exposed to natural hazards and Natech risks.

Several previous studies have explored the difficulties in implementing disaster risk reduction measures. Gaillard & Mercer (2013) identified the importance of integrating local knowledge with available scientific knowledge. On the one hand, they suggested that local knowledge gained through experience, can complement scientific knowledge and provide valuable insights into community-specific vulnerabilities and coping mechanisms. On the other hand, scientific knowledge can offer a broader understanding of disaster processes and inform evidence-based risk reduction strategies. The study also mentions the problems associated with top-down approaches, and the challenges in bringing all stakeholders together to participate in discussions for the necessary DRM and DRG measures. One of the most significant difficulties is bringing the stakeholders together and promoting trust among them to achieve the shared goals of DRR (Gaillard and Mercer 2013). Another study by (Kinoshita, 2014) emphasized that the risk communication process regarding natural and chemical accidents in Japan provided little to no information to local communities in the cases studied. After the Fukushima Daiichi accident in 2011, the information provided by the government was not systematic or consistent. Different government sources provided conflicting information, leading to public distrust. This study observed changes after the 1995 Kobe earthquake and 2011 Fukushima nuclear accident, finding that while there had been some improvements in risk communication approaches, significant gaps remained, and the general public remained uncertain about who or what to believe, highlighting the need for interdisciplinary communication teams.

Regarding Natech risks (Yu et al. (2017) investigated how households perceive and respond, specifically focusing on the 2011 earthquake and tsunami and the subsequent explosions and fires at an industrial park in Sendai prefecture, during the Great East Japan Earthquake and Tsunami in 2011. The study found that Natech risk perception fluctuated during the evacuation process. Residents exhibited higher risk perceptions when they directly experienced the Natech event, particularly while being evacuated to the shelters, after receiving the orders. Additionally, the research confirmed that risk perception significantly and positively influenced evacuation behaviors.

The general public awareness can be defined as the extent of common knowledge about disaster risks (UNISDR 2009). Risk communication can be used to raise risk awareness in the exposed public, and to raise risk awareness, one needs to take risk perception into account (Charrière et al. 2017). Previous mentioned studies (Gaillard and Mercer 2013) also looked at other challenges to implement

disaster risk reduction DRR measures, highlighting the problems to bring stakeholders together and build trust among them.

Identifying the most relevant stakeholders is crucial to manage disaster risks. Various stakeholders, such as government entities, industry representatives, first responders, and local communities, play a vital role in addressing Natech risks. Understanding the perspectives, concerns, and responsibilities of these diverse stakeholders is essential for developing and implementing successful risk management strategies. Aven & Renn (2010) have defined who the stakeholders are, when talking about risk management and risk governance. They defined a stakeholder as “a socially organized group that are or will be affected by the outcome of the event or activity from which the risk originates and/or by the risk management options taken to counter the risks”. When it comes to selecting the necessary stakeholders, it’s necessary to remember that Natechs events constitute a complex and highly uncertain problem for disaster risk management (DRM) and disaster risk governance (DRG), and according to this it is required for many stakeholders to be involved in the process, and discussion and participation is needed for DRM and DRG strategies to be accepted (Aven & Renn, 2010). There are two criteria for selecting the stakeholders, one is inclusion and the other is closure, and once should balance the other (See Figure 4. 1). According to the complexity and level of uncertainty of the Natech problem, DRM and DRG strategies should be discussed with the major stakeholders: (Political, business, scientific and civil society), and other stakeholders, such as media, cultural elites, opinion leaders and general public.

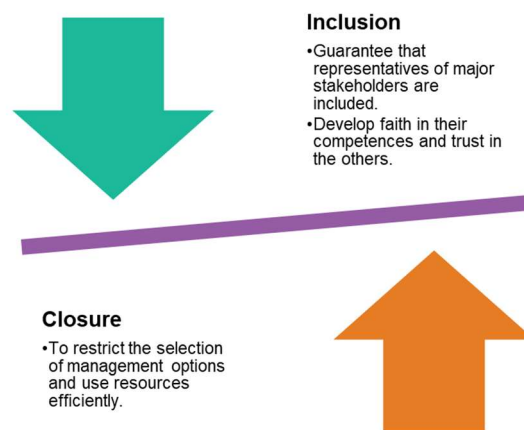


Figure 4. 1. Stakeholders selection criteria. Adapted from (Aven and Renn 2010).

Several studies have examined the relationship between demographic characteristics, such as gender or age, and risk perceptions and risk awareness regarding natural hazards (Ewa Lechowska 2018; Stefan Schneiderbauer et al. 2021; Xue Sun, Elisabeth Maidl, and Matthias Buchecker n.d.). Previous research has found that independent variables like demographic characteristics can influence natural hazards risk awareness. However, to the best of our knowledge, existing literature lacks is focused on natural hazards and not Natech risk perception and Natech risk awareness.

Raising risk awareness and risk communication among stakeholders, especially local communities, is still an issue that needs to be addressed to develop and implement effective risk reduction measures (OECD 2015). Risk communication process can be used to raise risk awareness on the different actors exposed to natural hazards. Some past studies have shown that there is little to no information provided to the local communities. Kinoshita et al. (2014) studied the risk communication process regarding natural and chemical accidents in Japan. This study observed the changes after 1995 Kobe earthquake and 2011 Fukushima nuclear accident, finding that while there had been some improvements in risk communication approaches, significant gaps remained and the general public did not know who or what to believe. When it comes to Natech risk Yu et al. (2017) identified that sometimes the industry limits the information access and transparency provided to other key stakeholders, such as government entities and local citizen communities (Tzioutzios 2022). This lack of open communication and information sharing can result in adverse effects, such as a negative impact on risk awareness among the public, and subsequently lead to less effective disaster prevention measures and preparedness planning for these events. Improved information sharing and collaboration between the industry, government, and local stakeholders is crucial for enhancing DRR and community resilience (Mohammad 2019).

4.2.2. Approaches for Disaster risk awareness and communication

Researchers have explored various approaches that can broadly enhance DRA and DRC for Natech risks and disaster risk reduction. Solinska-Nowak et al., (2018) argues that top-down approaches (e.g., lectures, webinars, exhibitions) typically involve centralized decision-making and control by governments and experts and often fail to address the needs and perspectives of local communities. They also highlight how bottom-up approaches (e.g., getting knowledge from communities) can

empower communities, enhance local ownership of DRM initiatives, and improve the effectiveness of risk reduction efforts by incorporating local knowledge and experience. However they are still not enough to bring stakeholders together, and discussion and more participation is needed for DRM and DRG strategies to be accepted (Solinska-Nowak et al. 2018). Participatory approaches, like focus groups or serious gaming, can help raise risk awareness and bring the relevant actors together. This can create an environment conducive to building trust. Without trust among the actors, meaningful discussion and establishing effective communication channels will be challenging.

Additionally, according to Navarro de Corcuera et al. (2022), the traditional methods for promoting DRC, such as classroom-based education, face limitations in effectively communicating DRM information and have been found to have limited reach and effectiveness (Navarro de Corcuera et al. 2022). For transferring new knowledge only, top-down or bottom-up approaches are very popular. In complex and highly uncertain situations, such as Natech and natural events, a more deliberative and participatory approach that brings together diverse stakeholders can be more effective in developing a shared understanding of the issues, identifying mutually acceptable solutions, and building trust and collaboration among the stakeholders (Cayamanda and Paunlagui 2020).

One example of a top-down approach was used by (Charrière et al. 2017). The researchers evaluated the risk awareness of inhabitants in the Ubaye Valley region of southern France by implementing an exhibition on natural hazards. They employed a pre-test/post-test design and a longitudinal study to measure changes in risk awareness among adult, teenage, and child visitors. The researchers evaluated the risk awareness of inhabitants in the Ubaye Valley region of southern France by implementing an exhibition on natural hazards. They employed a pre-test/post-test design and a longitudinal study to measure changes in risk awareness among adult, teenage, and child visitors. Generally, risk awareness increased after visiting the exhibition in all the groups, however, it showed the greatest impact on visitors with limited prior experience of natural hazards or low baseline knowledge. Furthermore, the results indicate that the exhibition enhanced awareness of infrequent hazards more effectively. Alternative communication methods may be more suitable for more common and locally relevant hazards, such as debris flows.

Previous studies examining disaster risk perception and risk awareness were identified. One study assessed geo-hydrological and seismic risk awareness among students and community members in a

region of Italy (Bandecchi et al. 2019). The researchers used questionnaires to investigate the participants' knowledge of emergency behaviors and procedures and their overall risk awareness and perception. The findings revealed that as age and responsibilities increased, geo-hydrological and seismic risk awareness and preparedness did not increase proportionally. Furthermore, researchers identified a disconnection between the school evacuation plans and the city civil protection plan. In addition, Ahn et al. (2021) studied earthquake risk perception in Seattle in the US, and Sendai in Japan, two zones with high seismic activity. In particular, the authors aimed to look for the relationship between the residents' perceived earthquake risk and the effectiveness of an Earthquake Early Warning EEW (one possible action), as well as their willingness to pay WTP for it. They found that risk perceptions and perceived effectiveness of some actions in personal protection were significant determinants of WTP.

As an example of a bottom-up approach, Nakano et al. (2020) described a study that engaged children in Nepal to develop school-based disaster risk reduction education (Nakano et al., 2020). The researchers worked with students to identify local hazards and vulnerabilities, and then co-created educational materials and activities. The study found that this participatory process helped students develop a sense of agency and increased their motivation to engage in disaster preparedness. This allowed the students and researchers to co-create solutions that were tailored to the local context and resonated with the students' experiences.

While traditional top-down and bottom-up approaches can be effective in certain contexts, there is growing evidence that more interactive and participatory methods may be better suited to enhancing disaster risk awareness. Nowadays, it is widely recognized that top-down and bottom-up approaches alone are insufficient to engage stakeholders and that discussion and participation are necessary for disaster risk management and disaster risk governance strategies to be accepted. Participatory approaches, such as focus groups or serious gaming, can be beneficial for raising risk awareness and bringing the relevant actors together, thus creating an environment conducive to building trust (Fleming et al. 2020; Solinska-Nowak et al. 2018). However, without trust among the actors, meaningful discussion and establishing effective communication channels will be challenging.

Overall, while traditional top-down and bottom-up approaches can be effective in certain contexts, there is growing evidence that more interactive and participatory methods may be better suited to

enhancing disaster risk awareness. Nowadays, it is widely recognized that top-down and bottom-up approaches alone are insufficient to engage stakeholders, and that discussion and participation are necessary for disaster risk management and disaster risk governance strategies to be accepted. Participatory approaches, such as focus groups or serious gaming, can be beneficial for raising risk awareness and bringing the relevant actors together, thus creating an environment conducive to building trust (Fleming et al. 2020; Solinska-Nowak et al. 2018). However, without trust among the actors, meaningful discussion and the establishment of effective communication channels will be challenging.

Serious games, on the other hand, have emerged as a promising approach to engage stakeholders and facilitate collaboration in disaster risk management.(Solinska-Nowak et al. 2018). Therefore, serious games can be seen as a powerful tool to raise risk awareness, disaster risk management education and training. However, a study analyzing the effectiveness of a serious game to increase risk awareness among actual stakeholders in a territory was not found. Therefore, serious games can be seen as a powerful tool to raise risk awareness, disaster risk management education and training. However, a study analyzing the effectiveness of a serious game to increase risk awareness among actual stakeholders in a territory was not found.

4.2.3. Serious games for raising DRA and promoting DRC

The concept of serious gaming refers to the use of games for purposes beyond mere entertainment (Clark C. Abt 1987), and it has been proven to be a powerful tool for education, bringing together the stakeholders involved in different and addressing problems related to different disciplines. One of the key advantages of serious gaming is its ability to engage participants in an interactive, immersive, and dynamic environment, which can enhance their understanding of complex issues and enable them to explore different scenarios. In the context of risk communication and risk awareness, serious games can provide a platform for different stakeholders, such as the ones mentioned, to collaborate and learn about Natech's risk-related challenges. Furthermore, serious games have the potential to bridge the gap between public understanding, scientific knowledge, and changes in behavior. This approach has been used in the past for a variety of problems such as natural resources management, climate change education, and engagement (Wu and Lee 2015), climate change adaptation (Tina-Simone Neset et al. 2020), collaborative water management (Deborah J. Bathke et al. 2019)and promoting changes in risk

communication and risk awareness among multiple stakeholders (Tzioutzios 2022).

Solinska-Nowak et al., (2018) reviewed serious games related to disaster risk management (DRM), serving as educational and engagement tools for affected communities, policymakers, and other stakeholders. The authors examined the potential benefits and constraints of gaming in the context of DRM (Solinska-Nowak et al. 2018). Additionally, the research identified potential opportunities that game developers and researchers could leverage to create more user-focused game designs and rigorous evaluation methods. The study indicated that DRM-focused serious games and simulations can provide a valuable social experience where players work collaboratively to address problems. However, the research also reveals a scarcity of quantitative and qualitative studies examining the efficacy of these gaming approaches.

One approach that could help to address this problem was developed by (Tzioutzios 2022) aiming at the design of a serious game to promote information sharing and raising awareness. This previous work designed and tested a serious game to promote information sharing and awareness raising using a non-traditional approach. The name of the serious game is EGNARIA, and it's based on a collaborative and experience-based learning approach. To evaluate the game's impact, Tzioutzios developed a survey based on the Situational Theory of Problem Solving (STOPS) (Jeong-Nam Kim and James E. Grunig 2011). STOPS attempts to model how individuals communicate during a situation that requires problem-solving and the factors that drive their motivation to do so. A more detailed survey description can also be found in section 3.1. While the potential of serious gaming in enhancing risk communication and awareness is evident, implementing and evaluating these games require careful consideration. This approach was never used with actual stakeholders before, but only with students.

4.2.4.Stakeholders' involvement

As mentioned above, Natech events are complex and highly uncertain. Therefore, requiring all the main stakeholders to be involved. (Aven and Renn 2010). Aven & Renn have defined a stakeholder as “a socially organized group that is or will be affected by the outcome of the event or activity from which the risk originates and/or by the risk management options taken to counter the risks”. When it comes to selecting the necessary stakeholders, given the nature of Natech events, it is required for

many stakeholders to be involved in the process, and discussion and participation is needed for DRM and DRG strategies to be accepted (Aven and Renn 2010).

There are two criteria for selecting the stakeholders: inclusion and closure, which should balance each other (See Figure 1). According to the complexity and level of uncertainty of the Natech problem, DRM and DRG strategies should be discussed with the main stakeholders (Political, Business, scientific, and civil society) and other stakeholders, like Media, cultural elites, Opinion leaders, and the general public.

4.2.5. Investigating Natech risk awareness in Japan and Colombia

Colombia and Japan are no exception when it comes to Natech risk. Natech events are a problem for both countries since they are exposed to natural hazards, and therefore, they can and have had the occurrence of Natechs. To understand the relevance of this problem, it's important to understand the incidence of natural events first. On the one hand, Colombia faces the highest frequency of extreme natural events in South America, with 84% of the population and 86% of its assets situated in areas exposed to two or more hazards (World Bank, n.d.-a). Rapid urbanization in poorly planned areas, informal settlements, and densely populated coastal regions, combined with the impacts of climate change, have exacerbated flooding and landslides within the country (World Bank, n.d.-a). The country also faces risks from earthquakes, droughts, and cyclones. On the other hand, Japan is one of the most disaster-prone countries in the world. Several factors contribute to Japan's high susceptibility to natural disasters (MOFA, n.d.). The country experiences extreme climatic variations, including seasonal rain fronts, typhoons, and heavy snowfall along the coast of the Sea of Japan, Japan's rugged topography, with numerous faults and steep inclines, also increases its vulnerability. Furthermore, the nation's location within the Pacific earthquake belt and the circum-Pacific volcanic zone exposes it to frequent earthquakes, tsunamis, and a concentration of active volcanoes (MOFA, n.d.).

4.3. Methodology

The first step of this study refers to the literature review about Risk Awareness and Risk Communication, as presented in the previous section (See Figure 4. 2). The second step was to revise and adjust previously available tools (Tzioutzios 2022), referring to the survey and the board's serious

game. Both tools were revised, translated, and implemented in English, Japanese, and Spanish during some trials with undergraduate and graduate students at Kyoto University. These trials served to understand the gaming adjustments needed to prevent the dice rolls from determining the actions and allow the players to take more actions according to their risk awareness levels and not only by probabilities. It also allowed researchers to understand how to make the gaming workshop an enjoyable experience, allowing the participants to be involved in open discussions deeper than the game dynamics limitations.

The game uses a board with a seismic hazard map from a Japanese city and an additional board with flooding hazards, as well as action cards and dice. The trials suggested that some modifications were needed. First, the player roles needed to be balanced to lower the influence of dice rolls, preventing players from taking action and, therefore, leading to restricted discussions. Second, an instructions manual was required. Third, the action cards needed to be designed to make them easier to read, requiring some standardization. After the trials, both the game and the surveys, initially in English, were translated into Spanish and Japanese for the workshops.



Figure 4. 2. Steps conducted for the study.

After reviewing past research and the tools adjustments (Step 1 and Step 2), gaming workshops were conducted in Colombia and Japan to investigate the potential of serious games to raise awareness and promote risk communication.

To conduct the present study, we employed a mixed approach for data collection. Quantitative data was collected from the surveys, and some feedback was gathered from the recordings. The gaming workshops, or Step 3, were conducted in 4 steps (See Figure 4. 2). At the beginning of each workshop, a short presentation was given to the participants, explaining the workshop's objective and the game dynamics and providing some context. As described above, the survey based on STOPS was implemented, followed by the workshops and the post-game survey after the gaming sessions. The data collected from all the workshops were then analyzed at a later step (Step 4).

During each workshop, the first stage is the implementation of the pre-game survey. The mentioned survey was uploaded online using a Google Form. This was distributed to the participants using a QR code that allowed them to fill out it immediately after starting the workshops. The survey was developed by Tzioutzios (2022), based on the Situational Theory of Problem Solving framework STOPS proposed by (Jeong-Nam Kim & James E. Grunig, 2011). This also includes some items to evaluate risk perception, risk awareness and communication.

The second stage was the gaming workshops involving all the mentioned stakeholders (Section 4.2.4), according to what is presented in Table 4. 1. Nine gaming workshops were scheduled. Eight workshops were held in 4 Colombian cities during a mission to Colombia in November 2023, with national and regional government entities such as the UNGRD (Colombia's National Unit for Disaster Risk Management) and AMVA (Metropolitan Area of Aburra's Valley, a regional government entity in Colombia), as well as industry associations like ANDI (an industrial association) in the region of Santander and Andercol (a chemical sector company in Colombia), helping to convene participants from various stakeholder groups. Additionally, one workshop was conducted in Sakai City, Osaka Prefecture, Japan in December 2023. A total of 84 individuals from different stakeholder groups participated in the workshops, including representatives from national, regional, and local government entities, industry, first responders, communities, and academia. Further details on the game are provided in Section 4.3.2, and a description of the participants can be found in Section 4.4.1. The workshops followed a similar format: an introduction to the serious game, a play session, a debriefing, and a survey. The data collected during the workshops includes the following:

- Gameplay observations
- survey responses, and

- transcripts of audio recordings from the debriefing sessions.

Table 4. 1. Workshops conducted for this study

City	Dates	Government	Industry	Community	Academia
Bogotá (3 sessions) Workshops #1,#2,#3)	Nov 21 st - 22 nd	UNGRD, local and national gov (National) first responders) Organized: UNGRD (National gov.)	Industry representatives.	Citizens invited by UNGRD.	N.A.
Medellín (2 sessions) Workshops #4, #5)	Nov 24th	Local and regional gov., first responders,	Industry Responsible Organized: Care (Industry association).	Citizens invited by RC.	N.A.
Cartagena (1 session) Workshops #8	Nov 27th	Local gov, first responders, industry,	Organized: UNGRD (Regional government).	Citizens invited by UNGRD.	N.A.
Bucaramanga (2 sessions) #6, #7	Nov 27th	local gov., first responders, industry,	Organized: ANDI Santander (Industry association).	Citizens invited by ANDI Santander.	N.A.
Osaka (Sakai) (1 session) #9.	December 9 th .	local government, first responders,	Industry representatives.	Citizens invited by Osaka University.	Organized by Prof. Aoki, Osaka University (in Japanese).

The third stage was the implementation of the post-game survey. The survey questions were translated into Spanish and Japanese and uploaded online using Google Forms. This was distributed to the participants using a QR code immediately after finishing the workshops. Most participants filled out the form before leaving the room, but some filled it later on the same day or week.

Finally, the fourth stage refers to the data analysis presented in section 4. Statistical analyses were carried out to learn more about how demographic factors affect changes in risk perception, awareness, and risk communication. These analyses included independent samples t-tests. Furthermore, paired samples t-tests showed the changes in the variables as presented in section 4.4.

4.3.1. Risk communication survey

A survey was developed based on the one used by Tzioutzios (2022) to assess the impact of the game on risk perception, and communicative behaviors based on the Situational Theory of Problem Solving (STOPS) framework (Jeong-Nam Kim and James E. Grunig 2011), risk awareness, risk communication, expectations about the game and some general questions to describe the sample's demographics.

The STOPS framework aims to describe how individuals communicate about a problem and their motivation during a problem-solving situation. The framework comprises three components: the perceptual and cognitive frame, the situational motivation, and the communicative behavior. The survey's communicative behavior section was structured using STOPS measures. It included at least three items for each STOPS latent construct, with the wording of the questions based on previously tested and validated measurement items, with minor adjustments to reflect the Natech risk context.

The first component examines the following factors: first, the Problem recognition PR, referring to the person's perception of the problem (Natechs); second, the perceived connection between the individual and the problem Involvement Recognition IR; and third, the perceived barriers impeding the individual from addressing the problem Constraint recognition CR. Additionally, the framework considers Referent Criterion RC related to the individual's prior knowledge, experiences, and anticipations. The second component is Situational Motivation, which refers to the degree to which an individual contemplates, is curious about, or seeks further understanding of a problem, as described by (Jeong-Nam Kim and James E. Grunig 2011). This Situational Motivation serves as an intermediary between the situational precursors and the communicative behavior (Tzioutzios 2022). The third component corresponds to communicative behavior, conceptualized as a multifaceted construct encompassing three distinct dimensions of individual behavior related to problem-solving: information acquisition, selection, and transmission. Each of these dimensions is characterized by passive and active expressions. For the first dimension (information acquisition), the expressions are IAtt Information Attending (passive) and ISek Information Seeking (active); for the second dimension (selection), the expressions are IPrm Information Permitting (passive) and IFrf Information Forefending (active); and finally for the third dimension (transmission), the expressions are IShr Information Sharing (passive) and IFwd Information Forwarding (active).

The pre-game questionnaire is structured in 6 sections (Tzioutzios 2022). The sections refer to:

- Natech risk perception on the workshop's participants' perception of Natech event's potential occurrence and their ability to remain safe (6 questions),
- Risk communicative behaviors (based on the STOPS framework) (33 questions),
- Natech risk awareness on their territories (5 questions),
- Risk communication, referring to the importance of information for the participants (5 questions),
- Expectations about the game (6 items), and finally,
- General questions.

The post-game survey is also divided into 6 sections. Sections 1 through 4 are comparable and analogous to the pre-game questionnaire. The fifth section of the post-game survey aims to evaluate the participants' gaming experience. The sixth section seeks to obtain feedback on both the game and the workshops. The surveys are linked by an identifier, which enables the comparison of individual responses across the pre-game and post-game questionnaires. Both surveys in Google Forms present the participants with open questions, multiple choice questions, and 7-point Likert scales.

4.3.2. The Natech Game

The previous work of (Tzioutzios 2022) aimed to design and implement a serious game to promote information sharing and raise awareness through a non-traditional approach. The name of the game is EGNARIA.

The Game was developed considering the following principles:

- a. Risk Dialogue: Fostering an open dialogue about risk is crucial to engaging the participants.
- b. Participation in decision-making: Engaging stakeholders in decision-making processes related to risk management is crucial for building trust among them.
- c. Collaborative and experience-based learning: The game-based learning approach encourages collaborative experiences and can effectively enhance risk awareness and communication.
- d. Real-life problems (incomplete information, conflict of interests, etc.): The game reflects real-life situations and problems that participants might encounter. Due to limited information and unpredictable events, participants will face uncertainty when making decisions.

The game aims to accumulate preparedness points by maintaining the resources necessary to act during a natural disaster or a Natech. Participants earn points by being more "prepared" for potential

natural events. Points are lost for being exposed to danger, losing the community's trust, or going into debt. The game elements were designed to be visually appealing and expected to encourage active participation in risk-related scenarios and decision-making processes.

4.3.3. The participants

Government agencies and industrial associations summoned the participants in Colombia, while in Japan, they were recruited by a professor from the Osaka University network. However, the sample may not be representative regarding age, roles, or education level, as the recruitment was based on convenience rather than random sampling. Most workshop participants in both countries were aware of natural hazards, and some were even familiar with the term "Natech". This can be attributed to the fact that the country has undergone a process of changing regulations related to industrial accidents (Decreto 2157 de 2017, 2017, p. 21; Ley 1523 de 2012, n.d; Programa de Prevención de Accidentes Mayores - PPAM, 2021), which involved various stakeholders in the related discussion phases. Several participants were involved in this process, which made them more aware of these scenarios

As mentioned before, individuals playing different roles in society were invited to participate in the workshops. These included members of national, regional, and local government entities; first responders such as police, firefighters, and civil defense; representatives of industry and the general public; and students and researchers from universities. To conduct this study, we collaborated with the Colombian national government and Industry associations, who wished to participate. On the one hand, the National Unit for Disaster Risk Management UNGRD helped us to summon the stakeholder representatives in Bogota and Cartagena. On the other hand, Responsible Care Colombia helped organize a couple of workshops in Medellin, and ANDI Santander organized a couple more in Bucaramanga. This way of inviting the participants has a direct influence on the participant's demographics. The researchers are aware that the Colombian population is not represented accurately by this sample when it comes to age or education level.

In Japan, Professor Shinichi Aoki of Osaka University and his network helped organize a workshop in Sakai City, Osaka prefecture. This sample does not represent the Japanese population, or the same reasons exposed to the Colombian population.

4.4. Results

4.4.1.Characteristics of the workshop participants (Demographics)

A total of eighty-five individuals joined the nine workshops. However, we could not get eighty-five valid responses, given that some of them were not able to reply to the pre-game survey (84 pre-game valid responses) and some of them didn't reply to the post-game survey (72 valid responses). After checking the survey participants for the pre-game and post-game, we identified that not all the workshop participants filled out both surveys and as a result, we have 65 valid responses, including 52 from Colombian participants and 13 from Japanese participants, to evaluate and conduct the analysis for this work. In what follows, the analyses are focused on these 65 valid responses after checking the availability of complete responses from both the pre-and post-game survey.



Figure 4. 3. Workshops conducted in: Bogotá city (a, b), Bucaramanga city (c) in Colombia, and Sakai city (d)

Table 4. 2. Available responses for the study.

Survey	Colombian	Japanese
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Pre-game	71	13
Post-game	58	14
Valid responses	65	

The following figures show the sample distribution according to gender, age, and marital status. The sample has a slight majority of males (57%) (Figure 4. 4a), and young adults (49%). According to World Bank information, in Colombia 50.7% corresponds to the female population, and in Japan is 51.2% (World Bank n.d.-c). Regarding age distribution, meaning the majority of individuals are in their 20's and 30's (See Figure 4. 4.b), followed by adults (40's and 50's) and finally elder people (60 or more). Finally, almost half of the people replied they were in a partnership (49%), followed closely by single people (46%). The authors acknowledge that the Colombian and Japanese populations are not represented here, and this is explained by how the individuals were chosen to participate. The Japanese sample is older; the sample is more educated in Colombia.

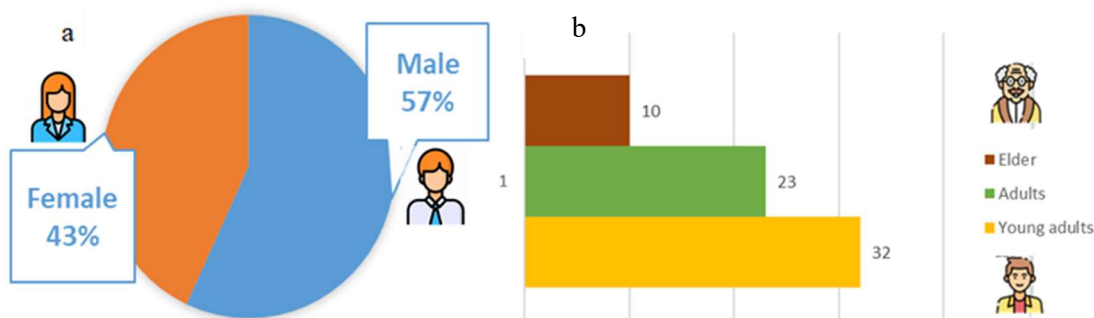


Figure 4. 4. Participant's genders (a), age (b) and c) marital status in Colombia and Japan.

Figure 4. 5 shows that most of the participants worked for the government, whether national, regional, or local. As for education levels, most participants achieved at least an undergraduate or bachelor's degree (Figure 4. 5.a). Of course, this is not a realistic representation of the Colombian or Japanese population, but it's explained by the way the participants were invited to the workshops.

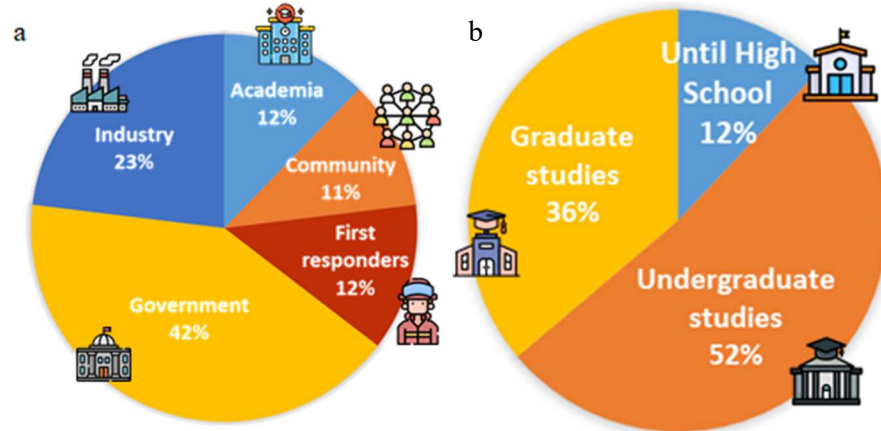


Figure 4. 5. a) Participant's roles and b) education level. Source: the authors.

The workshops were conducted in 5 different cities, 4 in Colombia and 1 in Japan. The total participants were divided into 80% from Colombian, and 20% from Japan. Forty percent of the participants joined in Bogota, the Colombian capital, 24,5% in Medellin, Colombian second biggest city, followed by 20% in Osaka, Japan. The remaining participants joined from Bucaramanga and Cartagena, smaller Colombian cities.

Regarding the participants' gender, 43.1% were female and 56.9% male. Regarding the Colombian sample, 48.1% were female and 51.9% male; the Japanese sample was constituted by 23.1% female and 76.9% male. When it comes to age, the Colombian sample is younger (See Figure 4. 6). The blue bars correspond to Colombia and the red ones to Japan.

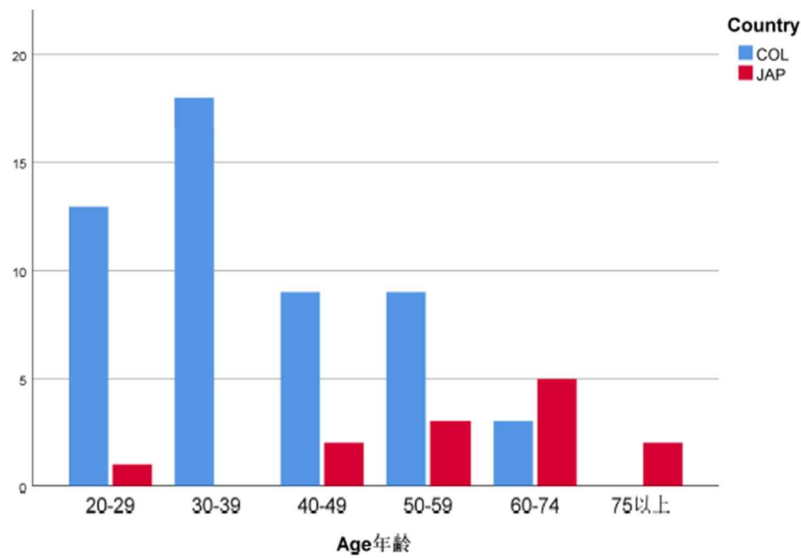


Figure 4. 6. Distribution of age in the sample. Colombian and Japanese.

In both samples, the majority of individuals belonged to government entities, including national, regional, and local levels (See Figure 4. 7). In Colombia, 38.5% of the participants and 53.8% in Japan.

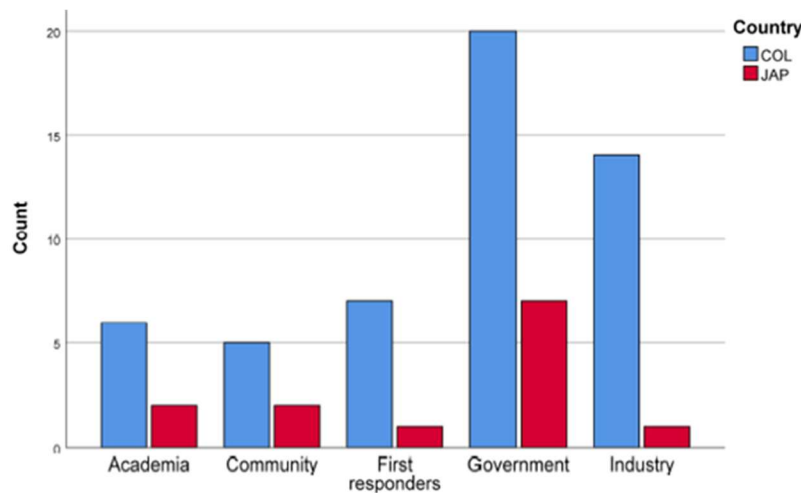


Figure 4. 7. Role distribution of the participants in both samples.

Individuals holding a bachelor's (50%) and a master's degree (38.5%) dominate the Colombian

sample; however, individuals who finished high school (23.1%) and a bachelor's degree (61.5%) are the majority of the Japanese sample.

4.4.2.Changes in Risk awareness and Risk perception

This section discusses the changes in risk awareness and risk perception of the participants after attending the serious gaming workshops. The pre-game survey aimed to understand the participants' risk awareness and perception of risk prior to the workshop. The post-game survey aimed to identify changes in risk awareness and risk perception of the participants after experiencing the serious gaming workshops.

Regarding Natech risk perception, when looking at the pre-game survey results, the majority of participants (74.6%) considered Natech as an important problem, this percentage raised up to 89.7% after the workshops. The situation was similar when they about the possibility to have a Natech after an earthquake in their cities, while prior to the workshops 60.6% considered this possibility in industrial areas and 45.1% in their working/residential areas, this percentage raised to 79.3 % for industrial areas and working/residential areas 67.2% after the workshops. When asked about their perceived ability to remain safe after a Natech, the change was more visible. Around 25.4% considered that they would manage it very well / somehow well, and this percentage increased to 65.5% after the workshops. These preliminary results show that participation in the serious gaming workshops increased the Natech risk awareness, but also the perception of their perceived ability to remain safe.

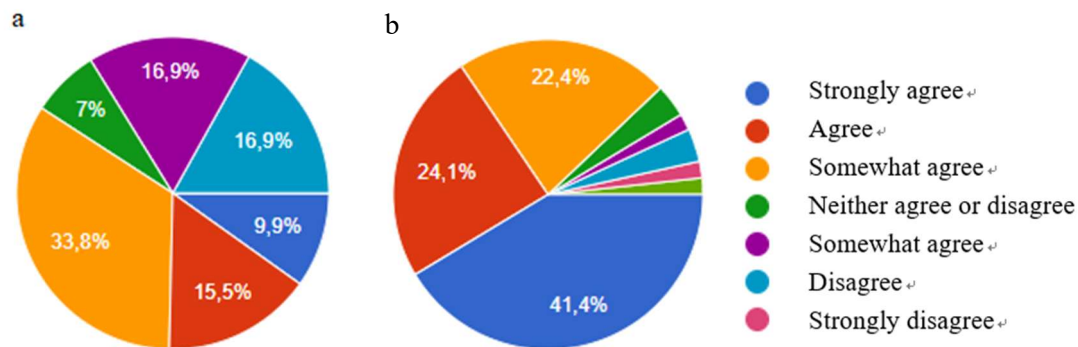


Figure 4. 8. Workshop participant's perception about their ability to remain safe a) before the

workshop, b) after the workshop.

For the 33 questions corresponding to the STOPS framework (See section 4.3.1), we conducted 33 paired t-tests to compare the game's impact. The questions were grouped according to the framework element they aimed to evaluate. The results showed a significant change in all the variables, as depicted in the following figure.

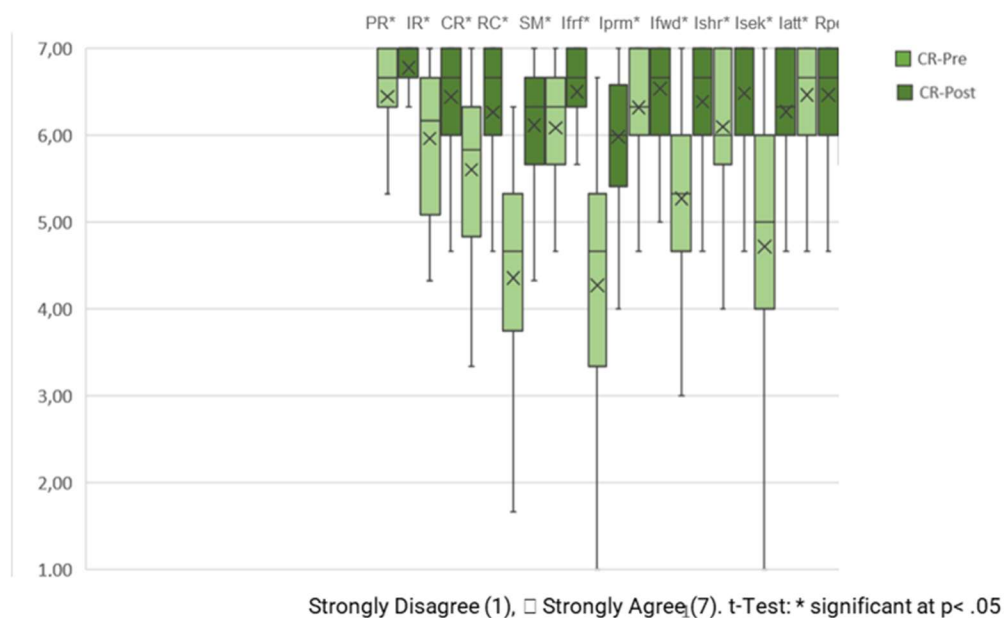


Figure 4. 9. Changes in risk communicative behaviour. Source: the authors

The results showed that the serious gaming workshops had a positive and significant impact on the participants' risk awareness and risk perception. After participating in the workshops, we obtained higher values in their replies, showing an increase in their understanding of the problem, the barriers to taking action, the benefits of taking action, and their own self-efficacy and response efficiency. On the following subsections, we will have a closer look at the changes in the mean score for each topic, view of genders, roles, age and education levels.

4.4.2.1. Relationship with gender

To examine the relationship between gender and Natech risk perception before the workshops (NatechRPerc Pre), Natech risk perception after the workshops (NatechRPerc Post), Risk Awareness before the workshops (NatechRAw Pre), Natech Risk Awareness after the workshops (NatechRAw Post), and Natech Risk Communication, before the workshops (NatechRComm Pre) and after the workshops (NatechRComm Post) an independent sample t-test were conducted to compare these variables, between the female participants and the male participants. One of the key findings of this study relates to the differences in the impact of the serious gaming workshops between male and female participants. The results showed that female participants reported greater risk awareness levels before the game (female mean value= 6.00, males mean value M= 5.84) and greater risk perceptions levels (female mean value M= 6.21, males mean value= 6.03).

Table 4. 3. Natech Risk Awareness, perception, and communication among male and female participants

Gender	Female		Male		T - test	
Item	M	SD	M	SD	df	t
NatechRPerc Pre	6.21	0.49	6.03	0.52	62	0.081
NatechRPerc Post	6.69	0.33	6.54	.41	63	.060
NatechRAw Pre	6.00	0.57	5.84	0.73	63	0.176
NatechRAw Post	6.42	0.52	6.13	0.54	63	0.018*
NatechRComm Pre	6.59	0.44	6.38	0.68	61.64	0.070
NatechRComm Post	6.77	0.38	6.64	0.48	62.82	0.106

t-Test: * significant at $p < .05$

When comparing the changes prior to and awareness levels after the workshops, both female and male participants showed a significant difference in risk communication behaviors. However, the effects on risk perception and risk awareness are not statistically when the significance is less than 0.05.

The results showed there were no statistically significant differences between females and males in their Natech Risk Perception ($t = 0.162$, $p = \text{communication.}0.55$), Natech Risk Awareness ($t=0.352$, $p=0.094$), and Natech Risk Communication ($t=0.163$, $p=0.455$). There was no significant difference in Natech Risk perception, Natech Risk Awareness and Natech Risk Communication

between Female and Male, however, accordingly with previous studies, female individuals tend to be more aware of risk, Natech Risk in this case, and perceive them to be higher.

4.4.2.2. Relationship with age

To examine the relationship between age and Natech Risk Awareness, Natech risk perception, and Natech Risk Communication, a one-way ANOVA was conducted to compare these variables for the different age groups. Three ages groups were defined: 1. young adults (from 20 to 39 years old), 2. adults from 40 to 59 years old and 3. The older adults (from 60 to 75 years old).

Table 4. 4. ANOVA results for different age groups

Age groups	Young adults		Adults		Older adults		ANOVA		
Item	M	SD	M	SD	M	SD	Df combined	Df within groups	Sig
NatechRPerc Pre	6.05	0.47	6.16	0.55	6.16	0.56	2	61	0.68
NatechRPerc Post	6.61	0.39	6.57	0.39	6.65	0.39	2	62	0.88
NatechRAw Pre	5.97	0.63	5.74	0.73	6.08	0.60	2	62	0.32
NatechRAw Post	6.24	0.57	6.26	0.54	6.32	0.55	2	62	0.93
NatechRComm Pre	6.56	0.49	6.48	0.67	6.16	0.67	2	62	0.17
NatechRComm Post	6.81	0.37	6.65	0.48	6.46	0.48	2	62	0.07

t-Test: * significant at $p < .05$

The results indicated that there were no statistically significant differences in the levels of Natech Risk Perception, Natech Risk Awareness, and Natech Risk Communication across the different age groups of the participants, suggesting that age did not play a significant role in influencing these variables.

4.4.2.3. Relationship with role

When it comes to individual's real life roles, our hypothesis was that they would have a significant influence on the Natech Risk Awareness, perception and Communication behaviors roles. A one-way ANOVA was performed to compare the effects of different participant roles (government, industry, academia, first responders and communities).

Participants from government entities, both local and national, exhibited higher levels of Natech Risk Perception and Natech Risk Communication compared to those in other roles, such as academia, the private sector, and NGOs. The results revealed statistically significant differences in the levels of Natech Risk Perception after the workshops.

Table 4. 5. ANOVA results for different roles

Roles	First responders		Industry		Government		Communities		Academia		ANOVA		
Item	M	SD	M	SD	M	SD	M	SD	M	SD	Df combined	Df within groups	Sig
NatechR Perc Pre	6.31	0.48	6.26	0.50	6.09	0.49	5.76	0.56	6.02	0.49	4	59	0.20
NatechR Perc Post	6.72	0.19	6.68	0.38	6.67	0.34	6.30	0.40	6.37	0.53	4	60	0.05*
NatechR Aw Pre	5.97	0.51	6.02	0.54	5.90	0.77	5.71	0.60	5.82	0.77	4	60	0.87
NatechR Aw Post	6.42	0.64	6.36	0.53	6.27	0.51	5.97	0.54	6.12	0.64	4	60	0.47
NatechR CommPre	6.72	0.45	6.68	0.43	6.40	0.66	6.00	0.63	6.5	0.51	4	60	0.08
NatechR CommPost	6.77	0.37	6.86	0.29	6.62	0.50	6.40	0.51	6.85	0.27	4	60	0.11

* significant at $p < .05$

This finding suggests that an individual's professional role and the associated responsibilities and experiences can shape their Natech risk perceptions and communication behaviors. However, no significant differences were found in the levels of Natech Risk Awareness and Risk communication through the different roles.

The analysis revealed differences in certain risk communication behaviors between individuals from the industry sector and those from academia and between the industry sector and government entities. These findings suggest that an individual's professional role and associated experiences can shape their risk communication behaviors in the context of Natech hazards.

Levene's test for equality of variances was not violated in the present analysis. The test revealed that the roles only gave a statistically significant difference on the following variables: IR Pre, IR Post, CR Pre, and Ishr Pre. These results will be discussed in depth in the conclusions section. significant differences were found between the groups of and Industry and Government. This suggests that the participants' roles influence their risk perception, awareness, and communication behaviors.

4.4.2.4. Relationship with nationality

The hypothesis was that participant nationality would not have a significant effect, as individuals from both Colombia and Japan were summoned due to their involvement in the DRA, DRC, and DRR processes within their respective communities and countries. To examine the influence of nationality, an independent sample t-test was performed to compare the Colombian and Japanese participants. In general, the Colombian sample exhibited higher scores across all evaluated variables, both before and after the workshops, participants' nationality was that it wouldn't have a significant effect since participants of both groups were summoned because of their closeness to the DRA, DRC, and DRR Risk Perception.

Table 4. 6. ANOVA results for different age groups

Item	Colombia		Japan		t-Test
	M	SD	M	SD	
NatechRPerc Pre	6.16	0.48	5.88	0.57	.121
NatechRPerc Post	6.62	0.37	6.55	0.45	.599
NatechRAw Pre	5.97	0.60	5.64	0.84	.204
NatechRAw Post	6.28	0.54	6.18	0.60	.600
NatechRComm Pre	6.59	0.46	6.00	0.82	.001*
NatechRComm Post	6.78	0.37	6.35	0.52	.013*

t-Test: * significant at $p < .05$

The results indicated no statistically significant differences in the levels of Natech Risk Perception, before or after the workshops. A similar pattern emerged for Natech Risk Awareness. In contrast, differences were found in Natech Risk Communication between Colombian and Japanese participants. These findings suggest that an individual's nationality may not substantially influence their Natech risk perceptions or awareness, but could shape their Natech risk communication behaviors, potentially due to cultural and social factors specific to each country.

4.4.2.5. Relationship with education level

Regarding education level, previous studies have suggested might be some influence. However, they also acknowledge the fact that this might be a more complex relationship between education level and risk perceptions. Therefore, we hypothesized that education level would significantly affect Natech Risk Awareness, Natech risk perception, and Natech Risk Communication.

To conduct. In the analysis, we defined three education levels: High School or lower education, Undergraduate education group, and Graduate education group. A current study, a one-way ANOVA was used to compare the levels of different education levels on the key variables.

Levene's test for equality of variances was not found to be violated in the present analysis. Natech Risk Perception, Awareness, and Communication across three education levels: high school, undergraduate/bachelor's, and graduate/postgraduate. The results indicated no statistically significant differences in the levels of Natech Risk Perception, Awareness, or Communication between the different education groups.

Table 4. 7. ANOVA results for different education levels

Education level	High school		Undergraduate		Postgraduate		ANOVA		
Item	M	SD	M	SD	M	SD	Df combined	Df within groups	Sig
NatechRPerc Pre	6.20	0.46	6.06	0.55	6.15	0.48	2	61	0.69
NatechRPerc Post	6.66	0.39	6.54	0.37	6.67	0.41	2	62	0.42
NatechRAw Pre	5.9	0.76	5.86	0.69	5.98	0.60	2	62	0.81
NatechRAw Post	6.62	0.37	6.11	0.46	6.36	0.65	2	20.826	0.01*
NatechRComm Pre	6.17	0.78	6.44	0.64	6.62	0.38	2	17.968	0.19

NatechRComm	6.45	0.63	6.65	0.46	6.85	0.25	2	17.527	0.07
Post									

* significant at $p < .05$

Only between the group with High School or less education and Undergraduate education group, and the group with High or less education and Graduate education group.

4.5. Discussion and conclusions

The study presented explores a critical, yet often overlooked, aspect of disaster risk reduction: raising awareness and improving communication surrounding Natech events. This study employed a serious game approach within workshops held in Colombia and Japan, targeting diverse stakeholders including government officials, industry representatives, first responders, community members, and academics, selected according to the complexity of the problem (Aven and Renn 2010). This approach offers several advantages for exploring complex risk scenarios and fostering collaborative learning.

One of the key points of the study refers to the multi-stakeholder engagement. The inclusion of diverse participants allowed for a more comprehensive understanding of Natech risk awareness and communication challenges. This has been conducted in the past with some of the stakeholders representatives, such as communities, considering the differences between age groups and education levels (Charrière et al. 2017). This study was able to bring different stakeholders often have varying levels of awareness, different priorities, and distinct communication needs. By bringing these groups together, the study captures a more holistic and sometimes opposites view of the problem.

The serious game approach offered an engaging and interactive platform for learning and exploring complex scenarios. Workshops when EGNARIA implemented, showed that it can simulate real-world situations, allowing participants to experience the potential consequences of Natech events and practice appropriate responses in a safe environment.

The use of surveys before and after the workshops has been implemented by previous studies in the short and mid term (Charrière et al. 2017) after some interventions for natural events. This

provided a valuable quantitative data on changes in risk perception, awareness, and communication behaviors in the previous study, and also in the present thesis. This data-driven approach allows for a more objective assessment of the game's effectiveness in achieving its learning objectives.

The study makes a valuable contribution to the field of Natech risk management by demonstrating the potential of serious games as a tool for raising awareness and improving communication among diverse stakeholders. The findings highlight the importance of engaging all relevant parties in the risk management process and underscore the need for innovative approaches to address the complex challenges posed by Natech events. Further research building upon these findings can lead to more effective risk reduction strategies and enhance community resilience in the face of these growing threats.

4.5.1. Discussion on individuals' characteristic

This study examined the impact of serious gaming workshops on participants' Natech Risk Awareness, Natech risk perception, and Natech Risk Communication among multiple stakeholders. The participants manifested being receptive to the workshops and expressed interest in replicating them within their own communities. These individuals were invited due to their previous experiences with risk management and governance in their respective regions. Regardless of their specific roles, the participants had been exposed to Natech and disaster risk-related concepts to some degree.

After conducting the workshops and analyzing the data, we found that female participants displayed slightly higher risk perceptions compared to male participants, accordingly to previous studies (Delin Liu et al. 2018; Sund, Svensson, and Andersson 2017). Small differences were also found between male and female participants regarding risk awareness and risk communication, although the differences were not found to be statistically significant.

A previous study by (Charrière et al. 2017) have shown that age can play a role in influencing risk perceptions and risk awareness. The researchers found that in their study, this was related to the participants' previous experiences. Their study included participants who were children and teenagers, who exhibited very different behaviors and changes compared to adults. Other researchers (Ewa Lechowska 2018; Stefan Schneiderbauer et al. 2021; Xue Sun et al. n.d.) have indicated that the

relationship between age and risk perception and risk awareness regarding natural hazards, is more complex, and can have both positive and negative associations depending on the age range examined and the topic. In our study, all participants were adults and had some existing ideas about natural hazards and technological events, and some were even familiar with Natech. Furthermore, the current study found no significant differences in the levels of Natech Risk Communication across age groups, indicating that older and younger adults may engage in similar levels of communication about these types of risks.

When comparing the different stakeholder roles, the government-affiliated participants showed the highest levels of Natech risk perception and risk communication. Government officials, being responsible for disaster management and public safety, may have a heightened awareness and concern about Natech risks, leading to more active engagement in communicating these risks to the public, community stakeholders, and other agencies. The role of community's representative's participants showed increased Natech risk awareness and perception through their engagement in the workshops, highlighting the potential of serious games to empower these stakeholders. The role of academia participants demonstrated higher Natech risk awareness and communication compared to other groups, likely due to their existing technical knowledge and understanding of risk assessment principles. The role of government participants displayed the highest levels of Natech risk perception and communication, reflecting their responsibilities in disaster management and risk governance.

Furthermore, our analysis revealed that an individual's role and associated have a significant influence on their Natech risk perceptions and some communicative behaviors, but not on their overall Natech risk awareness. (Charrière et al. 2017) findings, suggesting that there is an influence if individuals work or study in a field related to natural hazards. In our study, this can be related with the fact that government representatives and academia representatives participating in the workshops, have been somewhat involved in the process of developing related Natech Risk Management regulation. After performing the analysis of the data, one can see that the gaming experience and discussion direction is highly influenced by the participant's backgrounds and past experiences. The analysis revealed differences in certain risk communication behaviors between individuals from the industry sector and those from academia, as well as between the industry sector and government entities. These findings suggest that an individual's professional role and associated experiences can shape their risk communication behaviors in the context of Natech hazards.

Notably, the participant's nationality did not have a significant influence on their Natech risk perceptions, awareness, and communication behaviors within the scope of this study. The analysis provided insights on the impacts of the game on Natech risk awareness, considering the participants' different profiles based on their actual roles, previous experiences, age, education, and gender. Our analysis supports that the gaming experience and the direction of the discussion were highly influenced by the participants' backgrounds and past experiences.

The serious gaming workshops were deemed effective in enhancing Natech Risk Awareness and Natech risk perception among the diverse stakeholders. Participants expressed a keen interest in integrating the workshops into their own communities and organizations. This study contributes to the growing body of research on the application of serious gaming approaches in the context of Natech risk management, highlighting the value of using such tools to engage diverse stakeholders and improve their understanding and communication of these complex risks. Beyond the quantitative data, the participants expressed their feedback from the workshops. They expressed finding the game valuable for raising their awareness and expressed a desire for its wider use in their communities. This positive feedback reinforces the game's potential as an effective tool for community-based risk reduction efforts.

While the study provides valuable insights based on these characteristics, a more detailed demographic analysis could further enhance our understanding of how different groups perceive and communicate about Natech risks. This information could be used to tailor risk communication strategies and educational interventions to specific audiences, maximizing their effectiveness.

4.5.2.Recommendations

Natech Risk Communication emerged as an important yet overlooked area that requires further research, across all participant groups regardless of their age, gender, roles, education levels, or nationality. The workshops demonstrated the suitability of the game to promote dialogue between different actors within a territory. Furthermore, the workshops aided each of the involved stakeholders in better understanding their real-life role in Natech risk management, considering the national regulations in place in Colombia. Some implications for risk governance can be derived from the

findings:

- **Enhanced stakeholder engagement:** The study's success in engaging diverse stakeholders highlights the importance of inclusive risk governance. Serious games can be valuable tools for fostering dialogue and collaboration among different groups, leading to more comprehensive and effective risk management strategies.
- **Improved Risk Communication:** The observed improvements in risk communication behaviors suggest that targeted interventions, such as serious games, can enhance the effectiveness of risk communication efforts. This is crucial for ensuring that all stakeholders understand the risks they face and can take appropriate actions to protect themselves and their communities.
- **Data-driven decision-making:** The study's use of pre- and post-workshop surveys demonstrates the value of data-driven approaches. Collecting and analyzing data on risk perception, awareness, and communication can inform the development and evaluation of risk reduction strategies.
- **Integration of non-traditional tools:** The positive results achieved with the serious game suggest that risk governance frameworks should embrace innovative tools and technologies. These tools can enhance stakeholder engagement, improve risk communication, and facilitate more effective decision-making.
- **Focus on education and training:** The study's findings regarding the impact of education level underscore the importance of investing in education and training programs related to Natchez risks. Equipping individuals and communities with the knowledge and skills they need to understand and manage these risks is essential.
- **Community-based risk reduction:** The participants' expressed interest in using the game within their communities suggests that serious games can empower local communities to take ownership of their risk reduction efforts. This bottom-up approach can complement top-down risk governance strategies and foster a more holistic approach to disaster risk management.
- **Cross-Cultural comparison:** Conducting workshops in two different countries offers insights into potential cultural influences on risk perception and communication. This cross-cultural perspective can be the initial step for developments of more tailored and effective risk

communication strategies.

4.6. Future work

This study provided valuable insights into the influence of demographic factors on Natech risk perceptions, awareness, and communication behaviors. However, the sample size was relatively small, and the study was conducted in a specific cultural and geographic context.

The study only analyses the immediate changes in participants' Natech risk perceptions, awareness, and communication behaviors. It would be beneficial to Explore the long-term impact of serious gaming workshops on Natech risk awareness and communication over time. Additionally, future studies could explore the potential of serious games to influence actual implemented actions, such as preparedness planning and implementation of DRR measures.

More in-depth qualitative research, such as interviews and focus groups, could provide richer insights into the mechanisms underlying the observed differences in Natech risk perceptions, awareness, and communication across the various stakeholder groups. Lastly, this study focused on the role of individual demographic factors, but there may be other contextual factors, such as organizational culture, political influences, and socio-economic conditions, that could also shape Natech risk perceptions, awareness, and communication.

Therefore, some potential areas for further exploration are:

- Exploring the scalability of the serious game approach is crucial for wider implementation.
- Investigating the mid to -long-term impacts: While the study demonstrates immediate changes in awareness and communication behaviors, further research is needed to assess the long-term impact of the serious game intervention. Do these changes persist over time, or do they fade as the experience becomes less salient?
- The study involved a relatively small number of participants in workshop settings. To further strengthen the generalizability of the findings, future research should expand the study to include larger and more diverse samples across different regions and cultures.
- Integration with existing Risk Management frameworks: How can the insights gained from

the serious game be integrated into existing national and local risk management frameworks?

This requires further investigation into the practical application of the findings.

- Specific communication strategies: The study highlights the importance of improved risk communication, but further research could delve into specific communication strategies that are most effective for different stakeholder groups. Tailoring messages to specific audiences can enhance their impact and promote more effective risk reduction behaviors.

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5. Evaluating the impact of serious gaming workshops on Natech risk awareness and risk communication on multiple stakeholders on the mid-long term

Abstract

This chapter aims to investigate the mid-to-long-term impacts of the serious gaming workshops on risk awareness, risk communication, and potential protective actions for Natech risk reduction. The study first evaluated the effects on risk awareness and risk communication among multiple stakeholders in the mid to long term, following the serious game workshops (Chapter 4). The study carried out a series of nine multi-stakeholder workshops, and the changes in risk awareness perceptions and awareness was measured through the application of a survey before and after the workshops. The results of the workshops showed an increase in Natech risk awareness levels and the effectiveness of the workshops on promoting the dialogue among them. The results reported were quite positive. However, the midterm to long-term effects of the workshop remained unknown, and therefore their effectiveness. Furthermore, potential protective actions for disaster risk reduction that may have been implemented as a result of the workshops remained to be explored.

Representatives from different stakeholders were invited and participated (national, regional and local government, industry, first responders, communities and academia). Previously this thesis showed the results of conducting some serious games workshops, and studied the changes in Natech risk perceptions, awareness, and their views about the risk communication processes. This chapter now studies the evolution of these variables almost one year after the workshops were conducted. Additionally, as one of the big challenges of DRR remains the implementation, the study explores the potential implemented actions by the participants and their views about the outcomes of the workshops. To evaluate the changes around one year after the workshops, a follow-up study was conducted. The presented research adopts a mixed-methods approach, combining quantitative assessments of risk awareness and communication with qualitative insights into the participants' experiences and their implemented actions. The study then was constituted by two parts: a follow-up survey that aimed for all the participants of the workshops, and a series of semi-structured interviews with some of the participants, to know more about their perceptions of Natech risk, awareness, and their roles in the communication process, and finally potential risk reduction measures implemented by them as a result of the workshops. The results show that serious gaming workshops can positively impact Natech risk awareness, communication, and mitigation actions

across multiple stakeholders in the mid-term period.

5.1. Introduction

Two aspects are to be evaluated in this chapter. One related to the impacts of serious gaming in the mid-to long term on risk awareness and communication, and the other related to the implementation of mitigation measures as a result of the workshops. They both aim to support the Natech Risk Management implementation process, in the end, aiming to achieve disaster risk reduction (DRR). approach to DRR practices (UNDRR 2019). While the scientific and technical capabilities to assess Natech risks have advanced in recent years, the uptake and implementation of risk reduction measures remain a challenge. It has been identified in the past, that one of the main challenges remain lack of communication between multiple stakeholders during the different phases of the risk management and governance processes. Namely, industrial facility managers/ operators, government authorities, civil protection, experts and local communities, among others as, are not always aware of their roles and responsibilities, and sometime are not familiar to the other actors taking part on it, making it difficult to do the necessary coordination for taking preventive actions and for the communication needed to manage Natech risks.

However, it has also been established that for DRR measures to be effective, some implementation challenges remain due to the lack of trust and dialogue among the different stakeholders, including local communities who live in the territory and the experts who play a role in the DRM process (Gaillard and Mercer 2013). As it was established in Chapter 4, it is widely recognized that top-down or bottom-up approaches alone are insufficient for engaging stakeholders and gaining acceptance for DRM and DRG strategies. Participatory approaches, such as serious gaming, can be effective in raising risk awareness and bringing diverse actors together, thereby creating a space to foster trust. Without trust among the stakeholders, meaningful discussion and the establishment of effective communication channels remain elusive. In the previous chapter, a serious gaming approach was used to promote stakeholder dialogue, to raise risk awareness, and foster the risk communication process among them, however the question remained on the evolution over time.

Nakano et al. (2020) argued that long-term, action-oriented evaluation is crucial for understanding the true effectiveness of disaster risk reduction education. They criticize the prevalent short-term,

knowledge-transfer paradigm, which primarily focuses on immediate knowledge gains rather than sustained behavioral changes and actual disaster preparedness actions. They highlight how long-term evaluation can reveal the development of proactive attitudes, the impact of DRR education on long-term community engagement, and the effectiveness of risk reduction efforts during actual disasters. The study showcases the benefits of this approach through a case study of a DRR education program in Nepal, demonstrating how long-term evaluation revealed the sustained impact of the program on students' attitudes and actions, even years after their initial participation. They conclude that long-term evaluation is essential for gaining a comprehensive understanding of the effectiveness and sustainability of DRR education initiatives.

The second studied item in this chapter, is how the changes in the described variables (awareness and communication) relate to the implementation of mitigation measures, has been explored in the past. Previous studies (Wachinger et al. 2013) have mentioned about the risk perception paradox. According to this, the increase in risk awareness and risk knowledge does not necessarily lead to the implementation of mitigation measures. Wachinger et.al (2013) have showed that a risk perception paradox exists, where it is assumed that high risk perception leads to personal preparedness and risk mitigation behavior. However, this is not always the case. In fact, the opposite can occur, where individuals with high-risk perception still choose not to personally prepare themselves in the face of a natural hazard. This suggests that the relationship between risk perception, preparedness, and mitigation behavior is complex and not straightforward.

This chapter explores the mid to long term impacts of serious gaming workshops, conducted approximately one year after the original workshops. It examines the evolution of Natech risk perceptions and awareness levels, as well as risk communication processes in the midterm to long-term aftermath of these workshops. It also investigates how the workshops participants, representing the main stakeholders, report being impacted by these activities, and if the information that was presented can potentially transform into actions according to individuals. Furthermore, the study investigates whether the serious gaming approach is suitable for creating impact and promoting multi-stakeholder collaboration to support Natech Risk Management.

5.2. Literature review

The study of risk perception, awareness, and communication in the context of natural hazard-triggered technological disasters has gained increasing attention in the literature. Researchers have recognized that individuals' perceptions of risk and their understanding of disaster preparedness can significantly impact their decision-making and protective actions. This literature review aims to synthesize the current state of knowledge on Natech risk perception, awareness, and communication, with a particular focus on long-term evaluation the protective actions the participants might have taken after the interventions.

Nakano et al., (2020) advocates for a shift from short-term, knowledge-based evaluations of disaster risk reduction education to a long-term, action-oriented approach. It argues that traditional evaluations often fall short because they focus on immediate knowledge gains rather than sustained behavioral changes and actual risk reduction actions. The study highlights the importance of evaluating how DRR education influences real-world behavior and contributes to tangible improvements in disaster preparedness over time. Using a case study of a DRR education program in Nepal, (Nakano et al., 2020) demonstrates how a long-term evaluation approach can reveal the evolution of proactive attitudes and their impact on community resilience. It concludes that long-term evaluation is crucial for developing truly effective DRR education strategies that empower individuals and communities to take sustained action to reduce their risks. These authors critique the dominant paradigm of short-term evaluation, highlighting two key problems:

1. Inconsistency between evaluation and objectives: Traditional evaluations often focus on immediate knowledge gains, which don't necessarily translate into sustained behavioral changes or improved disaster preparedness. Nakano et al. (2020) emphasizes the need to align evaluation methods with the ultimate goal of DRR education, which is to empower individuals and communities to take effective action to reduce their risk.
2. Dissociation of knowledge from action: Simply acquiring knowledge about disaster risks doesn't guarantee that individuals will act on that knowledge. Nakano et al., (2020) stresses the importance of evaluating how DRR education influences actual behavior and contributes to tangible risk reduction outcomes.

Despite the growing body of research related to disaster risk awareness and communication, the literature review also reveals a significant gap in the understanding of Natech risks. The existing

research has largely focused on general natural disasters, without adequately addressing the unique challenges posed by Natech events (Cruz and Suarez-Paba 2019).

A literature review carried out by Johnson et al. (2014) on the evaluation of disaster education programs for children emphasizes the importance of long-term, action-oriented evaluation in understanding the true effectiveness of such programs. They reported that the current knowledge transfer paradigm in DRR education research produces two main tendencies in evaluations of DRR education. First, the evaluation methodology tends to be a questionnaire survey comparing the pre-DRR education with post-DRR education to identify extent to which the knowledge gap between experts and the public has been closed. Second, DRR education interventions in schools and communities are evaluated over only the very short term. These authors argue that this short-term knowledge transfer model does not capture the deeper and more long-lasting impacts on attitudes, behaviors, and in the end, in disaster preparedness actions.

Long term evaluation of risk perception and awareness, after implementing actions is crucial for understanding the effectiveness of risk communication strategies and, in the end for developing more resilient communities. A few studies have evaluated the implemented actions or long-term results after DRR related activities, however, the long-term evaluation of the risk perception and risk awareness or communication strategies is still lacking, especially in the context of Natech disasters.

To provide credibility to the agencies and institutions in charge of risk information, they need to deal with the diversity of the stakeholders and to cope with their differences (Aven and Renn 2010). Giving these challenges risk communication is necessary and required by public pressure sometimes by stakeholders' demands. People expect the government entities in the industry to provide more information for the general public. In addition, globalization has made mandatory some communication needs about potentially dangerous products for people in different nations to cope with different risk situations (Naciones Unidas 2011). The risk communication process plays a critical role in shaping risk perceptions and fostering disaster risk reduction measures. Effective communication strategies should consider the target audience's risk perception, level of awareness, and cultural context to develop tailored messages that resonate with the community.

Previous studies (Gaillard and Mercer 2013) looked at the difficulties to implement DRR. One of

the identified problems is to bring stakeholders together and build trust. Raising risk awareness and risk communication among stakeholders is still an issue to be addressed, to develop and implement effective DRR measures (OECD 2012, 2015). Past studies have shown that there is little or even no information provided to the local communities regarding natural and chemical hazards and risks (Kinoshita et al., 2014) and Natechs (i.e., Natech' - Natural hazard -triggered technological accidents) (Yu et al., 2017). It has been identified that sometimes industry limits the information access to other stakeholders (Tzioutzios, 2022), such as government entities and citizens. This can result in adverse effects, such as a negative impact on risk awareness, and less disaster prevention measures and preparedness planning for these events (Mohammad, 2019).

Disaster risk perception is a complex and multifaceted construct that is influenced by various factors, including socio-demographic characteristics, personal experiences, and cultural values (Mohammed et al., 2019; Ullah et al., 2018). The general public awareness can be defined as the extent of common knowledge about disaster risks (UNISDR 2009). Studies have shown that individuals' perceptions of risk can deviate significantly from the actual risk, and this gap can have important consequences for disaster preparedness and response. The relationship between disaster risk perceptions and awareness has been explored in multiple contexts, including flooding (Ramasubramanian et al., 2019), climate change (Ullah et al., 2018)] and Natech events (Agrawal et al., 2020)] The literature suggests that risk awareness is a crucial prerequisite for effective risk communication and the adoption of protective behaviors.

The risk communication process plays a critical role in shaping risk perceptions and fostering disaster risk reduction measures (Aven and Renn 2010). Effective communication strategies should consider the target audience's risk perception, level of awareness, and cultural context to develop tailored messages that resonate with the community. Effective risk communication strategies should consider the target audience's socio-cultural context, as well as their level of risk literacy and understanding. Risk communication is defined as an interactive process of exchanging information and opinions among individuals, groups, and institutions. It involves multiple messages about the nature of risk and other messages not strictly about risk, which express concerns, opinions, or reactions to risk messages or to legal and institutional arrangements for risk management. The ultimate goal of risk communication is to assist stakeholders and the public in understanding the rationale behind risk-based information, and to help them arrive at balanced judgments that reflect

the factual evidence about the matter at hand in relation to their own interests and values. In other words, effective risk communication practices are meant to help all affected parties make informed choices about matters of concern to them. The purpose of risk communication is not to persuade people, such as consumers of risk-bearing products, that the communicator (e.g., a government agency) has done the right thing. Rather, the aim is to provide people with the information they need to make decisions or judgments that reflect the available knowledge and their own preferences (Aven and Renn 2010).

The review of the literature also reveals that socio-demographic factors, such as gender, age, and personal experiences, play a crucial role in shaping individual risk perception (Ullah et al., 2018). For example, studies have shown that individuals with higher numeracy and flood knowledge tend to have a better understanding of their vulnerability to flooding, which in turn influences their risk comprehension, weather risk perceptions, and decision-making quality (Ramasubramanian et al., 2019). Similarly, place attachment and socio-cultural practices have been identified as important but less tangible factors that influence risk perception (Ullah et al., 2018).

Measuring the effectiveness of serious games is crucial to understanding their potential as tools for addressing complex societal issues like Natech risk (Den Haan and Van Der Voort 2018). Recent studies have highlighted the potential of serious games to foster learning and behavioral change in various domains, it has been established that effects of such games remain underexplored (Mitgutsch and Alvarado 2012).

To evaluate the impacts of the workshops, qualitative tools were reviewed. Mark Saunders & Philip Lewis (2019) provided a review of different available qualitative approaches. The authors evaluate the appropriateness of qualitative techniques such as focus groups, interviews, case studies, and grounded theory in understanding the efficacy of serious games in risk communication. Considering the interactive and immersive nature of the serious game, semi-structured interviews, one of the qualitative approaches allowing for in-depth exploration of participants' experiences and perspectives, were deemed particularly suitable. Previous studies conducted qualitative research using semi structured interviews consulting different stakeholders, suggesting they are proven tools in similar fields. On the one hand, Nombulelo Kitsepile et al. (2024) consulted with communities in Japan and Zimbabwe affected by risks, to assess their engagement and the benefits from their participation to

improve their decision making using semi-structured interviews. On the other hand, industries in Colombia implementing the risk management national policies were interviewed by Namulun Borjigin (2024), highlighting the importance of understanding flood risks and risk communication needs from the industry perspective.

Research interviews have been recognized as a powerful tool to gather valid data from the community and relevant stakeholders about their perceptions about a specific situation, through a conversation with researchers. Semi-structured interviews allow for some flexibility in the conversation, while providing the opportunity to explore participants' personal perceptions, beliefs, and attitudes in-depth. Interviews have been used (Ullah et al., 2018) to study the perceptions of local communities in mountain regions regarding climate change, livelihood practices, and climatic shocks. The literature suggests that individual risk perception in these areas is heavily influenced by a range of socio-demographic and socio-cultural factors, including gender, age, place attachment, and traditional practices (Ullah et al., 2018).

5.3. Methodology

The aim of this study is the assessment of Natech risk awareness and perceptions changes and Natech risk communication potential improvements and the potential subsequent implementation of mitigating actions, taken by workshops participants. To achieve this, a four-step methodology was utilized, as described below. Given the research questions, we decided to use a mixed approach that allowed us to explore the changes in Natech risk awareness, perceptions risk communication behaviors of workshop participants, through semi-structured interviews and also try to describe identified patterns, analyzing the mentioned follow up survey (Figure 5. 1).

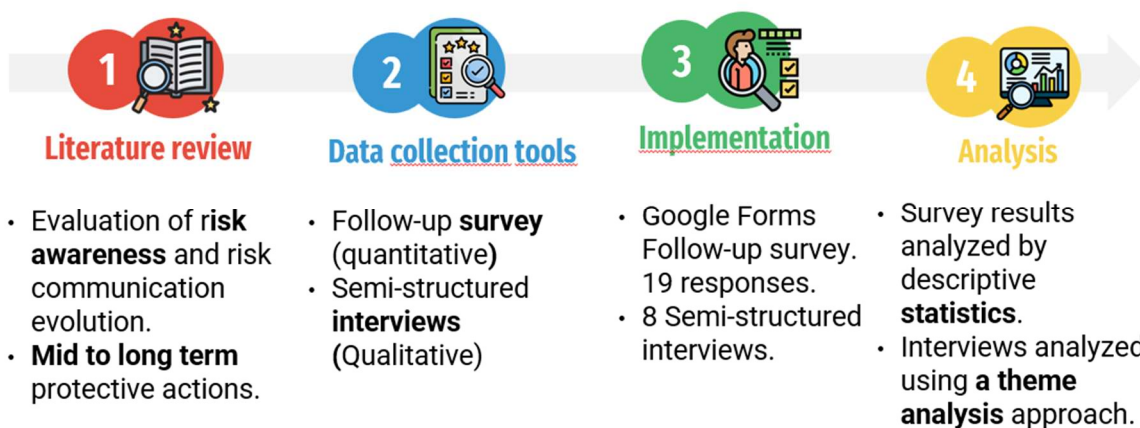


Figure 5. 1. Methodology steps

The first step was to carry out a literature review on risk awareness changes and how this can translate into actions. It was also important to evaluate how these changes have been evaluated by previous studies. This allowed us to key concepts to guide the research design.

The second step was to develop the tools to evaluate the changes in the midterm. A mixed approach allowed us to describe the changes and understand the motivations behind them more deeply. The quantitative tool was a survey developed using a previous survey as a base (Chapter 4), that had evaluated the immediate changes in the risk awareness of participants during serious gaming workshops as a base and modifying it to allow us to explore more about the possible midterm effects. This survey is based on the STOPS model (Jeong-Nam Kim and James E. Grunig 2011), Section 3.1 will explain this development in detail. The qualitative tool involved a series of semi-structured interviews used to explore deeper into the changes observed in the survey. Drawing from established qualitative research practices, these interviews were designed to encourage open-ended discussions and enable participants to elaborate on their impressions about the activities, as well as any changes observed in themselves and other workshop participants. The interviews were conducted with workshop participants, ten to twelve months after the workshops concluded. See section 3.2 for more details about semi structured interview guide. The interviews covered their overall perspectives on Natech risks, their awareness and understanding of Natech risks before and after the workshops, and the extent to which they had implemented or were planning to implement any Natech risk reduction measures.

The third step consisted of the implementation of the mentioned tools developed in the second step to a cohort of participants that underwent serious gaming workshops related to risk management. The aim of the quantitative part was to be sent to all the workshops participants. For the qualitative part, we used a stratified sampling, considering the roles of the participants. 8 interviews were conducted, including participants representing all the stakeholders included in the mentioned workshops, to identify the key concepts behind the whole learning and implementation process. We divided the population into five distinct groups based on their roles on the Risk management process in the country, to ensure we captured a diverse range of perspectives.

Finally, the fourth step was to conduct a comprehensive analysis of the data gathered through the survey and interviews. The survey results were analyzed using descriptive statistics and regression models, while the interviews were transcribed and analyzed using a grounded theory approach.

5.3.1. Quantitative evaluation tool: Follow up survey

This part of the study aimed to describe participants' changes in perspectives after 10-12 months following the serious gaming workshops implemented by the authors in Colombia, as described in Chapter 4. The survey was sent to all the participants we could contact via email, using Google forms. The survey was active online for 6 weeks.

The present survey built upon the previous post-workshop survey as a foundation. It was then modified to account for the time elapsed and the new objective of evaluating mid-term changes and potential implemented actions. Questions related to the game dynamics were eliminated, as this had already been addressed in a prior stage of the study. Similarly, questions about previous expectations were removed, since the workshops had already been conducted. Additionally, new questions were included to explore any actions taken by the participants.

The following outlines the key components of the follow-up survey Table 5. 1. The modified survey included 68 questions, distributed across 7 sections. The first section contained 14 entirely new questions to follow up on the possible effects of participating in the workshops and any actions that may have been implemented as a result. The second section included 6 questions about Natech

risk perception. The third section had 33 questions regarding risk communicative behaviors. The fourth section entailed 5 questions about Natech risk awareness. The following, the fifth section, contained 5 questions about the importance of the Natech risk communication process. Finally, the sixth section contains questions about the expectations about the serious game workshop, and the impressions after them. Questions regarding the gaming experience were not included anymore in the follow up survey, since this has been already discussed in the post-workshop survey. Sections 2 through 6 are completely comparable to the post-survey presented earlier. Finally, some general questions were added to identify the demographics of the participants, enabling analysis of the importance of role, age, and other factors. The survey utilized a 7-point Likert scale, with 7 indicating the highest agreement or highest importance of the presented information and being 1 the lowest agreement or lowest importance.

Table 5. 1. Sections and questions of the surveys

Pre-workshop	Post-workshop	Follow-up
N.A.	N.A.	14 questions Possible effects the workshops and any implemented actions
6 questions Natech Risk Perception before the workshops	6 questions Natech Risk Perception immediately after the workshops	6 questions Natech Risk Perception in the mid-long term
33 questions Risk communicative behaviors before the workshops	33 questions Risk communicative behaviors immediately after the workshops	33 questions Risk communicative behaviors in the mid-long term
5 questions Natech Risk awareness before the workshops	5 questions Natech Risk awareness immediately after the workshops	5 questions Natech Risk awareness in the mid-long term
Workshop and game expectations	Workshop and game impressions	N.A.
General questions about individuals' backgrounds	General questions about individuals' backgrounds	General questions about individuals' backgrounds

5.3.2. Qualitative evaluation tool: Follow up – interviews

The study involved conducting semi-structured interviews to gain deeper insights into participants' perspectives. The interviews explored participants' perceptions of Natech risk, any changes in their Natech risk awareness, and any disaster risk-related actions they had taken after the workshops. The interviews also sought to understand participants' views on their own performance in the risk management and risk governance processes, as well as their perceptions of other participants' performance during and after the workshops.

The questionnaire development was guided by a researcher who is an expert in qualitative research methods. The author Ortwin Renn (2008), has developed a framework that offers a common structure for examining and supporting the management of risk issues by the pertinent actors in society. This approach does not solely concentrate on how the authorities address risks but rather places equal emphasis on the roles and interactions of the corporate sector, scientific community, other stakeholders, and civil society. The semi-structured interview guide included a mix of pre-determined questions and flexibility to explore relevant topics that emerged during the conversation. The questions were grounded in participants' experiences since the workshops, avoiding complicated theoretical concepts or jargon. Open-ended questions encouraged participants to provide their perspectives and describe their experiences in their own words. Probing questions were used to delve deeper into specific insights or activities mentioned by the participants. Closed questions were also included to clarify particular data points. The following table shows the questions used for the interviews (

Table 5. 2).

Table 5. 2. Semi structured interview questions.

Section	Question
I. General questions	1. Demographics (Age, Sex, role, education, marital status):
	2. One question to engage the participants. Something to refresh their memory or connects with their <i>emotions</i> .

	3. It is now eight months that you attended the Natech Workshop: Now, with a distance in time, what do you think were the lasting accomplishments induced by the workshop, and what were, in your view, the main shortcomings that still remain unresolved? a. Probe for both positive and negative impressions b. Probe for naming the actors that were instrumental for the positive or negative <i>outcomes</i>
II. Self image	4. Have you taken any practical measures related to what you have learned in the workshops
	5. If nothing comes, suggest some options such analyzing your house surroundings, to look for industrial facilities presence in your area, looking up for your house constructions codes, early warning systems in your phone, preparing an emergency kit for your house).
	6. Have you been personally involved or requested to become involved in any activities related to DRR ?
	7. If so, could you explain the nature of this involvement and where is has been or will be performed?
	8. Have you communicated any needs, complaints, or requirements to the local government? Regional? National?
	9. Did you experience any change or request for change with respect to the expectations of others about your role in the DRR?
III. Image about others	10. Have you met or communicated with any of the other participants in the workshops in the aftermath of the workshops?
	11. Are you aware of any efforts taken by the other participants of the workshops?
	12. Could you explain the nature of these efforts (such as measures taken, or communication campaigns started) and who has been involved? a. Probing: What about the (actors that were not mentioned, such as industry, local government, national government, academia etc.))
	13. Did the other actors performance meet your expectations or were you dissatisfied with their performance after the workshop and, if so, why?
	14. Is there anything else you would like to mention about these activities? Something you might have learned, would like to share, or any recommendation of how to improve the process and to be more effective?.

To conduct the semi-structured interviews, we needed to select a sample of participants. A Non

probabilistic (stratified) sampling approach was chosen given the nature of the research questions. The researchers purposefully selected participants who had attended the workshops to obtain a diverse range of perspectives on the topics of interest. Efforts were made to include participants from different backgrounds, roles, genders and education levels.

Given the diverse demographics, professional backgrounds, and locations of the initial participant pool, we wanted to ensure that our interview sample mirrored this diversity. Since our goal was to understand the perspectives of multiple stakeholders, we made sure to include at least one representative from each group. To achieve this, we first categorized the participants into different groups based on their roles. We considered characteristics such as age, gender, education level, and location as secondary. From each of these groups, we then purposefully selected 1 or 2 individuals to participate in the interviews, resulting in a total sample size of 8 interview participants.

The survey was conducted through online meetings, which were recorded for further revision upon participant approval. Each interview consisted of 14 questions, lasting between 20 and 30 minutes. All the participants were reminded about the academic purpose of the activity, then provided with some research background information, asked their permissions to record and reminded about their right not to answer to any questions. The questions focused on: i) some general questions to obtain more information about the participants' personal and professional backgrounds, as well as their roles in the Natech Risk Management process in Colombia, ii) the participants' self-image, which encompasses their attitudes, opinions, and ideals regarding risk awareness and their role in the risk communication process. Additionally, this section includes questions about any actions taken by the interviewees as a result of their participation in the workshops, as well as their knowledge and awareness of Natech Risk gained from the workshops, iii) and also questions to compare their perceptions of changes in other participants. To choose the participants, a sample was chosen based on grounded theory. The interviews were transcribed and analyzed using an inductive approach to identify key themes and insights. The main findings of the interviews are presented in the following results section.

5.4. Results

The roles of the survey participants were distributed, according to the following figure. The

majority of respondents belonged to the national government level, the industry and the academia.

Roles of the participants

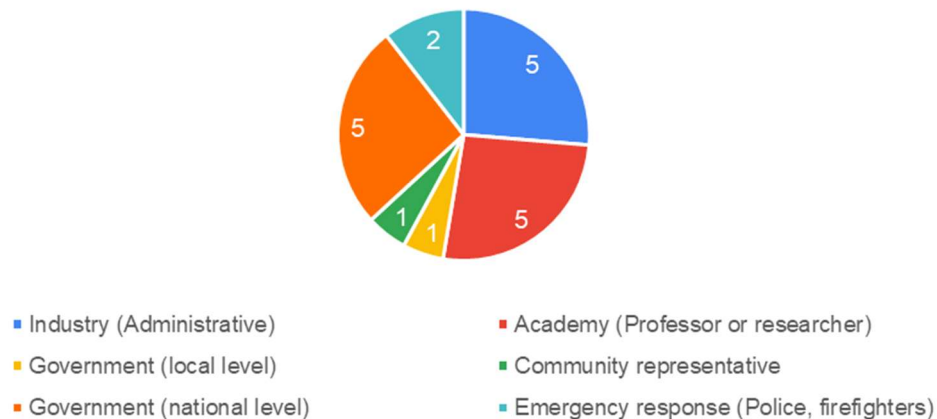


Table 5. 3. Roles of the participants in real life

The survey contained questions related to their impressions about the workshops, knowledge and risk perceptions, actions taken after the workshops, and factors influencing the adoption of risk reduction measures (

Table 5. 2). The first part, regarding the follow up part, included 14 questions.

When it comes to the positive outcomes, most participants (11 out of 19) mentioned realizing the importance of the participation of multiple stakeholders during the decision-making process, and how the workshops allowed them to meet individuals from different backgrounds and recognizing how important this is for real life. The second most mentioned topic (9 out of 19) was the game helping them to be more aware about risks and sometimes not being prepared enough, as individuals and as a society. When asking them about the needed improvements in the tool and workshops, the replies were more diverse. They mentioned the need to include more and more adapted game scenarios, showing the specific hazards of their regions (5 out of 19), followed by the sense of better logistics needed (simpler instructions to have more time available for discussion) by 6 participants out of 19, and finally the need for more stakeholders to participate (3 out of 19). All 19 (100%) participants expressed they shared their workshops experiences in their personal (family and friends) and professional circles, showing the activity left and impression on them.

When analyzing the reported actions 84% of the participants (16 out of 19) reported having implemented actions, some of them reported more than 1 action. The implemented actions corresponded to: the preparation of a family emergency kit (63.2%, 12/19), reviewing and identifying of the presence of industrial facilities near their homes (47.4%, 9 out of 19), the analysis of potential natural hazards in the areas where they live (42.1%, 8 out of 19), checking for available early warning systems (26.3%, 5 out of 19), and finally reviewing building codes for their households (15.8%, 3 out of 19). One participant mentioned having implemented the mentioned actions before the workshop (See the following Figure).

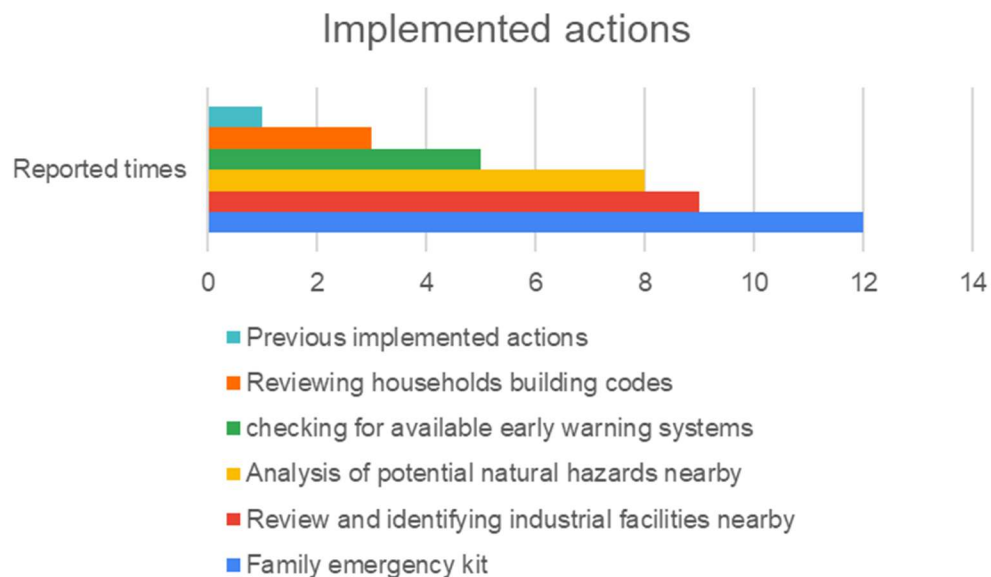


Table 5. 4. Reported implemented actions in the follow up survey.

Regarding their perception about themselves and their roles in the Natech risk management process, the majority of participants reported not being involved in any initiatives related to Natech risk management (79%), nor having communicated any needs or requests to local, regional, or national government entities (58%). Additionally, they indicated that they had not experienced any change in their perceived expectations about their roles from other participants (83%). Seventy-one percent, reported they had not met with any other participants since the workshop (71%) (See Table 5. 4).

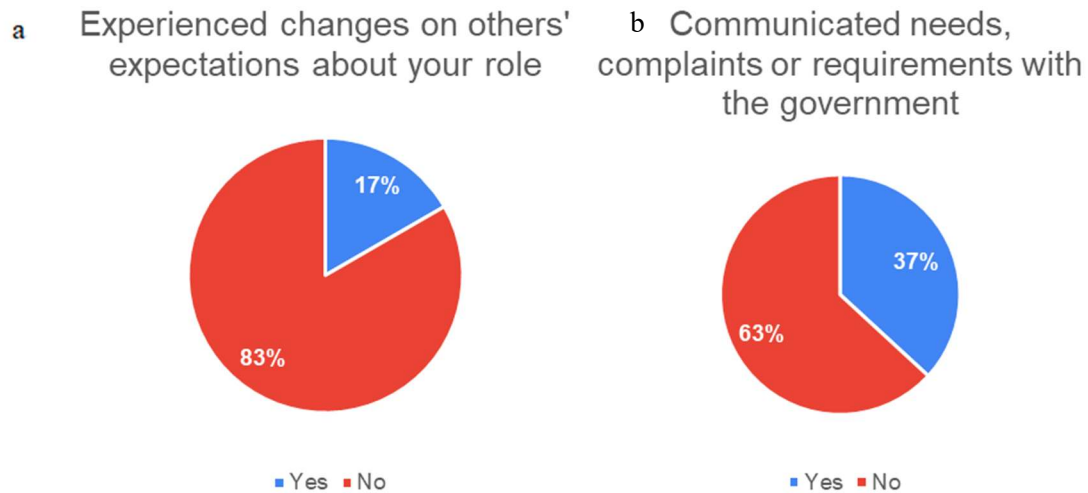


Figure 5. 2. Perceived change in others' expectations, b. Meeting other participants after the game.

The majority of participants reported not being aware of any initiatives undertaken by other participants when asked about their perceptions of others (89%). Furthermore, most participants reported being satisfied with the performance of other participants in their roles (90%). Only one participant reported feeling frustrated, because in reality, taxes mean they lose economic capacity to face real life, and in during and emergency, everything can be lost by not taking actions for the protection of assets because of this (See Figure 5. 2).

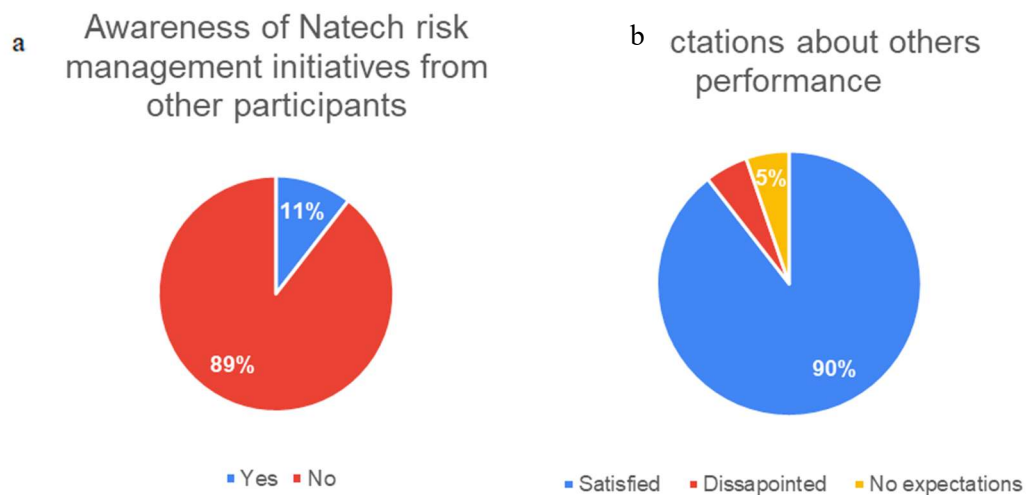


Figure 5. 3. a. Reported awareness about others participation in Natech risk management, b. Reported satisfaction about others performance.

Finally, an open question was asked about any additional points the participants wanted to communicate. The responses highlighted the importance of the topics covered, the desire to have access to the serious game to use in their territories and also stressed the need to adapt the game to the Colombian territory.

5.4.1.1. Stakeholders risk perception

The results of this survey were compared to the previous results, from the survey conducted before the workshops and after them (Chapter 4). The pre-workshop survey was designed to assess the participants' baseline risk awareness and perceptions prior to the workshop activities. The post-workshop survey aimed to evaluate any changes in the participants' risk awareness and risk perceptions following their engagement with the serious gaming workshops. The findings indicated that engagement in the serious gaming workshops heightened the participants' awareness of Natech risks. When asked about their perception on how important they think Natechs constitute a problem, the majority of participants (74.6%) considered Natech as an important problem, this percentage raised up to 89.7% after the workshops and it stayed stable in the mid-long term (89.5%) (See Figure 5. 4).

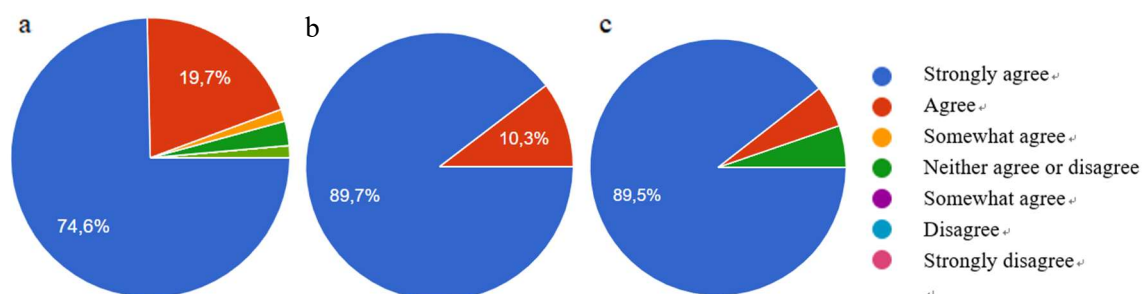


Figure 5. 4. Workshop participant's perception on how important they think Natechs constitute a problem a) before the workshop, b) after the workshop and c) in the mid-long term.

When asked how strongly they agreed with the statement "Currently I'm concerned about technological events that might be triggered by natural hazards and their consequences", the percentage of participants who reported "Strongly agree" increased from 64.8% before the workshops,

to 79.3% after the workshop, and maintained at 78.9% in the mid-long term survey (Figure 5. 5).

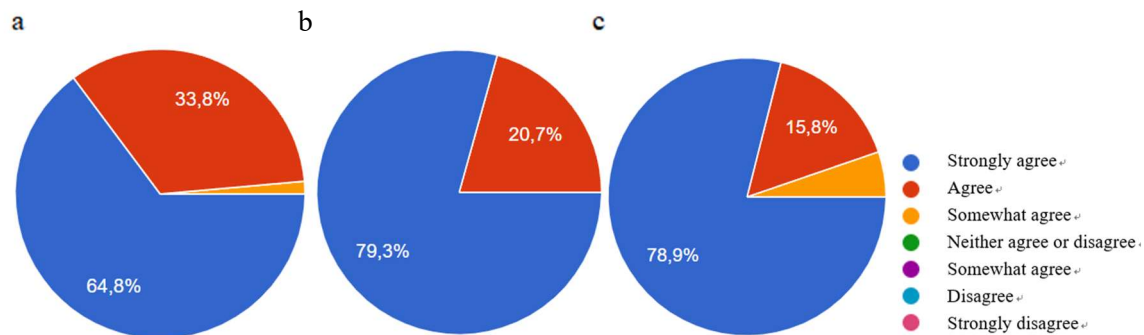


Figure 5. 5. Workshop participant's expressed concerned about possible technological events that may be triggered by natural events and their consequences a) before the workshop, b) after the workshop and c) in the mid-long term.

The percentage of participants who strongly agreed with the statement "If a large earthquake occurs, I think it could trigger a technological event in one of the industrial areas in the city where I live" went from 60.6% before the workshops to 79.3% after the workshops, remaining at 63.2% in the mid-long term.

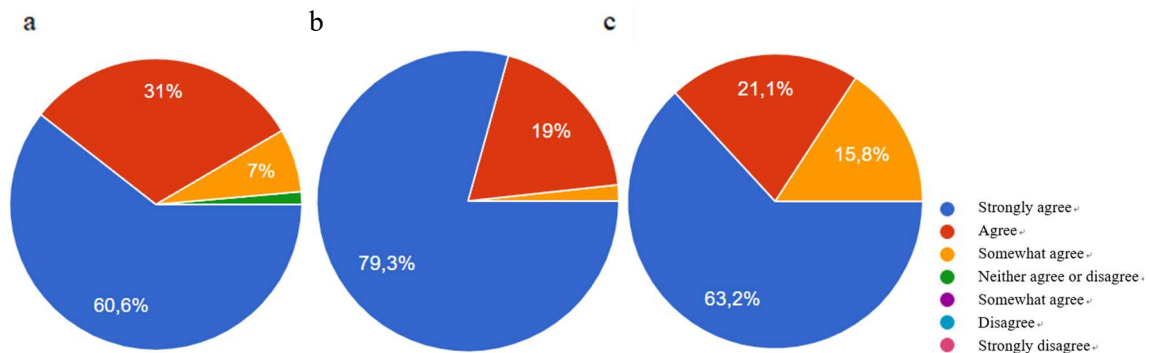


Figure 5. 6. Workshop participant's perception about the possibility of a large earthquake triggering a technological event in one of the industrial areas in their cities a) before the workshop, b) after the workshop and c) in the mid-long term.

It is interesting to compare, when a similar question is asked, but about the areas near their households or their workplaces, all the values are lower, showing a difference in their perception

about the city in general terms, and their familiar areas. However, the trend is similar, raising from 45.1% before the workshops, to 67.2% after the workshops, and showing a decrease in the mid-long term to 52.6%, but still higher than before the workshops (Figure 5. 7).

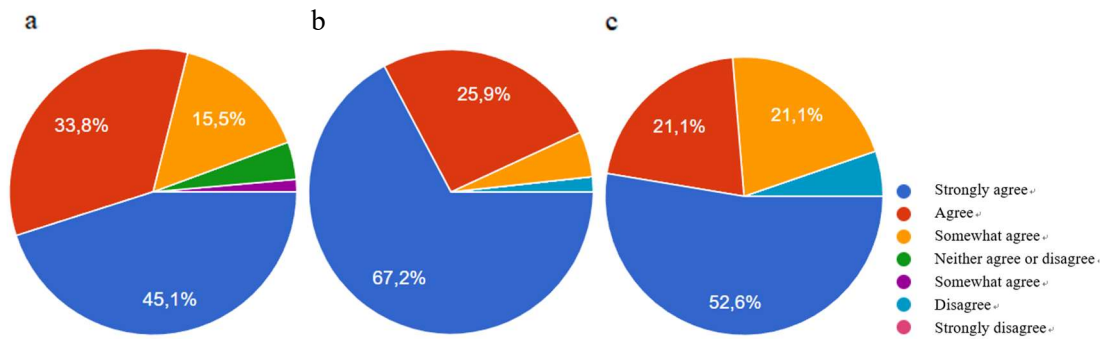


Figure 5. 7. Workshop participant's perception about the possibility of a large earthquake triggering a technological event in one of the industrial areas in their cities a) before the workshop, b) after the workshop and c) in the mid-long term.

Similarly, when asked about their level of concern regarding the potential Natech events and associated consequences, the percentage of participants who reported "Strongly agree" increased from 74.6% before the workshops to 79.3% immediately following the workshops, and remained relatively stable in the mid-to-long-term assessment (78.9%) (See Figure 5. 8).

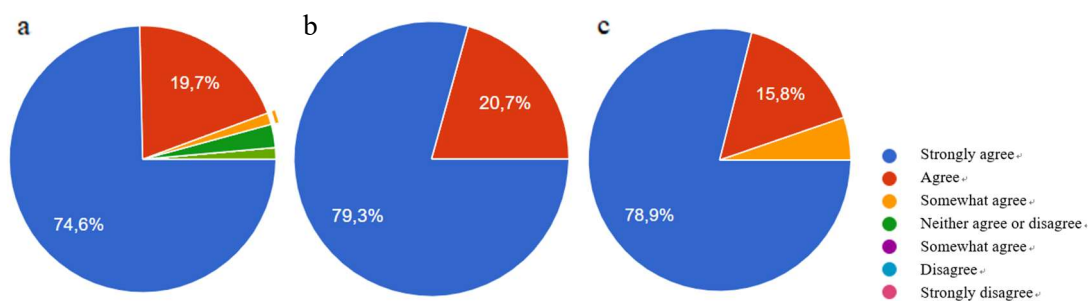


Figure 5. 8. Workshop participant's concern about the possible Natechs and their consequences a) before the workshop, b) after the workshop and c) in the mid-long term.

When analyzing their perceived capacity to ensure their safety, before the workshops only 38.2% of participants reported being "prepared" or "very prepared" to face Natech risks. After the workshops, this percentage increased to 79.3%, showing a significant improvement in their self-reported level of

preparedness Figure 5. 9.

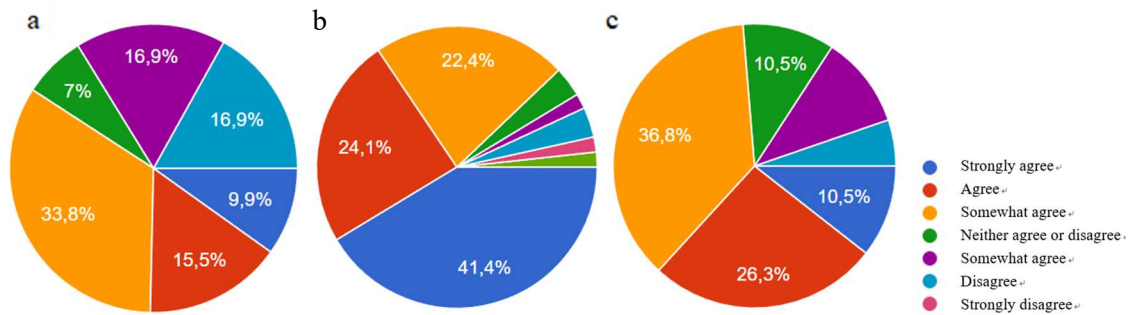


Figure 5. 9. Workshop participant's perception about their ability to remain safe a) before the workshop, b) after the workshop and c) in the mid-long term.

In general terms, the risk perceptions consistently raised up to a point after the workshops, and remained relatively stable in the mid-long term evaluation, suggesting that the workshops contributed to increasing the participants' awareness of Natech risks.

5.4.1.2. Risk awareness changes

The current research further explored changes in the participants' risk awareness about Natech risks, following their engagement with the serious gaming workshops. Results showed that before the workshops, 71.8% of participants agreed that the hazards or threat level influence on the consequences of the potential events, reaching 86.2% after the workshops, and decreasing to 78.9% in the mid-long term (Figure 5. 10).

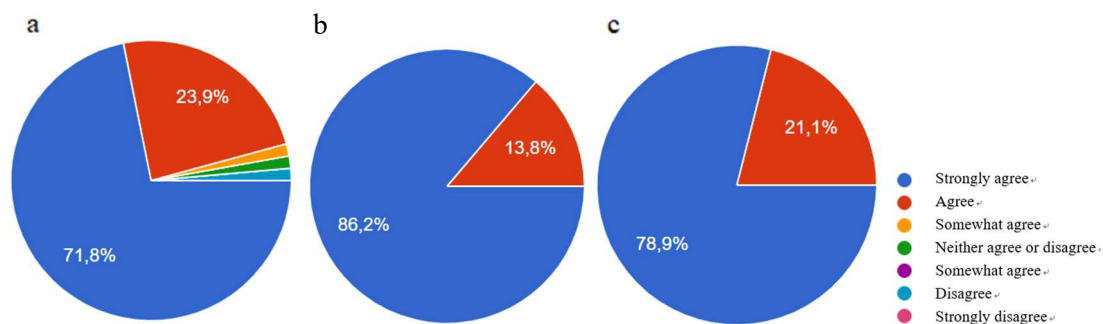


Figure 5. 10. Awareness about the influence of the intensity of the hazard on the possible consequences. a) before the workshop, b) after the workshop and c) in the mid-long term.

The situation also changed when participants were asked about the exposure to Natech of all the areas in a territory. Before the workshops, only 12.7% reported expressing "Strongly agreeing" and 14.1% "Agreeing" that all the areas are equally exposed to Natech, increasing to 25.9% "Strongly agreeing" and 15.5% "Agreeing" after the workshops. The situation showed a completely trend in the mid-long term, where only not a single participant reported "Strongly agreeing" and only 5.3% "Agreeing". This signals that the serious gaming workshops contributed to a better understanding among the participants of the spatial heterogeneity and uneven exposure to Natech risks within a given territory.

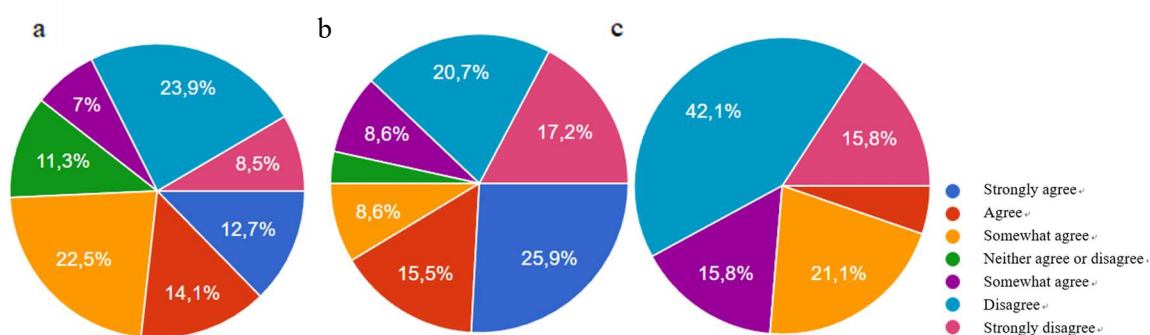


Figure 5. 11. Awareness about the differences in spatial exposure to Natech risks. a) before the workshop, b) after the workshop and c) in the mid-long term.

When analysing the awareness about how important it is to avoiding hazards when choosing a place to live, the results showed an increase from 54.9% "Strongly agree" and 36.6% "Agree" before the workshops, to 75.9% "Strongly agree" and 24.1% "Agree" after the workshops, and a decrease to 68.4% "Strongly agree" and a slight increase 36.6% "Agree" in the mid-long term (Figure 5. 11).

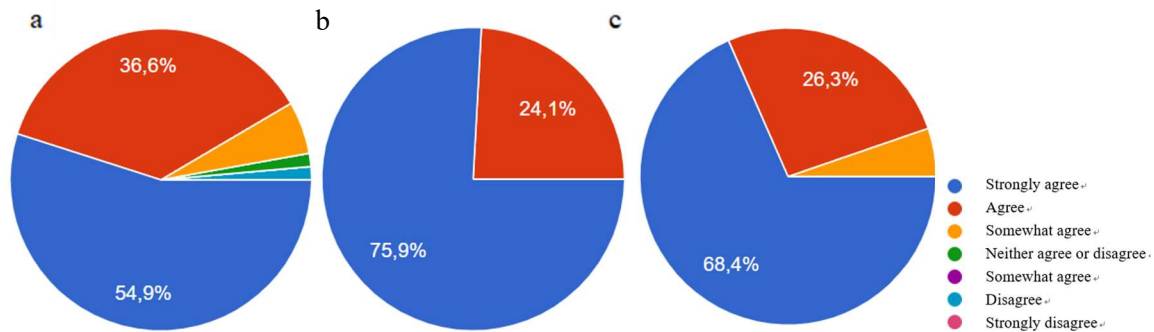
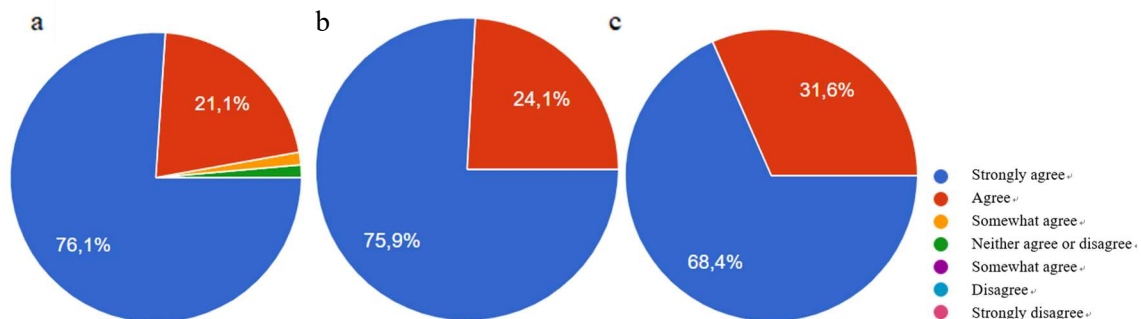


Figure 5. 12. Awareness about the importance of avoiding hazards when choosing a place to live a) before the workshop, b) after the workshop and c) in the mid-long term.

The awareness regarding the significance of urban planning and resource allocation to mitigate the impacts of potential Natech events exhibited a distinct trend compared to the other factors examined. This was the sole parameter evaluated in the risk awareness assessment that exhibited a decline on the "Strongly agree" responses, the post-workshops (75.9%) compared to the pre-workshops (76.1%), and kept decreasing in the mid-long term (68.4%). However, when considering both "Strongly agree" and "Agree" responses, the total percentage was higher after the workshops (100%) and kept in the mid-long term (100%) compared to the situation before the workshops (97.2%) (See Figure 5. 12).



. The importance of urban planning and resource allocation to reduce the impacts of potential Natech a) before the workshop, b) after the workshop and c) in the mid-long term.

When looking at the awareness about the importance to access information about the risk of industrial accidents and its influence on the preparedness actions of area residents, the trends are similar, showing an increase from the pre-workshops to the post-workshops, and a slight decrease in the mid-long term, but still higher than the pre-workshop values, starting at 56.3%, raising up to 87.9% and finally decreasing to 68.4% (Figure 5. 13).

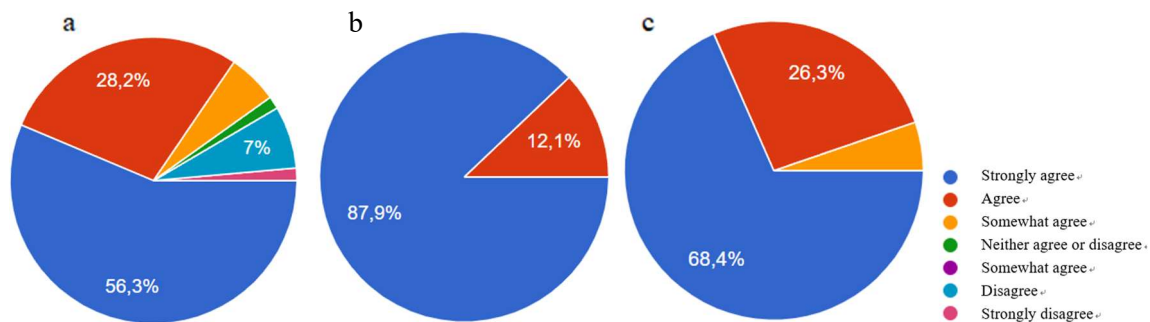


Figure 5. 13. Awareness of the importance to access information about the risk of industrial accidents and its influence on the preparedness actions of area residents a) before the workshop, b) after the workshop and c) in the mid-long term.

5.4.1.3. Risk communication changes

In regards to the participants' perceptions about risk communication, the workshops seemed to have a positive impact. When comparing the results before the workshops and the follow up survey, in the mid-long term there was an increase in the mean of the replies related to Natech Risk perceptions, however, regarding Natech Risk awareness, the mid-long term values were found to be lower compared to the pre-workshop values.

Figure 5. 14 provides a summary of the participants' perspectives on the importance of Natech risk communication. Regarding the information about hazardous chemicals and their adverse health effects, the responses of "Extremely important" increased from 77.5% before (blue) the workshops to 84.5% after the workshops (yellow), and went even higher in the mid-long term 89.5% (orange). Regarding the information about areas potentially affected by Natech, the "Extremely important" responses increased from 64.8% before to 82.8% after the workshops but decreased to 73.7% in the

mid-long term. A similar trend was observed for the importance of information on preparedness and response actions for Natech events, with the "Extremely important" responses increasing from 64.8% before to 82.8% after the workshops, and 84.2% in the mid-long term. The results for the importance of information on evacuation shelters in case of Natech events showed a more balanced increase, from 69% "Extremely important" before to 75.9% after, and 73.7% in the mid-long term. And, the importance of information on plans and preparedness measures taken by government and industries for possible Natech events followed a similar trend, with "Extremely important" responses increasing from 69% before to 79.3% after, and 78.9% in the mid-long term. Overall, the workshops seemed to have a positive impact on the participants' regarding the importance of different types of risk communication information related to Natech events.

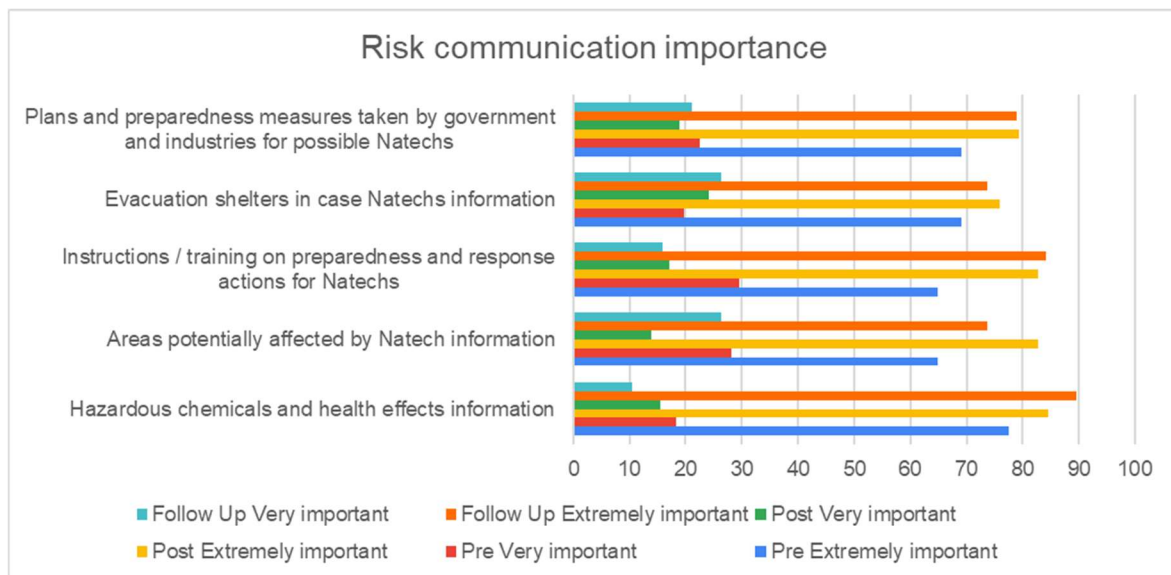


Figure 5. 14. Changes in the risk communication importance given by the workshop participants

Regarding the importance of the information about hazardous chemicals and their adverse health effects, the responses of "Extremely important" increased from 77.5% before the workshops to 84.5% after the workshops, and went even higher in the mid-long term 89.5%. Regarding the information about areas potentially affected by Natech, the "Extremely important" responses increased from

64.8% before to 82.8% after the workshops, but decreased to 73.7% in the mid-long term. A similar trend was observed for the importance of information on preparedness and response actions for Natech events, with the "Extremely important" responses increasing from 64.8% before to 82.8% after the workshops, and 84.2% in the mid-long term. The results for the importance of information on evacuation shelters in case of Natech events showed a more balanced increase, from 69% "Extremely important" before to 75.9% after, and 73.7% in the mid-long term. And, the importance of information on plans and preparedness measures taken by government and industries for possible Natech events followed a similar trend, with "Extremely important" responses increasing from 69% before to 79.3% after, and 78.9% in the mid-long term. Overall, the workshops seemed to have a positive impact on the participants' regarding the importance of diverse types of risk communication information related to Natech events.

5.4.2. The qualitative part: follow-up interviews

The aim of the quantitative part of the study was to obtain responses from all the participants, as mentioned earlier. Drawing from established qualitative research practices, these interviews were designed to encourage open-ended discussions and enable participants to elaborate on their impressions about the activities, as well as any changes observed in themselves and other workshop participants. Since our goal was to understand the perspectives of multiple stakeholders, we made sure to include at least one representative from each stakeholders group.

To achieve this, we first categorized the participants into different groups based on their roles. It was important to build trust with the interviews. The researchers believe this was overcome by their career background, related to the level of knowledge about the topic of the interviews. The researchers' profile is known to the interviewees. The following table shows the summary of the interviewees.

Table 5. 5. Conducted interviews summary.

Interviewee	Identifier	Role	City	Role in the workshop
#1	A	Academia	Medellín	Citizen
#2	B	Academia	Bogotá	Community leader
#3	D	First responder	Bucaramanga	Community leader
#4	E	Community	Bogotá	Community leader
#5	F	First responder	Bogota	Industry leader
#6	G	Industry	Bogota	Citizen
#7	H	Government	Bogota	Citizen
#8	I	Industry	Bucaramanga	Citizen

The interview data was analyzed using a thematic analysis approach. The initial round of coding identified broad themes such as risk perceptions, risk communication, and disaster risk reduction measures (Table 5.6). This process involved reviewing the interview transcripts, identifying key quotes and concepts, and grouping them into preliminary themes.

Table 5. 6. Initial coding

Labels	Codes
Roles	Real life codes
	Transmitted information
Midterm actions	Actions
	Emergency kits
	Emergency preparedness
	Checking surroundings for natural events
	Checking surroundings for technological events
	Checking surroundings for Natech
	Sharing with coworkers
	Sharing with family
	Sharing with friends
	Risk perception
	Domestic risks
	Checking for early warnings systems
	DRR initiatives (Not related with the workshops)
	DRR initiatives (related with the workshops)
	DRR requirements (Not related with the workshops)
	DRR requirements (related with the workshops)
	Risk commission/group/committee member
Trust	Preventive actions
	Teamwork
	Unknown people

	Positive Peoples interaction
	Negative people's interaction
Past experiences	Unexperienced people
	Experienced people
	Initiatives
	Natech related activities
	Related/ real scenarios
	Real maps
	Practical activities
	Videogames
	Personal interaction
	Natech risk education
	Stakeholders Communication problems (when an emergency)
Game experience	Short instructions
	Pilot game
	Time constraints
	Participants experience related to disaster risk management
	Participants sharing the experiences
	Games methodology
	Desire to have access to the game
	More diverse scenarios
	Difference between the game and the reality (when decisions are made)
	Lack of trust in reality
	Stakeholders trust
	Workshops participants trust
Discussed topics	Hazardous materials transportation
	Hazardous materials leak
	Flooding
	Data registering
	Natural Gas leak
	Domestic explosions
	Domestic fires
	Multidisciplinary
	Stakeholders' performance

These themes were then further refined and categorized into sub-themes through an iterative process of reviewing the interview transcripts. The coding process was performed using Taguette, a website that allows for qualitative data analysis. The finalized themes and sub-themes are presented in the following table:

Table 5. 7. Finalized themes and sub-themes.

Themes	Codes	Description	# Codes
Actions (mid-long term)	action.nonrelated	Non-workshop related risk reduction initiatives	22
	action.emergencyprep	Emergency preparedness actions implementedlike preparing an Emergency Kit or Family Emergency plan	4
	action.nondrmrequ	Actions and Requirements for non related with the workshops disaster risk reduction, like Participating in a Risk committee, Risk committee roles	4
	action.surroundings	Check neighbors, neighboring industries, dangers in the neighborhood	4
	action.earlywarning	Early warning systems	2
Natech Risk perceptions and awareness	aware.industrialevents	awareness of technological events, industrial accidents, including the possibility	21
	aware.lack	Being aware of lacking awareness	21
	aware.natech	awareness about Natech events, natech event, accident after a natural event, what they are and the potential risk	17
	aware.changed	Sharing about experiencing changes in awarenes levels	13
	perception.others	performance of other actors	9
	aware.flooding	being aware of the risk of flooding is important	8
	perception.risk	risk perception, risk awareness	8
	aware.earthquake	being aware of the risk of eartquake is important	7
	mixingmemories	Being sure about something about the game, when there is proof it happened in a different way	4
	perception.self	self-perception	4
	aware.domesticrisks	Awareness of domestic risks, at home, fire at home, explosion at home, event at home	3
Risk communication	comm.issues	Related issues to achieve risk comm, Information not shared, not	21
	comm.sharinfo	Information transmitted, shared, received from others	14
	comm.lacktrust	There is no trust, Lack of trust, no dialogue	11
	comm.trust	Trust in others, trust in actors, strangers, interacting with strangers	11
	comm.sharingprofessional	Participants sharing the experiences with coworkers and colleagues	10
	comm.sharingpersonal	Sharing with family and friends	6
Experiences	exp.industrialevents	Industrial, domestic, gas, gasoline, LPG, chemicals, substances, hazardous	9
	exp.naturalevent	Having experienced a natural event	8
	exp.previous	Having lived through events, having past experiences, Court	7
	exp.drm	Participants experienced in related to disaster risk management	2
	exp.lacking	Lack of experience, they have not experienced natural, industrial or Natech events, they have no experience	2
Game workshop experience	game.posexp	Good experiences and impressions about the game, they like the methodology, the feeling, enjoyed the eperience, meeting others	38
	game.particip	More participation is needed from more stakeholders	30
	game.negexp	Things to improve in the game: short instructions, very quick explanation, Japanese, kanji,rudimentary materials,	20
	game.access	The wish to have access to the game to play in their environments	14
	game.scenarios	To their realities, to feel closer and more related.	13
	game.realmaps	More grounded maps	10
	positive.interaction	Positive interaction, very positive interaction	8
Multi-stakeholders roles	roles.industry	Talking about the industry responsibilities in DRM	30
	roles.natgov	Talking about the national gov responsibilities in DRM	25
	roles.community	Talking about the communities responsibiliti in DRM	23
	roles.first responders	Talking about the partes and responsibilities of police, firefighters, civil defense in DRM	17
	roles.multidisciplinarity	the importance of Multidisciplinarity in the roles diversity in backgrounds and experiences	14
	roles.reallifediff	Talking about the difference of the roles during the game and the roles in real life	6
	roles.locgov	Talking about the local gov responsibilities in DRM	5
	roles.academia	Talking about the partes and responsibilities of professors, researchers and students in DRM	4
	roles.conflict	conflicts that arised during the game or might arise in the real life	3
	roles.reggov	Talking about the national gov responsibilities in DRM	2
	teamwork	Experienced the importance of teamwork	2

Regarding the first theme, Natech Risk perceptions and awareness (Table 5. 8), the most recurring themes were awareness of the risk of industrial accidents, including fires and explosions and the lack of awareness about Natech risks. After that, awareness of the risk potential Natechs in general, earthquakes and flooding were frequently mentioned. Some participants also discussed changes in their risk awareness over time and how their perceptions were influenced by the experiences of others

Table 5. 8. Theme analysis. Natech Risk perceptions and awareness codes

Themes	Codes	Description	# Codes
Natech Risk perceptions and awareness	aware.industrialevents	Awareness of technological events, industrial accidents, potential fires and explosions	21
	aware.lack	Being aware of lacking awareness	21
	aware.natech	Awareness about Natechs, accident after a natural event, what they are and potential risks	17
	aware.changed	Sharing about experiencing changes in awareness levels	13
	perception.others	Awareness about stakeholders performance	9
	aware.flooding	Flooding risk awareness	8
	perception.risk	Risk perception, risk awareness	8
	aware.earthquake	Earthquake risk awareness	7
	mixingmemories	Being sure about the workshops experience, evidence it happened in a different way	4
	perception.self	Self-perception	4
	aware.domesticrisks	Awareness of domestic risks, fires or explosions at home, event at home	3

The second main theme was Risk communication (Table 5. 9), and the most mentioned sub-theme was communications issues. The most prevalent issues were the lack of information sharing and the lack of communication channels between different stakeholders, along with a lack of trust and dialogue. However, the participants also referred to the game workshops allowed to exercise information sharing and building trust in a controlled environment. Finally, some of them expressed having shared their experiences in the workshops with colleagues or family members and friends.

Table 5. 9. Theme analysis. Risk communications codes.

	Codes	Description	# Codes
Risk communication	comm.issues	Related issues to achieve risk comm, Information not shared	21
	comm.sharinfo	Information transmitted, shared, received from others	14
	comm.lacktrust	There is no trust, Lack of trust, no dialogue	11
	comm.trust	Trust in others, trust in actors, strangers, interacting with strangers	11
	comm.sharingprofessional	Participants sharing the experiences with coworkers and colleagues	10
	comm.sharingpersonal	Sharing with family and friends	6

The third theme corresponds to mid-long-term actions (Table 5. 10) related to disaster risk reduction measures and strategies, they were classified into several sub-themes. The one that was raised the most was actions not related with the workshops, that the participants either took before the workshop or independently of it. For example, some reported being part of risk committees. Most commonly taken actions after the workshops were preparing and maintaining emergency kits and emergency family plans, both at the household and community levels, as well as checking their surroundings for industries and natural hazard information, and finally using early warning systems.

Table 5. 10. Theme analysis. Actions in the mid-long term codes

	Codes	Description	# Codes
Actions (mid-long term)	action.nonrelated	Non-workshop related risk reduction initiatives	22
	action.emergencyprep	Emergency preparedness actions implemented. Preparing an Emergency Kit / plan	4
	action.nondrmrequ	Actions and Requirements not related with the workshops disaster risk reduction, Participating in a Risk committee, Risk committee roles	4
	action.surroundings	Check neighbors, neighboring industries, dangers in the neighborhood	4
	action.earlywarning	Early warning systems	2

The fourth theme refers to the roles and responsibilities among the multi-stakeholder's in disaster risk management (

Table 5. 11). The responsibilities more frequently mentioned were the industry and the national government, followed by the community, and first responders. Another topic frequently brought up by the interviewees was the importance of multi-disciplinary collaboration in DRM and all the related decision making. Others mentioned about the differences between the workshops and real-life situations, were conflicts and differing views can arise. Some other notable topics refer to the responsibilities of the local government, academia, and the potential for conflicts among stakeholders. The least mentioned role was that of the regional government level. Finally, a small number of participants highlighted the importance of teamwork during the workshops.

Table 5. 11. Theme analysis. Multi-stakeholder's roles codes

	Codes	Description	
Multi-stakeholders roles	roles.industry	Talking about the industry responsibilities in DRM	30
	roles.natgov	Talking about the national gov responsibilities in DRM	25
	roles.community	Talking about the communities responsibiliti in DRM	23
	roles.first responders	Talking about the partes and responsibilities of police, firefighters, civil defense in DRM	17
	roles.multidisciplinarity	the importance of Multidisciplinarity in the roles diversity in backgrounds and experiences	14
	roles.reallifediff	Talking about the difference of the roles during the game and the roles in real life	6
	roles.locgov	Talking about the local gov responsibilities in DRM	5
	roles.academia	Talking about the partes and responsibilities of professors, researchers and students in DRM	4
	roles.conflict	Conflicts that arised during the game or mighth arise in the real life	3
	roles.reggov	Talking about the national gov responsibilities in DRM	2
	teamwork	Experienced the importance of teamwork	2

The fifth theme relates to the participants' previous experiences (

Table 5. 11), related to previous technological events and natural events. Other experiences included events that the participants observed or heard about, from media coverage or other sources, but did not involve any hazardous materials or energy liberation. Finally, other previous experiences were related to the disaster risk management process, and the lack of experience perceived as a barrier.

Table 5.12. Theme analysis. Past experiences codes

	Codes	Description	# Codes
Experiences	exp.industrialevents	Industrial, domestic, gas, gasoline, LPG, chemicals, substances, hazardous materials	9
	exp.naturalevent	Having experienced a natural event	8
	exp.previous	Having lived through events, having past experiences	7
	exp.drm	Participants experienced in related to disaster risk management	2
	exp.lacking	Lack of experience, they have not experienced natural, industrial or Natech events, they have no experience	2

The sixth theme is related to the serious game workshops, and how the participants remember them (Table 5.12). The codes related to this theme reflect their thoughts about the usefulness and relevance of the workshops, the positive learning experiences, the challenges they faced, and their suggestions for improvement. The most common feedback was that the workshops were useful enjoyable and relevant, and they helped increase their disaster risk awareness and preparedness, and allowed them to meet other stakeholders, broadening their perspectives and fostering collaboration. A commonly mentioned topic was the need to bring more stakeholders to the workshops to increase participation and diversity of perspectives.

Other feedback included the need for shorter and clearer instructions, the need to adapt the materials to their environments and regions to make them feel more engaged and to have better quality materials. The desire to have the game available was mentioned by almost all the participants (6 out of 8), particularly stressed by the representatives of the government, community and first responders. Finally, other subjects refer to the need to have more diverse scenarios included in the game, to consider more natural events and more Natech risks, and finally to have real maps to have the participants more engaged to foster more grounded discussions.

Table 5. 13. Theme analysis. Game workshop experience codes

	Codes	Description	# Codes
Game workshop experience	game.posexp	Good experiences and impressions about the game, they like the methodology, the feeling, enjoyed the experience, meeting others	38
	game.particip	More participation is needed from more stakeholders	30
	game.negexp	Things to improve in the game: short instructions, very quick explanation, Japanese, kanji, rudimentary materials,	20
	game.access	The wish to have access to the game to play in their environments	14
	game.scenarios	To their realities, to feel closer and more related.	13
	game.realmaps	More grounded maps	10
	positive.interaction	Positive interaction, very positive interaction	8

The analysis of the qualitative data gathered from the Natech risk management workshops provides valuable insights into the perceptions, awareness, and disaster risk reduction measures of multiple stakeholders.

5.5. Discussion and limitations

The study presented in this section examines the mid- to long-term impacts of serious gaming workshops on Natech risk management. Focusing on changes in stakeholder awareness, risk communication, and risk reduction actions, the research provides valuable insights into the effectiveness of serious games as a tool for enhancing disaster preparedness. The study builds upon previous work that explored immediate changes following these workshops, offering a more comprehensive understanding of the sustained effects.

Some of the key aspects to highlight are:

- **Focus on Mid- to Long-Term Impacts:** A significant contribution of this study lies in its examination of the lasting effects of serious gaming workshops. Many studies focus on immediate post-workshop changes (Nakano et al., 2020), but understanding the sustained impact is crucial for evaluating the true effectiveness of such interventions.
- **Mixed-Methods Approach:** The researchers employed a mixed-methods approach, combining a follow-up survey with semi-structured interviews. This combination allows for a more nuanced understanding of the observed changes. The survey provides quantitative

data on broader trends, while the interviews offer deeper qualitative insights into individual experiences and perspectives.

- **Emphasis on Implementation:** A key challenge in disaster risk reduction is the implementation of effective measures (OECD 2012) directly addresses this challenge by exploring the actions taken by participants after the workshops. This focus on practical application adds significant value to the research, moving beyond theoretical understanding to assess real-world impact.
- **Multi-Stakeholder Perspective:** Like the previous section, this study also involves a diverse range of stakeholders, including government representatives, industry professionals, first responders, community members, and academics. This multi-stakeholder perspective is essential (Gaillard and Mercer 2013) for understanding the complexities of Natech risk management and ensuring that interventions are relevant and effective for all involved parties.

While the study provides valuable insights, it is important to acknowledge its limitations. This study was conducted in Colombia, and the findings may not be fully generalizable to other contexts. Additionally, the sample size, while diverse, was relatively small, and the study relied on self-reported data, which can be subject to biases. Despite these limitations, the study provides important insights into the complex dynamics of Natech risk perception, communication, and disaster risk reduction among multiple stakeholders. The findings can inform the design of more effective and inclusive Natech risk management strategies in Colombia and potentially other countries facing similar challenges. Some other identified limitations of these study are discussed:

- **Longitudinal Follow-up:** While assessing changes one year after the workshops is a significant step, even longer-term follow-up studies would be beneficial. Tracking changes over multiple years could provide a more complete picture of the sustained impact of serious gaming interventions.
- **Comparison with Other DRR Methods:** Comparing the effectiveness of serious games with other DRR methods, such as traditional training programs or public awareness campaigns, would be valuable for determining the relative strengths and weaknesses of each approach (Iwahori et al., 2017; Nakano & Yamori, 2021; Yamori, 2008).
- **Context-Specific Factors:** Exploring the influence of context-specific factors, such as local regulations, cultural norms, and existing risk management frameworks, could further enhance

our understanding of how serious games can be best implemented in different settings.

This chapter contributes to the growing body of research on serious games for disaster risk reduction. By focusing on mid- to long-term impacts, implementation challenges, and a multi-stakeholder perspective, the research provides valuable insights for practitioners and policymakers seeking to enhance Natech risk management. The findings support the use of serious games as an effective tool for raising awareness, improving communication, and promoting the implementation of risk reduction measures. Further research building upon these findings can lead to more resilient communities and better preparedness for Natech events.

5.5.1. Demographics of the survey respondents

While some specific demographic details like age, gender, or socioeconomic background of the participants are provided, information about their affiliations or other private details are not, which can serve as a proxy for certain demographic characteristics. The participants represented a variety of stakeholder groups crucial for comprehensive Natech risk management:

- National, regional, and local government: These participants have differentiated knowledge and experience in disaster management and policy-making, according to the government levels they work for. While national entities representatives possess more theoretical knowledge, the local representatives have more practical knowledge. Their inclusion ensures that the research captures the perspectives of those responsible for developing and implementing risk reduction strategies.
- Industry representatives: Participants from industrial sectors potentially exposed to Natech risks bring valuable insights into the practical challenges and opportunities for risk mitigation within their specific operational contexts.
- First responders: The inclusion of first responders, such as firefighters, police, and emergency management personnel, provides crucial perspectives on the immediate response to Natech events and the practical needs for effective disaster management.
- Community members: Representing the potentially affected population, community members offer insights into local vulnerabilities, risk perceptions, and the social dynamics that influence disaster preparedness and response.

- Academia: Researchers and academics contribute their expertise in risk assessment and management, providing a scientific foundation for discussion.

This diverse range of stakeholders ensures a comprehensive understanding of Natech risk management from various perspectives. However, future research could benefit from collecting more detailed demographic information to analyze how factors like age, gender, socioeconomic status, and educational background influence risk perceptions and behaviors. This would allow for more targeted and effective risk communication and mitigation strategies.

5.5.2. Demographics of interviewees

Interviewees were selected based on sampling, aiming for representation from all major stakeholder groups involved in the initial workshops. While the exact demographics aren't detailed, this selection strategy suggests a purposeful effort to gather diverse perspectives. Similar to the survey participants, the interviewees likely included representatives from government, industry, first responders, communities, and academia. This multi-stakeholder approach strengthens the qualitative data by capturing a wide range of experiences and insights related to Natech risk perception, communication, and mitigation actions. However, the study acknowledges limitations in contacting all original workshop participants for the follow-up survey and interviews due to changes in personal information. This potential attrition could introduce some bias, and future research could explore strategies to maintain higher participant retention rates in longitudinal studies. While the stakeholder representation is a strength, the lack of specific demographic details (age, gender, etc.) limits a deeper analysis of how these factors might influence the observed changes in risk perception and behavior. Including such demographic information in future studies would enhance the understanding of how tailored risk communication and mitigation strategies could be developed for specific demographic groups.

The findings from this study reveal several key insights regarding Natech risk perceptions, communication, and disaster risk reduction measures among diverse stakeholders. First, the study highlights the importance of engaging a wide range of stakeholders, including industry, government at various levels, first responders, the community, and academia, in Natech risk management efforts. For this study, all individuals were Colombians, living in 4 different cities in Colombia. Most individuals have been participating in the national regulation development process (Decreto 2157 de

2017, 2017; Ley 1523 de 2012, n.d.; Programa de Prevención de Accidentes Mayores - PPAM, 2021), particularly for the UNGRD officers, industry representatives and communities.

Interviews revealed a range of perspectives among the participants. People with the same role had different positions and experienced different changes on their perceptions about Natech and the workshops activities impacts on themselves and the others. For example, two individuals who belong to academic institutions, changed in different ways. One is still exposed to the Natech risk regulation process on a daily basis, that persons expressed that he didn't experience any change on his perception, he was already aware. However, he expressed that even the workshops were great to build trust, the people with the power to actually promote a change in real life were not invited or did not attend, and in that sense the workshops are not efficient. This participant expressed the need to have different voices represented in the discussion. The other individual belongs to an academic institution but is not directly involved with the Natech risk management process. This person expressed a significant change in perception, becoming more aware of the complexity of the problem and the need to involve different stakeholders. This participant expressed having bought a house in the following months after the workshops, and remembering the lessons from the workshops. She looked for the apartment surrounding and shared this experience with their partner before the purchase.

Participants who had no previous familiarity with Natech risk showed a significant increase in awareness and a desire to promote further action. Those with more experience in disaster risk management were less likely to report changes in their perceptions, as they were already aware of Natech risks.

These workshops have been an opportunity to bring these groups together and promote a shared understanding of Natech risks and responsibilities. As highlighted in (Solińska-Nowak et al., 2018), the involvement of diverse stakeholders is crucial for effective Natech risk management, as each group brings unique perspectives, experiences, and capabilities to the table.

The study also reveals the need to enhance risk communication and awareness-raising efforts regarding Natech risks. As noted by (Gaillard & Mercer, 2012), there is a need to have different stakeholders and build trust among them to ensure effective risk communication. The study also reveals the value of using serious games and participatory approaches to foster knowledge co-creation

and collaborative Natech risk reduction.

The risk perception is highly affected by the roles the participants play in the Natech Risk Management process in the country, which has been linked to their previous experiences. The previous experiences also shape their perceptions and opinions, as it has been expressed by previous studies such as (Mohammad, 2019) (Yu et al., 2017) (Krausmann et al., 2017).

Some participants expressed strong concerns about the potential consequences of Natech events since they participated in the workshops while others expressed their perceptions have not changed since they have been exposed previously to the Natech possibilities. The researchers believe the outcomes of the study provides insights that can inform the design of more inclusive and effective Natech risk management strategies in Colombia and potentially other countries facing similar challenges.

Some potential data quality issues relate to the fact that the gathered data about risk perceptions and changes, is self-reported, and such perceptions can be subject to biases. Interviewer bias may have also influenced participant responses, by give a tone after the interviewees replies, causing them to reply in a certain manner. Interviewee bias may have motivated to give socially desirable responses to appear more knowledgeable or concerned about Natech risks. Participation bias - those who chose to participate may have had strong opinions on the topic and not representative of the broader population.

Further exploration of these topic with larger, more representative samples and through multiple data collection techniques would strengthen the validity of the findings. Another limitation refers to the geographical scope, as the study was conducted only in Colombia, limiting the generalizability to other contexts.

5.6. Conclusions

This study investigated the mid- to long-term effects of serious gaming workshops on Natech risk perception, communication, and mitigation actions among diverse stakeholders. Building upon previous research that focused on immediate post-workshop changes, this study provides valuable

insights into the sustained impact of these interventions. The mixed-methods approach, combining a follow-up survey and semi-structured interviews, allowed for a comprehensive understanding of the evolving perspectives and actions of participants roughly one year after the initial workshops.

The findings confirm that serious gaming workshops can have a positive and lasting impact on Natech risk management. Participants demonstrated sustained improvements in risk awareness, communication behaviors, and a willingness to implement risk reduction measures. This suggests that serious games can be a powerful tool for fostering a culture of preparedness and resilience within organizations and communities. Specifically, the study revealed:

- Sustained improvements in risk awareness: Participants maintained a heightened awareness of Natech risks even a year after the workshops, indicating that the knowledge and understanding gained through the game experience were retained over time. This sustained awareness is crucial for promoting proactive risk management and informed decision-making.
- Enhanced risk communication: The workshops fostered improved communication practices among stakeholders, facilitating more effective information sharing and collaborative problem-solving. This enhanced communication is essential for coordinating responses and ensuring that all relevant parties are informed and prepared.
- Increased implementation of risk reduction measures: Participants reported taking concrete steps to mitigate Natech risks within their respective spheres of influence. This demonstrates that the workshops not only raised awareness but also motivated action, translating knowledge into practical risk reduction efforts.

This study contributes to the field of disaster risk reduction by demonstrating the long-term effectiveness of serious gaming workshops for enhancing Natech risk management. The findings support the integration of serious games into broader DRR strategies, particularly for engaging diverse stakeholders and promoting a culture of preparedness.

People were really receptive to the game and even asked to have it available to replicate the workshop with their own communities. The fact that the people were invited because of the previous experiences with Risk management and Risk governance in their territories cannot be overlooked. Regardless of their actual role, the individuals were all exposed to some extent to Natech and disaster

risk related concepts.

The researchers believe the outcomes of the study provides insights that can inform the design of more inclusive and effective Natech risk management strategies in Colombia and potentially other countries facing similar challenges.

5.6.1.Future research directions:

Future studies should explore the long-term impacts of such participatory approaches on Natech risk perceptions, communication, and DRR measures, with larger and more diverse samples. The sampling strategy for this study was purposive, aiming to capture a range of stakeholder perspectives. However, a more comprehensive understanding of Natech risk awareness in the general population could be gained by conducting more workshops and surveys with a broader, random sample.

Longitudinal studies could shed light on the durability of the observed changes in risk perceptions and behaviors. Additionally, comparative studies across different contexts would help validate the findings and identify context-specific factors shaping Natech risk management.

Based on the research, the following future directions for research are also proposed:

- Promote the wider adoption of serious games: Organizations and communities involved in disaster risk management should consider incorporating serious games into their training and awareness-raising programs.
- Develop tailored game scenarios: Games should be designed to address specific Natech risks and tailored to the needs and characteristics of the target audience.
- Integrate serious games into comprehensive DRR strategies: Serious games should be used as part of a broader, multi-faceted approach to disaster risk reduction, complementing other tools and strategies.

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6. Discussion, conclusions, limitations and contributions

6.1. Summary of the findings and conclusions

This thesis aimed to expand the understanding of Natech risk management using a nontraditional approach, namely a serious game. First, the thesis set the context by analyzing Natech risk trends and challenges in Colombia, a country prone to both natural and technological hazards. Then it implemented a series of serious gaming workshops including stakeholders from diverse backgrounds, such as industry, academia, first responders, communities, and government officials. The aim was to support the Natech Risk Management process. Subsequently it explored the effectiveness of serious gaming workshops as a tool to enhance risk management and governance, by focusing on stakeholders' risk awareness and risk communication. The literature review in Chapter 2 explored the studies being carried out currently, their strengths, and the areas for improvement in terms of research gaps. While related work has been done in the areas of serious games for disaster and hazard management, as well as serious games in general, no previous studies have specifically focused on the use of serious games to support Natech risk management involving multiple stakeholders simultaneously. This thesis, therefore, fills an important gap in the literature by being the first to explore the application of serious games for multiple stakeholders to support Natech risk management. Another key aspect is that this study examined the actual protective actions implemented after the serious game interventions.

Chapter 3 lays the groundwork by examining the historical incidence of Natech accidents affecting oil and gas pipelines in Colombia. By analyzing accident reports from 2000 to 2022, the study reveals the frequency, causes, and consequences of these events, highlighting the vulnerability of pipeline infrastructure to natural hazards like landslides and flooding. The lack of homogeneity in data collection practices also posed a challenge (Ricci et al., 2021). This study provides crucial context for understanding the specific Natech challenges faced by the Colombian oil and gas industry and underscores the need for effective risk mitigation strategies. In agreement with other studies, the trend in reporting Natech is increasing. The most common natural hazard related to the reported Natech was flooding, followed by landslides. Some facilities, namely oil and gas transmission pipelines segments were affected more than once during the studied period, calling for a deeper analysis. The

lack of awareness about previous events or Natech in general was evident among stakeholders was evident. Communication channels between stakeholders were not well established, and therefore not activated during the emergencies, this was mainly caused by unclear roles and responsibilities between stakeholders at local and national level, as it has also been established in the past (Girgin et al., 2019). The need for improvement in the risk communication process among stakeholders was highlighted as a crucial factor for effective risk management.

Building upon this foundation, Chapter 4 investigates the immediate impact of serious game workshops on Natech risk awareness and communication among diverse stakeholders in Colombia and Japan. The study employs a mixed-methods approach, utilizing pre- and post-workshop surveys and observations during the serious game sessions. The findings demonstrate the potential of serious gaming to enhance risk perception, promote dialogue, and foster a more collaborative approach to Natech risk management. The interactive nature of serious games allows participants to experience simulated Natech scenarios, explore different risk management strategies, and develop a deeper understanding of the complex interplay between natural hazards and technological systems.

Chapter 5 extends this analysis by examining the mid- to long-term effects of the serious game workshops, approximately one year after the initial interventions. This provides valuable insights into the sustained impact of serious gaming on risk awareness, communication practices, and the implementation of risk reduction actions. The study found that levels of awareness and communication were lower before the workshops, and reported higher during the post workshop stage, but diminished during the mid-long term, however, in general they remained higher than before the workshops. The study's findings suggest that serious gaming can lead to enduring changes in stakeholder behavior, promoting a more proactive and collaborative approach to Natech risk management. The research also highlights the importance of longitudinal evaluation for assessing the long-term effectiveness of such interventions.

Taken together, these three studies offer a comprehensive perspective on Natech risk management in the context of the Colombian industry, establishing the prevalence and consequences of Natech accidents, and demonstrating the immediate benefits of serious gaming workshops, and the sustained impact of these interventions on risk awareness, communication, and risk reduction actions. The studies collectively support the argument that serious gaming is a valuable tool for enhancing Natech

risk management. Further research could explore the specific mechanisms through which serious gaming achieves these positive outcomes and investigate the contextual factors that may influence their long-term sustainability. Additionally, future studies could examine the scalability and adaptability of serious gaming approaches to other geographical contexts and industrial sectors.

Chapters 4 and 5 involve diverse stakeholders in their studies of Natech risk management, encompassing government officials, industry representatives, first responders, community members, and academics. Chapter 4 focusses specifically on participants from Colombia across four different cities, and in one Japanese city, who have largely been involved in national Natech risk regulation development. Chapter 5, while not explicitly detailing participant locations within Colombia, likely includes a similar range of stakeholders based on its broader scope. Therefore, while both studies share a similar stakeholder composition, the second provides more specific demographic information regarding participant location and involvement in national policy processes.

Furthermore Chapters 4 and 5 both examine the impact of serious gaming workshops on Natech risk management, but they focus on different timeframes. Chapter 4 one assesses the immediate changes in risk perception, awareness, and communication following the workshops, while Chapter 5 one analyzes the mid- to long-term changes approximately one year later. The third chapter is aligned with (Nakano et al., 2020), who advocates for a shift in evaluating disaster risk reduction education, moving away from short-term knowledge assessments towards a long-term, action-oriented approach. The authors argue that traditional evaluations, which primarily focus on immediate knowledge transfer, fail to capture the true impact of DRR education, which ultimately aims to promote proactive behavior and tangible risk reduction actions. This long-term perspective, they argue, is essential for understanding the effectiveness of DRR education in fostering sustained behavioral change and building community resilience.

Both studies found positive changes in risk awareness, perception, and communication after the serious games workshops. They observed immediate improvements in these areas, suggesting that serious gaming can quickly enhance participants' understanding and engagement with Natech risks. Chapter 5 demonstrates that these positive changes persist in the mid-term, indicating the potential for sustained impact. Furthermore, it goes further by also examining the implementation of risk reduction actions, a crucial aspect not directly addressed in the second, given their immediate nature.

It was found that the workshops positively influenced the implementation of such actions, providing stronger evidence for the practical effectiveness of serious gaming in promoting tangible risk reduction efforts. In summary, both studies demonstrate the positive impact of serious gaming on Natech risk management. One highlights the immediate benefits, while the other reveals the sustained impact and the influence on actual risk reduction actions, providing a more comprehensive picture of the long-term effectiveness of this approach.

6.2. Discussion and policy recommendations

The findings allowed us to gain a deeper understanding of the Natech situation and the associated risk management process. We gained a deeper understanding of the Natech risks, particularly in Colombia, and were able to identify the critical need for improved reporting practices to understand the impacts, both direct in the affected areas and indirect in wider regions, as well as the trends over time and the relevant stakeholders. The current reporting systems overlook these indirect impacts systematically, missing the opportunity to gather valuable lessons for the risk management process. The low levels of risk awareness, shown by the lack of knowledge about previous events, sometimes in the same locations, proved the need to raise risk awareness and promote effective risk communication among all relevant stakeholders, in line with previous research. This was identified for specific cases while developing a Natech database. The lack of formal roles and defined responsibilities was evident in two aspects: the lack of standardized actions taken during different phases of the emergency response, indicating a lack of pre-defined procedures; and the diversity in reporting these events, both at the initial stage and in follow-up, which further demonstrates this issue.

To address the gaps in Natech risk awareness and communication, we conducted serious gaming workshops and assessed their effectiveness over different timeframes. We observed positive changes in risk awareness and communication within the targeted communities after implementing the serious gaming workshops. Our results demonstrate the suitability of serious gaming approaches for enhancing Natech risk awareness and communication among diverse stakeholder groups.

The literature on governance and innovation in risk management indicates that technical issues related to risk assessment and risk reduction choices are not the central factors driving innovation in risk management practices. Instead, institutional culture, traditions, and capabilities have great

potential to be significant factors. Governance frameworks that enable collaboration and participation of diverse stakeholders, including the public, private sector, and community groups, are essential for effective risk management. In this context, adopting a participatory approach for Natech risk awareness and communication can be a promising strategy. The immediate and sustained improvements in risk understanding suggest that serious gaming can effectively engage participants and help them better comprehend Natech risks. Incorporating approaches that foster active stakeholder participation in decision-making processes can lead to a more risk-informed and holistic understanding of Natech events, ultimately enhancing the overall disaster risk management process.

Furthermore, we found that the implementation of protective actions was positively influenced by the serious gaming workshops, providing evidence for the practical implications and benefits of this approach. By engaging stakeholders, the serious gaming workshops helped improve their understanding of their roles and responsibilities in Natech risk management, ultimately leading to more effective protective action implementation.

The study results point at the need to establish a standardized reporting system with well defined roles and responsibilities, during the risk management process. The incorporation of indirect impacts assessment is needed too.

The integration of participatory approaches to enhance Natech risk communication and awareness holds promise as a strategic direction. The findings highlight the value of adopting serious gaming as an effective tool to engage diverse stakeholders, improve risk understanding, and facilitate more collaborative decision-making in Natech risk management. The overall risk management process should include activities that promote stakeholders' understanding of the general risk management situation, their roles, and the roles of others, in order to improve communication and collaboration for more effective risk management.

Participatory approaches such as serious games should be incorporated into training activities, as they have been proven to effectively meet this aim. To enhance the impact of these efforts, multi-stakeholder activities should be promoted to build trust among them, ultimately fostering the risk management implementation process.

These findings offer valuable insights for policymakers, risk management practitioners, and researchers in the field of industrial risk management, particularly in the context of Natech events.

6.3. Limitations

During the development of this thesis, I have identified the following limitations. Regarding past events, it lacked a complete available data set, as not all disasters are reported to public sources or insurance companies and had to build by mixing the different available information sources. The following summarize these limitations:

- Limited data availability: The study relied on publicly available accident reports, which may not capture all Natech incidents due to underreporting or incomplete data. This could lead to an underestimation of the true frequency and impact of Natech events.
- Focus on specific infrastructure: The deeper analysis primarily focused on oil and gas facilities, as they were reported as the most frequently affected by Natech involving multiple stakeholders. The deeper accident analysis was performed only for transmission pipelines, given the resource limitation to carry out these analyses, providing a more detailed panorama about pipelines, but potentially overlooking other critical infrastructure vulnerable to Natech events.
- Challenges in data analysis: The diverse nature of Natech accidents and the lack of standardized reporting formats made it challenging to systematically analyze the data and draw definitive conclusions about specific trends or patterns.

As for the Chapter 4, regarding the serious gaming workshops and the surveys to evaluate the impacts on risk awareness and risk communication, the general acknowledged limitations are:

- Limited geographic scope: The study focused on specific regions mainly in Colombia, and one city in Japan, limiting the generalizability of findings to other areas with different geological, climatic, or socio-economic conditions.
- Challenges in long-term evaluation: The study primarily assessed short- to medium-term impacts of the serious game workshops, with limited data on long-term changes in risk

perception, communication practices, or implemented risk reduction actions.

- Potential biases in participant feedback: Participant feedback may be influenced by social desirability bias or recall bias, affecting the accuracy and reliability of self-reported changes in awareness or behavior.
- Need for standardized game implementation: The study highlights the need for guidelines to standardize the implementation of the serious game across different contexts and ensure consistent delivery and evaluation of the intervention.

By conducting a deep qualitative study about games and discussion recordings, valuable insights are expected to be produced, as well as recommendations on how the risk communication process between different stakeholders is being carried out and how it can be improved by promoting changes in the participant's point of views towards information disclosure. Also, important elements in communication processes that are relevant for risk reduction could be identified, to support the development of guidelines to standardize the game's implementation of real hazard maps for different cities, and how to balance the game for new areas. Another important aspect to start considering would be the influence of having experienced previous natural events or Natech.

The authors also consider important to examine the impact of changing game scenarios between flooding and earthquakes, as well as differences across Colombian cities, could offer valuable insights. Modifying the game to enable repeated play and implementing a post-test questionnaire could help evaluate long-term effects on risk awareness, which this study did not consider.

6.4. Future work

Based on all the previous conclusions and the limitation of the work, the following opportunities for improvements in the future have been defined:

- Information Disclosure: Investigating changes in participants' views on information disclosure and identifying key elements in communication processes relevant for risk reduction.
- Standardized Game Implementation: Developing guidelines for standardizing the

implementation of the serious game with real hazard maps for different cities, addressing the challenge of balancing the game for new areas.

- **Influence of Prior Experiences:** Studying the influence of prior experiences with natural events or Natech incidents on participant engagement and learning outcomes.
- **Game Scenario Variations:** Examining the impact of varying game scenarios, such as switching between flooding and earthquakes, and exploring differences across Colombian cities. Develop guidelines to standardize the game's implementation of real hazard maps for different cities, and how to balance the game for new areas.
- **Long-Term Effects:** Modifying the game to enable repeated play and implementing post-test questionnaires to evaluate the long-term effects on risk awareness.

6.5. Research contributions

This thesis described the incidence of the Natechs trends in Colombia, showing an increase in the reports along the last couple of decades. The lack of communication among stakeholders was identified as a main problem for the risk management process in the country. It was then necessary to find a way to promote a better articulation among the different actors involved in Natech risk management to improve the response capacity and the resilience. The following summarizes the main points:

- **Quantifying Natech Accidents:** The study provides a quantitative analysis of Natech accidents related to oil and gas pipelines in Colombia, identifying 245 events between 2000 and 2022. This data offers valuable insights into the frequency and trends of these incidents.
- **Identifying Key Natural Hazards:** The research identifies landslides, floods, and seismic activity as the primary natural hazards triggering Natech accidents involving pipelines in the region.
- **Pinpointing Vulnerable Infrastructure:** The study identifies the oil and gas pipelines types most frequently affected by Natech events, revealing vulnerabilities in specific locations and infrastructure types. This information can be used to prioritize risk mitigation efforts.
- **Highlighting Stakeholder roles and responsibilities:** The research underscores the challenges associated with communication and coordination among stakeholders involved

in Natech risk management. This emphasizes the need for improved communication strategies and collaborative approaches.

This thesis also contributes to the field by testing a serious game approach combined with pre- and post-game surveys to analyze changes in Natech risk awareness and communication among various stakeholders in Colombia and Japan (Chapter 4). The key contribution is demonstrating the potential of serious games as a tool for raising awareness, changing risk perception, and promoting dialogue and information sharing among stakeholders in Natech risk management. The following was achieved:

- Analysis of the changes in stakeholder perceptions and awareness levels, risk communication, after serious gaming workshops focused on Natech risks . This involves assessing the impact of the workshops on participants' understanding of Natech risks, their communication practices, and the actions they take to mitigate these risks.
- Examine participants' views about the outcomes of the workshops. This seeks to gather feedback from participants on their experiences with the serious gaming approach and their perspectives on the workshops' impact on their understanding and actions related to Natech risk management.

Finally, Chapter 5 contributes to the field of Natech risk management by providing a comprehensive evaluation of the mid- to long-term impacts of serious gaming workshops, including an analysis of stakeholder's risk perceptions and awareness levels, and communication practices evolution. It also considers the implemented risk reduction actions, participant feedback, highlighting the importance of multi-stakeholder collaboration.

- Assessing Mid-term Impacts of Serious Gaming: The study evaluates the mid-term effects of serious gaming workshops on Natech risk awareness, communication, and risk reduction actions. This extends beyond immediate post-workshop assessments, providing insights into the longer-term impact of these interventions, and as new feature, among multiple stakeholders.
- Analyzing Stakeholder Evolution: The research analyzes how stakeholder perceptions, awareness, and views on risk communication evolve over time after participating in serious

gaming workshops. This contributes to a deeper understanding of the learning process and the factors influencing sustained changes in behavior.

- **Investigating Implemented Actions:** The study investigates the specific risk reduction measures implemented by participants following the workshops. This provides valuable insights into the practical application of knowledge gained through serious gaming and its translation into concrete actions.
- **Gathering Stakeholder Feedback:** The research gathers feedback from participants on their experiences with the serious gaming approach and the outcomes of the workshops. This participatory approach allows for a more comprehensive evaluation of the intervention and identifies areas for improvement.
- **Highlighting the Role of Multi-stakeholder Collaboration:** The study emphasizes the importance of multi-stakeholder collaboration in Natech risk management and demonstrates how serious gaming can facilitate communication and coordination among diverse actors.

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7. Appendix

ID, Year, Month, Day, Natural Hazard, Region name, City/Village, Operator, Actual reported coordinates, Type Coordinates, Reported Cause category, Consequence classification, Final event, Event description (From ANLA, UNGRD databases and additional information sources), Hazardous material, Released volume bbl, System name, Predominant Pipeline diameter [inch], Construction year, System length km (latest information), Age (failure time), Soil type, El Niño Index (trimester), Threat SGC (predominant), Identified stakeholders, Environmental impacts, Emergency reported costs COP, Societal impacts, Infrastructure impacts, Media, government and operators sources , main information sources, Additional information sources.

7.1. Game materials example in Spanish and Japanese. Adapted from (Tzioutzios 2022)

Carta de acción de preparación Simulacro de desastre comunitario  Costo (por turno): 100 ₺ Beneficio (por turno): reducción de las pérdidas. 1 jugador 30%; 2 jugadores 40%; 3 o más jugadores 50%. <u>+1 punto de preparación por uso.</u>	Carta de acción de emergencia Refugiarse en casa  Tras recibir una alerta temprana acerca de un evento natural, permanezca en su hogar.
Carta de acción de preparación Refuerzo estructural de la vivienda  Costo: 50% del costo de compra de la vivienda. (Único uso). Beneficio: 60% de reducción de la pérdida tras un terremoto. <u>+ 3 puntos de preparación</u>	Carta de acción de emergencia Evacuar hacia un refugio  Tras recibir una alerta temprana de un evento natural, seleccione un refugio hacia el cual evacuar.
Carta de acción de preparación Entrenamiento para respuesta Natech: Tóxicos e inflamables  Costo (por turno): 120 ₺ Beneficio: protege a los jugadores en caso de un accidente químico durante un turno. <u>+1 punto de preparación por uso.</u>	Carta de acción de preparación Adecuación del refugio: Tóxicos e inflamables  Costo (refugio/turno): 400 ₺ Beneficio: protege a los jugadores en caso liberación de sustancias tóxicas o explosiones.

防災アクションカード（工業地域）



基本技術情報
の開示

初期費用: 1000 円 (地方自治体と分担可能); 維持
費用 (1ラウンドあたり): 300 円。

効果: Natech事故の際の罰金を500 円に減額。
「Natech事故リスク分析」カードを使用できる
ようになる。

+1 防災ポイント (全プレイヤー)

防災アクションカード（工業地域）



Natech事故
リスク分析

初期費用: 1200 円 (地方自治体と分担可能); 維持
費用 (1ラウンドあたり): 300 円。

「基本技術情報の開示」カードを先に使用して
いなければならない。効果: 事故シナリオを開示
する。Natech事故の際の罰金が科されなくなる
(0円となる)。**+2 防災ポイント (全プレイヤー)**

防災アクションカード（工業地域）



施設保護
のための
措置の強化

初期費用: 1000 円 (一施設につき一度だけ使用可
能)。「基本技術情報の開示」カードを先に使用
していなければならない。

効果: 自然災害時の損失を軽減する (50%)。
さらに、Natech事故の発生確率を減少させる。

+1 防災ポイント (全プレイヤー)

防災アクションカード（工業地域）



施設の拡大

初期費用: 1500 円 (一施設につき一度だけ使用可
能)。「基本技術情報の開示」カードを先に使用
していなければならない。

効果: 利益が増加する (+50%) が、損失も増
加する (+70%)。

+1 防災ポイント (全プレイヤー)



物件 9



種類: アパート
価格: 1000 円
避難所(10分以内): 2 & 3

物件情報

築年数	物件の エリア	公園、レストラ ン、スーパーへ のアクセス	公共交通機関 および道路の アクセス

サイコロの目	1	2	3	4	5	6
収入	200円			250円	300円	350円



物件 14



種類: 一戸建て
価格: 1000 円
避難所(10分以内): 2 & 3

物件情報

築年数	物件の エリア	公園、レストラ ン、スーパーへ のアクセス	公共交通機関 および道路の アクセス

サイコロの目	1	2	3	4	5	6
収入	200円			250円	300円	350円



物件 17



種類: 一戸建て
価格: 900 円
避難所(10分以内): 4

物件情報

築年数	物件の エリア	公園、レストラ ン、スーパーへ のアクセス	公共交通機関 および道路の アクセス

サイコロの目	1	2	3	4	5	6
収入	200円			240円	280円	320円

7.2. Pre-game and post-game questionnaire in Spanish

Cuestionario Pre-juego	
Por favor responda el cuestionario a continuación. Se tienen 6 secciones con un total de 62 afirmaciones/preguntas para responder. Las respuestas que envíe son solo para fines de investigación y no se compartirán con personas no autorizadas.	
Por favor indique qué tan de acuerdo se siente con respecto a cada una de las siguientes afirmaciones relacionadas con la ocurrencia de eventos tecnológicos desencadenados por amenazas naturales (terremotos, deslizamientos, inundaciones, etc.), denominados Natech.	
PERCEPCIÓN DEL RIESGO NATECH	
Considero que los eventos tecnológicos causados por eventos naturales (Natech) constituyen un problema importante (por ejemplo el evento de Dosquebradas en 2011, en el cual un deslizamiento causó el rompimiento de un poliducto, un derrame y un posterior incendio y explosión) .	☐ Totalmente de acuerdo ☐ de acuerdo ☐ Algo de acuerdo ☐ Ni de acuerdo ni en desacuerdo ☐ Algo en desacuerdo ☐ en desacuerdo ☐ Totalmente en desacuerdo
Me preocupan los posibles eventos tecnológicos que puedan ser desencadenados por eventos naturales y sus consecuencias.	☐ Totalmente de acuerdo ☐ de acuerdo ☐ Algo de acuerdo ☐ Ni de acuerdo ni en desacuerdo ☐ Algo en desacuerdo ☐ en desacuerdo ☐ Totalmente en desacuerdo
Si ocurre un sismo de gran magnitud, pienso que podría desencadenarse un evento tecnológico en alguna de las zonas industriales en la ciudad en la cual resido.	☐ Totalmente de acuerdo ☐ de acuerdo ☐ Algo de acuerdo ☐ Ni de acuerdo ni en desacuerdo ☐ Algo en desacuerdo ☐ en desacuerdo ☐ Totalmente en desacuerdo
Si ocurre un sismo de gran magnitud, pienso que podría desencadenarse un evento tecnológico en alguna de las zonas industriales cercanas a mi lugar de vivienda/trabajo.	☐ Totalmente de acuerdo ☐ de acuerdo ☐ Algo de acuerdo ☐ Ni de acuerdo ni en desacuerdo ☐ Algo en desacuerdo ☐ en desacuerdo ☐ Totalmente en desacuerdo
Si un gran terremoto provoca un evento tecnológico en una instalación industrial, creo que los residentes en el área podrían verse afectados directamente.	☐ Totalmente de acuerdo ☐ de acuerdo ☐ Algo de acuerdo ☐ Ni de acuerdo ni en desacuerdo ☐ Algo en desacuerdo ☐ en desacuerdo ☐ Totalmente en desacuerdo

Creo que sé cómo mantenerme seguro si ocurre un evento tecnológico en una instalación industrial cerca de donde vivo/trabajo.	☐ Totalmente de acuerdo ☐ de acuerdo ☐ Algo de acuerdo ☐ Ni de acuerdo ni en desacuerdo ☐ Algo en desacuerdo ☐ en desacuerdo ☐ Totalmente en desacuerdo
Los eventos tecnológicos desencadenados por un evento natural serán llamados Natech de ahora en adelante.	
2. COMPORTAMIENTO ANTE LA COMUNICACIÓN DE RIESGOS DE NATECH	
Creo que los Natech constituyen un problema importante	☐ Totalmente de acuerdo ☐ de acuerdo ☐ Algo de acuerdo ☐ Ni de acuerdo ni en desacuerdo ☐ Algo en desacuerdo ☐ en desacuerdo ☐ Totalmente en desacuerdo
Las instituciones del gobierno deben tomar acciones relacionadas con los Natech.	☐ Totalmente de acuerdo ☐ de acuerdo ☐ Algo de acuerdo ☐ Ni de acuerdo ni en desacuerdo ☐ Algo en desacuerdo ☐ en desacuerdo ☐ Totalmente en desacuerdo
Con respecto a Natech, considero que existe una brecha entre la manera como deberían ser las cosas y la manera como son actualmente.	☐ Totalmente de acuerdo ☐ de acuerdo ☐ Algo de acuerdo ☐ Ni de acuerdo ni en desacuerdo ☐ Algo en desacuerdo ☐ en desacuerdo ☐ Totalmente en desacuerdo
Considero que los Natech representan consecuencias serias para mí.	☐ Totalmente de acuerdo ☐ de acuerdo ☐ Algo de acuerdo ☐ Ni de acuerdo ni en desacuerdo ☐ Algo en desacuerdo ☐ en desacuerdo ☐ Totalmente en desacuerdo
Considero que los Natech podrían constituir una diferencia en mi vida cotidiana.	☐ Totalmente de acuerdo ☐ de acuerdo ☐ Algo de acuerdo ☐ Ni de acuerdo ni en desacuerdo ☐ Algo en desacuerdo ☐ en desacuerdo ☐ Totalmente en desacuerdo

Existe una relación fuerte los Natech y mi vida cotidiana.	☐ Totalmente de acuerdo ☐ de acuerdo ☐ Algo de acuerdo ☐ Ni de acuerdo ni en desacuerdo ☐ Algo en desacuerdo ☐ en desacuerdo ☐ Totalmente en desacuerdo
Considero que puedo mejorar la situación relacionada con los Natech.	☐ Totalmente de acuerdo ☐ de acuerdo ☐ Algo de acuerdo ☐ Ni de acuerdo ni en desacuerdo ☐ Algo en desacuerdo ☐ en desacuerdo ☐ Totalmente en desacuerdo
Creo que existen algunos obstáculos que me impiden tomar acciones con respecto a los Natech.	☐ Totalmente de acuerdo ☐ de acuerdo ☐ Algo de acuerdo ☐ Ni de acuerdo ni en desacuerdo ☐ Algo en desacuerdo ☐ en desacuerdo ☐ Totalmente en desacuerdo
Siento que mis opiniones son importantes para los entes y personas del gobierno trabajando en el tema Natech.	☐ Totalmente de acuerdo ☐ de acuerdo ☐ Algo de acuerdo ☐ Ni de acuerdo ni en desacuerdo ☐ Algo en desacuerdo ☐ en desacuerdo ☐ Totalmente en desacuerdo
Tengo una idea clara sobre cómo manejar los Natech.	☐ Totalmente de acuerdo ☐ de acuerdo ☐ Algo de acuerdo ☐ Ni de acuerdo ni en desacuerdo ☐ Algo en desacuerdo ☐ en desacuerdo ☐ Totalmente en desacuerdo
Tengo una idea sobre cómo el gobierno debería gestionar los Natech.	☐ Totalmente de acuerdo ☐ de acuerdo ☐ Algo de acuerdo ☐ Ni de acuerdo ni en desacuerdo ☐ Algo en desacuerdo ☐ en desacuerdo ☐ Totalmente en desacuerdo

Tengo en mente un ejemplo sobre cómo abordar los Natech.	☐ Totalmente de acuerdo ☐ de acuerdo ☐ Algo de acuerdo ☐ Ni de acuerdo ni en desacuerdo ☐ Algo en desacuerdo ☐ en desacuerdo ☐ Totalmente en desacuerdo
Tengo curiosidad acerca de los Natech.	☐ Totalmente de acuerdo ☐ de acuerdo ☐ Algo de acuerdo ☐ Ni de acuerdo ni en desacuerdo ☐ Algo en desacuerdo ☐ en desacuerdo ☐ Totalmente en desacuerdo
Pienso frecuentemente en los Natech.	☐ Totalmente de acuerdo ☐ de acuerdo ☐ Algo de acuerdo ☐ Ni de acuerdo ni en desacuerdo ☐ Algo en desacuerdo ☐ en desacuerdo ☐ Totalmente en desacuerdo
Quisiera entender mejor los Natech.	☐ Totalmente de acuerdo ☐ de acuerdo ☐ Algo de acuerdo ☐ Ni de acuerdo ni en desacuerdo ☐ Algo en desacuerdo ☐ en desacuerdo ☐ Totalmente en desacuerdo
He invertido mucho tiempo y energía aprendiendo acerca de los Natech.	☐ Totalmente de acuerdo ☐ de acuerdo ☐ Algo de acuerdo ☐ Ni de acuerdo ni en desacuerdo ☐ Algo en desacuerdo ☐ en desacuerdo ☐ Totalmente en desacuerdo
Me siento capacitado para evaluar la calidad de la información relacionada con los Natech.	☐ Totalmente de acuerdo ☐ de acuerdo ☐ Algo de acuerdo ☐ Ni de acuerdo ni en desacuerdo ☐ Algo en desacuerdo ☐ en desacuerdo ☐ Totalmente en desacuerdo

Tengo fuentes confiables de información identificadas para buscar información actualizada relacionada con los Natech.	☐ Totalmente de acuerdo ☐ de acuerdo ☐ Algo de acuerdo ☐ Ni de acuerdo ni en desacuerdo ☐ Algo en desacuerdo ☐ en desacuerdo ☐ Totalmente en desacuerdo
Me interesan todos los puntos de vista relacionados con los Natech.	☐ Totalmente de acuerdo ☐ de acuerdo ☐ Algo de acuerdo ☐ Ni de acuerdo ni en desacuerdo ☐ Algo en desacuerdo ☐ en desacuerdo ☐ Totalmente en desacuerdo
Me interesa conocer más acerca de los Natech desde diferentes fuentes.	☐ Totalmente de acuerdo ☐ de acuerdo ☐ Algo de acuerdo ☐ Ni de acuerdo ni en desacuerdo ☐ Algo en desacuerdo ☐ en desacuerdo ☐ Totalmente en desacuerdo
Escucho puntos de vista diversos con respecto a los Natech, incluyendo aquellos opuestos a los míos.	☐ Totalmente de acuerdo ☐ de acuerdo ☐ Algo de acuerdo ☐ Ni de acuerdo ni en desacuerdo ☐ Algo en desacuerdo ☐ en desacuerdo ☐ Totalmente en desacuerdo
Estoy tratando de informar a mi familia y amigos acerca de los Natech.	☐ Totalmente de acuerdo ☐ de acuerdo ☐ Algo de acuerdo ☐ Ni de acuerdo ni en desacuerdo ☐ Algo en desacuerdo ☐ en desacuerdo ☐ Totalmente en desacuerdo
Frecuentemente expreso mi opinión acerca de los Natech.	☐ Totalmente de acuerdo ☐ de acuerdo ☐ Algo de acuerdo ☐ Ni de acuerdo ni en desacuerdo ☐ Algo en desacuerdo ☐ en desacuerdo ☐ Totalmente en desacuerdo

Creo que vale la pena usar tiempo para persuadir a otros a involucrarse en la resolución de la problemática Natech.	☐ Totalmente de acuerdo ☐ de acuerdo ☐ Algo de acuerdo ☐ Ni de acuerdo ni en desacuerdo ☐ Algo en desacuerdo ☐ en desacuerdo ☐ Totalmente en desacuerdo
Estoy dispuesto a hablar sobre los Natech con otros, si me preguntan al respecto.	☐ Totalmente de acuerdo ☐ de acuerdo ☐ Algo de acuerdo ☐ Ni de acuerdo ni en desacuerdo ☐ Algo en desacuerdo ☐ en desacuerdo ☐ Totalmente en desacuerdo
Si alguien me pregunta sobre los Natech., estoy dispuesto a compartir cualquier información si así lo requieren.	☐ Totalmente de acuerdo ☐ de acuerdo ☐ Algo de acuerdo ☐ Ni de acuerdo ni en desacuerdo ☐ Algo en desacuerdo ☐ en desacuerdo ☐ Totalmente en desacuerdo
Me gusta participar en la discusión sobre los Natech, cuando otras personas lo mencionan.	☐ Totalmente de acuerdo ☐ de acuerdo ☐ Algo de acuerdo ☐ Ni de acuerdo ni en desacuerdo ☐ Algo en desacuerdo ☐ en desacuerdo ☐ Totalmente en desacuerdo
Busco información relacionada con los Natech en internet, aplicaciones móviles o fuentes similares, de manera activa.	☐ Totalmente de acuerdo ☐ de acuerdo ☐ Algo de acuerdo ☐ Ni de acuerdo ni en desacuerdo ☐ Algo en desacuerdo ☐ en desacuerdo ☐ Totalmente en desacuerdo
De manera periódica busco información relacionada con los Natech.	☐ Totalmente de acuerdo ☐ de acuerdo ☐ Algo de acuerdo ☐ Ni de acuerdo ni en desacuerdo ☐ Algo en desacuerdo ☐ en desacuerdo ☐ Totalmente en desacuerdo

	☐ Totalmente de acuerdo ☐ de acuerdo ☐ Algo de acuerdo ☐ Ni de acuerdo ni en desacuerdo ☐ Algo en desacuerdo ☐ en desacuerdo ☐ Totalmente en desacuerdo
Solicito a otras personas información relacionada con los Natech.	
	☐ Totalmente de acuerdo ☐ de acuerdo ☐ Algo de acuerdo ☐ Ni de acuerdo ni en desacuerdo ☐ Algo en desacuerdo ☐ en desacuerdo ☐ Totalmente en desacuerdo
Cuando encuentro información relacionada con Natech, leo artículos en periódicos, revistas, sitios web o redes sociales.	☐ Totalmente de acuerdo ☐ de acuerdo ☐ Algo de acuerdo ☐ Ni de acuerdo ni en desacuerdo ☐ Algo en desacuerdo ☐ en desacuerdo ☐ Totalmente en desacuerdo
Si alguien habla de Natech, escucho de manera cuidadosa sus opiniones al respecto.	☐ Totalmente de acuerdo ☐ de acuerdo ☐ Algo de acuerdo ☐ Ni de acuerdo ni en desacuerdo ☐ Algo en desacuerdo ☐ en desacuerdo ☐ Totalmente en desacuerdo
Presto atención a las noticias relacionadas con los Natech.	☐ Totalmente de acuerdo ☐ de acuerdo ☐ Algo de acuerdo ☐ Ni de acuerdo ni en desacuerdo ☐ Algo en desacuerdo ☐ en desacuerdo ☐ Totalmente en desacuerdo
3. CONCIENCIA SOBRE EL RIESGO	
La intensidad del peligro o amenaza influye en las posibles consecuencias.	☐ Totalmente de acuerdo ☐ de acuerdo ☐ Algo de acuerdo ☐ Ni de acuerdo ni en desacuerdo ☐ Algo en desacuerdo ☐ en desacuerdo ☐ Totalmente en desacuerdo
Todas las áreas están potencialmente expuestas a los mismos peligros.	☐ Totalmente de acuerdo ☐ de acuerdo ☐ Algo de acuerdo ☐ Ni de acuerdo ni en desacuerdo ☐ Algo en desacuerdo ☐ en desacuerdo ☐ Totalmente en desacuerdo

Evitar peligros juega un papel importante a la hora de elegir una casa.	☐ Totalmente de acuerdo ☐ de acuerdo ☐ Algo de acuerdo ☐ Ni de acuerdo ni en desacuerdo ☐ Algo en desacuerdo ☐ en desacuerdo ☐ Totalmente en desacuerdo
La planeación urbana y la asignación de recursos son importantes para reducir los impactos de posibles Natech.	☐ Totalmente de acuerdo ☐ de acuerdo ☐ Algo de acuerdo ☐ Ni de acuerdo ni en desacuerdo ☐ Algo en desacuerdo ☐ en desacuerdo ☐ Totalmente en desacuerdo
El acceso a la información técnica industrial afecta las acciones de preparación de los residentes.	☐ Totalmente de acuerdo ☐ de acuerdo ☐ Algo de acuerdo ☐ Ni de acuerdo ni en desacuerdo ☐ Algo en desacuerdo ☐ en desacuerdo ☐ Totalmente en desacuerdo
4. IMPORTANCIA DE LA COMUNICACIÓN DEL RIESGO	
Información sobre sustancias químicas peligrosas y sus efectos adversos para la salud.	☐ Extremadamente importante ☐ Muy importante ☐ Importante ☐ Moderadamente importante ☐ Algo importante ☐ Ligeramente importante ☐ No es importante
Información sobre zonas potencialmente afectadas por accidentes químicos provocados por peligros naturales.	☐ Extremadamente importante ☐ Muy importante ☐ Importante ☐ Moderadamente importante ☐ Algo importante ☐ Ligeramente importante ☐ No es importante
Instrucciones y/o capacitación sobre acciones de preparación y respuesta ante accidentes químicos provocados por peligros naturales.	☐ Extremadamente importante ☐ Muy importante ☐ Importante ☐ Moderadamente importante ☐ Algo importante ☐ Ligeramente importante ☐ No es importante

Información sobre refugios de evacuación disponibles en caso de accidentes químicos provocados por un peligro natural.	☐ Extremadamente importante ☐ Muy importante ☐ Importante ☐ Moderadamente importante ☐ Algo importante ☐ Ligeramente importante ☐ No es importante
Información sobre planes existentes y medidas de preparación tomadas por el gobierno y las industrias para posibles accidentes químicos causados por peligros naturales.	☐ Extremadamente importante ☐ Muy importante ☐ Importante ☐ Moderadamente importante ☐ Algo importante ☐ Ligeramente importante ☐ No es importante
5. EXPECTATIVAS SOBRE EL JUEGO	
Disfruto jugando juegos analógicos, como juegos de mesa o de cartas.	☐ Totalmente de acuerdo ☐ de acuerdo ☐ Algo de acuerdo ☐ Ni de acuerdo ni en desacuerdo ☐ Algo en desacuerdo ☐ en desacuerdo ☐ Totalmente en desacuerdo
Aprendo jugando.	☐ Totalmente de acuerdo ☐ de acuerdo ☐ Algo de acuerdo ☐ Ni de acuerdo ni en desacuerdo ☐ Algo en desacuerdo ☐ en desacuerdo ☐ Totalmente en desacuerdo
Espero disfrutar el juego.	☐ Totalmente de acuerdo ☐ de acuerdo ☐ Algo de acuerdo ☐ Ni de acuerdo ni en desacuerdo ☐ Algo en desacuerdo ☐ en desacuerdo ☐ Totalmente en desacuerdo
Espero hacerlo bien y lograr una puntuación alta en el juego.	☐ Totalmente de acuerdo ☐ de acuerdo ☐ Algo de acuerdo ☐ Ni de acuerdo ni en desacuerdo ☐ Algo en desacuerdo ☐ en desacuerdo ☐ Totalmente en desacuerdo

	☐ Totalmente de acuerdo ☐ de acuerdo ☐ Algo de acuerdo ☐ Ni de acuerdo ni en desacuerdo ☐ Algo en desacuerdo ☐ en desacuerdo ☐ Totalmente en desacuerdo
Espero aprender mucho del juego.	
	☐ Totalmente de acuerdo ☐ de acuerdo ☐ Algo de acuerdo ☐ Ni de acuerdo ni en desacuerdo ☐ Algo en desacuerdo ☐ en desacuerdo ☐ Totalmente en desacuerdo
Creo que el uso de juegos serios para la educación es valioso en general.	
6. PREGUNTAS GENERALES	
Escriba aquí un código numérico de 4 dígitos de su elección (por ejemplo, 6714 o 5532). Guarde este código, ya que se le pedirá que lo ingrese nuevamente en el cuestionario posterior al juego.	
¿Cada cuánto juega juegos de mesa, de cartas u otros analógicos?	Diariamente, Semanalmente, Mensualmente, un par de veces al año, nunca.
Con cuál género se identifica	Femenino, masculino, otro
¿Cuántos años tiene?	19 o menos, 20-29, 30-39, 40-49, 50-59, 60-74, 75 o más
	Primaria, secundaria, media vocacional/técnica, pre-grado, maestría, doctorado.
¿Cuál es su nacionalidad?	
¿Cuál es su estado civil?	Viudo, Divorciado, Casado, Soltero
¿Cuál de las siguientes refleja mejor su rol?	Ente gubernamental (Nivel regional)
	Ente gubernamental (Nivel nacional)
	Ente industrial (Personal técnico)
	Ente industrial (Personal administrativo)
	Líder comunitario
	Atención de emergencias (Bomberos, defensa civil, cruz roja, etc)
	Academia (Estudiante)
	Academia (Investigador o Profesor)

7.3. Workshop records

Workshop # 1	Bogotá, Nov 21st 2023
Participants	10 participants. Community leader: Industry rep. in real life Industry leader: Industry rep. in real life
Location	UNGRD
Organizer	Organized by UNGRD
Scenario	Earthquake
Group dynamics / Discussion description	9 participants started the game. 5 teams were formed in this workshops, each one of them was confirmed by 2 participants, except one. The only single player was the industry representative, who was joined by a 10th participant after the second round. In 2 teams, one of the participants was had 2 special roles: one was assigned to play a dual role as a citizen and the community leader, and the other had the dual role of citizen and industry leader. Community leader (Industry representative, male, 50-59 years, married, master degree) old aimed for all the participants to take preventive actions since the beginning, he proposed to organize the community drill since the first round, and promote all the citizen's participation in every round, in the second round he offered to pay half of the common money, but one citizen said it would be better to have the government saving the money, as long as everyone had the resources. The same individual maintained the role during all the rounds, all citizens expressed their satisfaction with the performance. The Industry leader (Industry representative, male, 40-49 years, married, bachelor degree) took a very open part, sharing his costs and intentions, but a subtle role. He shared the technical information since the first round, but was very open about the will to take further actions to protect the community, but being limited by his budget. After this, the community leader and citizens even proposed to help and share the costs of risk analysis, because the decided it's worth more to take actions than to keep money on their pockets. On round 3, the industry asked for help from the community to pay for a Natech risk analysis, and after a little resistance from some citizens all agreed to help. The same individual maintained the role during all the rounds, all citizens expressed their satisfaction with the performance. A team of citizen, conformed by two government officers, was particularly active, asking the industry leader to provide all the information as feasible. This might be influenced by their actual roles in real life. During first and second rounds, there were no natural events and no Natechs. Third round an earthquake happened, causing a Natech on one of the installations. Fourth round an earthquake occurred, there was only a minor Natech affecting the industrial facility but no major event.

	In this group there was a lot of trust and therefore collaboration, since the first the majority of the citizens had an active role in the discussion.
Workshop duration	The time taken to take the initial survey and explaining the game was a little less than 30 minutes. 4 rounds were played. 1. Game introduction, explaining the rules and defining the roles: 7:40 – 22:35, 26:24 – 27:11 2. Game rounds: first: 27:12 – 47:03, second: 47: 04 – 1:00:00, break, third 1:18:40 – 1:54:31, fourth 1:54:32 – 2:16:10 3. Debriefing: 2:16:10 - 2:33:35
Discussion leader	In this group, the industry representative who took the role of community leader dominated the discussion and proposed taking preparation actions, such as organizing and motivating people to participate in drills every round. He even offered official aids to citizen who didn't have enough resources to participate. however, a couples of citizens also had a very active role on asking the leaders on possible actions they can take to assist all the community.
Positive feedback	Participants expressed how interesting is to combine roles, as citizens and leaders. Participants expressed enjoying the experience and the all felt learning by gaming is better and the concepts are easier to understand and relate to.
Feedback to improve	Having more participants so there are no dual roles, because of the time constraint. Including real controls, getting the input from industrial facilities. Get input from universities. The industry role needs to be more realistic in the sense, that getting income is the industries objective.

Table 1. Demographics, Workshop #1.

Male	30-39	Master degree	Single	Community
Male	50-59	Master degree	Married, partnership	Industry (admin)
Male	40-49	Bachelor degree	Married, partnership	Industry (admin)
Female	30-39	Bachelor degree	Single	Community
Female	50-59	Bachelor degree	Single	Government (local)
Female	50-59	Master degree	Single	Industry (tech)
Male	20-29	Bachelor degree	Single	Government (national)
Female	20-29	Bachelor degree	Single	Government (national)
Male	30-39	Master degree	Single	Government (national)

* Community leader highlighted in green, industry leader highlighted in blue.



Figure 1. Participants of workshop # 1, Bogota November 21st. Source: the authors.

Workshop # 2	Bogotá, Nov 22nd 2023
Participants	6
Location	UNGRD
Organizer	Organized by UNGRD
Scenario	Earthquake
Group dynamics / Discussion description	Initially only one workshop was planned for 22nd November, but the group was separated in 2, to accommodate the facilities. Workshop #2 and #3 were conducted in parallel. This caused the game introduction took longer than in the other workshops. As industry leader, an actual industry representative was chosen (Female, 30-39 years old, single, Master degree, in charge of an emergency service). As a community leader an academia representative was chosen (Male, 30-39, PhD, single). The industry leader was interested in investing in preventive measures. On the first round she shared the technical information, in the third round she paid to reinforce one of the facilities. She was always willing to help the citizens to pay for the drills. On the third round she decided to pay for the Natech Risk Analysis, this measure allowed the citizens to be more aware of the hazards, and they stated considering measures against it. A community representative who had a citizen role (Male, 60-74, High School, community) had a very active role, proposing to have interactions among all the stakeholders. He proposed to conduct the drills every round, and asked the community and industry leaders to provide help to all the community. He was seconded every time by another citizen who was an industry representative (Male, 40-49, married, Bachelor degree). This couple of citizens had the most active role, initiating the negotiations, proposing ways to share the costs, getting aids from the leaders. The first two rounds there were no natural events, therefore no Natech occurred. This group was very interested in reinforcing the houses, even though this is the most expensive measure for the citizens. There was an earthquake on the third round, fourth and fifth. Drills were conducted in all the rounds. In the fourth round after Natech risk analysis divulgation, they were informed about the risks and expects areas to be affected by potential events, and this allowed all the participants to take measures and managed to protect themselves and secure their houses. They also conducted drills, took the trainings, reinforced the houses. In the fourth round they had a natural event, but the probability of a technological accident was reduced by reinforcement. After the 4th round, this group wanted to have an additional one,

	because they were already familiar with the group dynamics, and this allowed them to protect everyone. In the 5th round they experience an earthquake and a minor Natech, that only affected the industry this group expressed they wanted to experience a big event, because they were prepared but all the measures they took, allowed them to reduce the probabilities of experiencing it, however they realized they had this outcome because they had the information on time, and took measures. In the last one, they industry leader went bankrupt, however the community helped the industry to cover the expenses and continue working. In the debriefing sessions, all the participants wanted to share their past experiences, as stakeholders.
Length	The time taken to fill the initial survey and explaining the game was more than 30 minutes. 5 rounds were played. 1. Game introduction, explaining the rules and defining the roles: 0:00 - 30:30 2. Game rounds: - first: 30:31- 47:50, second: 47:51- 1:06:30, break, third 1:25:20 – 1:43:38, fourth 1:43:40 – 2:05:06, fifth: 2:05:08 – 2:24:48 3. Debriefing: 2:24:49 – 2:43:00.
Discussion leader	In this workshop the discussion was mainly lead by two individuals who had the role of citizens. They were both male, with lower education level than the designated leaders (Community and industry). After them, the two leaders followed up the discussion, they had more related real life experiences with Natech and chemical accidents. The added important points, related to their technical knowledge, however the discussion was not dominated by them. We could see this discussion was lead by experience rather than formal education.
Positive feedback	The participants wanted to replicate the game in their communities and their jobs.
Feedback to improve	Use real maps of their areas to make the participants feel more related.



Figure 2. Participants of workshop # 2, Bogota November 22nd. Source: the authors.

Table 2. Demographics, Workshop #2.

Male	30-39	PhD	Single	Academia (prof.)
Female	30-39	Master degree	Single	First responders
Male	40-49	Bachelor degree	Married, partnership	Industry (Tech)
Male	20-29	Bachelor degree	Single	Community
Male	60-74	High School	Married, partnership	Community
Female	50-59	Vocational / Technical School	Married, partnership	First responders

Workshop # 3	Bogotá, Nov 22nd 2023
Participants	6
Location	UNGRD
Organizer	Organized by UNGRD
Scenario	Flood
Group dynamics / Discussion description	Initially only one workshop was planned for 22nd November, but the group was separated in 2, to accommodate the facilities. Workshop #2 and #3 were conducted in parallel. This caused the game introduction took longer than in the other workshops. Industry leader (Male, 20-29 years old, industry representative working on an emergency line, had a very open role. He even made the community to participate in the reinforcement of the industrial facilities. He was the youngest participant. The industry leader proposed his preventive measures to the community leader, to hear their input, and also asked all the other stakeholders to share their costs. The community leader (Female, national government, master degree, 30-39 years old) had an open approach to help the industry with paying the industry reinforcement and offered aids to the citizens after consultation with everyone. In the first round, there was no natural event, and they all participated in the drill. On the second round citizens were more interested in the costs-benefits to take the measures. There was a natural event, but there were no major technical events (Natech). On the third round the industry leader shared the technical information and carried out the Natech Risk Analysis. This group had a unique dynamic, in the sense that the industry's costs were shared by all the stakeholders, because the industry leader asked for this since the beginning. There were no major Natech in this workshop, only minor Natech affecting the industry's economy.
Length	The time taken to take the initial survey and explaining the game was a little less than 30 minutes. 4 rounds were played. 1. Game introduction, explaining the rules and defining the roles: 0:00:00 – 16:00 2. Game rounds: first: 16:00 – 37:10, break

	Second (second recording): 0:00 – 26:40, third 26:41 – 54:00, fourth 54:01 – 1:14:50 3. Debriefing: 1:14:51 – 1:32:40
Discussion leader	In this group the discussion was led mainly by the designated community and industry leader's negotiations to share costs.
Positive feedback	Adapt the game to include the local risks to conduct workshops with the communities. During this workshop the participants felt the game rules were changing, and they expressed they would like to have all the rules explained since the beginning, however, one of the participants clarified that this is actually a good aspect, since every round represents a 10 year period, rules and regulation will be changing along the years, making the game an experience closer to real life.
Feedback to improve	Financial aspects should be included in the game. The possibility of buying insurances and paying taxes should be included to make it more relatable to real life and making it more competitive. Community leader should have more available actions when acting as government officers.



Figure 3. Participants of workshop # 3, Bogota November 22nd. Source: the authors.

Table 3. Demographics, Workshop #3.

Female	20-29	Master degree	Single	Government (National)
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Male	20-29	Master degree	Single	First responders
Female	30-39	Master degree	Single	Government (National)
Male	60-74	Bachelor degree	Married, partnership	First responders
Female	50-59	Bachelor degree	Single	Government (local)
Female	50-59	Bachelor degree	Married, partnership	Community

Workshop # 4	Medellín, Nov 24 th 2023
Participants	9
Location	Andercol El Poblado
Organizer	Organized by RC
Scenario	Earthquake
Group dynamics	There is strong sense of negotiation among all the individuals in this workshops as contrasting with the previous groups in Bogotá. The industry leader (Female, 30-39, government) chose to share the technical information since the first round, even though there was a resistance to pay to being able to share. On the third round they carried out the Natech risk analysis. They had enough time to have a discussion about adapting shelters and take extra measures. The industry leader also reinforced one of the facilities. We saw some individualism aspects in this teams, they had some difficulties agreeing on the actions to take every turn. This group's citizen was constantly asking what aids they can get from the community and industry. Not all the players participated in the drills. The community leader (Female, 30-39, industry, Janeth) did take such an active role to promote drills. This team was more financially driven than other groups. This group wanted the community leader to fine the industry to prevent them to expand, minimizing the affectation areas. This group was confirmed by a female majority. This group's discussion was not dominated by one individual, but all the participants held an active part of the discussion. The discussion seemed to be more familiar to them allowing them to express agreement and disagreements in an open environment. It doesn't seem there was an established sense of hierarchy, not related to gender, age nor education level. It is important to mention that the individuals in this group are all familiar with disaster risk regulations. This region in Colombia has unique dynamics, in the sense all the stakeholders participate in all the decisions and are familiar with the risks posed by industry but also the benefits from it. They are all very cooperative, however they all had a strong sense of protecting their finances. This had an influence in the industry leader being able to ask from community leader and citizens to help paying for the studies costs.

Length Recording time	The time taken to take the initial survey and explaining the game was a little less than 30 minutes. 5 rounds were played. 1. Game introduction, explaining the rules and defining the roles: 21:43 - 45:44 2. Game rounds: First. 45:45- 1:00:30, Second 1:00:41 -1:14:40 Third 1:14:41 - Fourth.1:41:16 Fifth 1:59:05 3. Debriefing: Debriefing 2:17:05
Discussion leader	There was not a clear leader of the discussion. All the participants expressed their points of view during all rounds.
Positive feedback	The participants mentioned enjoying the experience, but kept some learnings, related to measures they can actually take, given their roles in real life. Adapt to the Colombian national territory, considering the real maps they can relate more and including other natural events that people can relate more to, like floodings.
Feedback to improve	Check the possibility to include more action cards for the community leaders, so they can act more, specially about action preventive actions. This could add more complexity, affecting the game complexity. Consider to include a moderator role playing in the game, to lead the communication between the stakeholders.

Table 4. Demographics, Workshop #4.

Female	50-59	Master degree	Married, partnership	Academia (Investigador o Profesor)	Academia
Male	50-59	Master degree	Married, partnership	Ente industrial (Personal administrativo)	Industry
Female	30-39	Master degree	Single	Ente gubernamental (Nivel local)	Government
Male	30-39	Bachelor degree	Married, partnership	Ente gubernamental (Nivel local)	Government
Female	40-49	Bachelor degree	Married, partnership	Ente industrial (Personal administrativo)	Industry
Female	30-39	Master degree	Single	Ente industrial (Personal administrativo)	Industry
Female	30-39	Bachelor degree	Married, partnership	Ente industrial (Personal administrativo)	Industry
Female	30-39	Master degree	Single	Ente gubernamental (Nivel nacional)	Government
Female	30-39	Bachelor degree	Single	Ente gubernamental (Nivel local)	Government



Figure 4. Participants of workshop # 4, Medellin November 24th. Source: the authors

Workshop # 5	Medellín, Nov 24th 2023
Participants	10
Location	Andercol El Poblado
Organizer	Organized by RC
Scenario	Earthquake
Group dynamics	In the first round the industry released the technical information to all the citizens. All the participants expressed their will to take part on the drill, since they are all familiar with these concepts. This group showed a strong sense of being financially oriented. There was a strong desire to replicate the game in different ways, not only in communities, provided by the government, but to find a way to make the game popular, as any other game, involving money. However, the participants of the game, even though they are actual stakeholders, they are all related to the regulation development. Community leader Female, 20-29 years old, industry, bachelors degree, single. Industry leader Male, 30-39 years old, government, bachelors degree, single, single
Length	The time taken to take the initial survey and explaining the game was a more than 30 minutes. For this workshop, explaining the rules took longer, because there was a logistics issue, so many participants arrived later to the venue, and were asked to join the participants who already knew the games rules. 4 rounds were played. 1. 00:00 – 48:10 2. First: 48:11- 59:20 Second: 59:21 Third: Fourth: 3. Debriefing 2:17:05
Discussion leader	Similarly to the other group in Medellín, there was not a clear leader of the discussion. All the participants expressed their points of view during all rounds.
Positive feedback	The participants found the workshop experience being enjoyable, but expressed learning some things, even though the topic was not completely new to them. This lessons were related to the measures they can actually take in real life, as citizens. Adapt to the Colombian national territory, considering the real maps they can relate more and including other natural events that people can relate more to, like floodings.
Feedback to improve	Check the possibility to include more action cards for the community leaders, so they can act more, specially about

	action preventive actions. This could add more complexity, affecting the game complexity. Consider to include a moderator role playing in the game, to lead the communication between the stakeholders.
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Figure 5. Participants of workshop # 5, Medellin November 24th. Source: the authors

Table 5. Demographics, Workshop #5.

Male	20-29	Bachelor degree	Single	Ente gubernamental (Nivel local)	Government
Male	30-39	Bachelor degree	Single	Ente gubernamental (Nivel local)	Government
Male	40-49	Master degree	Married,partnership	Ente industrial (Personal técnico)	Industry
Female	20-29	Bachelor degree	Single	Ente industrial (Personal administrativo)	Industry
Female	50-59	Master degree	Married,partnership	Academia (Estudiante)	Academia
Male	30-39	Bachelor degree	Married,partnership	Ente industrial (Personal administrativo)	Industry
Male	30-39	Bachelor degree	Single	Ente gubernamental (Nivel local)	Government
Female	30-39	Bachelor degree	Married,partnership	Ente gubernamental (Nivel local)	Government
Female	30-39	Voc./Tech. School	Single	Atención de emergencias	First responders

Male	40-49	Master degree	Married,partners hip	Ente gubernamental (Nivel local)	Government
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Workshop # 6	Cartagena, Nov 27th 2023
Participants	9
Location	UNGRD Cartagena
Organizer	Organized by UNGRD
Scenario	Flood
Group dynamics / Discussion description	It's important to take into account this group played the game with some changes in the rules. They had 2 chances to roll the dice. The industry leader had to pay for each facility to share the basic information. The information about Natech related measures was revealed after sharing the basic information, as opposed to the others, where it was revealed only after Natech Risk Analysis. Also, this group was allowed to keep discussions and taking measures after the time has passed for each round. Both leaders remained all the game. Community leader (Male, first responders, education level not defined, 60-74) and Industry leader (Male, government, 30-39). Community leader proposed a community drill at the very beginning. All the participants decided to participate in the drill and wanted to reinforce the house, but they didn't have enough resources to carry this out. The industry was not asked to take any measures and therefore did not. On the second round, the moderator suggested this, and as a response, they industry leader shared the basic information. This was performed differently from the other workshops, moderator asked to pay to share the information separately for each facility. At the beginning of the second round the game master reminded the group to ask the industry to take actions, since in the first round no actions were taken. The community leader organized the community drill in every round. Despite everyone expressed the will to participate, some of the players didn't, mostly because they were confused between they payments they made for this measure and other preventive measures, such as reinforcements and Natech trainings. In the third round, Natech risk analysis were conducted for all facilities. This made all the participants to ask community leader for shelters reinforcements, they were conducted, however the selection of the locations was not discussed with the group. A natural event (flooding) occurred, but the participants noticed that in case a toxic cloud would be released, the shelters' location wouldn't make sense for them to evacuate. This caused doubts in the groups whether to evacuate or not, and it was only decided by each group on the very last minute, but there was no consensus about the measures taken could keep them safe.

Length	The time taken to take the initial survey and explaining the game was a little more than 30 minutes. The initial participants were 5, the others arrived later, joining the others who were already explained what to do. This caused the introduction to take longer. 3 rounds were played. In this workshop the beginning of the first round was done in parallel with the game introduction to the additional roles (industry and community leaders) 1. Game introduction, explaining the rules and defining the roles: 0:00:00 – 46:12 2. Game rounds: first: 46:13 – 55:36, second: 55:37 – 1:39:41 , third 1:39:42 -2:07:54 , fourth 3. Debriefing: 2:07:55 – 2:31:00
Discussion leader	In this group, there was not a clear discussion leader, since all the participants took turns to express their points of view, and this allowed them to complement their insights according to their different roles in real life.
Positive feedback	The participants expressed how they gather some insights about real life behaviors. They realized that when people, and them, attempt to buy a house, they are usually moved by economic reasons mostly, and of course the house features, however, even for them, being aware of some of the natural and technological risks, they don't take this into account when buying. They said the game allowed them to realize this. They also expressed how convenient it would be for them the game to their area maps to make the participants relate more to the potential risks. Government representatives expressed having a program where they ask the communities to build together a hazard maps, considering their knowledge and past experiences. They would like to use this game and adapt to continue this program.
Feedback to improve	To include the possibility to buy insurances as action cards. Including more hazardous areas would allow the players to see the contrast more clearly, when buying houses and give more importance to this item.

Table 6. Demographics, Workshop #6.

Male	50-59	Master degree	Married, partnership	Ente gubernamental (Nivel local)	Government
Female	20-29	Bachelor degree	Single	Ente industrial (Personal técnico)	Industry
Male	40-49	Master degree	Single	Ente gubernamental (Nivel local)	Government
Female	20-29	Bachelor degree	Single	Academia (Estudiante)	Academia

Male	30-39	Master degree	Married, partnership	Atención de emergencias	First responders
Male	30-39	Bachelor degree	Single	Ente gubernamental (Nivel regional)	Government
Female	50-59	Bachelor degree	Married, partnership	Ente gubernamental (Nivel local)	Government
Female	30-39	Voc. / Tech. School	Single	Atención de emergencias	First responders
Male	30-39	Voc. / Tech. School	Married, partnership	Atención de emergencias	First responders
Female	60-74	Voc. / Tech. School	Single	Ente gubernamental (Nivel local)	Government
Male	60-74	Bachelor degree	Widowed	Ente gubernamental (Nivel local)	Government
Female	50-59	Bachelor degree	Single	Ente gubernamental (Nivel regional)	Government
Female	40-49	Bachelor degree	Married, partnership	Ente gubernamental (Nivel regional)	Government
Male	40-49	Bachelor degree	Married, partnership	Ente industrial (Personal administ)	Industry
Female	50-59	Bachelor degree	Single	Ente gubernamental (Nivel regional)	Government



Figure 6. Participants of workshop # 6, Medellin November 24th. Source: the authors

Workshop # 7	Bucaramanga, Nov 27th 2023
Participants	9
Location	ANDI Santander
Organizer	Organized by ANDI Santander
Scenario	Earthquake
Group dynamics	This group insisted on understanding the hazards information before buying the houses, influenced by the government officers who are familiar with risk management. In the first round, the industry leader (Female, first responders, 30-39, Voc. / Tech. School, single) wanted to share all the basic information with the community, and they received it in a positive way. In the second round the industry reinforced the facilities and carried out a Natech Risk Analysis. This information was taken as an advantage and many citizens decided to reinforce and take trainings, however, they forgot to conduct the drills event though it was organized by the community leader, but this was a matter of time limitations. Then community leader (female, government, 50-59 years old, bachelor's degree) proposed having drills since the first round until the last one. She had a very inclusive role, always consulting all the actions with everyone in the community. In the first round there was no natural event, in the second one they had a natural event but no Natech. In the third round they had Major Natechs on both facilities, however they were protected, except one group, all the participants were government officers. In the fourth round there was an earthquake but they didn't have major events, thanks to all the taken measures. All the players had all implemented measures and no one was exposed in the last round.
Length	The time taken to take the initial survey and explaining the game was more than 30 minutes. 4 rounds were played. 3. Game introduction, explaining the rules and defining the roles: 00:00:00 - 53: 09 3. Game rounds: first: 53:10 – 1:08:15, second: 1:08:16 – 1:21:00, third 1:21:01 - 1:36:10 – 2:10:20, fourth 1:49:50 - 2:28:18. 3. Debriefing: 2:28:18 – 2:50:00
Discussion leader	Describe the profile of the discussion leader and for how long did that person dominated it

Positive feedback	The first responders said they found motivation to perform their risk management duties. First responders and government officers asked the way to develop their awareness activities with communities, using these kind of activities, since they work with diverse stakeholders, and it would be useful to help with young and uneducated people.
Feedback to improve	



Figure 7. Participants of workshop # 7, Bucaramanga November 27th. Source: the authors

Table 7. Demographics, Workshop #7.

Workshop # 8	Bucaramanga, Nov 27th 2023
Participants	5
Location	ANDI Santander
Organizer	Organized by ANDI Santander
Scenario	Earthquake
Group dynamics	Community leader Female, 20-29, bachelor, singles, industry Industry leader Male, 20-29, bachelor, singles, academia Both leaders remained all the game.
Length	The time taken to take the initial survey and explaining the game was a little more than 30 minutes. 4 rounds were played. 1. Game introduction, explaining the rules and defining the roles: 2. Game rounds: first: 41:26-55:17, second: 55:18-1:26:16, third 1:26:17 – 1:47:55, fourth 1:47:56 – 2:03:40 3. Debriefing: 2:03:41 – 2:20:28.
Discussion leader	Describe the profile of the discussion leader and for how long did that person dominated it Community leader proposed a drill since the first round and all the citizens decided to participate, she also asked since the beginning for the Industry leader to provide resources for disaster prevention. The industry leader offered the technical information on round one. On the second round, the community leader proposed to help all the participants conducting the drill (25% of the cost), because she felt the industry helped the whole community in the first round. This should be regarded with extra detail, since both roles are not expected to behave the same. In this round there was an earthquake, the industry faced a major Natech in the toxic facility and a minor one on the flammable facility. The industry went bankrupt, but all the community deliberated on how to help the industry to continue the business and how to prevent this from happening again. The industry didn't buy a Natech Risk Analysis, so a fine was charged. On the third round, after the Natech occurred and the industry got fined and ended up not having resources, the community leader insisted on the industry to take measures to prevent events but also be prepared in case something happens. One of the citizens (Female, Master degree, Academia professor, 50-59) took an active role, asking for both leaders to protect the citizens, mostly based on her

	real life experiences. She also explained to the other participants about national regulations. The discussion in this round was joined by everyone, but sadly they didn't focus on the time management, and even though they all agreed on the measurements to take, they were not able carried their plan out because they ran out of time. There was an earthquake on this round, but no Natech occurred. On the fourth and final round, the community leader proposed a joint effort to reinforce both industrial facilities, to lower the possibilities of having Natechs. With different percentages, all the participants agreed on this initiative and not only public money was used (managed by the community leader), but event citizens used their private funds to support the industry. This group was able to see how the affected areas changed by reinforcements. They meant to reinforce all the houses and more shelters to use their resources to take more preventive actions, but again they ran out of time. This game presented the first experience for the industry leader to have negative points, or so many points to be taken from them.
Positive feedback	The participants expressed they expected to attend to a lecture, because they were not completely informed about the event they would attend, but the activity exceeded their expectations when it comes to learning. They feel they will remember and they wanted to know about the results when the study is finished. The citizens from this region expressed they don't feel listened and included by the national authority policies.
Feedback to improve	The professor attending to this workshop insisted on how her university has been studying the seismic risk an developing tools to inform the risk, but they don't feel listened and included, and expressed all their efforts are not being considered and they would like this group to communicate this to the national authority, however we as researchers do not have the authority to do more than expressing this.



Figure 8. Participants of workshop # 8, Bucaramanga November 27th. Source: the authors

Table 8. Demographics, Workshop #8.

Female	20-29	Bachelor degree	Single	Ente industrial (Personal administrativo)	Industry
Female	30-39	Master degree	Divorced	Ente industrial (Personal administrativo)	Industry
Female	30-39	Master degree	Married, or in a domestic partnership	Academia (Investigador o Profesor)	Academia
Male	20-29	Bachelor degree	Single	Academia (Investigador o Profesor)	Academia
Female	50-59	Master degree	Married, or in a domestic partnership	Academia (Investigador o Profesor)	Academia
Female	20-29	Bachelor degree	Single	Ente gubernamental (Nivel local)	Government

7.4. Follow up questionnaire in Spanish

Cuestionario de seguimiento

Natech workshops Colombia noviembre 2023

Objetivo:

Investigar si los talleres realizados hace 6 meses dejaron una impresión en los participantes, que los llevara a algún cambio en la imagen de los otros participantes y a tomar acciones concretas relacionadas con la Gestión de Riesgos Natech.

Listado de preguntas

1. Datos demográficos: edad, sexo, rol, educación, estado civil. Al final, no preguntar lo obvio.
2. alguna pregunta en particular para involucrar los participantes. Algún dato o anécdota para refrescar la memoria o conectar con su parte emocional.
3. Muchas gracias por aceptar este espacio. Han pasado 6 meses desde su participación en los talleres. Después de este tiempo, ¿cuáles cree UD que son los logros más duraderos, producto de los talleres? ¿Cuáles cree que son los objetivos más importantes que aún requieren más trabajo?
 - a. Sondeo sobre Impresiones negativas y positivas
 - b. Sondeo sobre los actores que condujeron a los resultados positivos y negativos.

Auto-imagen

4. ¿Ha compartido su experiencia en el taller con otros, como los miembros de su familia, amigos, compañeros de trabajo u alguien más?
5. Si no surge ninguna idea, sugerir opciones como análisis de las inmediaciones de su casa, revisar la presencia de instalaciones industriales cercanas a la vivienda, buscar códigos de construcción de la vivienda, sistemas de alerta temprana en su teléfono, preparar un kit de emergencia familiar).
6. ¿Se ha involucrado personalmente o solicitado hacer parte de actividades de RRD? (En su compañía, casa, comunidad)?
7. En caso afirmativo, ¿podría explicar la naturaleza de este compromiso y dónde y cuando se ejecutó o ejecutará?

Sondeo potencial: vivienda, compañía, evento público.

8. ¿Ha comunicado alguna necesidad, queja o requerimiento relacionado con la RRD con el gobierno local? ¿Regional? ¿Nacional?
9. ¿Ha experimentado algún cambio, o se le ha solicitado algún cambio relacionado con las expectativas de otros actores sobre su rol en la RRD?

Imagen sobre otros actores

10. ¿Se ha reunido o comunicado con alguno de los otros participantes de los talleres después de realizarlos?
11. ¿Conoce alguna iniciativa de otros participantes de los talleres?
12. ¿Podría explicar la naturaleza de estos esfuerzos, tales como medidas tomadas o campañas de comunicación iniciadas? ¿Quién ha estado involucrado?
Sondear acerca de otros actores que no fueron mencionados tal como la industria el gobierno local la Academia el gobierno nacional.
13. ¿Cómo se siente al respecto del comportamiento de estos otros actores? ¿Cree que cumplieron con las expectativas o se siente usted insatisfecho con su desempeño acerca de los talleres? ¿Por qué?
14. ¿Hay algo adicional que quisiera mencionar acerca de estas actividades? ¿Algo que quizá haya aprendido, que le gustaría compartir o alguna recomendación acerca de cómo mejorar el proceso y ser más efectivo?

7.5. Example of a coded interview

A refers to the Interviewee

B refers to the interviewer

B: como que si te hablo de este tipo de cosas y de la actividad, qué es lo primero te viene a la cabeza,

A: lo primero que me acuerdo es lo que me parece interesante es cuando pues en emergencias en C11 es un reflejo de donde en los primeros posts no veo mucho como la edificación los líquidos es importante que se empiecen a hacer las pimas que son líquidos, pueden ser en una siguiente año los líquidos...era tóxico llegaron un asión, llegaron termótipos no queríamos ir porque se enferma Si, el oriente de aquí, gracias. ¿Está bien así ya? Si, ¿no escuchas? [*aware.industrialevents, exp.industrialevents*]

A: Entonces, Rina, usted decía que lo primero es la identificación de los peligros, ¿sí? Que me parecía importante, por ejemplo, si llega a haber un terremoto, una inundación, cómo estamos preparados, porque uno siempre piensa, bueno, tenemos productos inflamables, ¿qué hacemos? Entonces contemos con sistemas de ingeniería, ¿cierto? o contemos con diques, pero solo estamos contemplando si llega a haber una pérdida de contención de cierta manera mediana, pero no nos imaginamos si hay un terremoto, ¿qué va a pasar si todo el estante nos viene con los productos tóxicos y llega a haber una fisura de los productos que vamos a hacer. [*aware.industrialevents, aware.natech, aware.earthquake, roles.first responders*] Lo segundo que me pareció interesante del ejercicio fue varias entidades, varios personajes que participamos, que participan, entonces que ayuda de la policía, ayuda de Cruz Roja, ayuda de bomberos, identificar también nuestra comunidad, quién está al lado de nosotros, porque a veces nosotros como industria, bueno, hagamos un plan de ayuda mutua, pero a veces nos llega una emergencia, pues se nos abarca la comunidad, qué hacemos, si está preparada, si está enterada de lo que más me parece relevante de ese ejercicio. [*roles.community, roles.industry, roles.first responders, comm.issues*] Y así te quería comentar, aprovechando ese espacio, por ejemplo una de las gerentes regionales me dijo, ay ustedes invitaron a algunas empresas del consejo pero no les dieron ninguna realimentación, sí, después de que se acabó por ejemplo la charla, digamos así, una reunión, no se volvió a citar entonces la gerente me dijo que hubiera sido chévere porque a los dos meses tres meses hubieran dado como una retroalimentación de seguir comentando qué más pensaban ejercicios eso fue una de las observaciones que tuvieron que estar comprometidas [*game.negexp*]

B: ¿se refiere a los ejercicios que hicimos en el consejo?

A: no, con el que hicimos cuando nos reunimos en la unidad, ¿sí? Ah, ok, ok. En práctico, en el taller práctico.

B: Ah, listo, listo, muchas gracias.

A: Ese sí fue, pero a mí lo que me parece interesante fue eso, mapear prácticamente que comprendíamos la importancia de los peligros de las personas clínicas. Comprender y diferenciar, ¿sí? Por ejemplo, que es un evento Natech ¿sí? Que uno dice, bueno, puede ocurrir en tal lugar, 0:05:36 ¿por qué es importante? ¿Por qué puede ocurrir un terremoto, porque puede ocurrir una inundación, es como lo que más uno recuerda de la importancia de que las empresas guarden sus recursos y de que las alcaldías tengan sus recursos, de que el gobierno tenga sus recursos. Eso también es importante porque a veces, pues, medimos, o la alcaldía piensa solo para ello, la empresa piensa solo en ella, y ella se vea mar por ejemplo afectada así pero nos pues por todo es eso me parece como el taller así de lo que me acuerdo es eso.} [game.posexp, roles.industry, aware.flooding, roles.natgov, roles.locgov]

B: Eso por el lado de lo positivo, y te pronto algo negativo?

A: pero más para mí me parece más positivo que negativo si invitar y por mejorar, no fue más por mejorar que de ustedes, yo creo que más por mejorar, que de pronto hubieran llegado más invitados, sí, pero pues nosotros los invitamos, pero pues la gente no llegó y eso es importante porque por ejemplo llegaron los líderes de HSE, llegaron representantes de organismos de ayuda, pero que mejor que hubieran de verdad llegado gente de la alcaldía, gente del gobierno, otras personas, unos gerentes de empresas, [roles.multidisciplinarity, game.particip, roles.natgov, roles.locgov, roles.industry, roles.first responders] entonces hubiera sido chévere para el ejercicio haber de pronto alargado un poquito más el ejercicio con distintos escenarios no solo el de inundaciones, el de terremotos, sino distintos escenarios para que todos pudieran participar pronto en todos hubiese sido también como chévere de pronto por mejorar, pero a mí me pareció que fue una experiencia bonita porque fue de aprendizaje [game.posexp, game.scenarios]

B: y también nos ayudó el paro, ¿no?

A: Entonces, en tema de participación de otros actores, y de pronto si uno dijera mejorar, si vamos a hacer de nuevo el ejercicio, no sé, de pronto hacer una diapositiva, dos diapositivas ya explicando la clase, los eventos que son, nada, técnico, algo muy puntualito que a las personas se les quede pronto con dibujitos. [game.particip, game.negexp]

B: o algo así también podría ser ok, vale, muchas gracias.

A: pero no, a mí me pareció muy interesante mucho el ejercicio me gustó, el mapa como lo colocaron de que mire lo que irradia, mire hasta dónde puede llegar y eso me pareció chévere de lo que me acuerdo de ese taller va, y bueno, con respecto a... [game.posexp]

B: ¿Quiénes tres de los actores que estuvieron como más relevantes en la participación en cuanto a lo que sacamos del ejército?

A: Ahí estaba gente de la Cruz Roja, Defensa Civil, si no estoy mal. Estaba gente también de empresas involucradas, donde se llegue a encadenar una emergencia de verdad, porque ellos tienen que ser los más

conscientes y son los que tienen que apoyar en caso de una emergencia, yo creo que un poquito más de peso, porque finalmente son sus productos, y ellos almacenan esos productos. De peso eso me pareció muy importante. Me parece que faltó lo que yo te digo, otro tipo de actores de pronto, de las alcaldías, de las gobernaciones, pues porque a veces uno dice, no sé, la mayoría de industrias está por ejemplo en Tocancipá, si uno dice movilizar, por ejemplo, si llega a haber una emergencia, bomberos desde Bogotá, Tocancipá, a veces falta un poquito más de conciencia de las personas que entregan recursos, por ejemplo, bomberos voluntarios, pues ellos no tienen todos los recursos como por ejemplo bomberos de materiales peligrosos, ¿sí? Y bomberos de materiales peligrosos solamente están en las ciudades principales, entonces también como... Y que tienen las unidades. Entonces falta también como ese compromiso de los actores involucrados que pueden dar estos recursos, por ejemplo, a bomberos, para que ellos también visualicen qué pasa si se llega a presentar un tipo, un panorama de esos. *[roles.first responders, aware.lack, aware.natech, aware.industrialevents]*

B: entiendo. Vale, gracias. Gracias.

A: Creo que eso es como lo más... Sí, no, y tienes razón, porque es que es simplemente como lo del pético de corresponsabilidad, que se supone que es lo que estamos haciendo, pero es complicado sentarnos juntos y tener este... pues, estos espacios. *[game.particip, game.posexp, comm.issues, comm.lacktrust]*

B: Y de pronto he tenido la oportunidad de, como, de conversar al respecto del ejército con otras personas?

A: Con la única persona fue Chevron, que inclusive estuvimos visitando esta semana, pues por lo que el tema se viene, aunque no es directamente relacionado por lo que se viene, con el tema del programa de prevención de accidentes mayores, entonces están como muy pendientes de invertir en recursos, de pronto, que verifique si sus instalaciones están clasificadas o no, ahorita se viene todo el tema de seguridad de procesos, pues con el consejo que tengan todos los pilares de la CCPS, les va como muy relacionado porque también dicen, bueno, no solo puede haber una emergencia por un acto inseguro, porque falle algo en una máquina, sino también porque puede ocurrir, por ejemplo, un terremoto, los temblores que a veces suceden de un momento a otro, uno dice estamos o no estamos preparados para eso *[aware.industrialevents, roles.industry, aware.natech]*

B: ¿Y las inundaciones? Sí, ahorita las inundan, es como el tema,

A: Y como que eso es lo que viene, pues, y más o menos lo que yo escucho es más como dirigido como a seguridad de proceso, que lo toca de cierta manera y uno dice bueno si llega a haber una emergencia estamos preparados pero es por seguridad de proceso más que decir hay prepáremos porque va a haber un terremoto prepáremos por una inundación no, es más como por la parte de seguridad de proceso, si hace falta como énfasis que pronto salga alguna circular, resolución, algo así si me entiendes o que diga una pequeña circular incorporarlo por ejemplo ahorita con el tema de seguridad procesos que se puede meter. *[aware.earthquake, aware.industrialevents, aware.natech, aware.flooding]*

B: si, yo creo que eso viene con el 2157, que habla de dos finales.

A: pero yo creo que también sea y eso mira, mira que tú cuando dices el 2157 quienes lo tocan por ejemplo las empresas del sector petrolero, ¿sí? Para el resto de la industria química a veces es como muy alejado. ¿Me entiendes? Si a veces no tienen... Si, si a veces no tienen contemplado sino el plan de emergencias... O imagínate ahorita toda la debilidad que hay con ser que ya salió la norma hace rato, pero no todas las personas tienen plan de contingencias, o hay empresas que dicen, no, definitivamente no nos aplica. Es como no les aplica, pues mucho menos van a llegar a tener contemplado esos fenómenos que puedan ocurrir [aware.industrialevents, roles.industry]

A: Si, es como que hay una baja percepción de que... de que hay vientos de tipo de viento porque por la forma en la que ... Inclusive en la matriz cuando el... y no, y no todo el mundo lo tiene contemplado incluso si hay personas que tienen la matriz ambiental entonces hay personas que lo contemplan que pasa si hay un terremoto, que pasa si es un sismo que pasa si es una inundación que pasa si, mejor dicho, que haya un relámpago, un trueno? Pero es muy poca las personas que lo tienen contemplado. Y tú sabes que aquí ni siquiera hay matriz son juiciosos en la matriz ambiental. A duras penas llegamos con la de securizarlo en el trabajo. [aware.lack, aware.natech]

B: Entonces, ¿se hace falta un corto plazo en este tema? No, pues, bastante. Ojalá no, porque no pasa nada. ¿Qué pasa? Dios mío, Dios mío, que Dios me lo prestó. ¿Por qué? No sé. ¿De pronto también le has compartido este taller con la familia, los amigos de otras personas en otro escenario que no es el de trabajo?

A: Pues más que pronto compartir el taller, sí de pronto tengo muy pendiente el tema del botiquín, por ejemplo, que no le dice a la familia si a los vecinos oiga vez si usted tiene un botiquín, usted si tiene un buen botiquín, es como lo primero que uno resalta, usted sabe qué haría si hay una emergencia, de verdad se van a reunir en el parque a la esquina, se van a reunir en la iglesia, si ustedes qué hacen si llega a ver por ejemplo, por lo general en lo que yo siempre me acuerdo es un terremoto porque en el consejo siempre como que lo mencionan mucho y hay por ejemplo viviendo en Bogotá, es a lo que uno más le tiene miedo, si? Yo digo para Bogotá, aunque hay sitios estratégicos, Bosa, pues rápido trae, no sé, los carrotanques y empiezan con las bombas de succión, es como el agua, que eso es lo que se ha visto, que cuando llueve muy duro y cae granizo y lluvia, que me da la impresión de pronto que se rompan los vidrios y que llegará a ser muy fuerte, porque en nuestro país hubo vientos, por ejemplo, en los de agosto, pero pues yo nunca he escuchado así que, uy ya volaron todas las tejas y las quemaron los vecinos, no porque cada vez que hay más seguridad pero a mí lo que si me preocupa es en caso de un terremoto, ya de todos los fenómenos que puedan ocurrir, porque aquí en Bogotá se ha temblado y cuando tiembla es fuerte no dice uno que alimentos tiene, tiene agua, tiene botiquín, tiene por ejemplo, alimentos enlatados, si? eso es en lo que uno piensa, uno dice, pero yo creo que cuando tu casa se ha colapsado en tu caso es más, en tu caso, perdón, es más por el trabajo.} [action.emergkits, action.emergencyprep, roles.community, aware.earthquake, action.nonrelated]

B: Y están relacionados con el taller?

Nosotros aquí con los vecinos también hablamos mucho del tema del terremoto, ¿sí? Aquí, por ejemplo, desde la Junta de Acción Comunal, a veces cuando hacen ejercicios, inclusive con las personas de tercera edad, les refuerzan mucho ese tema. Inclusive, ¡ay! Usted tiene las veterinarias, un kit de emergencias para mascotas. Entonces, a veces lo hablan desde la Junta de Acción Comunal a las señoras de tercera edad. Pues, más o menos, no es tan alejado ese tema en cuanto al terremoto [action.nonrelated, roles.community]to

B: sí ok, pues que bueno que toquen en los temas porque de ahí es que más marca también la pregunta es un poco como qué tipo de medidas se tomaron a partir del taller, si las hubiera.

A: pues yo digo que lo único que a mí me reforzó de pronto fue eso, o sea tener en cuenta en la casa si de verdad uno está preparado y tiene como todos los elementos, y a nivel personal, de pronto de casa, de lo que uno habla con los vecinos, solo esa parte, porque yo no puedo decir, no, es que yo tomé unas medidas, no sé, ir a hablar a la alcaldía o me fui para algún lado, porque no, sería una mentira de decir que ya uno escaló el tema más alto, no. [aware.earthquake, aware.changed]

B No, es más como si digamos, dado el ejercicio que se hizo, de esos guíos, como alguna idea nunca se puede seguir que te haces empezar a mirar los alrededores, donde vivís, donde vivís que ya se empezaron como a mirar

A: Lo único fue una vez que nos pusimos por ejemplo a hablar con los muchachos de nosotros, bueno aquí en Bogotá, cuando uno mapea por ejemplo en el barrio que puede ver, nosotros aquí tenemos cerca por ejemplo a mexiquenses Mexichem derivados, resinas, y uno sabe que manejan distintos productos químicos, que trabajan monómeros. Entonces, por ejemplo, aquí decimos, si nos vamos a la parte de Soacha, claro, uno analiza, uno dice, ¿por qué tantas emergencias con pólvora? ¿Sí? ¿Qué ha sucedido? En Tocancipá, pues, industria, es lo que hay al 100. Entonces, uno mapea, por ejemplo, eso, y uno dice, uy, en Soacha hay mucha empresa. Pues uno no decir que es ilegal porque a uno no le costa, pero que uno sabe que pues no tienen como toda la preparación de pronto, no cuentan con un sistema de gestión de seguridad en el trabajo, pues porque no lo reconoce, sí? Empresas por ejemplo que manejan poliuretano, para el tema de colchones, uno sabe que en Cazuca, en Ciudad Bolívar, hay todavía ese tipo de empresas. Entonces, sí, pero un poquito más en lo que uno analiza, si obviamente uno obviamente llega a ver una... Otra cosa que uno si analiza y que siempre me ha dado a mí como temor, y tal vez por el trabajo, no solo por el taller, pero uno si después analiza por ejemplo todas las estaciones de gasolina uno dice uy, un PrimaX pegado al conjunto que está al lado por ejemplo Andrés que vive en Surbana uno dice es una bomba de gasolina... [action.surroundings, aware.industrialevents, action.nonrelated]

L: Surbana? Sí, al lado del portal sur. Ah, ok.

A: Entonces, uno dice, si ves tantas estaciones que hay pegaditas a conjuntos, a viviendas, esa es una de las cosas que uno dice Dios nos ampare porque como que estar en esta razón es pasar a

L: ver cosas como normal.

A: Sí, por ejem *[aware.industrialevents, aware.domesticrisks]* plo, la de las estaciones, es algo que yo digo y encima de almacenar la casa no en esto sí no pero bueno ya tenemos

B: ¿Por lo tanto, hay otra cosa que no se ha notado? ¿Es que se ha empezado a mirar los sistemas de alerta temprano?

A: No, por el momento no. Eso sí me lo van a sacar. ¿El sistema de alerta es un poco más fuerte? No. Pues uno es quien está pendiente por el noticiero, ¿no? Y cuando hablan, por ejemplo, la Unidad Nacional de Gestión de Riesgo está notificando, no sé, como en otras ciudades, que el volcán de El Ruiz, ¿sí? que pilas porque está subiendo la temperatura, pero pues aquí en Bogotá que yo sinceramente, diga, yo he escuchado no sé, de pronto el respeto a la lluvia ¿En Medellín hay? Tienen una aplicación que se desarrolló en el de AMVA basada en Telenoche entonces por eh... locaciones, le avisan a la gente como pilas en el salón que va a llover o que pasa un marco largo tiene que ir directo cuando se acumula lo que llueve la última hora, lo que llovió el último día por las insinuaciones no pues aquí lo único que yo escucho es que uno está pendiente, pero entonces en el noticiero cuando la unidad nacional dice, se acerca el fenómeno del niño, se acerca el fenómeno de la niña el consejo salga alguna comunicación, sí, pero que uno vaya a tomar alguna medida o algo no es una cuestión de teléfono. Inclusive para los templos, nosotros teníamos uno en el celular, no me acuerdo quién fue el que nos la descargó del consejo, que sonaba cuando a principio del año pasó, empezaron varios templores, claro, uno estaba pendiente, pero respecto a la inundación, uno sabe que en octubre y noviembre llueve mucho, entonces que hace más personas del mundo mandar a arreglar las tejas pendientes y es como lo que uno puede hacer y los vecinos uno ve que hacen no reforcemos el tema de la vida de resultados canaletas que no estén taponadas y si es lo que uno hace porque no dice que más puede hacer uno sea para una inundación y cuando la gente dice si llega a haber alguna emergencia que de pronto las iglesias que uno dice las últimas se han construido que son termoresistentes pero de resumen es difícil. *[comm.issues, aware.flooding, action.earlywarning, action.nonrelated]*

B: ¿Pero no es como algo oficial que se ha organizado para convocar a la gente?

A: No,

B: Entonces también me decías que no han tomado como digamos una iniciativa objetada suele solicitar algo como a un gobierno o a un subordinado del taller? ¿No has escuchado que alguien al taller haya tomado una iniciativa objetada a partir del taller?

A: No, pues la verdad es que no me ha hablado así que yo diga como con las personas que se han relacionado solo con el ingeniero de Chevron, de resto no...

L: Pero no había como un estudio, ¿no?

A: No, no, o que nos hayan hecho a nosotros alguna solicitud o de ampliación, por ejemplo, el tema como pasa con seguridad de procesos, que a veces las personas como que si interesan o no le ven ese interés, no. O sea, que nos hayan llegado con juntas, no. *[aware.industrialevents, action.nondrmrequ]*
Ok. No, no, no.

B: No, pues eso es como... De pronto también, ¿cómo te sientes con respecto a cómo... el comportamiento que producen los otros autores en realidad, ¿qué opinión te genera? ¿te faltó algo? ¿algo que quieras resaltar?

A: Digo que es un tema que se debe seguir tratando, porque de pronto por el momento uno le pone cuidado pero ya después como que se va olvidando en el tiempo porque no es algo que uno lo vea como de frente, ¿me entiendes? como con esa importancia, todavía falta un poquito más de sensibilización, pero yo también estoy consciente de que falta esa percepción, por ejemplo, por parte de entidades como la Unidad Nacional de Gestión de Riesgo de Desastres, si da falta como el Ministerio de Trabajo, claro, que ellos participen, por ejemplo, pasen cartillas, si me entiendes, que la unidad dijeran, oiga, se acerca el fenómeno del niño, ellos sacan a veces algunas circulares pero a veces se queda como entre los ministerios las empresas y a mí se me da mi percepción que no llega como a la comunidad así como al resto de la sociedad. *[aware.lack, comm.issues, roles.natgov, aware.earthquake, aware.flooding, perception.risk]*

B: ¿Entiendes como el público general?

A: Sí, ya que no es un tema que esté fluyendo con la información, ya que no se le da la importancia.

B: ¿Y ese tema que me dices de las circulares es desde la unidad, desde el gobierno nacional?

A: Sí, por ejemplo, desde la unidad que pudieran sacar algo, porque finalmente ellos son los que tocan esos temas, con los ministerios. Entonces, por ejemplo, dice el ministerio del trabajo, no sé, si saliera hacia las empresas, el ministerio de salud, si saliera hacia la comunidad que le compete, sí, que con secretaría de salud, algo así se podría trabajar, pero es un tema como que así pasa, pero ya, hasta ahí.

O sea que si hay unas circulares pero no están llegando al público en general.

A: No, no, que sería chévere que las crearan, ¿sí me entienden? Sacan esa veces comunicados o como... Los ABC, también. Como artículos, pero como a nivel de empresa, ¿sí? Que se debe trabajar, por ejemplo,

en el fenómeno del niño, pero a mí se me hace que se queda a nivel de empresa y no va a la comunidad. O sea, de gobierno, del ministerio o de la unidad de guía en los lugares a los empresas. Hacen como un artículo, trabajaron yo sé una vez como una guía, algo así de ese tema relacionado. Para ver qué medidas las empresas, unido al plan de emergencias, ese plan de contingencia, como esa unión en que va, pero se queda como en las empresas. ¿Sí que está haciendo cada uno? [roles.community, comm.issues, roles.natgov, comm.sharinfo, roles.industry]

B: ¿Me entiende como ante el CNARIT?

A: Sí, claro, pero yo lo trato pero desde ese punto con las empresas, pero se queda ahí, no baja hacia la comunidad. Quizás no bajan las mismas empresas hacia abajo, se quedan los niveles superiores, en los niveles del de seguridad y salud en el trabajo, en los niveles del de seguridad de procesos, pero ¿será que le bajó a la secretaria? ¿Será que le bajó a los operarios, sí? Es decir, también por lo que atendí, esto es como, pues al nivel del gobierno nacional, estamos tratando si baja al nivel del gobierno local, es que también esa brecha se vio como en los talleres, no? [aware.lack, comm.issues]

A: No hay como ese flujo de información incluso entre las mismas instituciones, dependiendo de ese nivel. A mí se me parece que el tema todavía es muy apartadito si como como que no hay su club de información confianza yo no sé si confiando es conciencia yo creo que es más conciencia que confianza porque como sacan otros temas si me entiendes o se le ve como la urgencia 25 minutos [aware.lack, comm.issues]

B Entiendo, entiendo Para mi es como esto Ya para terminar nos di algo como más que quieras mencionar Lo bueno, lo bonito, no tan bonito, todo lo que sea, todo lo que sea No, ni noches, a mi lo que me pareció de pronto, a mi me pareció chévere el juego de los recursos, del dinero que le daban a cada entidad. Pero lo que te digo, que se hubieran tocado como más escenarios por grupo de pronto para poder identificarlo.

A: Eso me pareció como chévere. Y para mejorar, lo que te digo, de pronto un slide, un folletico, algo así como para dejar no solo, después de terminar el taller, no solo iniciando, sino que la gente quede con ese recordatorio de por qué se hizo el taller, de qué era un evento natal, de qué relación tenía de pronto con la gestión de ritmo químico, ¿sí? [game.negexp, game.posexp] Entonces, hubiera sido una persona y esos proyectos hubieran ayudado no solo a la persona a recordar, sino por ejemplo que muchos líderes o las personas que estaban en organismos de ayuda lo pusieran de pronto en su cartelera en la empresa, en organizaciones, en la alcaldía, para que multiplicaran esa información. Ok, entiendo. Vale, entonces eso me parecería que hubiese sido chévere de pronto en otro ejercicio para hacerlo. Claro, aquí anotado, de verdad te agradezco mucho la información, entiendo, pues eso era lo que quería preguntar. De verdad, gracias. De lo que me acuerdo, sí tengo en el radar, pero pues uno tiene que ser muy honesto con lo que queda. [comm.issues, game.particip, game.negexp]

B ¿Tú has experimentado como ya sea un accidente industrial o problemas con el tráfico de cargos en tu vivencia?

A: Que yo haya estado... no, lo único pues las noticias que uno escucha, ¿no? Por ejemplo, pero no, no porque el que ocurrió por ejemplo el último que fue en una empresa de pólvora que estaba por el lado de las salidas de Bogotá como hacia Tocantín pero no, ese fue por un acto inseguro según eso entonces no, que hubiese sido *[exp.lacking]*

B relacionado con Nater no. ¿Y cuál es tu tipo de trabajo? ¿Tú estás en la escuela? Uno más o menos va escuchando pero por Nater no. Bueno, pues... Tu sensibilidad no es diferente.

A: Tu día a día si entonces pero si que yo ya he escuchado que de pronto hay noticias o algo no hay igualdad no queremos esperar Yo cuando trabajaba en bogue, por ejemplo en el laboratorio, ese laboratorio aquí por el lado, antes de Cazuca, era como en Bosa, aunque ellos ya se fueron por otra planta en Funza. Esos se pegaban unas inundaciones, o sea, no alcanzaba a llegar el agua a los equipos, pero llegaba a la parte de los baños y todo, y yo decía, o sea, de milagro no llega a la planta donde están almacenados como la mercancía ya para salir. Pero se inundaba tenaz, o sea, era tanto que cubría los zapatos de los operarios cuando yo iba a la iglesia cuando llovía era el fin de año, yo ya volví y yo parecía que no me acordaba de lo que hacía en boca cuando yo llegaba a la iglesia todos los años lo mismo si uno se queda con el día del monjez *[exp.sharingprofessional, exp.industrialevents, exp.naturalevent]*

que va a llover cuando llega el monjez del mundo. ¿Ah, una vez? ¿Ahora qué he hecho cabeza? Sí, una vez llamaron de un SENA, pero no me acuerdo si fue en Medellín, un laboratorio que se les inundó y los reactivos se mojaron y no veían las etiquetas. Y llamaron a Distro King porque identificaron unos pictogramas y tocó mandarlos a disponer como recibo peligroso. Ese es el único que me acuerdo que se inundó *[exp.sharingprofessional, exp.industrialevents]* en un laboratorio del SENA. Pero no me acuerdo si fue en Medellín, en Palmira, pero fue un laboratorio. Es que no me acuerdo si fue ese año o el año pasado finalizando, pero sí hubo un laboratorio. Sí, a ver qué se hace. Pero pues mira lo que hicieron, ellos llamaron, cuántas empresas no se quedan en silencio y no dicen nada, no reportan porque pues, si me entiendes, hasta que no haya una emergencia grande no lo comento yo creo que la cantidad de

casiacrianos que la tenemos si eso lo compartieran no se evitaba pero podemos ver el registro como esta pero tiene que ser una cantidad y a veces el mismo el que esta haciendo las cosas

0:30:24

es el menos avergado de todos el mes de noviembre afortunadamente no hay nada que vaya a haber hay algo que reaccione si si, si también tienen *[exp.previous, exp.sharingprofessional, exp.industrialevents]*

B bueno Manuelita te agradezco mucho de verdad muy amable bueno Lina estamos hablando estamos comunicando y si te pasa cualquier cosita nos avisas

A: muchas gracias y que la gente quiera participar en ya no se nos ocurre Andresito estuvo Johan yo le digo para que esté pendiente que tú le vas a hacer la entrevista y que me digan esta semanita cuando puede

para avisarte a esta hora más o menos te queda bien? A esta hora? Sí. O a qué hora te queda bien?

A mañana no, porque no es el día de mañana. Porque hoy ya tenía todos los programados. No dale, yo mañana no creo, Lino. Mañana no, por lo que llegamos tarde allá en Nogal. Pero entonces yo le digo para que el teniente entre el miércoles y vuelve y que él te diga qué hora se fue a ir a la escuela. Yo les pido un correo. Entonces te quedaría bien tipo 7 o 8, ¿sí?

B: Sí, o más temprano para que no le quede tan... Pero a ti no te queda muy temprano, por ejemplo, las 6 de la tarde, ¿no? No, yo soy las 5 de la mañana. ¿Sí? Sí, y los hermanos que juegan no pueden ir, pero el viernes sí. Dale, yo digo el viernes.

A: Muchas gracias! ¡Yo les quiero dar un abrazo! ¡Que se venga un día juicioso! ¡Que te vayan muy bien! ¡Chao!