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Stakeholder Input for a Common, Global, Comprehensive Risk Management Framework for Industrial Parks to Manage Risks from Natural Hazards

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Synopsis

Towards the development of a comprehensive risk management framework for industrial parks to assess and manage risk from the conjoint natural hazards and technological accidents, meetings and industry visits were arranged in Colombia in order to obtain input that can help refine the proposed framework. Eight multi-stakeholder meetings were conducted with the participation of more than 80 experts. In addition, more than 20 public and private organizations were contacted as well as three industrial visits were carried out. The main aim of the visits was to obtain expert feedback on the proposed framework in addition to data collection for understanding the current state regarding Natech risk and risk management in Colombia. As a result, expert feedback was positive indicating the need for and usefulness of the proposed framework. Contributions to the framework include: validation of the need to consider risk governance and risk communication to integrate cooperation mechanisms among stakeholders and the importance of including external environmental aspects in the proposed framework.

Keywords: Disaster Risk Management, Natural hazards, Natech scenarios, comprehensive framework.

1. Introduction

Natural hazard triggered technological accidents, known as Natechs, have captured the interest of researchers for more than 30 years. Although initially not called Natechs, the study of natural hazards affecting industrial installations has been registered since around the 1980's (Showalter and Myers 1994, Cruz et al. 2004, Steinberg, Sengul, and Cruz 2008). Since then, research and lessons learned have both demonstrated the global impact and severe consequences of these accidental events. Past studies have demonstrated the capacity of Natech accidents to exceed industrial facilities' territorial limits, exacerbating response capabilities, due to concurrent damage to lifeline systems and impacts on neighboring communities (Cruz and Krausmann 2009, Steinberg and Cruz 2004, Krausmann and Cruz 2013, Krausmann, Cruz, and Salzano 2017)., As stated by Mileti (1999)''There is in general a higher population density, more industries and more infrastructure at risk''(Mileti 1999). The above mentioned, together with the occurrence of severe hydro meteorological and weather related events have become a challenge for industries and governments (Wuebbles 2016, Sengul et al. 2012) thus, highlighting the importance of better understanding and managing Natech risk.

To this end, many efforts and initiatives have been developed. Examples include the work done by (Antonioni et al. 2009), (Landucci et al. 2012), (Necci et al. 2013) and (Cruz and Okada 2008) which have focused on identifying equipment vulnerability relationships, and developing risk assessment methodologies. The scope of methodologies proposed thus far is for individual industrial plants. However, the need for area-wide risk assessment methodologies have been highlighted (Krausmann et al. 2017, OECD 2015). Furthermore, there are no tools available to evaluate the level of performance of industrial sites when faced with Natech scenarios.

Therefore, given the interaction of a variety of elements in a Natech scenario and the existing gaps in the Natech risk management context, there is a need to come up with an integrative framework. Consequently, we are currently developing a comprehensive Natech risk management framework for a rating system to evaluate the level of performance of industrial sites when faced with these kinds of scenarios.

With the development of the framework in mind and in an effort to obtain expert feedback, understand stakeholder needs and explore a possible case study to validate the framework, the authors carried out a field trip in Colombia. Colombia is currently introducing legislation for chemical and Natech risk management, which has raised awareness and led to active participation of diverse stakeholders.

Hence, the aim of the field work in Colombia was to present and obtain input concerning the proposed framework and methodologies to stakeholders from industry, local and national government organizations, civil protection, and researchers in Colombia. For this purpose, meetings and industry visits were arranged in the cities of Bogota, Medellin and Cartagena.

Accordingly, this paper presents the results of expert input, in addition to the main findings from the discussions that will be later used to refine the proposed framework. Findings include information that supports the identification and validation of crucial elements needed to be considered in the framework.

2. The Natech-RateME framework for the Performance Rating System

There are no rating systems available for Natech related impacts. Thus, the rating system framework is proposed based on an extensive review and comparison of rating systems for building infrastructure (Almufti and Willford 2013), green building (Zezhou et al. 2016), and sustainable infrastructure (Diaz-Sarachaga, Jato-Espino, and Alsulami 2016). Given the diversity of approaches, the selection of relevant systems to be analyzed was carried out employing a screening procedure based on their relevance, availability, topicality and measurability. In addition, the rating systems' defined categories and subcategories, use of weights and/or percentages, types of certifications granted, and indicators used were also compared. This procedure enabled the identification of key elements that could be considered in the context of Natech risk assessment.

Based on the above analysis, and the characteristics of Natech risk, four main components have been established for the Natech-RateMe framework, as shown in Figure 1, including: a) Infrastructure; b) Organization and management; c) Risk communication and risk governance issues; and d) External environment. The framework is comprehensive incorporating key elements that have been identified to contribute to overall damage and losses during Natech events.

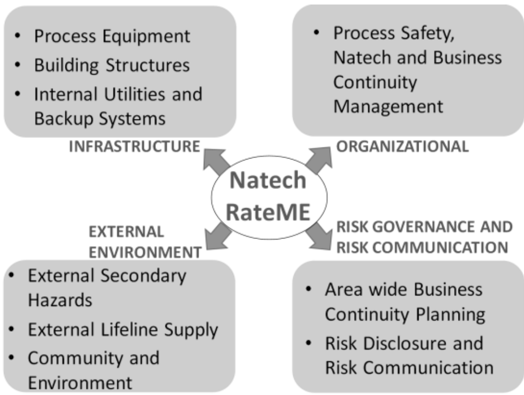

Figure 1. Components of the comprehensive risk management framework which is the basis for the Natech-RateME

Although the governmental, economical or organizational conditions and circumstances may vary in each country, the framework seeks to be applied in both developed and developing countries.

3. Natech risk in Colombia: a retrospective

In order to better understand the current situation of Natech risk management in Colombia, we first look at the evolution of disaster risk management in the country.

The volcanic eruption and mudflow disaster of *Nevado del Ruiz* in 1985 is probably one of the most severe natural disasters in Colombia. This catastrophe has been catalogued as the second worst volcanic disaster of the 20th century. Its consequences included 29,000 casualties, and the destruction of 5,092 homes. What is less known was the fact that the disaster also destroyed 58 industrial plants and triggered hazardous materials releases. The total economic losses exceeded 1 billion USD (Voight 1990). After this disaster, the government of Colombia became aware of the urgent necessity of having a national disaster risk management system. Thus, in 1988 the National System for the Prevention of and Response to Disasters (SNPAD) was created, and later amended, in order to coordinate actions for the prevention and mitigation of disasters at the national level (UNGRD 2018).

In 2011, after the consequences of a strong rainy season and the impact of La Niña phenomenon that exceeded SNAPD's response capacity, the National Unit for Disaster Risk Management (UNGRD) was created through Decree 4147 (Decreto 4147 2011); aimed at improving the previous system and including risk management as a key element of the national development policies.

Soon after, in 2012, the Colombian government approved Law 1523 (Law 1523, 2012), whereby the National Disaster Risk Management Policy was adopted and the National Disaster Risk Management System (SNGRD) was formally established. This new system (i.e. SNGRD) replaced the previous SNAPD system. The significance of Law 1523 lies not only on the creation of the SNGRD, but on that it expressly establishes the obligation for all public and private installations involved in industrial activities, to carry out risk analysis. This analysis must consider the possible effects of natural events on the exposed infrastructure. Furthermore, potential external consequences on the surrounding area must also be contemplated. Moreover, the interaction between public and private sectors, and the community is envisaged. In general, and as stated by Krausmann *et al.* (2017), the importance of such law relies on that it considers risks from natural and socio-natural origin, technological risks as well as Natech risks (Krausmann et al. 2017).

By and large, disaster risk management has become a priority in national policy, based on the need to counteract the consequences of natural events, their impacts on industrial facilities and communities and the economic losses these entails. A recent effort to contribute on reducing these potential accidental scenarios is the creation of Decree 2157 passed in December 2017. It establishes the Disaster Risk Management Plan for Public and Private Entities (PGRDEPP) and its guidelines. Nonetheless, specifications to develop detailed risk analysis still need to be determined.

4. Industrial visits and meetings in Colombia

4.1. Colombia's main hazards

Colombia is a country located in the northwestern part of South America, bordering the Pacific Ocean in the west and Caribbean Sea in the northwest. It has a privileged geographical location, but it is also a country prone to different kinds of natural hazards. Geological hazards (including earthquakes, landslides and volcanic eruptions) are among the main hazards that have historically affected the country. This is due to the presence of the Andes mountains together with the convergence of the Nazca plate, the South American plate and the Caribbean Plate and the fact that Colombia is part of the Ring of Fire (Comunidad Andina and Corporación OSSO 2009).

Other natural hazards for which the country is prone to, include La Niña and el Niño phenomena, represented by increased precipitation and droughts respectively. In addition, climate variability, hydrometeorological and mixed natural hazards are present in the Colombian territory (IDEAM et al. 2017).

On the other hand, technological accidents including hazardous materials releases have also had impacts on people, the environment and infrastructure (Alvarado-Franco et al. 2017, Munoz 2011) affecting the country's development and efforts to reduce poverty. In fact, the Andean Committee for the Prevention and Response of Disasters –CAPRADE has registered, 37,762 fatalities, 3,366,808 victims and 173,649 destroyed homes in the period 1970-2007 in Colombia, due to disasters of natural and anthropic origin (Comunidad Andina and Corporación OSSO 2009).

Consequently, considering the vulnerability of the Colombian territory, the current interest of government and industry on improving disaster risk management strategies and with the aim of presenting the proposed framework, field visits were conducted in Colombia.

4.2. Field visits and meetings

Visits included 8 multi-stakeholder meetings with the participation of more than 80 experts. In addition, more than 20 public and private organizations were contacted and three industrial visits were carried out. Stakeholders who participated in the discussions included private sector (e.g. engineering, consulting, chemical industry, petroleum companies) and public organizations involved in disaster risk management, emergency response and local governments. Therefore, the specific objectives of the field trip were:

1. To assess the current state regarding Natech risks in Colombia.
2. To obtain expert feedback and comments on the proposed framework.
3. To build networks for establishing a case study in an industrial park in Colombia.

Meetings with government and industry representatives were conducted in the cities of Bogota, Medellin and Cartagena. During the meetings the proposed framework was introduced, raising awareness about Natech risks and their characteristics with a view to show the relevancy of the Natech-RateME framework for Colombia.

Discussions were focused on existing needs and requirements by government agencies and industry. Both industry and government organizations were open to share current problems they are facing due to their location in natural hazard prone areas. In addition, experiences and lessons learned regarding past chemical and Natech accidents were shared. This included cases such as the ignition of a gasoline storage tank due to lightning or recent incidents due to heavy rain, landslides, flooding, or storm surge which impacted different kinds of chemical, and oil and gas infrastructure (e.g. transportation pipelines, coastal infrastructure and others).

Industrial stakeholders highlighted the framework’s usefulness to support Natech risk assessment efforts at industrial facilities. Both government officials and industry expressed the need for guidelines and a roadmap on how to address Natech risk given the requisites established by Law 1523 and Decree 2157. In general, stakeholders stated the need for a comprehensive Natech performance rating system in Colombia.

For this reason, there was a high interest on establishing cooperation agreements with academia in order to contribute to the improvement of Natech risk management. In addition, all stakeholders expressed their willingness to share available information on population vulnerability and exposure, data concerning previous Natech events and lessons learned. For instance, the local government of Cartagena said they could share information from previous studies they have conducted on technological risks in coastal areas. Local authorities in Medellin are willing to share the chemical risk maps they have developed and in the case of Bogota, detailed seismic maps as well as recent studies on the impact of floods and lightning are to be shared. Furthermore, government officials at the national, municipal and local levels were very interested in mechanisms that will support risk communication and will help to strengthen the interaction between private and public sectors, and the community, as has been proposed by the Natech-RateME framework.

5. Expert input

The discussions during the industrial visits and meetings provided input from different perspectives. Contributions to the framework were provided by expert input. Furthermore, common risk management problems faced by authorities and industry, served as examples to identify critical elements to be considered in the framework.

In the following sections we present the Natech risk management context in Colombia, and the results of the expert input. We also discuss current efforts for increasing risk awareness and gaps on DRM practices.

5.1 Current state of Natech Risks in Colombia

Findings from our meetings show that hazard scenarios of natural and technological socio-natural origin are contemplated in national policies. Consequently, there is an increasing awareness of Natech events, specially by industries. They have begun contemplating possible impacts of natural hazards on industrial facilities, as stated by law, but have not yet fully and formally incorporated these threats in risk analysis.

We found that the main natural hazards in Colombia for industrial facilities specifically, and for the inhabitants in general are, earthquake, landslides, flooding, storm surge and lightning. For instance, impacts of landslides on the oil and gas transportation pipeline infrastructure in several occasions, have caused Natech scenarios of different magnitudes (Gonzalez-Sanchez 2010, Revista Semana 2011) (Puig and Naswa 2015). In addition, and as a consequence of the pipeline right of way not being respected by inhabitants, there is a high exposure of communities living close to transportation pipelines. The causes of this vulnerability are due to a disorganized growth that has led to land-use planning problems.

Our findings also highlighted the vulnerability of coastal and offshore infrastructure to storm surge, lightning and tropical storms as well as a possible tsunami occurrence in Colombia's Pacific coast, where the Tumaco pumping terminal is located. Tumaco, a Colombian municipality in the southwest of Nariño Department, is an active seismic zone (Correa and Morton 2010). In fact, Tumaco experienced an earthquake (Mw8) in 1979 and tsunami with severe impacts (i.e. building collapse, and more than 220 fatalities) (Herd et al. 1981). Concern is also warranted by the results of the report on the Analysis of vulnerability and risk due to climate change in Colombia. In this report the national vulnerability to climate change is considered as a relationship between the sensitivity of the territory and the adaptive capacity management, identifying that 15.5% of the national territory is between the vulnerability range of High to Very High; thus, highlighting the need of implementing prevention measures in the Colombia's Pacific coast (IDEAM et al. 2017).

Another perspective of our findings on the current state of Natech risks in Colombia, shows that there is an increasing level of Natech Risk awareness. Antioquia region for example, whose capital city is Medellin, has developed tools for natural hazard characterization, chemical risk maps and implemented prevention measures at industrial facilities which has resulted in a 50% reduction in accident rates compared to the previous 3 years. Bogota on the other hand has developed detailed seismic maps for the city and has begun to have interactions with industry. In this regard, Medellin is much more advanced than the other two regions visited. Cooperation mechanisms and proper communication between government and industry, has given Medellin the capacity to develop useful tools for risk prevention and mitigation. Cartagena has just recognized the need to work towards better communication and cooperation strategies between industrial facility managers/ operators and local government officials in order to improve local DRM strategies.

5.2 Framework feedback and contributions

Findings regarding Natech risks in Colombia and the results from meetings and discussions, provided input to the proposed framework from different perspectives. The visits and meetings in Colombia confirmed the importance of two key elements in the framework: a) risk governance and risk communication, and b) external environment. We recognize that these two elements are fundamental when evaluating the influence of the surrounding area in the way the Natech event might evolve.

Public officials stated that the proposed framework will facilitate the incorporation of Natech scenarios in national risk management policies (as required by law 1523). Representatives from industry on the other hand, expressed the importance of having a framework that could help fill existing gaps such as the lack of guidelines for Natech risk assessment implementation. Secondly, industry experts acknowledged the benefit and usefulness of the Natech RateME framework to identify an industrial area's level of preparedness when faced with Natech scenarios. As mentioned by some of the engineers contacted, risk analysis, focused on

Natech area-wide scenarios, are necessary to support prevention strategies that adjust to the reality of industrial facilities in Colombia. Finally, it was clearly established that a performance rating system such as the one proposed, would be suitable to assess whether the mitigation and prevention mechanisms currently used are effective.

Other contributions to the framework include the validation of the need to have a comprehensive Natech framework, which considers a synergy among the 4 proposed elements (see Figure *1*). In this regard, shared experiences during the discussions showed the importance of having cooperation and communication mechanisms between stakeholders. These aspects are essential to support integrated Natech risk management. For instance, in Cartagena, absence of cooperation mechanisms between industry and local government has affected flood prevention measures taken by an industrial facility in a canal that crosses some areas of the installation. The negative impact of actions taken upstream by neighboring communities (e.g. garbage disposal to the river) have directly affected the industrial facility. The absence of public information to the upstream community, and failure to implement preventive measures by the local government in these areas have invalidated any positive action taken by the industry. In addition, this lack of cooperation and the absence- of appropriate emergency response teams (i.e. Hazmat response teams) has led industry to respond to their own accidental releases, discarding the need to inform local government. The reason for this behavior is not only related to the limited existing communication among both parties, but to the lack of technical equipment that affects the local government's response capacity.

Meetings and an industrial visit were held in the city of Medellin, one of the most industrialized cities in Colombia and part of the Top 10 most densely populated cities in the world (UN HABITAT 2018). The importance of considering the external environment on industrial installations (e.g. possible collapse of external infrastructure over industrial facilities) was clearly seen during the industrial visit. In this chemical plant, neighboring residential areas are located less than 30 m away, and a new bridge crossing was constructed overhead just 30 m away. This chemical plant stores hazardous materials, that if released accidentally could result in community impacts.

Our visits in Colombia showed that the above is not an isolated case; other cities in Colombia (e.g. Bogota, Cartagena) are facing similar problems. As a consequence, concern is high due to the combination of vulnerable communities located close to industrial facilities and the possible occurrence of natural hazard events.

All in all, the discussions and expert feedback on the proposed framework as well as the current state of risk awareness in Colombia were factors that influenced stakeholders' willingness to establish cooperation networks. Moreover, the eagerness of contacted organizations to improve disaster risk management strategies and reduce risk levels reinforce our intention to conduct a future case study in the country.

6. Conclusions

By and large, there is a high interest from Colombia's government officials and industries on having a framework for a Natech performance rating system. This is due to the country's vulnerability to potential Natech events, and to the recent changes in national policies.

As was mentioned previously, the visits and meetings provided positive expert feedback on the proposed framework. We were able to confirm the importance of including Risk Governance and Risk Communication, and External Environment as key components of the proposed framework.

In addition, collaborative networks were established and the possibility of having a case study in the Colombia was confirmed.

Future work for the framework's development includes analysis of an ongoing questionnaire distributed to industry and government officials in Colombia. In addition, more expert input from Colombia, Japan and other nations is needed to refine and adjust the framework to be applicable in different contexts.

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