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Industrial losses caused by floods: is it worthwhile to stay in risk?

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Abstract

Disasters are harmful events that damage natural and anthropogenic environments. Urban floods are a type of natural disaster with high negative impact to society. The economic effects of urban floods are under-researched within the Brazilian industrial sector. Esteio municipality, in the Metropolitan Region of Porto Alegre, Rio Grande do Sul State, Brazil, is rated in 18th place in terms of Gross Domestic Product (GDP) among 497 State municipalities, and it has the highest demographic density in Rio Grande do Sul, with almost 3,000 inhabitants per square kilometer. It is also highly vulnerable to floods, given its low topography and the presence of a main river and two tributary streams that run along its 32.5 square kilometers. This study employs open interviews with six private, two governmental, and four non-governmental agents based in Esteio. It has the aim to clarify their understanding of resilience to floods, and to unveil experiences of industrial losses in the main flood events, recorded in 2013 and in 2015. Private firms avoid talking about losses, and prefer instead to emphasize their mitigation actions, thereby taking risks regarding the high probability of future floods. The perception of resilience by firms is disguised or shallow, focused on palliative measures. Local firms, mainly small ones, usually accept the risk of keep their business in the municipality, because they have roots in Esteio. Further research is necessary to better classify and quantify industrial losses caused by floods. Such data would enable business owners to get better prepared for future natural disasters.

Keywords: *Industrial losses. Supply chain disruption. Floods. Resilience.*

1. Introduction

Natural disasters are adverse events caused by human beings that can harm the environment and individuals, and even bring negative consequences to public health (Kobiyama et al., 2006; Saito, 2010). Floods are a type of natural disaster, called a hydrological disaster (Damacena, 2012). Since the 1990s, natural disasters are increasing in frequency in Brazil, especially in urban areas, where the

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majority of the population is settled (Bertone and Marinho, 2013). Floods take place when the waters of rivers or streams reach places occupied by human settlements, exceeding the capacity of a hydrographic basin (Garrido et al., 2015). Hydrological disasters are under-researched when it comes to the assessment of the losses for industrial sectors. A review in the main international academic data bases (Web of Knowledge, Science Direct, Emerald) regarding floods, supply chain disruption, and industrial losses, retrieved 2,797 references from 2010 to 2016. Only 25 of these studies cover the issue of industrial losses. In the Brazilian database of the main Industrial Engineering congress proceedings, there were found 17 studies in the same period of time, but none related to industrial losses. Instead they cover the issue of humanitarian aid and logistics schemes that can be improved under Industrial Engineering tools and methods for making humanitarian aid more efficient. This paper presents the results of interviews with private, non-governmental, and public agents of Esteio municipality, Brazil, where more almost 63% of the urban area (27 square kilometers) is under threat of frequent flooding (César, 2015). This municipality has high relevance for the economy of Rio Grande do Sul State, Brazil, because it houses a variety of industrial firms, and is placed in the neighborhood of relevant federal (BR 116, BR 448) and State (RS 118) highways, that enable a privileged logistical situation. Furthermore, the main oil refinery of the Southern Brazilian region is on the edge of Esteio, influencing positively the local economy. In the last decade, especially in 2013 and 2015, the city suffered with severe floods that caused losses to citizens and the private sector. Nevertheless, firms' representatives avoid talking about losses, and prefer to focus on reactive measures, that they understand as resilience. In the next subsections there are presented a brief review of studies about industrial losses caused by floods (1.1), the profile of Esteio regarding recent floods (1.2), and resilience concepts (1.3) in the context of industry, mainly related to the supply chain.

1.1 *Floods and industrial losses*

Floods are events in which a watercourse breaches its banks, occupying meadows, that is a natural area of any hydrographic basin. When human activity or human settlement occupy such areas, floods become a threat to environment and communities (Goerl et al., 2012; Garrido et al., 2015). Brubacher (2016) defines floods as overflows of rivers, lakes, streams and dammed waters.

Studies on flood impacts are increasingly common in Europe (Merz et al., 2010), mainly in Germany and the U.K., that have been recently affected by such phenomena. Besides general losses estimations, investigation about supply chain disruption due to floods are increasingly common (Kumar and Havey, 2013) in Europe and Asia. A typical case took place in Thailand, in 2011, where industries were severely damaged: Toyota stopped its production for 42 days, and lost 240,000 automobile units; Nissan stopped for 29 days, and did not delivered 33,000 units of production; Honda had 174 days with no production, and lost 150,000 units of production (Haraguchi and Lall, 2015). Also in this event, Seagate, Western Digital, and Toshiba recorded supply chain disruptions – many of these companies that adopt lean manufacturing faced remarkable problems for parts and raw material delivery, which lead to the establishment of new strategies for supplier development and diversification (Matsuo, 2015). According to Bäumen et al. (2015), in 2013 a flood in Westphalia, in the north of Germany, resulted in export disruption, difficulties accessing raw materials, loss of production, with the main impacts in the automotive sector. Melcher and Bouwer (2015) have identified seven other studies about losses estimates for the automotive industry due to floods until 2040. Nevertheless, there is still little research on the mechanisms of supply chain disruption attributed to natural disasters (Andreoni and Miola, 2015), and more investigation is needed. It is especially critical in terms of quantification of the losses. In Brazil, the bulk of research on natural disasters in Industrial Engineering gives emphasis to logistics mechanisms for humanitarian help rather than to the assessment of industrial losses. The amount of resources spent with facilities recovery, roads (logistics infrastructure), communication lines, and general supply chain damages associated with floods are only roughly estimated in some States of Brazil, for instance, Rio de Janeiro. According to Young et al. (2014), Rio de Janeiro State has spent between ¹R\$ 48.4 and R\$ 58.5 million due to damages caused by floods from 2001 to 2010. However, this amount is likely larger, because much private data are not included. One of the missing links for this accounting is the fact that insurance firms usually do not cover losses caused by floods and other natural disasters, and private companies do not discriminate such spending in their accounting books.

¹R\$ = Real, Brazilian currency. R\$ 1 equals to more or less US\$ 0.33 (Jan/2017).

1.2 Recent floods in Esteio

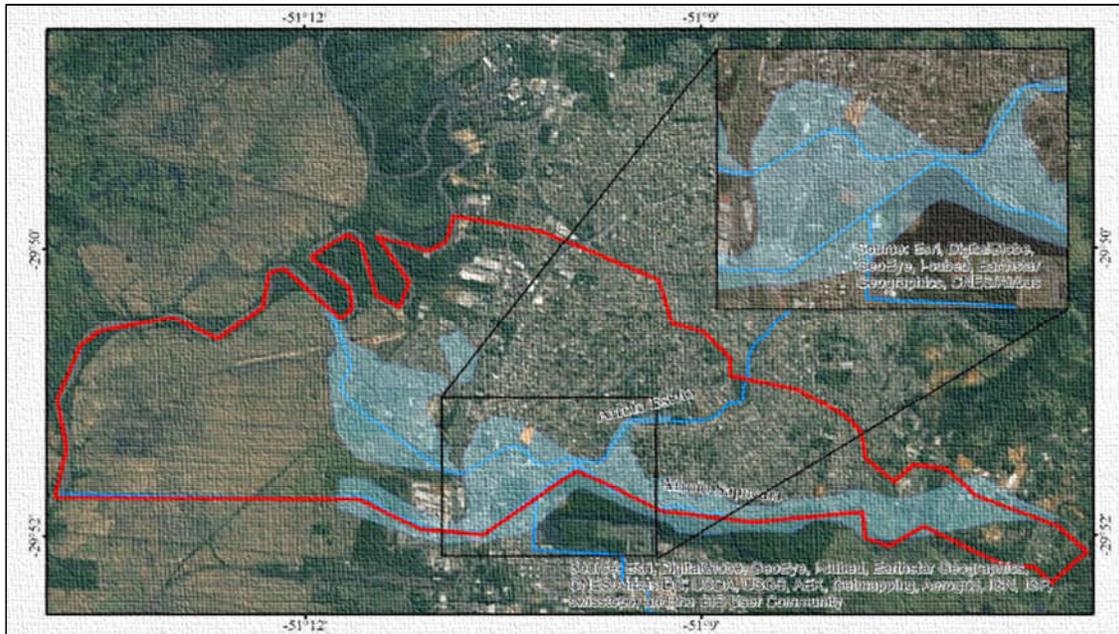
Esteio municipality is highly vulnerable to natural disasters such as storms, floods and hail. The level of urbanization of this city has grown in the last years (César, 2015), and rainfall levels were above those recorded for the whole Metropolitan Region of Porto Alegre (MRPA): in 2013, Esteio had 3,000 mm of precipitation, while MRPA had 1,500 mm; in 2015, such records were 4,100 mm and 1,800 mm, respectively (Civil Defence of Esteio, 2016). The usual monthly average precipitation in the MRPA is 150 mm. Besides, local topography is favorable to rainwater concentration in the downtown area (only 11 meters above the sea level), which drains into a principal river (Rio dos Sinos) and two tributaries – Esteio and Sapucaia - that split the small territory (32.5 square kilometers). Figure 1 shows the geographical localization of Esteio regarding Brazil (detail) and Rio Grande do Sul State (bigger picture). Figure 2 shows the limits of Esteio – the area inside the continuous line - and the flooded area in 2015 - hatched area. According to a hydrological assessment prepared by Brubacher (2016), the flood of 2015 affected all the urban area of the municipality. Figure 3 presents the precipitation rates of Esteio in 2013 and 2015, compared with the normal monthly average of the Metropolitan Region of Porto Alegre, that is historically around 150 mm.

Fig.1 – Localization and limits of Esteio



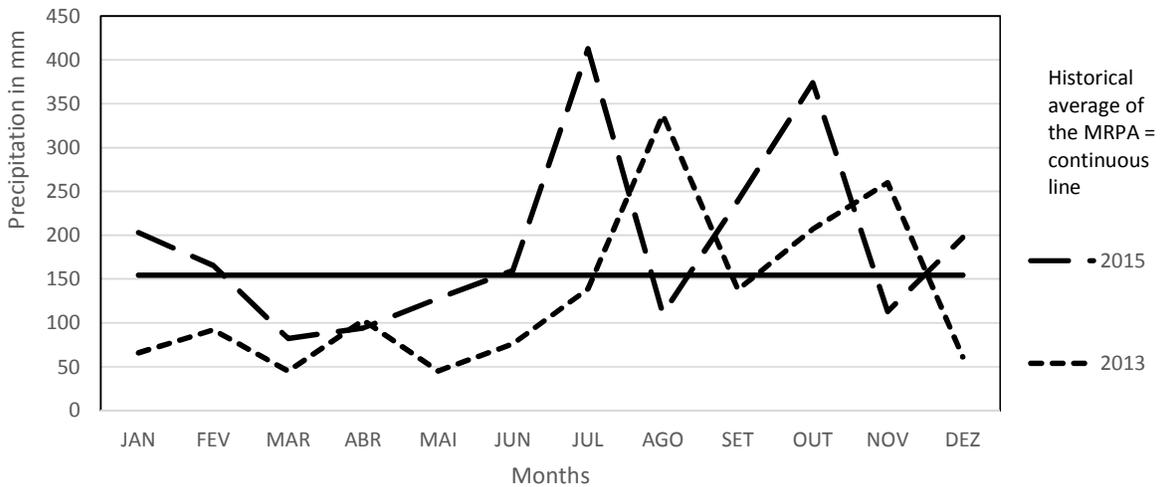
Source: Brubacher (2016)

Fig. 2 - Limits of Esteio and flooded area in 2015



Source: Brubacher (2016)

Fig. 3 - Precipitation rates in Esteio – 2013 and 2015



Source: Civil Defence of Esteio (2016)

1.3 Resilience concepts and supply chain resilience

Resilience can be understood as a mix of robustness, flexibility, and adaptation capacity. There are several dimensions in which resilience is employed – ecological, sociological, organizational, physics, materials science. When a material takes back its initial shape after a strain, it is known as elasticity or resilience (Scarvada et al., 2015). In a broad sense, resilience is the extent to which a system, organization, or individual is able to absorb changes, disturbances, and keep on functioning through adaptation, generally at a different level from the initial state. In a broad sense, resilience is the ability of continuous rebuilding (Soni et al., 2014), or returning to a previous disruption situation (Matsuo, 2015). Also, resilience is a term employed to describe the capacity of a system to recover its early state after a stressful event (Scarvada et al., 2015). Assessment of communities' resilience rather than individuals' is a relatively recent trend (Ainunnddin and Routray, 2012). Another focus of resilience studies is on supply chain management, and its ability to cope with adverse events that harm raw material and finished goods storage and transportation – all logistics planning that can be affected by natural disasters, bringing losses to suppliers and customers of an industrial chain (Melnik, 2014). In industrial engineering systems, resilience efforts are addressed to overcome threats that avoid the normal flow of materials, goods and energy in a productive chain. Resilience is measured by the time taken for the whole functional recovery of the system (Liao, 2012). Trust, information sharing, collaboration, and community involvement are among the characteristics of resilience in productive chains (Kumar and Havey, 2013; Papadopoulos et al., 2016), but such features are not always included in firms' strategies.

2. Method

This study employed open interviews with managers/directors of five private firms (of diverse sizes and sectors); with a representative of the local industrial and commercial association that supports around 200 affiliate firms; with four leaders of non-governmental organizations, and with two government representatives (of municipal Civil Defence and of Environmental Local Authority) – all placed in Esteio. Figure 3 illustrates the categories, profile of the interviewees, and questions asked for each group. To the private agents, questions investigated qualitative and quantitative losses related to the supply chain disruption – whether they were affected by the two major floods episodes, in 2013 and in 2015 – and to self-understanding of resilience in such circumstances. To non-governmental and to government agents, questions aimed to clarify their perception of general community resilience (residents, firms, government) to local floods. To the representative of industrial and commercial association, questions aimed at unveiling not only aspects of resilience, but also about perceptions of willingness of firms to stay or to move out of Esteio due to flood losses. Such interviewees were chosen by opportunity and availability, and effort was made to ensure a diverse profile of private agents – in size and business field. The triangulation technique (Thurmond, 2011) was employed to compare answers to similar questions proposed to each group.

Fig. 4 – Categories, profile of the interviewed, and questions

Private agents	Profile	Questions
A	Bakery, small firm, 66 employees, 15 years in Esteio.	1 What was the main flood episode in Esteio and how do you managed to endure it?
B	Plastic industry, big business, 2,500 employees, 20 years in Esteio.	2 How do you understand resilience? 3 Do you think your firm is resilient to floods? (Explain.)
C	Metallurgic industry, small firm, 45 employees, 20 years in Esteio.	4 What were the losses, caused by floods, you firm have had regarding to production, days of work, client, suppliers, logistics, infrastructure, and others? (Specify quantities.)
D	Mechanic industry, small firm, 10 employees, 11 years in Esteio.	5 Why do firms stay in Esteio even suffering losses with floods? Is it worthwhile to stay?
E	Service firm, small, 3 employees, 8 years in Esteio.	
Rep. of Ind. and Com. Association	Business leader, since 2013 in charge.	

Non governmental associations		Profile
Community center	Informal organization, leaders have not sure when they started to collaborate.	1 What was the main flood episode in Esteio? 2 Do you think that firms placed in Esteio, and general community, are resilient to floods? (Explain.)
Neighborhood association A	Formal organization, since 2014.	
Neighborhood association B	Formal organization, since 2011.	
Environmental organization	Formal organization, since 1988.	
Public agents		Profile
Civil Defence of Esteio	Public agent, in charge since 2011.	1 What was the main flood episode in Esteio? 2 Do you think that firms placed in Esteio, and general community, are resilient to floods? (Explain.)
Environmental Local Authority	Public agent, in charge since 2013.	

Source: Research data (2016)

3. Results and discussion

Results and discussions are presented by category of interviewee: firstly private agents; secondly, non-governmental; finally, government agents.

3.1 *Private agents: confidence on mitigation as resilience*

When asked about the worst flood episode they had faced, and whether and how they managed to endure it, four of the five directors of private business mentioned the 2015 flood. One of them (C) said that both recent floods (of 2013 and 2015) were equally harmful. They understand resilience as capacity to adopt mitigation measures, mainly regarding improvements in facilities and equipment acquisition. Entrepreneur A understands that “we are now more resilient because we are prepared. After the last flood, we spent R\$ 300,000 for water draining, and R\$ 23,000 for fixing power generators. We also hired a service to clean the sewers after the floods”. According to A, this is not the first time they have faced a severe flood. In 2013, they had less experience and greater damage than in 2015. “In this last flood we closed all the windows of the building that have some connection to the courtyard”.

Agent B indicated that until 2015 the firm’s facilities (two buildings) were not affected, but in that year, it was necessary to build a wall around the installations, in order to prevent future losses. For the first time, water reached the warehouse of the firm in the 2015 flood, “and now we are more prepared, we no longer ignore disaster alerts”.

According to representative C, submersible pumps were installed as a means of avoiding problems with floods after 2015. “Yes, we are more resilient than we were in the years before, we have learnt to not wait for public sector help”.

Firm D has also invested in submersible pumps and physical barriers for containing flood water in its building, and according to the director, “there is no willingness to leave the city”.

Representative E shows disappointment with the lack of support from the public sector. He needed to rearrange the entire layout of his office, raising the furniture to the second floor when water entered his building. “We are getting used to the floods”, he said.

The representative of the industrial and commercial association of Esteio thinks that the worst flood was that in 2015. In his opinion, resilience is manifested by many business' owners in the city when they rapidly recover and when they show no interest in moving out from Esteio. He is convinced that repeated floods have brought disruption in supply chains of several industrial and services activities, but he argues that the confidence of the firms is slowly coming back because public authorities have managed to change urban planning and have promoted sewer and street cleansing. "We have firms that have twice lost equipment and suffered other damages as lost days of work, but we need to see the whole economic picture. It is strategic. Esteio has an excellent location, and new storage and distribution oil firms have come near to this municipality. Two big ones in recent years. We have a privileged geographical position that enables us to supply all Rio Grande do Sul, and all other Southern states of Brazil with oil, and it is not possible to ignore the revenues of such an activity for boosting the local economy", explains the executive.

It is clear, from the discourses, that firms' representatives consider mitigation measures, mainly infrastructural ones, as representing resilience. If from one side, the capacity to absorb changes and adverse effects (Matsuo, 2015) is visible, as well as the ability to recover from a stressful event (Scarvada et al., 2015), from another one, the abstract and social elements of resilience seem not to be present. There is no sign of trust and confidence (Kumar and Havey, 2013; Papadopoulos, 2016) on public authorities by the entrepreneurs, except by the executive of the industrial and commercial association. The only reasonable argument for firms to keep their installations in Esteio is the whole geographical and economic picture: easy road logistical access, and presence of strategic sectors, such as oil distribution, that underpins the whole local economy, encouraging the permanence of traditional, usually small business.

3.2 *Floods and industrial losses*

Firms were reluctant to talk about their losses. Lost days of work due the floods were more significant for firms C and D. C stopped working for 30 days in 2013, and seven days in 2015. In the 2015 flood, the whole factory was submerged, and finished goods were destroyed. Contracts with customers were not honored, and communication was cut off. Firm D had 30 days of work lost in 2015, and had to renegotiate its contracts. Delays in deliveries of finished goods were the main problem. Also firm E needed to review the terms of contracts, and stopped its activities for five days. Firm B has suspended activities during a week in 2015, but it did not lose a significant amount of raw materials. Cleaning was very fast for B, and activities were back to normal in the same week as the flood. The only firm that revealed financial data was A. This is a traditional business in Esteio, and it stopped for 12 days in 2015. Raw material (flour) was totally wasted, new machines were damaged, because the firm was under modernization weeks before the flood. Firm A estimated it had lost R\$ 1.5 million –including a pickup truck, raw materials, and frozen bakery products (perishables that were wasted due to the lack of energy). According to the director of A, an emergency scheme of logistics was devised: the firm honored the main customer putting a improvised snack counter in a nearby local gas station – thereby avoiding the loss of a contract for R\$ 400,000. The lack of data, and even capacity to assess losses by firms, caused by natural disasters, is an issue of concern, as recognised by Andreoni and Miola (2015). It demands further research. Firms probably avoid talking about losses due to floods because they fear damage to their image, customers abandonment, or because they have neither the structure nor the expertise for such types of assessment.

3.3 *Resilience for non-governmental agents*

All but one representative of non-governmental organizations consider the 2015 flood the most damaging they have known. According to the community center leader, "the velocity of water and the inundation rate were daunting in 2015". The neighborhood association A representative indicated that "3,000 persons were affected by the flood in 2015, a number higher than observed in previous floods". "We had more houses inundated in 2015", explained the leader of the neighborhood association B. The leader of the environmental local organization consider both floods, in 2013 and in 2015, equally harmful: "In 2013, water entered the main highway, and in 2015 it hit the refinery facility (at the limit of Esteio)".

Non-governmental organizations are unanimous regarding the current lack of resilience from communities, private, and public agents. The leader of a community center is convinced that “usually, everyone keeps the same careless behaviour with streets and buildings, and it is easy to forget the pain of the last flood”. According to the leader of the neighborhood association A, there is a general idea that resilience refers to rearranging of physical spaces: “Many residents have hooks on the ceiling to hang furniture when water comes into the building”. For the representative of neighborhood association B, “firms are starting to build some resilience, as adaption, but population did not change”. The environmental association leader is more critical. According to him, without deep changes in urban planning and land change patterns, floods will always punish people, the environment and businesses: “We still have residential and industrial areas quite close to each other, and the placement of new oil storage in the municipality represents a threat in case of likely future flood episodes”.

From the discourse of the non-governmental agents, it is possible to realize that resilience of Esteio’s community and firms to floods is weak, because it is not based on general awareness, behaviour and action of local agents. Cohesion and confidence (Kumar and Havey, 2013; Papadopoulos, 2016) are not placed in the social relationships.

3.4 *Resilience for government agents*

The representative of the local Civil Defence organization thinks that the worst flood happened in 2015. He synthesises what the non-governmental organizations have expressed: the community keeps on putting garbage in manholes and streams, and this type of behaviour makes resilience just a matter of mitigation rather than prevention. Nevertheless, the environmental local authority representative is confident that a new drainage plan can bring alleviation for business and individuals settled in more vulnerable areas for future floods. According to this agent, there is no possibility to fully compare the 2013 and the 2015 floods, because the situation of the municipality regarding occupied places was different, and the municipal authorities have taken some measures to prevent flash floods in recent years. He says that the local government is cleaning sewers, draining flooded spaces, resettling people currently in irregular housing (close to the streams). “We can testify some improvement in comparison with years ago”, observe this agent. He also states that many business owners go frequently to the town hall to complain about their losses due to floods, and threaten to leave the city arguing that they have had better offers for relocating their facilities. However, many of them, at the same time, say that they do not want to leave the place they were born in, and say that the local authorities need to be more proactive in the conservation of streets and other public places.

Therefore, from the point of view of public agents, there is a similar perception given by the non-governmental representatives: resilience is heavily dependent on collaboration and behaviour changing. Especially for the environment authority, what makes business owners resilient is their link with their roots, which is a sense of belonging that makes them more robust, flexible, and adaptable to difficulties (Scarvada et al., 2015).

4 **Conclusions and recommendation**

Natural disasters, such as floods, are an increasing risk mainly in urban environments where demographic density is high, topographical and hydrological aspects are unfavorable for increasing economic activity, and municipal planning is not well developed. This is the case of Esteio municipality, in Rio Grande do Sul State, Brazil. With a privileged localization for industrial and service logistics, this city attracts strategic businesses, including oil distribution firms that underpin a whole diversified economy formed mainly by small firms whose owners keep a historic link with the municipality. This study, through several interviews with different local agents and leaders, enabled clarification of the understanding of resilience by such agents. It is noticeable that private agents are inclined to see resilience as a material resistance to adverse phenomena. The perception of resilience by firms is disguised or shallow, focused on palliative measures. Business owners feel safe with physical barriers

and pumps to drain rainwater after several floods have affected their buildings. They claim they have learnt about resilience, but the type of resilience they refer to is actually a set of mitigation strategies to alleviate or prevent future losses. Many of them have strong bonds with the municipality, and accept the risks in order to maintain their businesses in that place. They avoid talking about losses, and show concern with the possibility of noncompliance with contracts that can lead to the loss of suppliers and customers, and therefore to the dismantling of their supply chain. Non-governmental leaders recognize the efforts of firms to maintain their business, but they see resilience with a deeper meaning. Local authorities argue that firms prefer to accept risks in order to preserve their space in the business scenery. It is clear that further research is necessary to better classify and quantify industrial losses caused by floods. Such data would enable business owners to become better prepared for future natural disasters.

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