ELLA
Evidence and lessons from Latin America

The city of Rio de Janeiro has developed a highly efficient early warning system (EWS) that is having an impressive impact after just three years in operation. The measures employed are innovative, inclusive and non-resource intensive, and are thus highly applicable to cities in other developing regions.

RIO DE JANEIRO CITY'S EARLY WARNING SYSTEM FOR HEAVY RAIN

SUMMARY

Cities such as Rio de Janeiro in Brazil, that are highly vulnerable to rain-induced disasters due to inappropriate land-use on a massive scale, can greatly reduce risks with timely employment of early warning systems (EWS). After a rain-induced disaster in the city in April 2010, the City Council together with the Civil Defence, which is responsible for coordinating the efforts of all emergency services, invested in technology and integrated resources to build capacity throughout the chain of response right down to the community level. This Brief explores the success of Rio's EWS in terms of its strategies to improve risk knowledge, monitoring and warning, dissemination and communication, and response capability and, in doing so, identifies key enabling factors and lessons for other cities interested in implementing their own systems.

NATURAL DISASTERS IN CITIES: PRIORITISING PREVENTION OVER REACTION

Natural disasters and extreme events kill, displace and affect thousands of people and cause millions of dollars worth of damage each year. Between 2001 and 2010, a total of 4,022 natural disasters worldwide claimed some 1,221,332 lives.[1] Catastrophes caused by heavy rainfall such as flooding and landslides are of particular concern in cities in developing countries due to high population density and the unsuitable location and instability of buildings in informal settlements. These types of events happen suddenly, allowing only a small window of time for issuing accurate risk warnings and mobilising emergency plans. For this reason pre-emptive risk mapping, weather monitoring and the development of effective communication lines and contingency plans are fundamental to reducing the

KEY LESSONS LEARNED

Coordinated action of all public agencies under one umbrella organisation can improve monitoring, warning and response capacity.

Community involvement in the design and implementation of any EWS is essential and engaging the help of respected community workers and leaders can greatly facilitate this process.

Investments in monitoring technology are fundamental to improving the accuracy of risk mapping, thereby allowing more lead-time to provide warnings.

A range of low-cost, effective methods are available for raising awareness among local populations.

[1]International Federation of Red Cross and Red Crescent Societies (IFRC). 2011. *World Disasters Report 2011*. IFRC, Geneva.

potential impact of extreme events. Unfortunately, in many cases, coordinated action and investment only appear after a disaster. For example, in 2010, Brazil spent 14 times more on disaster response and damage repair as a result of heavy rainfall, than on preventing such devastation.[2]

Nonetheless, cities across Latin America have been investing in the development of early warning systems (EWS) for extreme weather events, which have demonstrated the capacity to get people out of harm's way in a timely manner. The implication of this is that with an adequate EWS in place, extreme weather events need not result in such severe losses of human life. This Brief describes a particularly innovative and effective EWS that has been set up in the Brazilian city of Rio de Janeiro over the last three years. Rio de Janeiro is a mountainous and coastal city. Rapid urbanisation has resulted in areas with a high-risk of landslides and flooding becoming highly populated and heavy rains claiming human lives year on year. Since 1966, the city has embarked upon a series of initiatives to better understand local risks, monitor weather and land-use change, warn people of impending extreme events, and improve preparedness and response capacity. The city's EWS was expanded significantly after the heaviest recorded rainfall in the city (305mm in 24 hours) claimed 67 lives in April 2010. Since then, the EWS has been designed and implemented with such success that on the 5th March 2013, when 86.2cm of rain fell in one hour, 45 sirens were sounded in 24 communities, thousands of people evacuated their homes, and zero fatalities resulted.

This Brief was developed through a series of interviews with personnel from the City Council of Rio de Janeiro, particularly from the Civil Defence Unit, responsible for disaster reduction and response. A wealth of information was provided by Under-Secretary, Marcio Moura Motta, and Operations Coordinator, Lauro César Botto Maia from the Civil Defence. Complementary resource materials were also consulted.

WHAT MAKES RIO'S EWS EFFECTIVE?

EWS provide a means to manage and reduce risk by improving understanding and increasing a community's ability to anticipate and then react to extreme events. According to the United Nations International Strategy for Disaster Risk Reduction (ISDR) an effective early warning system should be made up of four facets:

- *Risk Knowledge:* the collection of data to identify vulnerabilities in order to minimise the negative social, economic and environmental effects of unavoidable events
- *Monitoring and Warning:* rigorous scientific monitoring of the parameters with a potential to trigger disasters, together with the ability to predict changes in a timely manner
- *Dissemination and Communication:* effective communication networks with the 'right' amount of information for the receivers to understand the implications of the warning
- *Response Capability:* well developed action plans involving the full range of stakeholders, from the government to the community

These four pillars will be used as a framework for assessing the strengths of Rio de Janeiro's EWS.

1. Risk Knowledge

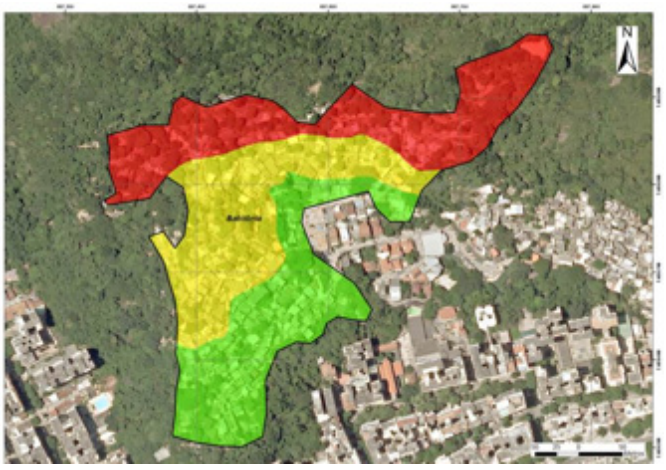
In order to be able to warn people of disaster risk it is necessary to understand local threats and identify the most vulnerable people and areas. In some cases, risks can be reduced via public works such as slope stabilisation, or by relocating certain communities, in other cases EWS can evacuate people safely.

As far back as 1966 the city council of Rio de Janeiro recognised that there was a need to reduce the risk of landslides caused by heavy rains. At that time a decree was passed to form a geo-technical foundation, today known as GEO-RIO. The city has since counted upon the analysis and work of its geologists, civil engineers and other technical experts, who are responsible for risk mapping and slope stabilisation work in the city.[3] Significant investments were made to expand the scope of this public institution after the 2010 rain disaster. A crisis team was set up and the mayor of Rio de Janeiro mandated Geo-Rio to develop a detailed risk map for landslides within the city as a first step towards building an effective EWS, and ultimately reducing the risk of rain-induced disasters. Geo-Rio worked in close collaboration

[2] Campanato, V. 2011. Um Ciclo de Calamidades Precisa Ser Interrompido (A Cycle of Calamities Needs to be Interrupted). In: *CREA/RJ Magazine*. 86.
[3] Government of Brazil. 2012. *Landslide Risk Reduction Measures by the Rio de Janeiro City Government (Chapter 4 of Improving the Assessment of Disaster Risks to Strengthen Financial Resilience)*. World Bank and G2012, Washington, DC.

with the Civil Defence[4] and established a multi-disciplinary team divided into various specialist working groups, each tasked with classifying risk in areas of occupied land. 117 communities were classified as being at risk, with areas categorised as having low-risk, medium-risk or high-risk. This classification was based on a series of factors such as ways in which the land has been occupied (in terms of types of buildings and density) gradient of the slope, composition and depth of the soil, geomorphology, and previous disasters in the area. Computer programmers at the Civil Defence mapped the areas susceptible to landslides onto the Google Earth platform. Google Earth updates any land-use change on a monthly basis and Civil Defence programmers add data about contention work carried out by Geo-Rio. These updates are then make available to Civil Defence coordinators. Risk areas are classified using a traffic light system, with red denoting high risk, and green denoting low risk (Figure 1).[5] This exercise was completed in just seven months.

Figure 1: Snapshot of the Risk Map of the Favela Babilônia, Rio de Janeiro



Source: Provided by GEO-RIO.

Once the risk mapping exercise was complete, detailed mapping began of people with special needs living within areas at risk. The Secretary of the Civil Defence set up an agreement with the Ministry of Health to call upon local health assistants living and working within slums (*favelas*) and low-income housing areas. Under the Family Health Programme (*Programa Saúde de Família* – PSF) these assistants make monthly visits to each household within their constituency. Given that they live in these communities and are trusted by inhabitants, the Civil Defence recognised the potential outreach that the health assistants could have in terms of raising awareness about risk.

Community health workers collected details of all known inhabitants with special needs, including name, age, address, phone number, disability, person responsible for evacuating this person, and location of the shelter to which they should be taken in times of alert. All of this information was passed back to the Civil Defence and was mapped onto the aforementioned Google Earth platform (Figure 2). The benefit of this supplementary mapping is that in times of alert, special attention can be paid to evacuating these people. When the alert is sounded and these areas are evacuated, social services calls each of these identified vulnerable people and those responsible for them. Should anything go amiss and these people be unaccounted for at the emergency shelters, social services requests that agents of the Civil Defence make house visits.

Figure 2: Detailed Risk Map of People with Disabilities within the Favela Formiga, Rio de Janeiro

Note: Disabilities are classified and colour-coded in the following way: physical – purple, mental – orange, audio-visual – white, and multiple – green.
Source: Provided by the Civil Defence of Rio de Janeiro.

As well as mapping members of communities at risk from heavy rains, it was necessary to understand when rain was likely to pose a threat. In order to account for this risk the city increased the number of pluviometers already installed throughout the city, and started to monitor weather patterns 24-hours per day. Collecting accurate detailed risk knowledge

[4] The Civil Defence is a Brazilian government agency responsible for coordinating all efforts to protect and defend the wellbeing of citizens. Its key responsibilities are disaster risk reduction, mitigation, preparation, response and recuperation. The Civil Defence operates at the national, state and municipal level in a coordinated manner with other emergency services. Community arms of the Civil Defence, known as NUDECs are formed and members are trained in order to have a team of people in the heart of each community working to reduce risk and ensure that the EWS is working effectively.
[5] Colour-coded systems for mapping risks, rainfall and level of alert are helpful when working with a large group of stakeholders, as they facilitate understanding.

and sharing it with the entity responsible for risk reduction and response is the first step towards building an effective EWS. In 2010, 20,247 people were classified as living in high risk areas. Today, that number has fallen to 18,000 due to the work of Geo-Rio and the Civil Defence.

2. Monitoring and Warning

In 2010, the Mayor of Rio de Janeiro decided that in order to reduce risk and improve the city's EWS it was necessary to invest in hardware that would facilitate both monitoring and warning. In terms of monitoring, the main investments included the purchase and installation of a meteorological radar and 117 pluviometers, as well as the development of a high-tech Operations Centre (*Centro de Operações*). In terms of warning, some 166 sirens were installed in risk areas,[6] an SMS service was developed to issue warnings and over 5,500 community members with basic training in civil defence were issued with mobile phones in order to receive these SMS alerts and initiate the response protocol.

The Operations Centre

Figure 3: Rio de Janeiro's Operations Centre

Source: Provided by Rio de Janeiro City Council.

This Operations Centre brings together many of the city's public service agencies[7] to monitor risks and work in a coordinated manner to anticipate and respond to any type of disturbance, threat or crisis. Within the centre some 80 screens transmit live footage from more than 1,000 cameras throughout the city. The Centre was developed in partnership with IBM, the first centre as part of the Smarter Cities Initiative.[8] The Operations Centre is located in close proximity to the City Council, and in time of crisis top decision makers from the council and the Civil Defence work from a dedicated crisis room.

Weather Monitoring Equipment

In 2010 the City Council bought a meteorological radar to be situated within the city of Rio de Janeiro in order to gain access to more timely and accurate weather data. The radar cost US$1.25 million and a team was set up in the Operations Centre to monitor data 24 hours a day. Prior to this, the closest radar, owned by another municipality, was located at a distance of 80km and at an altitude of 1,800m. Due to the fact that the radar was not the property of the city of Rio de Janeiro, it was not possible to carry out specific studies about coming rains, and due to its location, the radar was not able to capture information about rain formation at lower altitudes.[9] Reliable data is extremely important for an EWS to operate effectively: the more reliable the data, the more lead-time for moving vulnerable people out of risk areas.

After heavy rainfall claimed 52 lives in the city of Rio de Janeiro back in 1997, a monitoring branch known as Alerta-Rio[10] was established under the ambit of Geo-Rio. Alerta-Rio installed 33 pluivometers throughout the city, began to monitor rain patterns and used this information to react to disasters. In 2010 it was recognised that increased monitoring capacity was needed and as such the Civil Defence installed pluviometers and alert and alarm stations in each of the 117 communities identified as being at risk. These pluivometers are monitored remotely 24 hours per day, and a centralised system at the Civil Defence calculates how much rain has fallen over various periods of time, from 15 minutes to a month. A protocol has been put

[6] Rio Prefeitura. 2012. *Plano de Contingência (Emergency Plan)*. Rio Prefeitura, Rio de Janeiro.
[7] These include the emergency services, traffic analysts, public transportation providers and utility providers.
[8] For more information on the Smarter Cities Initiative, please see this short video, SmarterCities Rio. IBM helps Rio become a Smarter City.
[9] Rio de Janeiro Civil Defence and the City Council. 2013. *Rio de Janeiro em Busca da Resiliência Frente Chuvas Fortes (Rio de Janeiro: In Search of Resilience in the Face of Heavy Rains)*. Civil Defence and City Council, Rio de Janiero.
[10] Clicking on this link will take you to the site which offers real-time information on rainfall.

Figure 4: Meteorological Radar in the City of Rio de Janeiro

Source: Provided by Rio de Janeiro City Council.

into place so that after analysis of other key determinants, when 40mm of rain falls in one hour, 125mm in 24 hours, or 200mm in 96 hours, the alarm systems may be sounded.

Technology to Issue Warnings

In addition to the pluviometers, sirens were installed in communities at risk of landslides and were removed from communities no longer exposed to such risk. In total, there are 164 sirens within the city of Rio de Janeiro, all of which are remotely monitored 24 hours a day and can be activated online or manually. Both the pluviometers and the sirens are operated and monitored via 3G technology. Within the communities, local members of the Civil Defence are responsible for daily maintenance of the alarm and alert station. It was extremely important to remove sirens from areas that no longer present landslide risk, and to install new sirens in risk areas so as to raise awareness amongst the communities of the danger in their neighbourhoods.

In order to provide timely warning, an SMS system was developed by the Civil Defence. Within the neighbourhoods at risk, agents of the so called Community Nuclei of the Civil Defence (*Núcleos Comunitários de Defesa Civil* – NUDEC) and health assistants were given basic training on how to respond when warnings are received via SMS. The SMS alert system can target certain communities or can be used to send blanket warnings. The messages contain information about the state of alert: advising when light, moderate or heavy rains are coming. When the rainfall is critical these community agents are contacted by phone and requested to prepare shelters, sound the siren and start helping people to evacuate.

3. Dissemination and Communication

In order for communication lines to work during an extreme event, residents need to be aware of the fact that emergency warnings might be issued and what those warnings should mean for them including evacuation routes. This section outlines four cost-effective methods of disseminating warning and evacuation information implemented in the city of Rio de Janeiro.

1. During awareness raising campaigns the Civil Defence used to use printed flyers to disseminate information about what to do when the sirens are sounded, but found that these were generally discarded. In response, t-shirts were printed bearing these same instructions. The benefit of this strategy is that in low-income communities people are keen to receive a free t-shirt, and are not likely to throw it away. The use of these t-shirts has contributed to disseminating information, and they are very visible in risk communities. These t-shirts are generally handed out during evacuation simulations, which are described in more detail in the following section.
2. In Brazil, a federal law (No. 12.608/12) was passed on the 10th of April 2012 requiring all children in middle school to be taught about methods of civil defence. This law has not yet come into action, but within the city of Rio de Janeiro a pilot programme was launched to do just this – teaching children about risks and how to reduce them, and what to do in times of crisis. So far this pilot has reached 42 schools, with teachers being given courses and a teacher's manual, and children being provided with a workbook with a series of interactive exercises including evacuation simulations. A key advantage of this method is that children are well placed to pass on information to parents and other relatives, thereby helping to raise awareness amongst a wider population.
3. In addition to the text messaging service for community Civil Defence agents and health assistants, a city-wide

free text messaging service is available for all that sign up. This text messaging service sends blanket warnings about upcoming rains and the state of alert. An agreement has been made with all mobile service providers that these messages are for the public good, and, as such, no charges are incurred. In September 2013, the total number of people signed up to this public alert service totalled 52,927.

4. The community health assistants that visit households in risk areas are requested to take five minutes of each visit to disseminate information about the EWS. This piggy-backing has meant that the only extra costs involved were related to training these health assistants with basic civil defence knowledge.

4. Response Capability

The communication link between those monitoring risks and those at risk is very strong within the city of Rio de Janeiro, with the Civil Defence being responsible for the whole chain. As we have already seen, when risks start to present themselves in the form of moderate to heavy rain, key community members are activated. The relationship of trust within the community is very important and for that reason, as well as community Civil Defence agents and health assistants, respected community leaders are also enrolled to receive alerts, start the evacuation process and man emergency shelters. Typical community leaders include clergymen, teachers and football trainers, and the agents of the Civil Defence build relationships with these people and maintain strong communication ties. When rains start to fall, Civil Defence personnel from the Operation Centre call and speak directly to these community leaders to provide necessary instructions.

Location specific evacuation plans were developed for each community at risk and regular evacuation simulations take place. The simulations can only take place with perfect weather conditions, and need to be planned well in advance. Community members are advised as to the date of these exercises through community leaders, Civil Defence agents, and via the siren itself. On the 7th of July, 2013, 21 communities carried out a simulation exercise.

IMPACTS AND THE WAY FORWARD

Testament to the success of Rio de Janeiro's EWS is the fact that zero fatalities during heaving rains have been recorded in at-risk communities since the implementation of the system in late 2010. It is important to note that heavy rains have continued during this period, with examples including the 25th of April 2011, when 99.6mm of rain fell in 1 hour in the north of the city, and on the 5th of March 2013 when 86.2mm of rain fell in one hour.

The EWS in Rio de Janeiro is the first of its kind in the world. For that reason there is much room for improvement and the system is constantly being updated. The monitoring technology, for example, relies upon 3G and radio signals, which sometimes have problems and cause the technology to go 'offline'. There is a back up system of manual activation, but an alternative to improve reliability would be to use fibre optics, for example. In terms of participation levels, the Civil Defence would like to reach all schools in the municipality and have higher participation levels in evacuation simulations.

CONTEXTUAL FACTORS

ESTABLISHING AN EFFECTIVE EWS

The heavy rains of April 2010 spurred the City Council into investing in the development of an effective EWS and an all-encompassing disaster risk reduction plan. That was the heaviest rain recorded in the city since records began in 1966. The event received significant media coverage and the new mayor of Rio de Janeiro was keen to improve the resilience of the city in light of the World Cup and Olympics being hosted there in 2014 and 2016 respectively.[11]

The Civil Defence was undoubtedly the main actor responsible for the success of Rio de Janeiro's EWS. Only an EWS that has integrated the four pillars described earlier in this Brief can be truly successful and this integration was achieved through the management and oversight of the Civil Defence. The mandate of the Civil Defence is to unite all public agencies in the protection of citizens. The creation of the Operations Centre allowed for this to be done seamlessly, with all agencies working together under one roof.

Enlisting the help and support of community health workers enabled the Civil Defence to capture information about high-risk urban dwellers and establish an effective channel for communication. The advantage of using community health assistants is that they know their communities and community members know and trust them. In the same way, the involvement of community leaders for sounding the alarm and managing emergency shelters was extremely important. Trust is key when spreading messages about disaster risk and EWS and local inhabitants are much more likely to be listened to.

Investments in technology were key to the success of Rio de Janeiro's EWS. The meteorological radar, the sirens, the pluviometers, the Operations Centre, and the SMS alert service together have strengthened the EWS. The increased connectivity of city dwellers via mobile telecommunication has facilitated the dissemination of information about EWS. The Civil Defence provided mobile phones to community Civil Defence agents and community health assistants so that they might receive timely warnings. In addition to this, the public SMS alert service has increased awareness of what to do when alarms sound and when heavy rains are due. The cost of operation and maintenance of the EWS in Rio de Janeiro is less than US$0.03 per citizen per month.[12]

[11] Eduardo Paes, the mayor of Rio de Janiero, shares his ideas about leading cities into the future in a smarter way in this talk available online from the TED website.

[12] D'Orsi, R. 2013. *Sistemas de Alerta de Chuvas e de Dezlizamentos em Encostas (Alert Systems for Rain and Landslides)*. Presentation made at the Brazilian Conference on Natural Disasters, 20-22nd March 2013.

LESSONS LEARNED

1. Coordinated action of all public agencies under one umbrella organisation can improve monitoring, warning and response capacity.
2. Community involvement in the design and implementation of any EWS is essential if people are to get to safety in times of emergency. Engaging the help of respected community workers and leaders can greatly facilitate this process. This also creates effective channels for disseminating information about risks and emergency protocols, particularly amongst more vulnerable people.
3. Investments in monitoring technology are fundamental to improving the accuracy of risk mapping, thereby allowing more lead-time to provide warnings.
4. A range of low-cost dissemination and communication methods are available that have been shown to raise awareness among local populations about risk and emergency. Innovative use of ICTs, 'durable' publicity methods and children's education are three such examples from the city of Rio de Janeiro.

CONACT SNN

To learn more about Rio de Janeiro's Early Warning System, contact the author, Charlotte Olivia Heffer, ELLA Brazil Project Coordinator at the Environmental Laboratory at the Federal University of Rio de Janeiro (UFRJ), at charlotte@lima.coppe.ufrj.br.

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