A Way to Measure the Level of Response for Medium to Large Earthquakes and Provide a Disaster Emergency Planning in a Region

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SUMMARY
In order to establish a proper Emergency Planning for a study region, we should know and understand the region, its hazards, and the critical infrastructures that provide services for the population; the vulnerabilities and the objective functions of local and global authorities.

In this paper we will explain the characteristics of the Disaster Emergency Planning that a region should have to cope with disasters (for example: a moderate or a large earthquake); we will also provide ways to measure the Disaster Efficacy of a region, so that the disaster response of the region can be improved. The Disaster Emergency Planning can be extended to withstand other natural or man-made hazards.

Disaster Efficacy measures 10 characteristics that a region should have in order to successfully address the consequences of a disaster. Disaster Efficacy measurements can give the authorities an idea of their capacities to deal with such emergencies; and which fields they should invest in, in order to respond and recover quickly from the consequences. Five cases on earthquake planning will be discussed in this paper: Mexico, Canada, Haiti, Chile and Japan.

Keywords: Disaster, Emergency, Planning, Efficacy, Earthquakes

1. INTRODUCTION

It is well known that in order to prevent a disaster we should plan and prepare before it happens, and respond and recover with emergency activities after it has happened. But we should also know and understand the region, its hazards, the critical infrastructures, the vulnerabilities and their objective functions. There are five characteristics of a region that should be addressed while dealing with disasters:

1. Hazards
2. Vulnerability
3. Emergency planning
4. Models and scenarios
5. Response

1.1. Hazards and Vulnerability

For a region it is important to know the possible hazards that will affect its functionality, and most of all, characterize them with available methodologies. If a region is affected by earthquakes; snow, rain and wind storms; political and sports riots and terrorist threats; then all of these hazards should be characterized by their magnitude, possibility of occurrence, and sectors within the region that they can affect.

All critical infrastructure systems (CIs) of the region shall also be defined and characterized. Structural prototypes, fragility curves, or damage probability matrices shall be investigated and implemented for all the essential components of the CIs. It is important to consider the structure, non-structural components, building contents, pipelines, trunk lines or conduit lines, roads or transportation channels that are needed for the CIs' functionality conditions. The characterized hazard-damage relationships shall be studied, established and prepared; in doing this the region might need expert groups to begin with the characterization.

Expert groups in hazard threats and defining the damage-hazard relationships are invaluable human resources that will help increase the resiliency of the system, and therefore should be considered as valuable assets for the study area.

1.2. Emergency Planning

Emergency planning is a consequence of having hazard and vulnerability studies in a region. If we know the likelihood and magnitude of a hazard that will happen in a city, and therefore the consequences to the CIs, then we can begin with emergency planning strategies for mitigation and distribution of key survival "tokens". Emergency planning without knowing the hazards or the consequences to the CIs is just a good will reaction for the oncoming and unpredicted hazard events.

The definition of an organizational structure for emergency planning is also crucial, if there are manuals, and procedures in case of emergency, and everyone in the Emergency Operation Centres (EOC) are engaged and committed, then the interdependencies with the Hazard and Vulnerability components can be established automatically. The Emergency Planning Groups (EPG) should include expert-technical groups; otherwise EPGs will miss opportunities for survival and resiliency, preparation and response.

1.3. Models and Scenarios

With hazards and vulnerabilities established, then models for a region can be exercised, it can be used any type of simulator or software available. The advantage in using i2Sim and the Resource Layer in DR-NEP, Martí et al, (2008) and Juárez García, (2010), is that you can enhance the interdependency and connections within CI systems and within all physical system layers of a region (e.g. electrical system; first responders system; etc). The models of the region can be upgraded, and scenarios can be exercised for different hazard threats, with different magnitude levels.

The scenarios and the models will give ideas of the consequences that a region will face whenever a hazard unfolds, and therefore the objective functions of the region's emergency planning can be defined and dynamically changed. These models and scenarios will create learning and planning tools for the EPGs.

It is worth noting that disasters may be classified as light to severe disasters, even if only one hazard is considered. For example, consider the earthquake hazard: the disaster that caused the January 12th, 2010 Haiti Earthquake (Mw = 7.0) is totally different to the one that caused the March 11th, 2011 Tohoku Earthquake (Mw = 9.0), and so are the objective functions of the models and scenarios for these 2 earthquakes.

The Haiti Earthquake caused extended damage to the building infrastructure in several regions of Haiti, and most of the casualties were associated to structural damage; preparation and disaster response were non-existent. The Tohoku earthquake was a dynamic event; the violent main shock that provoked light to moderate non-structural and structural damage also caused interruptions to critical infrastructure systems; 30 minutes later a tsunami hit the north eastern region of Japan, Sendai City was considered ground zero; and finally, a few hours after the tsunami had hit the coast, the Fukushima Nuclear Power Plant began to have problems with the nuclear reactors, Carafano, (2011).

Models, scenarios and objective functions are dynamic. In the case of Haiti, the objective function was "Life safety"; but Haitian authorities could not react to the disaster. The Japan case was totally different, after the violent earthquake, Japanese authorities issued a tsunami warning, so that people could evacuate the expected flooded area. Even though they were prepared, they could not foresee that the tsunami waves reached almost 10 km inland. And several hours later, they had the nuclear crisis at Fukushima; they were prepared to have a great earthquake and even a tsunami, but they did not expect to have a serious nuclear crisis at Fukushima, Carafano, (2011).

We always tend to believe that earthquakes are static in nature, but we shall consider that they are dynamic events. Objective functions will move from "life safety" to "search and rescue" to "life safety" to "recovery"; they can change in just a few minutes, hours, days or weeks. We also must plan ahead, and the scenarios should include the worst possible situations, and therefore we will be able to foresee boundary event conditions and possible solutions.

1.4. Response

Immediate response is a key activity after disasters have been unfolded, the resiliency and the survival of the study area will depend upon the response of the region. If the consequences have been approximately predicted, then the response and the recovery activities can begin immediately while damage assessments are underway. But when reaction is the only tool available, then damage assessment becomes crucial and, most of the times, an inconvenient activity that will consume human and technical resources.

There are other factors that will affect the response in a region, and those are linked with human behaviour. Sometimes political issues will cloud the first responders' judgement, for fear of losing people's approval they will react in a political way, rather than in pre-designed emergency planning fashion. And authorities will waste time and media addressing the disaster situation in political ways.

Psychological issues are also important, and authorities should be prepared to respond to people´s needs. For example, fear and stress are two psychological problems that will become important due to aftershocks and other secondary effects that earthquakes might cause.

Individualistic nature of first responders, and antagonistic plans and procedures are also obstacles for response activities. The level of commitment of first responders is crucial, if they do not convey and answer people's need, then the response will become very difficult to address. Antagonistic objectives will create confusion and delay in the response of the authorities. All these problems are likely to be observed in the modelling and the scenario development for the region.

2. DISASTER STRUCTURE

In order to be successful in response, all efforts should be interdependent and focused on the disaster response and recovery of all systems. In the following paragraphs we will explain how to assess the possible disaster event for a region.

A region can be disassembled in human and physical systems that comprised the functional attributes of it. It is also known that hazards can affect the living conditions, due to functionality distress caused to CIs; Martí et al, (2005); Martí et al, (2008); UBC-JIIRP, (2009) and Juárez García, (2010). **Figure 1** shows the Disaster structure that shall be considered. In the first level of the structure there are 7 elements: Hazards, Infrastructure systems (CIs), Risk, Objectives, Participants, Interdependencies and Scenarios. The order in which those elements are established is a logical process to prepare a region to successfully cope with disasters.

One of the key aspects for planning for disasters is to characterize the hazard threat in the study area. **Figure 2** shows schematics of natural and man-made hazards that might affect a region. For example, in British Columbia, Canada there are three seismic sources that might trigger earthquakes that will affect the Downtown Area of City of Vancouver. There are no Tsunami threats and the potential for liquefaction is very low to non-existent. Wind, snow and rain storms are also likely to happen. Neither landslides, nor flooding have been witnessed, in general. Man-made threats do not include political riots, war or internal conflicts. All of those threats or hazards might affect the Downtown core of City of Vancouver, Clague and Turner (2003). Other regions might experience different hazards, such is the case of Mexico City, which is affected by several seismic sources; however, no landslides or tsunamis are considered. Wind and rain storms can be potential hazards, but no landslides have happened in the past. There is no chance that terrorist attacks, sport riots, or war to be possible. All these hazards are likely or not to happen in Mexico City. All the hazard information should be gathered for the study area and they should be characterized (recurrence laws, attenuation relationships, response spectra, uniform hazard spectra, PSHA or DSHA).

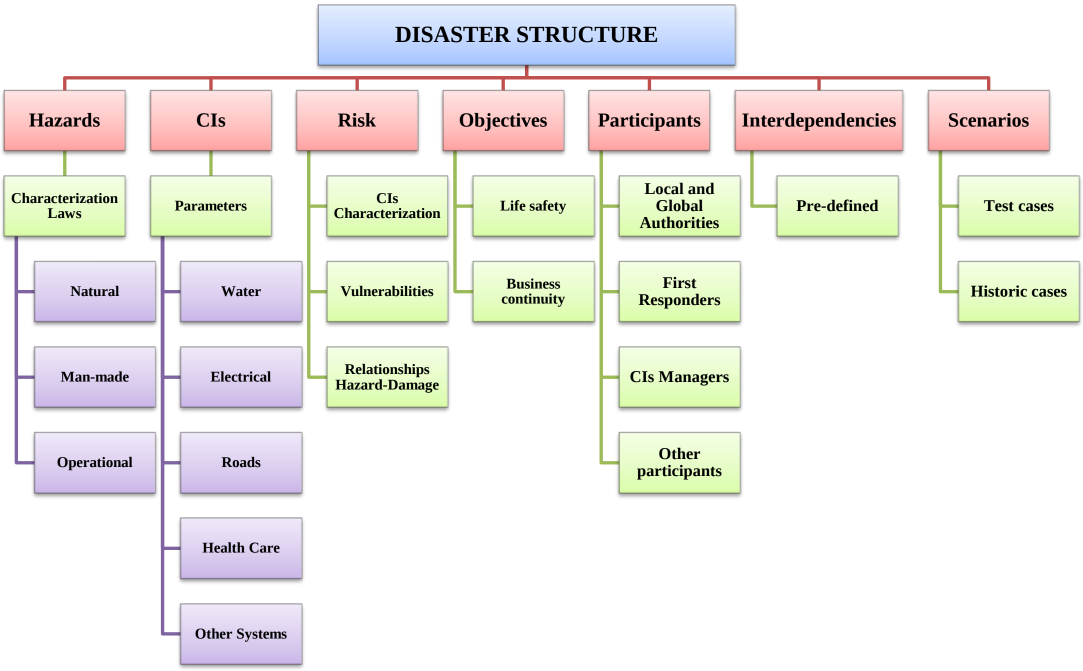

Figure 1. Disaster structure.

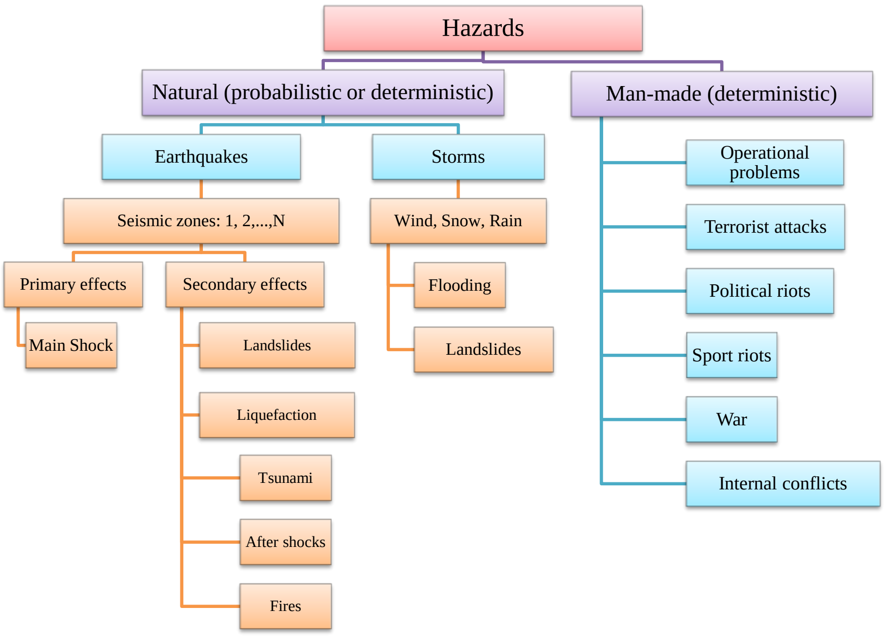

Figure 2. Hazards

Figure 1 shows all other parts that shall be considered and developed in order to fully understand the consequences that an earthquake threat might cause to a region. Interdependencies are a bit hard to predict, but as an example, consider that an electrical blackout has occurred, and therefore the water system is having problems in delivering the water pressure required in a hospital. If dialysis patients are located in the sixth floor, the dialysis process might be compromised. And this is an interdependency that can be predefined.

3. DISASTER EFFICACY OF A REGION

The Disaster Efficacy measures 10 characteristics that a region should address in order to cope with disasters. Disaster Efficacy measurements can give the authorities an idea of their capacities to withstand disasters; and which fields they should invest in, in order to reduce the consequences, Martí et. al. (2008); UBC-JIIRP (2009) and Juárez García (2010).
The 10 characteristics for a region are described below:

1. Hazard characteristics – are they well known by the regions' technical colleges and societies? (3 points)
2. Previous history of hazard events? How serious were they, and to what extent they disrupted normal life? (3 points)
3. How many years have passed after major hazards have occurred (3 points)
4. Ability to perform damage assessments, to establish overall functionality conditions of infrastructure systems. Does it have capacity to respond with technical groups? (5 points)
5. Expertise in the fields of hazards and damage to infrastructure (3 points)
6. Codes, procedures and policies established to help recovering the region, after hazards have happened, previous hazard experiences are important (5 points)
7. Preparation, response and recovery activities, (funding) (5 points)
8. Local and global authorities aware of the disaster situation and immediately addressing all the related problems with emergency plans (5 points)
9. Population is aware and prepared for any contingency – what is the population perception? (5 points)
10. Emergency Operation Centers (EOCs) are activated immediately (3 points)

The qualification grants 40 points. Some of the characteristics have more weight than others; the difference is reflected by giving 3 or 5 points to each one of them. For example, in 3) "how many years have passed after major earthquakes have occurred?" has a 3 point qualification, while 4) "ability to perform damage assessments, and to respond with technical groups" has 5 points. It is considered that having technical groups to support the damage assessment estimation is a key factor for resiliency recovery. According to these estimations, there are four possible states:

- No knowledge: 0 points (pale red in tables)
- Poor knowledge: 1 point (pale orange)
- Intermediate knowledge: 2 or 3 points (pale yellow)
- Full knowledge: 3 or 5 points (pale green)

3.1 Example of calculation of Disaster Efficacy – Earthquake Efficacy Case

The earthquake hazard and five regions were selected for this example: México City (before and after the 1985 earthquake), Haiti (before January 12th, 2010), Chile (before February 27th, 2010), City of Vancouver and Japan (before March, 2011). **Table 1** shows the qualifications in the 10 aspects that a region should take into account to properly respond during earthquakes. The qualifications were granted according to the author's point of view and experience. Some of the qualifications were defined by technical and media reports, Eberhard et. al. (2010a); Fierro and Perry (2010); Eberhard et. al. (2010b); Margesson and Taft-Morales (2010); Borosheck et. al (2010) and Carafano, (2011). **Table 1** was meant to be for example purposes.

Table 1. Earthquake Efficacy in México City, Haiti, Downtown Vancouver and Japan							
Activity	**Points**	**Mexico City**		**Haiti (2010)**	**Chile (2010)**	**Vancouver (2010)**	**Japan (2011)**
		before 1985	**after 1985**				
1. Hazard characteristics	3	**1**	**3**	**0**	**3**	**3**	**3**
2. History of hazards	3	**3**	**3**	**0**	**3**	**0**	**3**
3. Years after major disasters	3	**1**	**3**	**0**	**3**	**0**	**2**
4. Damage assessment ability	5	**2**	**2**	**0**	**2**	**3**	**3**
5. Expertise in hazard and damage	3	**3**	**3**	**0**	**3**	**3**	**3**
6. Codes, procedures and policies	5	**2**	**3**	**0**	**3**	**2**	**5**
7. Preparation, response and recovery	5	**1**	**3**	**0**	**3**	**3**	**3**
8. Authorities addressing the situations	5	**1**	**1**	**0**	**3**	**3**	**3**
9. Population is educated	5	**2**	**3**	**0**	**3**	**2**	**5**
10. EOCs are activated immediately	3	**0**	**0**	**0**	**2**	**2**	**3**
TOTAL	**40**	**16/40**	**24/40**	**0/40**	**28/40**	**21/40**	**33/40**

Table 1 can also be called the Disaster Efficacy Table. It can be observed that Japan is the country with a higher qualification, but the size of the earthquake caused the country to suffer serious consequences in several infrastructure systems. On the other hand, when Mexico City was investigated before and after the 1985 earthquake, it revealed that some characteristics have been improved, and others remain unchanged. Based on this table we can predict how Mexico City can cope with a major earthquake. It is interesting to note that there are at least three issues that have not improved in Mexico City: 1) the damage assessment ability; 2) authorities addressing the situation; and 3) EOCs are not activated immediately. For the City of Vancouver there are four characteristics that need to be improved: 1) history of hazards; 2) years after major earthquakes have happened; 3) codes procedures and policies; and 4) population needs education for preparedness.

Table 2 shows the details of the qualifications for Mexico City (after the 1985 earthquake) and the City of Vancouver level of Disaster Efficacy. The 1985 earthquake revealed some problems with the Mexican authorities to cope with the disaster that the earthquake brought in Mexico City, some of these problems are still current. Even though there are good technical expert groups and the population in Mexico City has a good level of preparedness, still organization, and authorities' level of response is not sufficient to cope with major disasters. On the other hand the problem for Vancouver is that there is no history of major earthquakes in the region, and therefore, most of the plans and procedures are based on probable earthquakes. This table gives an idea to the managerial levels of both regions on where to invest to increase or upgrade the level of disaster efficacy in a region.

4. CONCLUSIONS AND RECOMENDATIONS

The disaster efficacy measure will help authorities revealing the weak points in responding to disasters; and hence, authorities shall improve those weaker issues in order to properly address the consequences of the disaster.

Authorities shall also follow the disaster structure to prepare the response during a disaster and take into account that all disaster are dynamic in nature, and that several objective functions will be implemented before, during and after the disaster has happened. For example Mexico has a seismic warning system to let people and authorities know that a moderate to large earthquake will hit Mexico City. But during and after disaster activities are issues that are not contemplated right now.

Objective functions will move from “life safety” to “search and rescue” to “life safety” to “recovery”; they can change in just a few minutes, hours, days or weeks. We also must plan ahead, and the scenarios should include the worst possible situations, and hence we will be able to foresee boundary event conditions and possible solutions.

In terms of response we shall emphasize that immediate response is a key activity after disasters. The resiliency and the survival of a region will depend on it.

There are other factors that will affect the response in a region, and those are linked with human behaviour. Sometimes political issues will cloud the first responders’ judgement, for fear of losing people’s approval they will react in political ways, rather than in pre-designed emergency planning fashion.

Psychological issues are also important, and authorities should be prepared to respond to people´s needs. For example, fear and stress are two psychological problems that will become important due to aftershocks and other secondary effects that earthquakes might cause.

Individualistic nature of first responders, and antagonistic plans and procedures are also obstacles for response activities. The level of commitment of first responders is crucial, if they do not convey and answer people’s need, then the response will become very difficult to address. Antagonistic objectives will create confusion and delay in the response of the authorities.

Table 2. Earthquake Disaster Efficacy Measurement for Mexico City and City of Vancouver.

Activity		**Mexico (after 1985)**	**Vancouver**
Hazard characteristics	3	(3 points) Full knowledge. It is well known the oncoming earthquakes that might happen in the area, size and possible extent of the damage.	(3 points) Full knowledge. It is well known the oncoming earthquakes that might happen in the area, size and possible extent of the damage.
History of hazards	3	(3 points)Full knowledge. There have been light, moderate and large earthquakes in the area.	(0 points) No knowledge. There are no records of past earthquakes.
Years after major disasters	3	(3 points) Full knowledge. The population, local and global authorities have sensed what it is to have partial or total disaster zones, as México has experienced: hurricanes, earthquakes, flooding, pandemics and other disasters in the last 30 years.	(0 points) No knowledge. The last major earthquake happened 100 years ago.
Damage assessment ability	5	(2 points) Intermediate to poor knowledge. It is still learning how to quickly assess the situation in epicentral affected areas. Coordination among reconnaissance groups is a must, as most of the efforts have been distributed. Policies and procedures make it very difficult to investigate the full consequences in the Lifeline or Critical Infrastructure systems (electricity, water, etc.). The information is protected, hidden and hence difficult to acquire for further assessment. Centralized controlling groups are always supervising but without coordination. The information is discretionarily handled.	(3 points) Intermediate knowledge. But there have not been major disasters in the area. Technical groups are eager to participate, but no response action plans have been exercised.
Expertise in hazard and damage	3	(3 points) Full knowledge. There are Mexican experts and schools that reflect the knowledge in hazard and damage assessment fields.	(3 points) Full knowledge. There are experts and schools that reflect the knowledge in hazard and damage fields.
Codes, procedures and policies	5	(3 points) Intermediate knowledge. The México City code has evolved after every major earthquake, but in other zones there are no updated codes. Policies and procedures for global and local authorities are not known and probably nonexistent. Political issues among authorities affect the development of these important documents.	(2 points) Intermediate to poor knowledge. There is a National code, but it has evolved without real seismic activity. Policies and procedures for global and local authorities are known, but they have not been probed after major disasters. The individualistic nature of the population might provoke that first responders do not answer immediately to the situation, as they will be focused in helping their families and co-workers, neglecting the general population.
Preparation, response and recovery	5	(3 points) Intermediate knowledge. Political issues among authorities affect the development of these activities. No efforts have been recognized to improve their coordination, there have always been distributed efforts	(3 points) Intermediate knowledge. Political issues among authorities affect the development of these activities. No efforts have been recognized to improve their coordination, there have always been distributed efforts
Authorities addressing the situations	5	(1 point) Poor to no knowledge. Political issues among authorities affect the development of these activities. Authorities' efforts are non-coordinated and sometimes antagonistic, which have caused fatalities in the past.	(3 point) Intermediate knowledge. It requires that the authorities address the problem immediately after the disaster has happened. No previous experience makes it difficult to assess the authorities' response.
Population is educated	5	(3 points) Intermediate knowledge. Population knows the consequences of moderate and large disasters, but without the support of the authorities, this knowledge will not improve. In the past the solidarity of the population has been a success despite the little efforts of authorities to coordinate all efforts.	(2 points) Poor knowledge. Population does not know the consequences of moderate and large disasters. The population blindly relies on the system, and their individualistic nature will probably impede solidarity among them.
EOCs are activated immediately	3	(0 points) No knowledge. Political issues among authorities make it difficult to establish EOCs to cope with disasters.	(2 points) Intermediate to full knowledge. They will activate immediately Global and local EOCs, but their individualistic nature, might cause problems to bring all first responders to the EOCs, they might be focused in helping their families and each other, and as a consequence neglecting the general population.
TOTAL	**40**	**24/40**	**21/40**

REFERENCES

Martí, J.R.; Ventura, C.E.; Hollman, J.A.; Srivastava, K.D. and Juárez Garcia, H. (2008). I2Sim Modelling and Simulation Framework for Scenario Development, Training, and Real-Time Decision Support of Multiple Interdependent Critical Infrastructures during Large Emergencies, *NATO, RTA/MSG Conference on "How is Modelling and Simulation Meeting the Defence Challenges Out to 2015?"* – Vancouver, Canada.

Juárez García, H. (2010), Multi-Hazard Risk Assessment for Critical Infrastructures: An Interdependency Approach. Ph.D. Thesis submitted to Department of Civil Engineering, University of British Columbia, Vancouver, Canada.

Carafano, J. J. (2011). The Great Eastern Japan earthquake: Assessing Disaster Response and Lessons for the US. The Heritage Foundation: Douglas and Sarah Allison Center for Foreign Policy Studies. *Heritage Special Report SR-94*.

Martí, J.R.; Hollman, J.A.; Ventura, C. and Jatskevich, J. (2005). Transportation Matrix Model for *Infrastructures Disaster Coordination. JIIRP Seminar presentation*, Vancouver, BC, Canada.

UBC- Joint Interdependent Infrastructures Research Program, UBC-JIIRP final report (2009). *Institute for Computing, Information and Cognitive Systems.*

Clague, J. and Turner, B. (2003). Vancouver, City on the Edge; Living with a Dynamic Geological Landscape. Tricouni Press, Vancouver, Canada.

Eberhard, M.; Baldridge, S.; Marshall, J. and Rix, G. (2010a). The Mw 7.0 Haiti Earthquake of January 12, 2010: Report # 1. Earthquake Engineering Research Institute. *EERI Special Earthquake Report – April 2010. Learning from Earthquakes*.

Eberhard, M.; Baldridge, S.; Marshall, J.; Mooney, W. and Rix, G. (2010b). The Mw 7.0 Haiti Earthquake of January 12, 2010: USGS/EERI Advance Reconnaissance Team: Team report V 1.1.

Fierro, E. and Perry, C. (2010). Preliminary Reconnaissance Report – 12 January 2010 Haiti earthquake. The pacific Earthquake Engineering Research Center (PEER).

Margesson, R. and Taft-Morales, M. (2010). Haiti Earthquake: Crisis and Response. Congressional Research Service. *CRS Report for Congress. R41023*.

Borosheck, R.; Soto, P; Leon, R. and Comte, D. (2010). Terremoto Centro Sur Chile, 27 de febrero de 2010. Informe Preliminar no 4. Departamento de Ingeniería Civil, Departamento de Geofísica. Universidad de Chile. In Spanish.