Using Hazus to Assess Alternative Futures and Earthquake Scenarios for Haiti

Using the GIS-based methodology developed by Hansen and Bausch in 2006, a Hazus Haiti study region was developed in the immediate weeks following the devastating January 12, 2010 earthquake. Before the earthquake, Haiti lacked adequate GIS datasets to support detailed loss estimation. But with the combined efforts of the GIS and earthquake research communities, Haiti rapidly became a data rich environment. Enhancement of the original methodology for Haiti included the development of grid sizes of 10 km, and 1 km that represent rural and urban environments. "Shantytown" areas with their unique building stock, and very high population densities, were also defined using pre-event data from the United Nations. A new treatment for "urban" or high population density grids (1 km) where the team assigns the majority of non-residential building occupancy types was developed for Haiti. After setting up the study region, calibration runs were performed by comparing modeled and observed losses of the earthquake, and iteratively adjusting building distribution schemes, as well as the Hazus casualty analysis parameters. The USGS developed additional ShakeMap scenarios representing credible earthquakes based on those that destroyed Port-au-Prince at least twice in the 1700's. These were formatted for use in the Hazus Haiti study region and allowed the assessment of potential alternative futures for Haiti based on proposed seismic design levels and credible future earthquake scenarios.

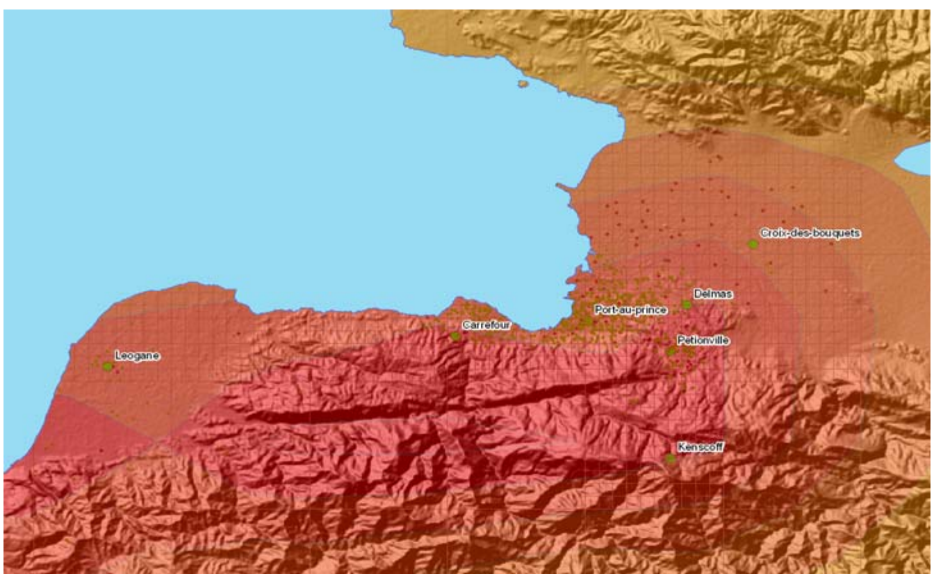

Figure 1: Hazus Haiti study region, illustrating the ShakeMap ground motions and Hazus modeled losses for the M 7.0 January 12, 2010 earthquake.

References

EERI's World Housing Encyclopedia
http://www.world-housing.net/index.asp

Hazus Advanced Engineering Building Module (AEBM)
http://www.fema.gov/hazus/dl_aebm.shtm

USGS Pager program
http://pubs.usgs.gov/of/2008/1160/

World Hazus User Group
http://www.usehazus.com/worldhug/

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An International Concept

The methodology used to support the development of a Hazus Haiti region starts with exporting a U.S. building stock distributed based on the Haiti population dataset provided by LandScan 2008™. Then the building distribution types are significantly modified based on information about local Haitian building types, distribution and seismic design (or lack thereof). Modifying these building-mapping schemes allows us to assess "what-if" scenarios in the Haiti study region for potential alternative futures involving the incorporation of seismic design into rebuilding scenarios. The work done by the Earthquake Engineering Research Institute (EERI), the World Housing Encyclopedia and the U.S. Geological Survey's (USGS) Loss PAGER program was used to help characterize building types and design levels. The project team developed schemes that represent Haiti's urban, rural and shantytown areas. These loss estimations also required the use of the USGS ShakeMaps as the source of ground motion. Zip files provided by ShakeMap include the necessary Hazus ground motion inputs (PGA, PGV, SA 0.3 and SA 1.0). It is important to note that as a result of not having strong ground motion instrumentation in Haiti, the ShakeMap for the January 12, 2010 earthquake is based on the best available information concerning the fault rupture parameters, soil amplification based on topography, distant instrumentation and felt reports.

3 Basic Steps for International Study Regions in Hazus

Three basic steps are required to implement and run an analysis of losses for an international study region using Hazus.

- Create and populate a user defined general building stock grid
- Develop and incorporate ground motion and hazard information
- Run analysis

These basic steps are described in more detail below. However, the user of these proposed methods should understand the technical methodology of the Hazus loss estimation program.

Step 1 requires advanced GIS skills and the ability to work with ArcGIS Geodatabases, as well as the ArcInfo-level software license available from Esri. The user of this method is required to replace U.S. proxy building stock data with that developed locally and to apply or modify the loss functions that best represent the local building stock. A number of resources can help facilitate this, including EERI's World Housing Encyclopedia. The EERI membership helped provide data specific to the Haiti region that demonstrated the need to separate the "shanty" areas because of their unique and vulnerable building types. The USGS's Loss PAGER program has developed building distribution schemes for global loss estimation. Developing building stock inventories can be a significant effort. But once these study regions are developed, users can import site-specific portfolios of buildings that may be available through a survey of essential facilities, such as schools or hospitals, using the Hazus Advanced Engineering Building Module (AEBM).

A diverse set of GIS and engineering skills are required to successfully implement this method. The user community typically includes emergency managers and public policy makers. Therefore, success in utilizing Hazus internationally, as well as in the U.S., requires a group of users. The success of the Hazus User Group program in the U.S. has proven the benefits of joining a diverse user community.

After developing a Haiti study region, the project team compared the observed and modeled building damages primarily by comparing building damage counts and reported casualties. Observed damage reports came from a number of sources, including the U.N., EERI, World Bank, and government reporting. When the study began, the project team felt that assistance would be needed in developing unique fragility functions that better represent the Haiti building stock. However, after assigning many of the most vulnerable U.S. building types already available in Hazus, including unreinforced masonry (URM)-pre-code and under-reinforced concrete frame with URM infill, the modeled building loss counts matched well with those observed. This is likely the result of strong ground motions in the areas analyzed. In cases of moderate ground motions with highly vulnerable building stock, it is believed that the existing Hazus fragilities would require modification. Well-known examples of moderate ground motions resulting in extensive casualties include the 1960 M 5.7 Agadir, Morocco and 2003 M 6.6 Bam, Iran earthquakes.

Once damage counts between modeled and observed losses were calibrated with ground-truthed observed data, the project team adjusted the casualty parameters based on observed losses associated with the January 12, 2010 earthquake. Today, only approximate fatality and injury numbers are available. However, the calibration required substantially increasing the Hazus building collapse rates for completely damaged structures from only 3% to 15% used in the U.S. upwards to 12% to 60% depending upon building types.

The table below shows Hazus Haiti modeled damage counts for the January 12, 2010 earthquake.

	None		Slight		Moderate		Extensive		Complete	
	Count	(%)	Count	(%)	Count	(%)	Count	(%)	Count	(%)
Wood	103,913	18.51	15397	21.50	8,096	9.21	504	0.43	9	0.01
Steel	61,718	10.99	7571	10.57	8,537	9.72	6,469	5.52	6,298	8.07
Concrete	57,527	10.25	3784	5.28	19,997	22.76	48,988	41.82	37,188	47.68
URM	336,577	59.94	44598	62.27	50,977	58.02	60,674	51.80	34,150	43.78
MH	1,750	0.31	268	0.37	252	0.29	501	0.43	355	0.46
Total	**561,485**		**71,617**		**87,859**		**117,137**		**77,999**	

*Note:
RM Reinforced Masonry
URM Unreinforced Masonry
MH Manufactured Housing

As shown in the table below, the modeled economic losses for the January 12, 2010 event using Hazus indicated over $9.5B. While this is less than many U.S. events and scenarios, it is 2.5 times the entire pre-event annual GDP of Haiti.

(Millions of dollars)

Category	Area	Single Family	Other Residential	Commercial	Industrial	Others	Total
Income Loses							
	Wage	0.00	1.24	5.80	0.18	0.34	7.56
	Capital-Related	0.00	0.53	4.87	0.11	0.07	5.58
	Rental	48.37	21.47	3.03	0.06	0.16	73.11
	Relocation	165.24	13.44	4.71	0.30	1.09	184.78
	Subtotal	**213.61**	**36.68**	**18.42**	**0.65**	**1.67**	**271.02**
Capital Stock Loses							
	Structural	1,963.36	256.46	72.24	10.53	9.42	2,312.01
	Non_Structural	4,598.89	1,018.50	177.70	34.18	27.52	5,856.80
	Content	928.05	194.51	79.89	20.94	11.92	1,235.32
	Inventory	0.00	0.00	0.33	0.45	0.01	0.79
	Subtotal	**7,490.30**	**1,469.48**	**330.16**	**66.11**	**48.87**	**9,404.93**
	Total	**7,703.91**	**1,506.16**	**348.58**	**66.76**	**50.54**	**9,675.95**

Hazus Haiti modeled casualties for the January 12, 2010 earthquake are shown in the table below.

Estimated Casualties : Day Time

Severity Level	*Description*	*# Persons*
Level 1	Medical Aid	262,000 - 1,048,000
Level 2	Hospital Care	174,000 - 697,000
Level 3	Life-threatening	41,000 - 162,000
Level 4	Fatalities	80,000 - 321,000

While the January 12, 2010 event was catastrophic for Haiti, the potential scenario of a repeat of either the 1751 or the 1770 earthquake would be much worse. The table below shows the Hazus Haiti estimates for an M 7.3 on the eastern Enriquillo fault.

		Level 1	Level 2	Level 3	Level 4
2 PM	Commercial	370,731	267,262	63,231	125,416
	Commuting	0	0	0	0
	Educational	131,665	93,348	21,834	43,196
	Hotels	543	395	96	191
	Industrial	103,986	74,428	17,451	34,544
	Other-Residential	43,567	30,675	7,369	14,598
	Single Family	322,050	225,708	54,244	107,427
	Total	**972,542**	**691,816**	**164,224**	**325,372**

Hazus also provides the capability to model what-if strategies including assigning different seismic design levels. For one of the future alternative scenarios for Haiti we assigned the same building types and seismic design level that are assigned to Puerto Rico. The modeling indicates that this assignment could have reduced fatalities by two orders of magnitude for the January 12, 2010 event, as shown in the table below.

		Level 1	Level 2	Level 3	Level 4
2 PM	Commercial	9,625	2,437	349	678
	Commuting	0	0	0	0
	Educational	3,616	909	130	252
	Hotels	15	4	1	1
	Industrial	2,796	705	99	191
	Other-Residential	1,273	318	47	90
	Single Family	10,761	2,688	399	753
	Total	**28,087**	**7,062**	**1,025**	**1,964**

Summary and Future Recommendations

The authors hope to continue working in partnership with others to apply not only the Hazus earthquake model, but also the hurricane and flood loss modeling capabilities for Haiti. Improving the inventory to capture the post event conditions, including incorporating site-specific locations for critical facilities and shelter needs, would greatly improve the ability to apply the model to support decision-making.