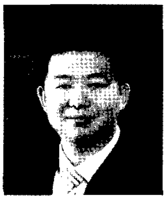
CASE Study: Policy implications of HAZUS analysis



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〈국문 초록〉

대형태풍 카트리나가 준 주요 교훈 중의 하나는, 위험도 분석에 기반한 종합적인 재해경감 프로그램의 중요성이다. 미국에서는 이를 위해 다양한 위험도 분석(risk analysis) 프로그램 개발에 노력해 왔다. HAZUS(Hazards-US) 프로그램은 대표적인 자연재해 예측 시스템으로서, 위험요인 파악(hazard identification), 지역사회의 취약성 분석(vulnerability of the society), 그리고 피해결과예측(loss estimation)의 세 가지 요소로 구성된다. 1992년 지진을 대상으로 개발된 이 프로그램은 현재, 지진.홍수.허리케인 윈드에 대해 피해예측을 할 수 있는 HAZUS-MH MR3가 사용 중에 있다. FEMA에서는 주정부에서 HAZUS를 활용, 피해예측에 기반한 재해경감 정책을 추진할 수 있도록 다양한 재정적.기술적 지원을 하고 있다. 이에 따라, 2004년 머릴랜드 주에서는 미국 최초로 주 전역에 걸친 홍수피해 예측을 실시하고 이를 바탕으로 다양한 경감정책을 추진하였다. 머릴랜드 주정부에서 Salisbury 대학에 의뢰하여 수행한 홍수 피해 예측 과정은, 조사구역 및 위험요인(홍수) 결정, 사용 데이터 확정, 수문학적 분석, 수리학적 분석, 피해예측(건물 용도별 피해면적, 건물 용도별 피해액, 건물 재질별 피해면적, 건물 재질별 피해액, 지역의 경제학적 피해)의 과정으로 수행되었다. 홍수피해 예측 결과, 100년 빈도 홍수가 재현될 경우, 주 전체 면적 중 13%이상의 지역에서 약 80조 이상의 피해액이 예측됨에 따라, 종합적인 재해경감 대책의 필요성이 제기되었다. 이에 따라, 머릴랜드 주정부에서는 홍수피해예측 결과를 토대로, 주정부 재해경감 예산 재분배, 홍수터 보호, 건물규제 강화, 토지이용계획 재조정 등 보다 과학적이고 종합적인 재해경감 프로그램을 추진하였다. 머릴랜드 주정부의 이번 연구는 주정부로서는 최초로 HAZUS를 활용하여 주 전역에 걸친 피해예측을 실시한 것으로서, 피해예측 시스템

이 어떻게 주정부의 과학적 피해경감 프로그램에 기여할 수 있는 지를 보여주는 사례이다.

Introduction

One of the lessons learned from Hurricane Katrina is that comprehensive mitigation activities based on risk analysis should be implemented at the mitigation phase. The risk-based approach is a critical step for disaster management in that risk analysis provides a scientific and sophisticated method of ensuring integrated mitigation policies. The United States government has developed many risk analysis methodologies, among which are Hazards-US(HAZUS), Risk Analysis and Management for Critical Asset Protection (RAMCAP), and Consequence Assessment Tool Set(CATS). Of these methodologies, HAZUS is the most useful model for natural hazards nationwide. Since the Federal Emergency Management Agency initiated the HAZUS program in 1992, many state and local governments have developed effective mitigation strategies by using the results of HAZUS analysis. An assessment of Maryland' s vulnerability to flood damage is considered as one of the most successful cases using HAZUS-MH for risk assessment.

Background of the studies

Maryland has had a long history of major flooding disasters since the first recorded flood on May 11, 1860. One of the biggest disasters in Maryland was the flood caused by the tidal surge of Hurricane Isabel in mid-September 2003, which resulted in $820 million in damage and seven deaths. There are three types of flooding in the state: nontidal flooding, tidal flooding, and coastal high hazard flooding. The state has made efforts to mitigate flood disasters since the 19th century. A recent achievement of these efforts was the risk-based design approach. Using Geographic Information Systems (GIS) technology, the state conducted an Assessment of Maryland' s Vulnerability to Flood Damage. For this assessment, the state utilized Hazards in United States (HAZUS)-MH software, which uses GIS software to map and display hazard data and loss estimates. The assessment project, which was implemented in 2005, generated maps and tables of the state' s potential for building damages from flooding on a county-by-county basis. In fact, this risk assessment project was the first statewide flood risk assessment using HAZUS-MH.

Flood Risk Assessment

The flood risk assessment consists of the flood hazard, vulnerability of the society, and the consequences of flooding. Ideally, a flood risk analysis should take into account all relevant flooding scenarios, their associated probabilities and possible damages as well as a thorough investigation of the uncertainties associated with the risk analysis.[2)]

The risk-based approach is a new important step for flood risk management in that it can provide decision makers with comprehensive and systematic method to mitigate flood damage.

Even before HAZUS was developed, the state made an effort to estimate potential loss by using 100-year flood maps. The 100-year floodplain is the area regulated by local floodplain ordinances of communities that adopted the National Flood Insurance Program (NFIP). Flood maps were developed on the basis of estimates of the 100-year flood discharge. Because the 100-year flood maps

2) Apel, H., Thieken, A.H., Merz, B., Bloschl, G. Flood risk assessment and associated uncertainty. Geophysical Research Abstracts, Vol. 5, 14190, 2003. , p.1.

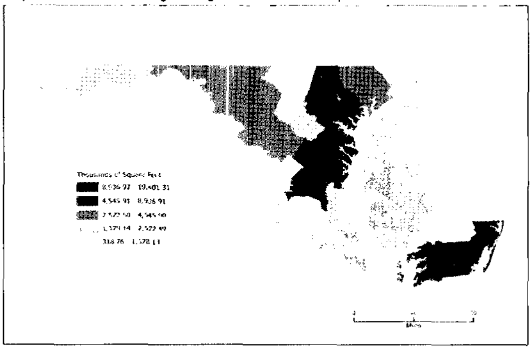
only tell the extent of flood, the state found it necessary to predict the impact of the flood on the built environment. Estimates of the built environment have been made using two methods. One was taken from the Community Assistance Visit (CAV) records, in which communities are asked to estimate the number of structures in their floodplains. Another estimate was taken by overlaying the Q3 digital floodplain lines onto parcel information from MDProperty View, which does provide a consistent methodology throughout the state.[3] GIS technology was used to overlay or intersect different geographical layers. However, the loss estimation method based on 100-year floodplain has many problems. First, county estimates were not high in the level of accuracy and some counties did not even provide any estimates. In addition, the fit of overlaying was not good. Lessons learned from Hurricane Isabel in 2003 required the state to develop more scientific and comprehensive mitigation strategy, which should be based on a systematic flood risk analysis.

In order to provide a systematic examination of flood risk, the state asked the Eastern Shore Regional GIS Cooperative (ESRGC) at Salisbury University to take a vulnerability modeling effort. With FEMA' s HAZUS-MH, the ESRGC measured the potential damage from flood in the state. The data used for the analysis was the Level 1 dataset provided by FEMA and 30-meter Digital Elevation Model (DEM) data from the United States Geological Survey (USGS). The procedure of risk assessment comprised five steps:

1. The ESRGC created a new study area. It chose the correct hazard (flood), state, and county. It also determined if a county should be examined for riverine flooding vulnerability, coastal flooding vulnerability, or both.
2. Required data were determined. The ESRGC chose level 1 analysis datasets provided by FEMA and 30-meter DEM provided by USGS.
3. It completed hydrologic analysis in the study area. It selected an appropriate minimum stream drainage area size (in square miles) and created one study case per county. And then, it calculated the flow volume for entire set of stream reaches.
4. The ESRGC calculated the extent and degree of the 100-year flood hazard. Hydraulic analysis (for riverine flood hazard) and flood and wave height analysis (for coastal flood hazard) were conducted.
5. The ESRGC ran five different analyses of the potential flood vulnerability: count of damaged buildings by type, count of damaged buildings by occupancy, amount of building damage by type, amount of building data by occupancy, amount of direct economic losses from damage to buildings.

Policy Implications of the Estimates

Map2. Residential building damage n thousands of square feet



Completion of the HAZUS-MH vulnerability scenario modeling for every county (and Baltimore City) in Maryland yielded a picture of varying degrees of vulnerability to flooding throughout the state. Regarding the physical nature of the flood

3) Maryland Department of the Environment. (2005). An Assessment of Maryland' s Vulnerability To Flood Damage. Baltimore, MD assessing flood damage p.16

zone, over 1,328 square miles of the state fall within the 100-year flood zone. In other words, 13.4% of the land area of the state is vulnerable to a 100-year flood event.[4] Compared to the estimates by using 100-year flood maps, the HAZUS-MH provided better estimates.

Table 5. Building damage by percent damaged in thousands of square feet

County	Degree of Damage							Total
	None	1-10%	11-20%	21-30%	31-40%	41-50%	Substantial	Damaged
Allegany	276.30	1,509.51	613.82	112.42	69.63	31.15	15.88	2,352.41
Anne Arundel	2,522.95	9,110.29	2,795.45	1,311.88	692.55	561.13	1,061.04	15,532.34
Baltimore City	435.07	3,873.79	1,667.82	1,137.21	220.49	58.20	699.38	7,656.89
Baltimore	2,418.92	5,707.85	1,175.96	531.32	594.19	180.78	615.12	8,805.22
Calvert	430.17	1,088.86	375.49	212.12	131.67	152.09	366.44	2,326.66
Caroline	75.91	245.27	59.88	37.37	14.14	11.54	23.48	391.69
Carroll	985.20	335.92	22.33	7.28	1.20	2.51	2.89	372.13
Cecil	447.58	1,010.32	376.13	237.80	41.02	16.17	10.45	1,691.90
Charles	554.00	955.74	138.88	24.46	1.83	0.00	32.20	1,153.11
Dorchester	83.03	899.12	486.03	266.41	131.23	151.14	774.14	2,708.08
Frederick	1,739.66	2,799.65	797.63	311.92	69.75	98.31	218.61	4,295.87
Garrett	236.80	477.45	149.78	79.21	33.41	4.97	127.00	871.83
Harford	1,440.27	2,258.76	756.15	202.48	230.90	117.76	69.83	3,635.91
Howard	3,995.27	2,589.41	59.70	28.16	0.95	0.00	0.00	2,678.21
Kent	175.98	290.21	69.96	42.11	35.64	12.46	26.86	477.23
Montgomery	3,943.62	3,144.28	708.48	377.96	94.36	40.91	70.82	4,436.80
Prince George's	2,200.68	8,462.98	1,531.75	424.68	151.58	114.50	364.39	11,049.88
Queen Anne's	349.63	1,101.53	230.67	89.94	24.61	0.72	30.35	1,477.82
Somerset	113.97	883.18	319.30	202.72	217.39	203.76	3,854.91	5,681.27
St. Mary's	407.85	906.39	297.78	192.37	114.07	103.44	319.05	1,933.10
Talbot	283.50	1,284.42	416.14	166.84	93.14	52.60	154.56	2,167.70
Washington	1,227.36	2,787.68	658.33	226.75	353.78	436.54	1,009.08	5,472.15
Wicomico	120.43	807.96	174.35	69.28	11.71	27.95	75.41	1,166.66
Worcester	304.45	8,220.97	5,316.36	2,693.36	1,258.75	1,463.71	2,371.01	21,324.16
TOTAL	24,767.48	60,754.23	19,199.15	8,987.30	4,587.98	3,843.18	12,293.70	109,665.55

Table 11. Direct economic losses from buildings in thousands of dollars

County	Capital Stock Losses			Income Loss				Total Loss	Percent of Total
	Cost Structural Damage	Cost Contents Damage	Inventory Loss	Relocation Loss	Capital Related Loss	Wages Loss	Rental Income Loss		
Allegany	54,808	56,612	1,353	2,873	16,700	30,479	2,012	164,837	2.0%
Anne Arundel	378,116	329,639	7,762	9,604	69,116	121,574	3,890	919,691	11.3%
Baltimore City	152,517	169,640	4,669	11,355	84,456	94,664	9,352	526,653	6.5%
Baltimore	237,974	179,172	2,207	5,563	41,166	62,728	2,347	531,157	6.5%
Calvert	41,710	33,328	359	2,265	7,084	12,663	903	98,312	1.2%
Caroline	6,601	5,317	161	343	817	4,425	135	17,799	0.2%
Carroll	34,063	26,791	453	55	4,386	7,278	29	72,055	0.9%
Cecil	38,126	33,817	412	3,548	17,862	26,835	2,520	123,120	1.5%
Charles	31,473	23,190	240	117	4,520	10,512	35	70,087	0.9%
Dorchester	35,364	26,812	396	4,152	2,758	6,516	1,386	77,384	1.0%
Frederick	176,954	149,970	5,387	5,226	31,232	75,407	2,828	447,004	5.5%
Garrett	22,676	22,153	494	1,583	6,265	32,507	1,013	86,691	1.1%
Harford	128,561	103,420	1,543	2,972	21,618	41,849	1,310	301,273	3.7%
Howard	207,881	162,760	2,343	30	39,156	166,059	21	578,250	7.1%
Kent	13,122	9,849	132	396	1,766	6,882	203	32,450	0.4%
Montgomery	296,456	212,153	1,670	3,731	39,626	145,253	2,904	701,793	8.6%
Prince George's	333,738	295,480	5,348	7,237	76,348	561,061	4,190	1,283,402	15.8%
Queen Anne's	30,250	22,497	223	135	3,898	12,745	45	69,793	0.9%
Somerset	70,435	62,083	1,155	18,224	8,362	25,949	7,803	194,011	2.4%
St. Mary's	34,071	25,548	159	1,945	3,751	13,955	635	80,064	1.0%
Talbot	35,702	25,797	320	1,272	3,878	7,629	856	75,454	0.9%
Washington	242,126	190,479	6,649	13,722	35,378	99,575	6,637	594,566	7.3%
Wicomico	16,021	13,160	134	730	4,301	11,372	281	45,989	0.6%
Worcester	448,618	345,160	3,627	16,851	85,557	118,408	12,009	1,029,230	12.7%
TOTAL	3,067,383	2,523,917	47,186	112,929	610,001	1,696,325	63,344	8,121,065	100.0%

The results of risk analysis were interpreted in several ways in order to guide policy makers. First, Worcester County has the most vulnerable building stock in the state. Second, residential building will be the majority of damage to buildings in the state. Third, the distribution of industrial building damage shows that Anne Arundel, Prince George' s, and Baltimore City are the most vulnerable areas for that kind of damage. Fourth, most construction types of vulnerable areas are wood(62%) and masonry(28%). Finally, the potential economic loss from a 100-year flood is $8.12 billion.

Based on the risk analysis, the state developed comprehensive flood mitigation plans. It also selected nine strategies to mitigate the potential flooding impacts. Those Strategies include reallocation of budgets of the State' s Flood Management Grant Program, better coordination of state agencies, tax incentives, and protection of floodplains.

Problems and Solutions

The major concern of this assessment is the effect of uncertainy on the accuracy of the results. Sources of this uncertainty include incomplete or inaccurate data, biased or uninformed expert judgment, modeling error, and computational error.[5] The first problem of this assessment has to do with getting the software to operate properly. There were a lot of bugs in the software which kept it from working. After upgrading the software to HAZUS-MH version 1.1 and ArcGIS 9.0.1 and getting technical assistance from FEMA, National Institute of Building Sciences(NIBS), and ABS consulting, the ESRGC was able to solve the problem caused by modeling error. The second problem is that the data underlying the analysis were incorrect. National data sets such as DEM and census block data, which were used to calculate the results, contained some errors. The ESRGC reduced data error by utilizing LiDAR(Light

4) Maryland Department of the Environment. (2005). An Assessment of Maryland' s Vulnerability To Flood Damage. Baltimore, MD. p.27

5) Van Dorp, J. R., Merrick, J. R. W., Harrald, J. R., Mazzuchi, T. A., & Grabowski, M. (2001). A risk management procedure for Washington state ferries. Risk analysis. Vol 21, No. 1, p.139.

Detection And Ranging) elevation data. Even though not all types of LiDAR data are available throughout the state, they helped the risk model generate more accurate stream reaches and stream profiles.

Conclusion

This project is considered as one of the most successful cases using HAZUS-MH for risk assessment. Even though this risk assessment has some problems about the inaccuracy of the results caused by data and modeling error, it has three important policy implications. First, it was the earliest state-wide flood risk assessment. Due to the assessment, the state can have a consistent method to compare between the different counties in the State to see on which county in the State the flood would have the greatest effect, in terms of depth of flooding and value of the structures flooded. Maryland' s study provides a useful framework for a statewide flood vulnerability analysis that can be adapted to other states. · The study establishes baseline data that can be used to measure and monitor trends in exposure of the built environment to flooding.[6] Second, the risk assessment project was executed with strong partnerships among federal, state, and local governments. FEMA and NIBS supported the state government in solving technical problems of the analysis, and local governments helped collect more accurate data. Finally, the results gave decision-makers important guidelines for the flooding mitigation strategy. The official report documented that the state should develop comprehensive mitigation strategy given tens of thousands of buildings vulnerable to flood and the economic loss estimating to be $8.1 billion. Based on the risk analysis, the state chose nine mitigation strategies such as reallocation of budgets and strong flood plain regulation.

In conclusion, this study shows how the systematic risk assessment could provide a sophisticated method of ensuring comprehensive mitigation strategies to reduce damages from hazards. Furthermore, this work will lay the foundation for future research on the development of loss estimation model in Korea.

6) FEMA website 〈http://www.fema.gov/plan/prevent/hazus/hz_mdfldstudy.shtm〉