Journal of Management and Sustainability; Vol. 5, No. 4; 2015
ISSN 1925-4725 E-ISSN 1925-4733
Published by Canadian Center of Science and Education

Taiwan Vulnerability Analysis: A Comparative Study with Japan, China, U.S.A., U.K., France, and the Netherlands

Yu-Shou Su[1&2]

[1] Inspector, National Development Council, Taiwan (R.O.C.)

[2] Fellow, Penn Institute for Urban Research (Penn IUR), University of Pennsylvania, U.S.A.

Correspondence: Yu-Shou Su, National Development Council, 3F., No. 3 Baoqing Road, Taipei City 10020, Taiwan (R.O.C.). Tel: 886-2-2316-5813. E-mail: yushou.su@gmail.com

Received: November 13, 2015 Accepted: November 21, 2015 Online Published: November 30, 2015

doi:10.5539/jms.v5n4p76 URL: http://dx.doi.org/10.5539/jms.v5n4p76

Abstract

Taiwan has performed well economically during the past four decades. However, economic development can be profoundly hampered by natural disasters. Sustainable economic development requires environmental resilience. With 23 million people occupying only 13,974 square miles of land, Taiwan is both densely populated and highly exposed to natural disasters: 73.1% of the total population lives in vulnerable areas, and Taiwan is ranked as the country most exposed to multiple hazards (The World Bank, 2005). Storms and floods damage Taiwan frequently, with an average of six typhoons hitting Taiwan annually for the past four decades. Taiwan had the highest occurrence and highest death toll on the natural disaster density indicator (NDDI) in comparison with China, Japan, U.S.A, U.K., France, and the Netherlands from 1985 to 2014. Also, Taiwan's economic losses during the past thirty years are estimated at $650, 000 per km². This is approximately 5 times that of the Netherlands' $134,362 and the U.K.'s $135,292, 8 times that of the U.S.A.'s $78,186 losses, and 9 times that of France's $70,599. Research finds that every dollar invested into disaster preparedness would save $4 to $7 dollars in post-disaster damages (Multihazard Mitigation Council, 2005; The National Academy of Sciences, 2012). Hence, promoting urban resilience policies for disaster risk reduction should become a priority in Taiwan and other Asian nations in the future. Most important is the need of a strong political commitment and leadership to initiate and implement spatial policies toward resilience.

Keywords: vulnerability analysis, environmental resilience, natural disaster

1. Introduction

Asian nations have inadequate risk and vulnerability information, weak transition from policies and legislation into actions, insufficient budget allocations for disaster risk reduction, and insufficient implementation capacities (UNISDR 2013). Asia is the highest loss region, accounting for 70% of the world's losses in 2011. Additionally, the insured losses in Asia account for only 17% of its losses in comparison with America's 51% (Munich RE 2012). Taiwan, is an Asian country with successful economic development (Note 1), but is also an environmentally vulnerable country. Major natural disasters include cyclones, typhoons, floods, earthquakes, and landslides. Taiwan was hit with 3.6 typhoons each year from 1898 to 2010, resulting in annual economic losses of $667 million (NAPHM 2011). The economic losses are expected to increase accordingly because the typhoons have doubled since the 1970s. According to the World Bank (2005), Taiwan, ranked as the country most exposed to multiple hazards, has 73.1% of its population, or 16.8 million people exposed and living in vulnerable areas. On the World Bank's list of the top 10 countries exposed to multiple hazards, Taiwan has double the percentage of its population exposed to natural disasters as does the Philippines with 36.4%; approximately 5 times that of Japan's 15.3%; and 15 times that of Vietnam's 5.1%.

This paper first studies natural disasters in Asia, explaining the context of natural disasters in general in Asia. Second, this research analyzes internationally reported disaster database from the EM-DAT (Note 2) to create a natural disaster density indicator (NDDI) to conduct a comparative study among seven countries from 1985 to 2014, including Taiwan, Japan, China, U.S.A., U.K., France, and the Netherlands. The international comparison will help to understand Taiwan's damages from natural disasters.

2. Natural Disasters in Asian Countries

Storms, floods, and earthquakes are the three major natural disasters in Asia. Asian countries have suffered from natural disasters for the past century. From the EM-DAT's database from 1900 to 2014, the results indicate that the Philippines, India, China, and Indonesia are the countries with the most frequent disasters (see Table 1). China has the largest death toll, with 6.6 million people dying from floods (see Table 2). Each catastrophic event could possibly cause more than a thousand deaths. For instance, the China Floods of 1931 was estimated to have caused up to 3.7 million deaths. Peduzzi et al. (2009) also discover that "least developed countries represent 11% of the population exposed to hazards but account for 53% of casualties. On the other hand, the most developed countries represent 15% of human exposure to hazards, but account for only 1.8% of all victims". In the Philippines and Vietnam, more than 40% of the urban poor population live in informal settlements with the highest flood risk (The World Bank, 2013). Also, Thailand's car manufacturing plants were located on floodplains. Flooding caused serious damage to the car industry's global supply chains in 2011, and GDP in Thailand fell by 9% in the last three months of 2011 compared with the same quarter in 2010 (Wahlström, 2015). In Japan, a developed country, natural disasters did not cause as many deaths as in China, India, Philippines or Bangladesh. However, Japan is the country with the greatest amount of economic loss and damage from natural disasters, especially due to earthquakes (see Table 3). Wahlström (2015) indicates GDP declined in Japan in 2011 after the Great East Japan Earthquake and Tsunami, which generated direct losses of over $200 billion. Hence, Asian countries have suffered greatly from natural disasters during the past century. Natural disaster statistics in Asian also indicate that disasters have increased dramatically since the 1980s, particularly floods.

Table 1. Countries with most frequent natural disasters in Asia

Country	Natural disaster	Occurrence (5,190 disasters in total from 1900 to 2014)
Philippines	Storm	316
India	Flood	254
China	Storm	241
China	Flood	237
Indonesia	Flood	167
Bangladesh	Storm	167
India	Storm	165
Japan	Storm	157
China	Earthquake	143
Philippines	Flood	136

Note. Original data collected from the EM-DAT and calculated by the author.

Table 2. Countries with largest amount of deaths caused by natural disasters in Asia

Country	Natural disaster	Death toll (persons) (26 million deaths in total from 1900 to 2014)
China	Flood	6.6 million
India	Epidemic	4.5 million
India	Drought	4.2 million
China	Drought	3.5 million
Bangladesh	Drought	1.9 million
China	Epidemic	1.56 million
China	Earthquake	0.9 million
Bangladesh	Storm	0.6 million
China	Epidemic	0.4 million
Indonesia	Earthquake	0.2 million

Note. Original data collected from the EM-DAT and calculated by the author.

Table 3. Countries with largest damage from natural disasters in Asia

Country	Natural disaster	Damage (US dollars) ($1.2 trillion in total from 1900 to 2014)
Japan	Earthquake	360 billion
China	Flood	201 billion
China	Earthquake	105 billion
China	Storm	64 billion
Japan	Storm	57 billion
Thailand	Flood	45 billion
India	Flood	37 billion
China	Drought	26 billion
Turkey	Earthquake	24 billion
China	Extreme temperature	21 billion

Note. Original data collected from the EM-DAT and calculated by the author.

Research has found that every dollar invested into disaster preparedness would save $4 to $7 dollars in post-disaster damages (Multihazard Mitigation Council, 2005; United Nations Development Programme, UNDP, 2012; The National Academy of Sciences, 2012). However, Asia is not well enough prepared or invested in prevention for natural disasters. The UNISDR (2013) observed issues in Asia: 1. weak transition from policies and legislation into actions; 2. inadequate risk and vulnerability information; 3. insufficient budget allocations for disaster risk reduction; 4. insufficient implementation capacities. Additionally, most properties are not covered by insurance. According to Munich RE (2012), there were overall world losses of $380 billion in 2011, 70% of all losses were in Asia. However, the insured losses accounted for only 17% in comparison with America's 51% of losses being insured. In European countries, a significant proportion of economic losses are insured. For example, in the July 2013 hailstorms in Germany and France, an estimated $3.8 billion of the total losses of $4.8 billion were insured, almost 80% (Swiss Re, 2014; United Nations, 2015). In Asian countries, the high exposure to natural disasters and extreme damage as well as being less prepared and having less insured property has made it more vulnerable.

3. Taiwan Vulnerability Analysis

Taiwan has been successful with economic development between the early 1960s and 1990s with a high annual GDP growth rate in excess of 6% sustained over a 30-year period (Sarel, 1996; IMF, 1997). In 2010 Taiwan still had a double-digit annual GDP growth rate. The GDP per capita has been increasing from $432 in 1970 to $21,141 in 2013 according to the International Monetary Fund, and is expected to target above $30,000 in 2016. According to Taiwan's Central Bank, as of September 2014, the foreign exchange reserve was $420.7 billion, making Taiwan the 7th in the world in reserves capacity. In addition, Taiwan ranks 14th in the Global Competitiveness Report released in 2014 by the Geneva-based World Economic Forum. Therefore, Taiwan has performed well economically with its effective economic planning and policy during the past four decades. However, economic development can be profoundly hampered by natural disasters. Examples around the world have proven this. Hurricane Sandy devastated the Northeast region of U.S.A. in 2012 (Note 3). The direct economic losses were estimated at between $78 and $97 billion. This storm event damaged 3% of total GDP in the Northeast region of U.S.A. (Regional Plan Association; The World Bank; Kunz et al., 2013). Hence, sustainable economic development requires environmental resilience.

Taiwan is an environmentally vulnerable Asian nation. Taiwan ranked as the country most exposed to multiple hazards with 73.1% of the population or 16.8 million exposed to and living in vulnerable areas (The World Bank, 2005). Taiwan is at the top of the World Bank's 10 countries most exposed to multiple hazards. Taiwan has double the percentage of its population exposed to natural disasters compared to the Philippines' 36.4%; about 5 times that of Japan' s 15.3%; and 15 times that of Vietnam's 5.1% (see Figure 1). Taiwan is exposed to cyclones, typhoons, floods, earthquakes, and landslides. According to the Taiwan Central Weather, an average of 3.6 typhoons have hit Taiwan every year from 1898 to 2010. This has resulted in $667 million of economic losses annually (NAPHM, 2011). However, typhoons have increased since the 1970s. On average 6 typhoons have hit Taiwan every year from 1975 to 2014. The economic losses are expected to increase by double, reaching at least $1 billion. Also, the number of earthquakes being felt annually is approximately 500 (Taiwan's Central Weather Bureau). Typhoons, floods and earthquakes impact Taiwan profoundly.

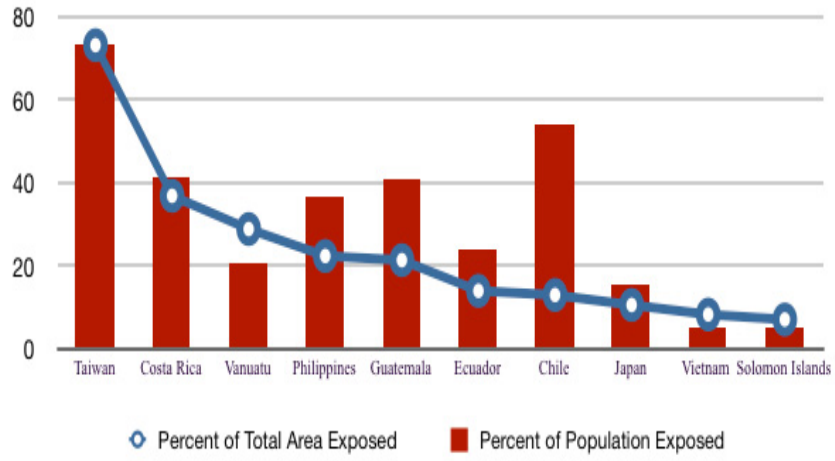

Figure 1. Taiwan is at the top of the 10 countries most exposed to multiple hazards

Source: The World Bank 2005.

4. A Comparative Study in Taiwan and Six Other Countries in Asia, North America and Europe

This study compares natural disasters in Taiwan to other counties in Asia, North America and Europe, including Japan, China, U.S.A., U.K., France, and the Netherlands. These countries are chosen because all of them have a large population, high economic growth, and frequent occurrence of natural disasters. In order to analyze Taiwan's vulnerability and damages from natural disasters, this research creates the natural disaster density indicator (NDDI) based on the EM-DAT dataset to conduct a comparative study among seven countries from 1985 to 2014, including Taiwan, Japan, China, U.S.A., U.K., France, and the Netherlands. The NDDI model explains Taiwan's vulnerability and actual damages from natural disasters in comparison with six other countries.

4.1 Method

Disaster risk index models have been developed by the United Nations and the U.S.A. In the United Nations' disaster risk index (DRI) model and U.S.A.'s existing models, identifying a country's disaster risk primarily focuses on these key factors: hazard frequency, exposure of population, vulnerability, and consequences. In the United Nations' DRI model, hazard frequency, exposure, vulnerability and risk are the major components (risk=hazard frequency*expected population exposed*vulnerability). However, some variables are not easily calculated. For example, the variable of vulnerability is based on socio-political-economical context of a country, it is a non-dimensional number between 0–1 (Peduzzi, 2009). Thus, identifying human vulnerability is a problem in the DRI model. Other models used to evaluate risk and resilience have been promoted in the U.S.A. in the twenty-first century, including: Coastal Resilience Index (CRI), Argonne National Laboratory Resilience Index (ANLRI), Social Vulnerability Index (SVI), Baseline Resilience Indicator for Communities (BRIC), Community Disaster Resilience Index (CDRI). The CRI model is a community-based or bottom-up approach to developing an index of low, medium, and high resilience ratings to storm events through self-assessment and a questionnaire survey. However, the CRI model relies heavily on the communities' subjective opinions and evaluations. The ANLRI model is a top-down and hierarchical approach by experts to collect data of critical infrastructures, do interviews, and justify weights to create a resilience index that ranges from 0 (lowest resilience) to 100 (highest resilience). Nonetheless, how to determine adequate weights is an issue. The SVI model attempts to measure the susceptibility of a population to harm from a natural disaster, and examines the characteristics that influence their resilience. This model concentrates on measuring the inequalities and varieties of socio-economic status in disaster impacts. The BRIC model attempts to measure community resilience based on social, economic, institutional, infrastructural, ecological, and community components. To evaluate community resilience, the CDRI model uses four phases of a disaster management cycle (preparedness, response, recover, and mitigation) and the combination of these with a community's five capital assets (social, economic, physical, human, and natural resources) (The National Academy of Sciences, 2012). Both the BRIC and CDRI models need comprehensive datasets to evaluate resilience. They are both costly and time-consuming in data collection and analysis.

This research's NDDI model is a simplified and appropriate model based on the historic analysis of natural disaster damages in different countries. The NDDI model helps to identify a country's vulnerability and damage. The NDDI model is suitable to do international comparison. This study compares natural disasters in Taiwan to other counties in Asia, North America and Europe, including Japan, China, U.S.A., U.K., France, and the Netherlands. These countries are chosen because all of them have a large population, high economic growth, and frequent occurrence of natural disasters. The reported damages from the EM-DAT can be lower than reports from other organizations. For example, the United Nations report, The Global Assessment Report on Disaster Risk Reduction (2015), indicates that in 2012, EM-DAT reported economic losses of $157 billion, an estimate that is lower than those published by Swiss Re ($186 billion), Munich Re ($160 billion) and Aon ($200 billion). Nonetheless, the EM-DAT database has been adopted worldwide by international organizations, including the UNISDR.

4.2 Results

This research's results of country comparisons indicate that China and U.S.A. both had the highest number of natural disasters, with more than 20 disasters each year. The death toll of 4,934 persons each year in China is about 15 times that of U.S.A.'s 349 persons per year. The natural disaster occurrence of 108 in France is only one-fifth that of U.S.A.'s 677, but the French death toll of 21,563 persons is about 1.5 times that of U.S.A.'s 10,476 persons. In summary, China had the highest occurrence rate and death toll; the U.S.A. and Japan had the highest occurrence rate but a lower death toll; France had a lower occurrence rate but higher death toll; U.K. had the lowest occurrence rate and lowest death toll (see Table 4).

Table 4. Taiwan's natural disasters in comparison with Japan, China, U.S.A., U.K., France, and the Netherlands

Natural disasters in 1985-2014	Taiwan	Japan	China	U.S.A.	U.K.	France	Netherlands
Occurrence	70	158	658	677	74	108	30
Death toll	3,747	27,961	148,027	10,476	1,471	21,563	2,016
People affected	3,799,228	3,679,603	3,043,299,378	27,429,994	702,563	4,096,733	265,321
Economic damage (US$ in thousands)	20,457,390	422,299,400	409,943,750	715,208,660	32,731,180	38,657,200	4,530,700

Note. Original data collected from the EM-DAT and calculated by the author.

Different countries have different amounts of territory and population sizes. There is no surprise that the raw number killed by disasters in China, India, or U.S.A. would be on the top of the list. On the contrary, if the comparison of the percentage of population killed by disasters is used, then the small islands and less populated countries will always be ranked first (Peduzzi, 2009). Hence, in order to enable relevant comparisons among different countries, this research's NDDI model adjusts historic raw data to produce an adequate comparative study. The NDDI model attempts to analyze the disaster damage per square kilometer among different countries.

The results of the NDDI model indicate that Taiwan had the highest number both in occurrence rate and death toll among the seven examined countries in the past three decades (see Figure 2 and 3). The occurrence rate of the NDDI model during the past three decades in Taiwan is 0.002 per km² or 2 natural disasters within 1,000 km² land area. This is 5 times that of Japan's 0.0004, and 10 times that of France's 0.0002. The death toll of the NDDI model during the past three decades in Taiwan is 0.1 per km² or 100 deaths within 1,000 km² land area. This is 100 times that of U.S.A.'s 0.001, and is 10 times that of China's 0.01.

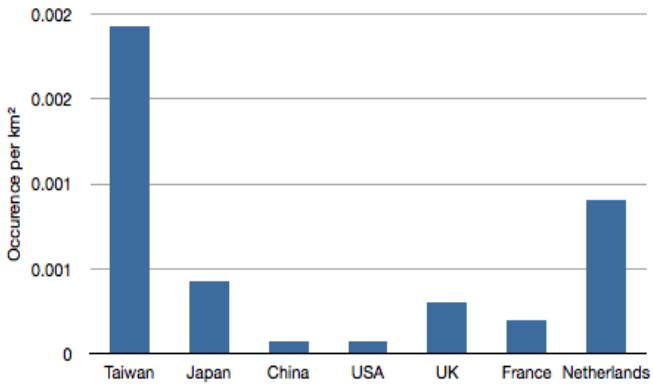

Figure 2. Natural disaster occurrence in the NDDI model in 1985-2014

Note. Author's drawing; original data from the EM-DAT.

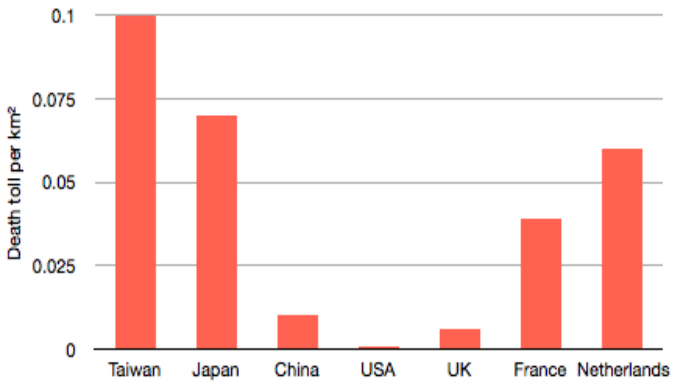

Figure 3. Death toll in the NDDI model in 1985-2014

Note. Author's drawing; original data from the EM-DAT.

China has the highest affected population density, 362 people affected per km² in 1985-2014. This is 3.5 times that of Taiwan's 104 affected people per km²; 36 times that of Japan's 10 affected people km²; and 100 times that of the UK and U.S.A.'s 3 affected people per km² (see Figure 4). In terms of economic loss from natural disasters, Japan has the highest density of economic losses in the NDDI model, $1.158 million losses per km² in 1985-2014 (see Figure 5). Taiwan's $0.65 million losses is about half of that in Japan. However, Taiwan's is 15 times that of China's $43,950 losses; 9 times that of France's $70,599; and 8 times that of U.S.A.'s $78,186 losses.

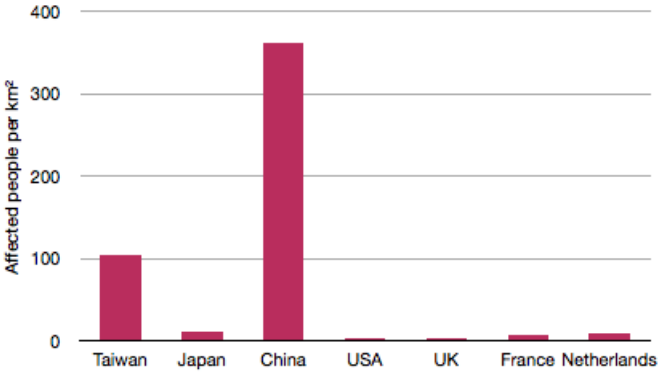

Figure 4. Affected people in the NDDI model in 1985-2014

Note. Author's drawing; original data from the EM-DAT.

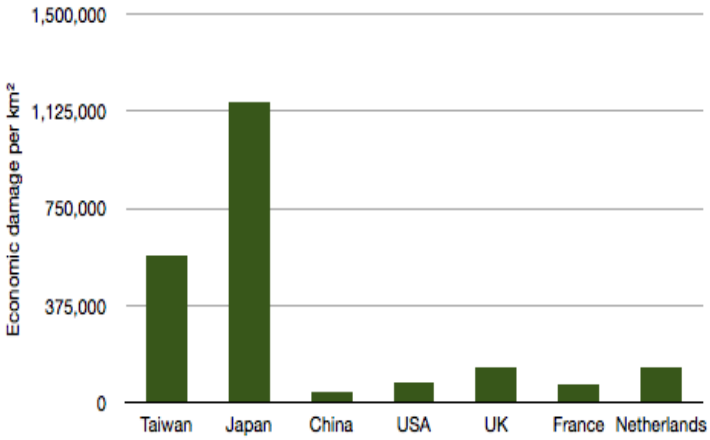

Figure 5. Economic damage (US Dollars) in the NDDI model in 1985-2014

Note. Author's drawing; original data from the EM-DAT.

In Europe, the Netherlands has the highest density of occurrence, death toll, and affected people. The U.K. has the highest density of economic losses. On the contrary, France has the lowest number of natural disasters and the lowest economic losses in the NDDI model in comparison to the Netherlands and U.K. France has less flooding damage, one destructive flood in Paris in 1910. However, according to OECD (2014) estimation, a Seine flood in the Ile-de-France region could affect 5 million people. The economic impact from such a catastrophe has been estimated up to $33 billion in damage, together with a significant reduction of 0.1 to 3% of total GDP (OECD, 2014).

In summary, in the NDDI model, China has the highest amount of affected people; Japan has the highest economic losses; Taiwan has the most frequent natural disasters and highest death toll. In Europe, the Netherlands has the most frequent natural disasters, highest death toll, and largest number of affected people, but the highest density of economic losses is in the U.K., presented in Table 5.

Table 5. An international comparison by the natural disaster density indicator (NDDI)

Natural disaster density indicator 1985-2014	Taiwan	Japan	China	U.S.A.	U.K.	France	Netherlands
Occurrence per km²	0.002	0.00043	0.00007	0.000074	0.000306	0.0002	0.0009
Death toll per km²	0.1	0.07	0.01	0.001	0.006	0.039	0.06
People affected per km²	104	10	362	3	3	7	8
Economic damage (US$) per km²	565,230	1,158,571	43,950	78,186	135,292	70,599	134,362

Note. Author's calculation; original data from the EM-DAT; land area of a country is based on the World Bank: Taiwan (36,193 km²), Japan (364,500 km²), China (9,327,489 km²), U.S.A. (9,147,420 km²), U.K. (241,930 km²), France (547,561 km²), Netherlands (33,720 km²).

5. Concluding Remarks

Asian countries have suffered from natural disasters for the past century. Asian nations in particular have experienced significant damage, accounting for approximately 70% of all disaster-related economic losses worldwide in 2011 (Munich RE, 2012). United Nations International Strategy for Disaster Reduction (2013) describes Asia as having weak policies and actions, inadequate risk information, insufficient budgets and poor implementation capacities. Taiwan is ranked as the country most exposed to multiple hazards (The World Bank, 2005). Storms and floods damage Taiwan frequently, with an average of six typhoons hitting Taiwan annually for the past four decades. Taiwan had the highest occurrence and highest death toll on the natural disaster density

indicator (NDDI) in comparison with China, Japan, U.S.A, U.K., France, and the Netherlands from 1985 to 2014. Also, Taiwan's economic losses during the past thirty years are estimated at $650, 000 per km². This is approximately 5 times that of the Netherlands' $134,362 and the U.K.'s $135,292, 8 times that of the U.S.A.'s $78,186 losses, and 9 times that of France's $70,599. Research finds that every dollar invested into disaster preparedness would save $4 to $7 dollars in post-disaster damages. Hence, promoting urban resilience policies for disaster risk reduction should become a priority in Taiwan and other Asian nations in the future.

Acknowledgments

This study is part of Yu-Shou Su's Ph.D. Dissertation in City and Regional Planning, University of Pennsylvania, U.S.A. A special thanks to Dr. Eugénie L. Birch for her professionalism, enthusiasm, and encouragement that have helped this research.

References

Birch, E. L., & Wachter, S. M. (Eds.). (2006). *Rebuilding Urban Places after Disaster: Lessons from Hurricane Katrina.* University of Pennsylvania Press.

EM-DAT. Retrieved from http://www.emdat.be/database

ICLEI-Local Governments for Sustainability. (2002). ICLEI's Resilient Communities and Cities (RC&C) initiative.

Kunz, M., Mühr, B., Kunz-Plapp, T., Daniell, J. E., Khazai, B., Wenzel, F., … Zschau, J. (2013). Investigation of Super Storm Sandy 2012 in a Multi-disciplinary Approach. *Natural Hazards and Earth System Science, 13*, 2579-2598. http://dx.doi.org/10.5194/nhess-13-2579-2013

Multihazard Mitigation Council. (2005). Natural Hazard Mitigation Saves: An Independent Study to Assess the Future Savings from Mitigation Activities. National Institute of Building Sciences, Washington, DC.

Munich RE. (2012). Review of natural catastrophes in 2011. Retrieved from http://www.munichre.com/site/corporate/get/documents_E1171980501/mr/assetpool.shared/Documents/0_Corporate%20Website/6_Media%20Relations/Press%20Releases/2012/2012_01_04_press_release_en.pdf

National Science and Technology Program for Hazards Mitigation (NAPHM) website. Retrieved from http://naphm.ncdr.nat.gov.tw/ (In Chinese)

OECD. (2007). OECD Territorial Reviews: Randstad Holland, Netherlands.

OECD. (2014). OECD Reviews of Risk Management Policies: Seine Basin, Ile-de-France, 2014 Resilience to Major Floods.

OECD. (2014). Water Governance in the Netherlands: Fit for the Future? *OECD Studies on Water*. OECD Publishing. http://dx.doi.org/10.1787/9789264102637-en

OECD. Poverty and Climate Change Reducing the Vulnerability of the Poor through Adaptation. Retrieved from http://www.oecd.org/env/cc/2502872.pdf

Peduzzi, P., Dao, H., Herold, C., & Mouton, F. (2009). Assessing global exposure and vulnerability towards natural hazards: the Disaster Risk Index. *Natural Hazards and Earth System Sciences, 9*, 1149-1159. http://dx.doi.org/10.5194/nhess-9-1149-2009

Regional Plan Association, America 2050. Retrieved from http://www.america2050.org/northeast.html

Regional Plan Association. (2015). Where to Reinforce, Where to Retreat? Draft for Fourth Regional Plan Roundtable. Retrieved from http://library.rpa.org/temp/files/4RP-Whitepaper-Where-to-Reinforce-Where-to-Retreat.pdf

Rodin, J. (2014). The Resilience Dividend. The Rockefeller Foundation, Published in the United States by Public Affairs.

Sarel, M. (1996). Growth in East Asia: What We Can and What We Cannot Infer. International Monetary Fund: Washington, D.C.

Su, Y.-S. (2015). *Rebuild, Retreat, Or Resilience: Can Taipei Plan For Resilience?* Ph.D. Dissertation in City and Regional Planning, University of Pennsylvania.

Swiss Re. (2014). Natural Catastrophes and Man-made Disasters in 2013: Large Losses from Floods and Hail; Haiyan Hits the Philippines. No 1/2014. Zurich.

Taiwan Central Weather Bureau (CWB)'s flooding maps. Retrieved from

http://photino.cwb.gov.tw/tyweb/tyfnweb/image/ty-flood/1962amy-r.jpg (In Chinese)

Taiwan Central Weather Bureau (CWB)'s Typhoon DataBase. Retrieved from http://rdc28.cwb.gov.tw/ (In Chinese)

Taiwan Construction and Planning Agency. Retrieved from http://www.cpami.gov.tw/chinese/ (In Chinese)

Taiwan Ministry of the Interior. Retrieved from http://www.moi.gov.tw/stat/ (In Chinese)

Taiwan National Development Council. (2014). Urban and Regional Development Statistics. Retrieved from http://www.ndc.gov.tw/encontent/m1.aspx?sNo=0001452#.VDW94SldXhp. (In Chinese)

Taiwan Water Resources Agency. Retrieved from http://www.wra.gov.tw/ (In Chinese)

The International Monetary Fund (IMF). Retrieved from http://www.imf.org/external/Datamapper/index.php

The National Academy of Sciences. (2012). *Disaster Resilience: A National Imperative.* Washington, D.C.: The National Academies Press.

The National Academy of Sciences. (2013). *Levees and the National Flood Insurance Program: Improving Policies and Practices*. Washington, D.C.: The National Academies Press.

The World Bank. (2001). *World Development Report 2000/2001: Attacking Poverty.* New York: Oxford University Press

The World Bank. (2005). Natural Disaster Hotspots: A Global Risk Analysis.

The World Bank. (2005). Natural Disaster Risk Management in the Philippines: Reducing Vulnerability.

The World Bank. (2009). Climate Resilient Cities A Primer on Reducing Vulnerabilities to Disasters: City Profiles Tokyo, Japan.

The World Bank. (2013). Building Urban Resilience: Principles, Tools, and Practice.

The World Bank. (2013). Turn Down Heat the Climate Extremes, Regional Impacts, and the Case for Resilience.

United Nations and The World Bank. (2010). Natural Hazards, UnNatural Disasters: The Economics of Effective Prevention.

United Nations Department of Economic and Social Affairs. (2013). The challenges of adapting to a warmer planet for urban growth and development. UN-DESA Policy Brief No. 25. Retrieved from http://www.un.org/esa/analysis/policybriefs/policybrief25.pdf

United Nations Development Programme (UNDP). (2012). Putting Resilience at the Heart of Development.

United Nations International Strategy for Disaster Reduction (UNISDR). (2013). The Hyogo Framework for Action in Asia and the Pacific 2011-2013.

United Nations International Strategy for Disaster Reduction (UNISDR). (2005). Hyogo Framework for Action 2005-2015: Building the Resilience of Nations and Communities to Disasters.

United Nations International Strategy for Disaster Reduction (UNISDR). (2013). Making Cities Resilient: Summary for Policymakers. United Nations.

United Nations International Strategy for Disaster Reduction (UNISDR) and World Meteorological Organization (WMO). (2012). UN System Task Team on the Post-2015 UN Development Agenda: Disaster Risk and Resilience. United Nations.

United Nations International Strategy for Disaster Reduction (UNISDR). (2013). Using Science for Disaster Risk Reduction.

United Nations International Strategy for Disaster Reduction (UNISDR). (2012). ANNUAL REPORT 2011.

United Nations International Strategy for Disaster Reduction (UNISDR). (2015). World Conference Adopts New International Framework for Disaster Risk Reduction after Marathon Negotiations, Press release 18 March 2015– UNISDR 2015/19.

United Nations Office for the Coordination of Humanitarian Affairs - Regional Office for Asia and the Pacific (OCHA ROAP) 2007. Retrieved from http://www.preventionweb.net/files/4201_OCHATWNHazardv1070706.pdf

United Nations. (2012). World Urbanization Prospects, the 2011 Revision: Highlights. United Nations Department of Economic and Social Affairs, Population Division, New York.

United Nations. (2012). World Urbanization Prospects: The 2011 Revision.

United Nations. (2013). The Global Assessment Report on Disaster Risk Reduction (GAR) 2013.

United Nations. (2013). Urbanization trends in Asia and the Pacific.

United Nations. (2014). Post-2015 framework for disaster risk reduction: Zero draft submitted by the co-Chairs of the Preparatory Committee. Third United Nations World Conference on Disaster Risk Reduction Preparatory Committee Second session, Geneva, 17-18 November 2014.

United Nations. (2014). Suggested elements for the post-2015 framework for disaster risk reduction. Third United Nations World Conference on Disaster Risk Reduction Preparatory Committee First session, Geneva, 14-15 July 2014.

United Nations. (2015). The Global Assessment Report on Disaster Risk Reduction (GAR) 2015.

United States Department of Agriculture. (1986). Urban Hydrology for Small Watersheds Technical Release 55 (TR-55). Retrieved from http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1044171.pdf

Vale, L. J., & Campanella, T. J. (2005). *The Resilient City: How Modern Cities Recover from Disaster*. Oxford University Press.

Wahlström, M. (2015). How can the world better prepare for natural disasters? World Economic Forum, Agenda. Retrieved from https://agenda.weforum.org/2015/03/how-can-the-world-better-prepare-for-natural-disasters/

Notes

Note 1. Taiwan has had successful economic development between the early 1960s and 1990s with high annual GDP growth rate in excess of 6% sustained over a 30-year period (Sarel 1996; IMF 1997). The GDP per capita has been increasing from $432 in 1970 to $21,141 in 2013 (IMF), and is expected to target above $30,000 in 2016.

Note 2. EM-DAT is under the Centre for Research on the Epidemiology of Disasters (CRED). EM-DAT was created with the initial support of the World Health Organization (WHO), United Nations Department of Humanitarian Affairs (UN-DHA), the Belgian Government, and United States Agency for International Development (USAID).

Note 3. According to the Regional Plan Association, the Northeast region is a powerhouse of economic output, producing 20% of the nation's GDP. Based on this, this region has approximately GDP of $3,232 billon in 2012.