Restoring and Improving Urban Infrastructure – A Grand Challenge for Civil Engineering

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Abstract

Civil Infrastructure systems are a part of the nation's economy, through expenditures, and are necessary to accommodate economic expansion and productivity, which implies that these systems must maintain the serviceability of the facilities in order to safely serve users, communities, and nations during their life-cycle. However, these structures deteriorate over time as a result of the variability inherent in the repetitive load conditions, the operating environment, the characteristics of the materials, the weather, etc. Urban areas in the world are continually expanding with the growth of urban populations as well as the industrialization in developing countries. According to a United Nations (UN) report, 3.5 billion people (50.5% of the world population) lived in urban areas in 2010. However, given the rapid increase in total urban population, most cities in the world are experiencing problems with urban infrastructure systems. Also, urban infrastructure systems are highly exposed to natural disasters. Furthermore, many cities in developing countries are suffering from lack of domestic or foreign investment for developing adequate basic infrastructure. As a result, residents in those cities are facing insufficient services with respect to clean drinking water, adequate wastewater treatment, electricity supply, education, and health care. Accordingly one of the grand challenges for civil engineering is to restore and improve urban infrastructure. This paper illustrates research needs and feasible solutions for addressing this grand challenge for civil engineering.

Keywords: *grand challenges, infrastructure management, disaster risk reduction, strategic risk mitigation*

1 Introduction

Urban areas in the world are continually expanding with the growth of urban populations as well as the industrialization in developing countries. According to a United Nations (UN) report, 3.5 billion people (50.5% of the world population) lived in urban areas in 2010 (UN, 2011). In particular, 84 percent of Americans have homes in densely populated urban areas (Glaeser, 2011). By 2050, the urban population is expected to be 6.3 billion, which is almost 70 percent of the expected world population (UN, 2011). Urban areas make significant contribution to the quality of human life and national economies (Wellman and Spiller, 2012). Investing in urban infrastructure systems is regarded as a source to stimulate the development of cities: for example, transportation networks (e.g., roads, bridges, and transits); drinking and waste water systems; power systems; public buildings (e.g., schools and hospitals); and parks and recreation areas (Moss, 1987). For example, reliable and efficient driving environment for freights can enhance delivery and service speed bringing economic benefits to the users, communities, and nations

However, given the rapid increase in total urban population, most cities in the world are experiencing problems with urban infrastructure systems. Cities in several developing countries are suffering from lack of domestic or foreign investment for developing adequate basic infrastructure. As a result, residents in those cities are facing insufficient services with respect to clean drinking water, adequate wastewater treatment, electricity supply, education and health care opportunities, and so on (Cohen, 2006). On the other hand, developed countries have more advanced but aging urban infrastructure systems. However, scarce funds for timely maintenance, repair, and rehabilitation (MR&R) not only endanger public safety but also prevent modernizing the fundamental structures (National Academy of Engineering (NAE), 2012). Since 1988 the American Society of Civil Engineers (ASCE) publishes a report card to grade America's infrastructure systems. The latest report card in 2009 highlighted that the condition of the nation's infrastructure systems have been getting worse from 'C (mediocre)' in 1988 to 'D (poor)' in 2009 (ASCE, 2009).

Urban infrastructure systems are also highly exposed to natural disasters, accidents, and terrorist attacks (NAE, 2012). In particular, increasing natural disasters (e.g., tropical storms, earthquakes, floods, etc.) accompanied by climate change becomes a big threat to residents and infrastructure systems in urban areas. For example, Hurricane Katrina in 2005 devastated the cities of New Orleans (Louisiana), Mobile (Alabama), and Gulfport (Mississippi) in the U.S., resulting in extensive loss of life, disruption to the oil and gas industry, power outages, and lack of drinking water (National Oceanic and Atmospheric Administration (NOAA), 2005; Knabb et al., 2011). Similarly, the 2008 Sichuan earthquake caused tragic loss of life with an estimated loss of about US $100 billion resulting from disastrous damage to the infrastructure in densely populated cities that were affected by the earthquake (Yuan, 2008; Liu-Zeng et al., 2009). Recent disaster-related research has focused on mitigating impact on infrastructure systems through pre-disaster planning and enhancing resilience of a community by improving the capacity of infrastructure systems (Tierney and Bruneau, 2007; Oh 2010).

The biggest concern with infrastructure systems in developed countries is not only to maintain the serviceability of infrastructure but also to modernize the fundamental structures by economically allocating limited funds. Furthermore, critical infrastructure systems such as transportation, utilities, housing, and public buildings in communities are exposed to formidable risks of damage by natural disasters that are only accentuated if they are also lacking in maintenance, repair, and rehabilitation. This problem is further enhanced in developing countries that not only lack in basic infrastructure but also availability of funds for improving the infrastructure systems. Therefore, restoring and improving urban infrastructure is clearly a grand challenge for the civil engineering community. This paper illustrates the issues surrounding this grand challenge and proposes feasible solutions for restoring and improving urban infrastructure in three specific categories: (1) efficient management of urban infrastructure; (2) enhancement of community resilience after natural disasters; and (3) infrastructure investment financing for developing countries.

2 Infrastructure Systems in Urban Areas

Civil Infrastructure systems are a part of the nation's economy, through expenditures, and are necessary to accommodate economic expansion and productivity, which implies that these systems must maintain the serviceability of the facilities in order to safely serve users, communities, and nations during their life-cycle (Goodman and Hastak, 2006). However, these structures deteriorate over time as a result of the variability inherent in the repetitive load conditions, the operating environment, the characteristics of the materials, the weather, etc. The European Union (EU) is facing infrastructure investment deficit of €4 trillion since 2007 (Urban Land Institute, 2011). According to the 2009 Report Card for America's Infrastructure (ASCE 2009), U.S. infrastructure in general is poorly maintained, unable to meet current and future demands, and is unsafe in many cases. The report estimated the current cost for repairs and needed upgrades at $2.2 trillion (based on a five-year need), which is an increase from the 2005 estimate of $1.6 trillion. This report offered five key solutions to improve the infrastructure condition:

(1) Increase federal leadership in infrastructure,
(2) Promote sustainability and resilience,
(3) Develop federal, regional, and state infrastructure plans,
(4) Address life-cycle costs and ongoing maintenance, and
(5) Increase and improve infrastructure investment from all stakeholders

Areas of importance that require research attention include water and waste water infrastructure, access to clean drinking water, air pollution, environmental remediation, sustainable solutions for infrastructure and energy needs, innovative materials, green design, innovative project management techniques and tools, cost effective management of urban infrastructure, as well as infrastructure vulnerabilities and resilience under disaster. Natural and man-made disasters impact civil infrastructure design, planning, construction, and maintenance. Systematic impact analysis is required within all areas of civil engineering to determine appropriate risk mitigation strategies. These are some of the areas that would define the research in Civil and Environmental Engineering in the coming years and would require interdisciplinary research efforts.

3 Efficient Management of Urban Infrastructure

Routine maintenance activities have limitations in terms of recovering better performance rate and extending the service life of infrastructure. Furthermore, the performance enhancement achieved from the maintenance activities is insufficient to sustain the infrastructure systems beyond a certain deterioration level (Wang 2005). Also, the selection of either rehabilitation or replacement to improve the serviceability of infrastructure systems, particularly replacing existing facilities in urban areas, is not always a feasible option due to the following reasons (Novick 1990):

i. It is difficult to acquire land for reconstruction in urban areas without the agreement of residents and commercial or industrial enterprises to move from their usual locations.
ii. Although land might be available, stakeholders might complain of any problem caused by the environmental impact, and consequently delay the replacement projects for many years
iii. Newly-replaced infrastructure systems might not be much useful to local demands compared to the old systems where local business activities have developed.

Effective rehabilitation can slow the deterioration process and possibly extend the service life, thereby reducing the social cost to the residents. Another issue that affects the extent of service life is rehabilitation interventions throughout the service life, which varies with respect to different rehabilitation frequencies (Wang 2005). The timing or frequency of rehabilitation procedures is the key to successful cost savings and extending service life. Such optimal rehabilitation strategies for infrastructure have been considered at the project level, the network level, or a combination of both over either single-year or multi-year plan. Current trends in both research and practice have focused on the development of optimal rehabilitation strategies: 1) at the combined level and 2) within an available budget over a multi-year program. However, those rehabilitation strategies continue to have limitations due to:

- Uncertainty to predict deterioration profiles of facilities
- No consideration of the deferred rehabilitation projects from previous fiscal years within multi-year plan
- Incompatibility of the purpose of a multiyear budget approach due to the inconsistent rehabilitation needs over the multiyear period

Therefore, it is important to develop a method that would provide more reliable as well as practical rehabilitation planning process by alleviating uncertainties and accommodating newly identified facilities.

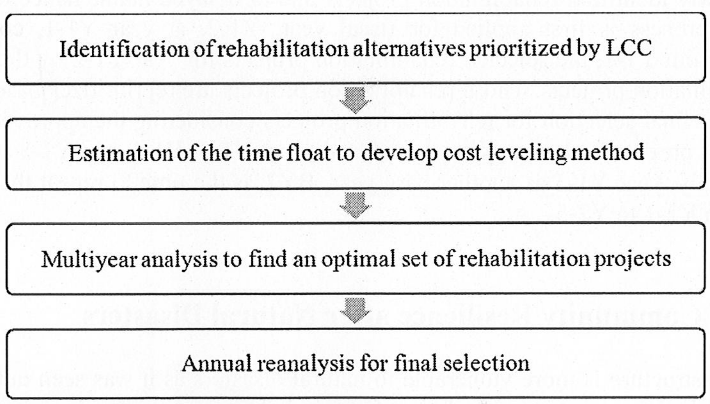


Figure 1 Optimal Rehabilitation Planning Model

Figure 1 shows four consecutive steps for the optimal rehabilitation planning model. The first step identifies the optimal rehabilitation strategy at the project level while the following steps are to select rehabilitation projects at the network level taking into account an available annual rehabilitation budget. Each step has an input and output that feed into the subsequent steps with additional information. For example, the first step identifies the general information such as structural features, information about the rehabilitation activities (e.g., cost and rehabilitation scope), deterioration rate, and trigger values to identify rehabilitation alternatives. Then, rehabilitation alternative, which has the minimal life-cycle cost during the service life, becomes an input to estimate the rehabilitation time floats. In this paper, the time float is defined as "the acceptable time frame within which a rehabilitation project can be accommodated to develop a leveled annual rehabilitation requirement cost over a multiyear analysis period" (Yoon, 2012). The second step is also responsible for developing a cost leveling method. The primary objective of the cost leveling model is to estimate the leveled rehabilitation cost, which is the flat "annual costs of rehabilitation projects" by shifting the rehabilitation projects within their allowable floats over the multiyear analysis period. As a result, public agencies can utilize the leveled rehabilitation cost as the annual rehabilitation cost that should be dedicated to the multiyear rehabilitation program.

The third step determines candidate rehabilitation projects at a target fiscal year at the network level. This step simulates the cost leveling model while maximizing the overall condition level of facilities at the network level over a multiyear rehabilitation planning period (e.g., 3-year, 5-year, etc.). Then, this step prioritizes the rehabilitation projects at the network level based on the prioritization scales as follows:

- Available time floats that are indicators for rehabilitation projects to be delayed
- Performance aspect that represents the physical condition of rehabilitation projects
- Economic aspect that shows the cost-effectiveness of rehabilitation projects
- Criticality aspect that estimate important level of rehabilitation projects for the national economic activities

The prioritized rehabilitation projects are selected considering available planned annual budget over a multiyear analysis period. The selection process of rehabilitation projects considers full and partial rehabilitation as well as transfer of residual amounts from previous years within a multiyear analysis period. In particular, applying full and partial rehabilitation is to accommodate more facilities that need rehabilitation so that public agencies can efficiently utilize the limited funds.

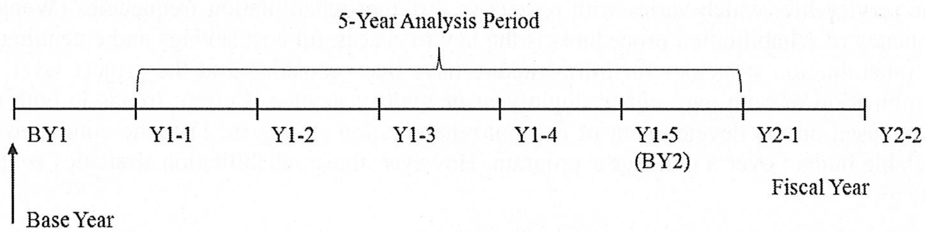


Figure 2 Multiyear Analysis

The last step is annual-based recursive process to finally determine rehabilitation projects to perform at next fiscal year. The main focus of this step is to reprioritize all rehabilitation projects for the next fiscal year. The candidate rehabilitation projects include the following categories: 1) rehabilitation projects selected by the third step, 2) delayed rehabilitation projects, which are not selected due the budgetary constraint, from the previous fiscal years, and 3) newly identified rehabilitation projects due to delayed maintenance or repair. For example, the annual reanalysis process is first applied for fiscal year, Y1-2, at year Y1-1, considering the delayed rehabilitation projects from Y1-1, the selected rehabilitation projects for year Y1-2 by the third process, and the newly-identified rehabilitation projects. Those rehabilitation projects are reprioritizes based on the prioritization scales, and one makes a final selection for rehabilitation projects considering the approved annual rehabilitation funds. Such a reanalysis process is also performed for fiscal years Y1-3, Y1-4, and Y1-5 at year Y1-2, Y1-3, and Y1-4 respectively. Finally, year Y1-5 as another base year, BY2, is the time to repeat the four steps for another 5-year fiscal years from Y2-1 to Y2-5.

4 Enhancement of Community Resilience after Natural Disasters

Poorly maintained infrastructure is more vulnerable to natural disasters as it was seen during Hurricane Katrina in 2005. The failure of the levee system around New Orleans led to massive flooding resulting in destruction of property and loss of life. Similarly, the 2010 Haiti earthquake extensively damaged the infrastructure and as a result the services provided by critical infrastructure were insufficient to support the recovery process. Furthermore, many of the important activities during recovery process such as debris removal, provision of medical aid, emergency services and provision of basic health services were without necessary infrastructure services delaying the recovery process considerably. As a result, even after 2 years the country is still struggling to recover from the impact of this disaster with more than 350,000 people still living in tents with unsanitary conditions and limited access to clean drinking water making them vulnerable to diseases like cholera due to inefficient waste management system (undertentshaiti 2012).

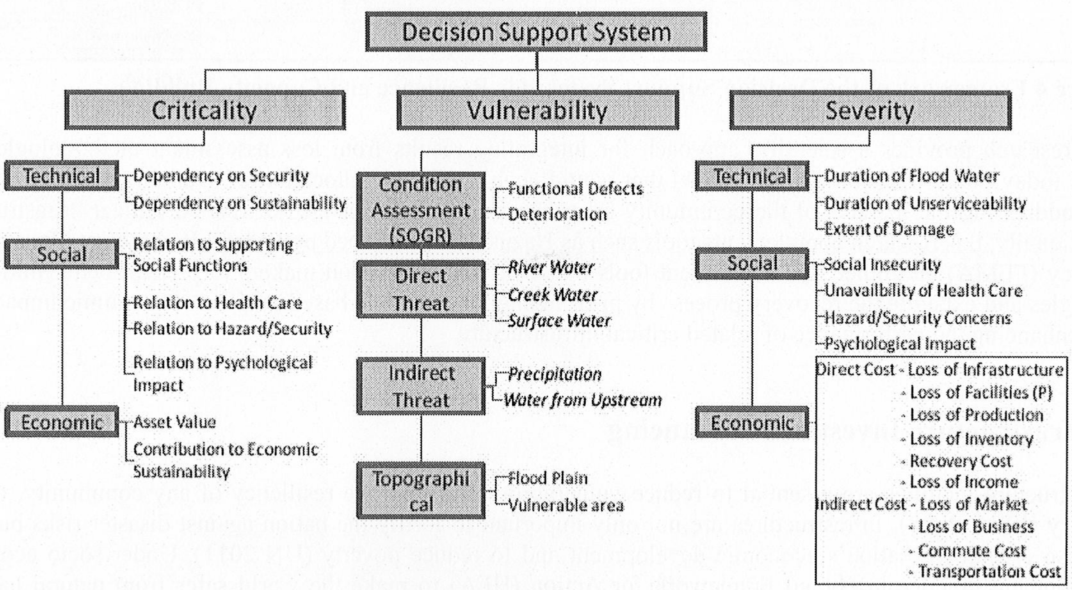
Recovery is aided by local resources such as manpower, machinery, medical relief and supplies etc., which help the community in getting back to the normal situation within the desired time. Absence of the vital resources further delayed the recovery process in Haiti. All these factors highlight the role played by infrastructure before, during and after the disasters. This section focuses on addressing the grand challenge of managing infrastructure in times of disasters under the hypothesis that:

(i) Identification and fortification of vulnerable critical infrastructure will help communities and industries prepare better against disasters
(ii) Community resilience can be enhanced by expediting post disaster recovery through capacity building and improving infrastructure serviceability.

Oh (2010) proposed a disaster impact mitigation support system (DIMSuS) for developing region and disaster specific mitigation strategies (Figure 3). The system is based on the inter relationship that exists between infrastructure and important activities of communities and industries and considers technical, social and economic aspects.

DIMSuS comprises of three assessment modules, i.e., criticality, vulnerability and severity that help measure the impact of natural hazards. In this research criticality has been defined as dependency of a community or an industry on a critical infrastructure in terms of their daily routine activities (Oh 2010). Vulnerability has been defined as threats or real hazards to infrastructure, industries or communities in disaster situations that can vary according to the conditions of infrastructure (Oh et al. 2012). Whereas, severity has been defined as the extent of impact on the communities and industries in terms of social and economic aspects due to the reduced serviceability level of infrastructure (Deshmukh, 2010; Deshmukh et al. 2011). Through this research, the methodology of disaster impact analysis and mitigation as well as the disaster-related preparedness of governmental and industrial agencies can be improved.

Identifying affected (or vulnerable) infrastructure against disasters will enable governmental and industrial organizations to better prepare, prevent, respond, and recover from potential natural disasters. The, public agencies, industries and communities can largely benefit by preparing better disaster mitigation strategies that would help speed up the recovery as well as provide an effective tool to handle the disaster-related resources.



Oh (2010) and Deshmukh et al. (2010)

Figure 3 Framework of the Decision support system DIMSuS

Besides, related parties can examine the conditions of the critical infrastructure to their own purposes before the occurrence of natural disasters and also improve the readiness of the main infrastructure facilities and services to such disasters. Another aspect of research in this field is focusing on capacity building and enhancing resilience of communities prone to natural disasters. This research will enable disaster response managers to build capacities required in each of the response phases, i.e., emergency, short term and long term for mitigating impact in the desired recovery time. Also, by improving infrastructure serviceability and building capacity with time will expedite recovery process that will enhance the resilience of community.

Based on the previous work of Oh (2010) and Deshmukh et al. (2010), this research aims to develop a decision making model to assist emergency managers and disaster response personnel for building capacity and enhancing resilience of a community prone to natural disasters. The decision making model will be based on the interrelationship existing between infrastructure, capacity (resources available) and important sustaining and recovery activities of the community. This decision making model will help to assess the capacity gap and infrastructure serviceability requirement to support recovery phase specific activities that will expedite post disaster recovery (Figure 4). Emergency managers and disaster response personnel will be able to identify the capacity gap as well as infrastructure serviceability requirements in each recovery phase. This will help in developing strategies and mitigation plans to expedite recovery after disasters.

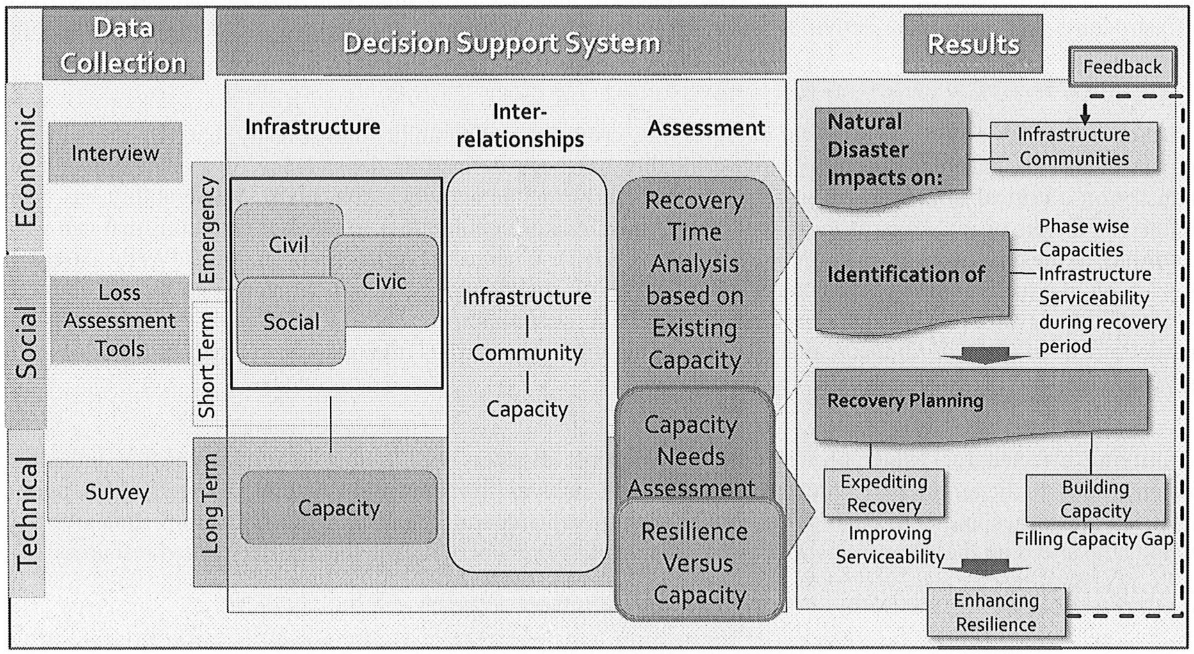


Figure 4 Framework of the Decision Support System for Resilience and Capacity Building

This research provides a scientific approach for integrating results from loss assessment methodologies that exists today into a decision making model that would enable effective allocation of available resources for not only addressing the impacts of the community by enhancing the performance of related critical infrastructure. Additionally, this research complements tools such as Hazus-MH developed by Federal Emergency Management Agency (FEMA) and other loss assessment tools that will enable decision makers to prepare better mitigation strategies and expedite the recovery process by prioritizing not only time based social and economic impacts but also enhancing the performance of related critical infrastructure.

5 Infrastructure Investment Financing

Infrastructure facilities are essential to reduce vulnerability and improve resiliency of any community, city or country (ISDR 2005). Infrastructures are not only important to fortify the nation against disaster risks but they are also crucial for nation's economic development and to reduce poverty (UN 2011). Under socio economic development practice in Hyogo Framework for Action (HFA) to make the world safer from natural hazards, emphasis is given to protecting and strengthening public infrastructure through proper design, retrofitting and re-building, in order to render them adequately resilient to hazards (ISDR 2005). While their need is well known to decision makers, they are still short supplied and in poor condition mainly in developing countries (Briceno-Garmendia et al- 2004). Substantial investments in construction and related spending on operations and maintenance (O&M) are required to improve the quality and provide access to most of the people. This scenario is even found in some of the developed countries like United States of America (USA). It is critical to reduce or nullify this finance gap in the current infrastructure system in both developing and developed countries, particularly in areas prone to natural disasters. Figure 5 below shows possible funding sources for a typical infrastructure project.

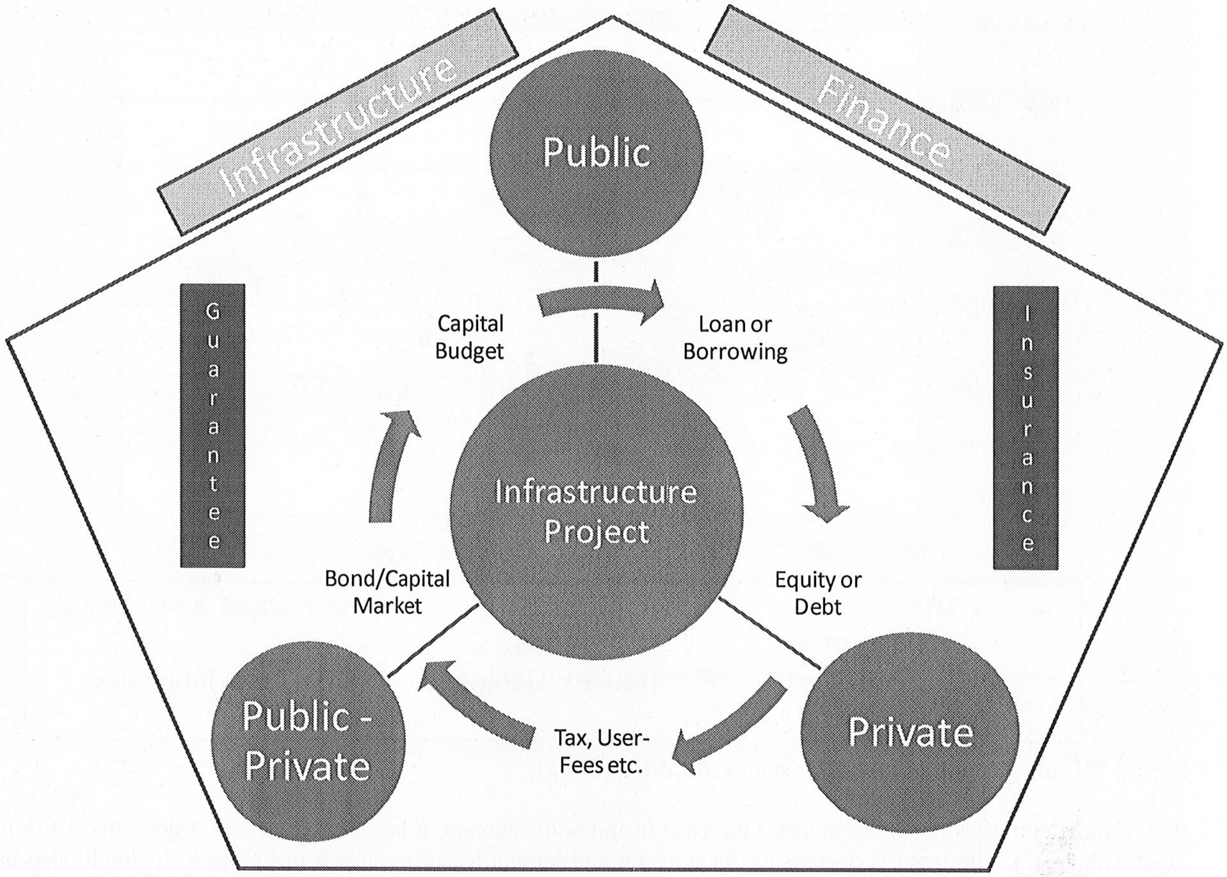


Figure 5. Entities and sources of infrastructure finance

Moreover, many nations have shown proactive approach in reducing their vulnerability to disaster risks by proper investments in infrastructure. For example, in the Asia and the Pacific region, the countries of the Republic of Korea and Japan have demonstrated the importance of investing in infrastructure in order to mitigate disaster risks. According to EM-DAT, the Office of U.S. Foreign Disaster Assistance/Centre for Research on the Epidemiology of Disasters (OFDA/CRED) International Disaster Database, Asia and the Pacific being world's most disaster prone region suffered about 91 percent of the deaths from natural disasters in the past century and accounted for 49 percent of the resulting economic damages (Figure 6). Moreover, natural disasters have caused an average of 41,000 deaths in the region in last 15 years with $29 billion worth of damages inflicted annually. Five of the 10 most severe natural disasters in the year of 2004 occurred in this region accounting for $55 billion of damages that is about 70 percent of total estimated damage of $80 billion.

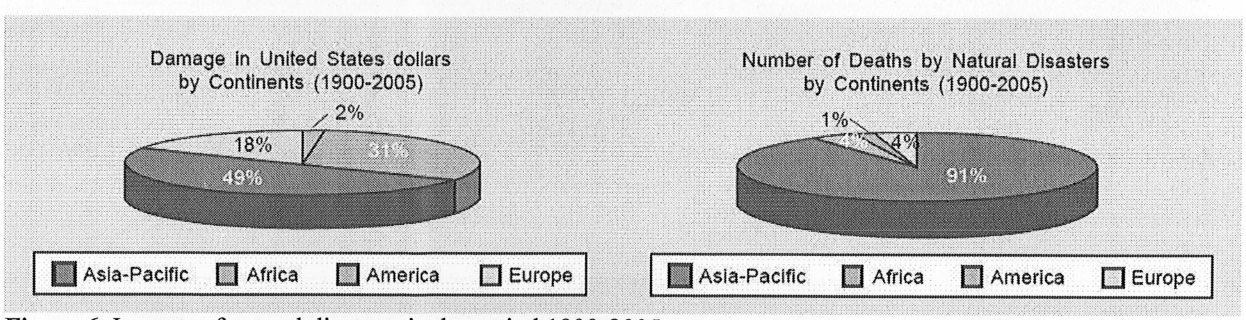


Figure 6. Impacts of natural disasters in the period 1900-2005

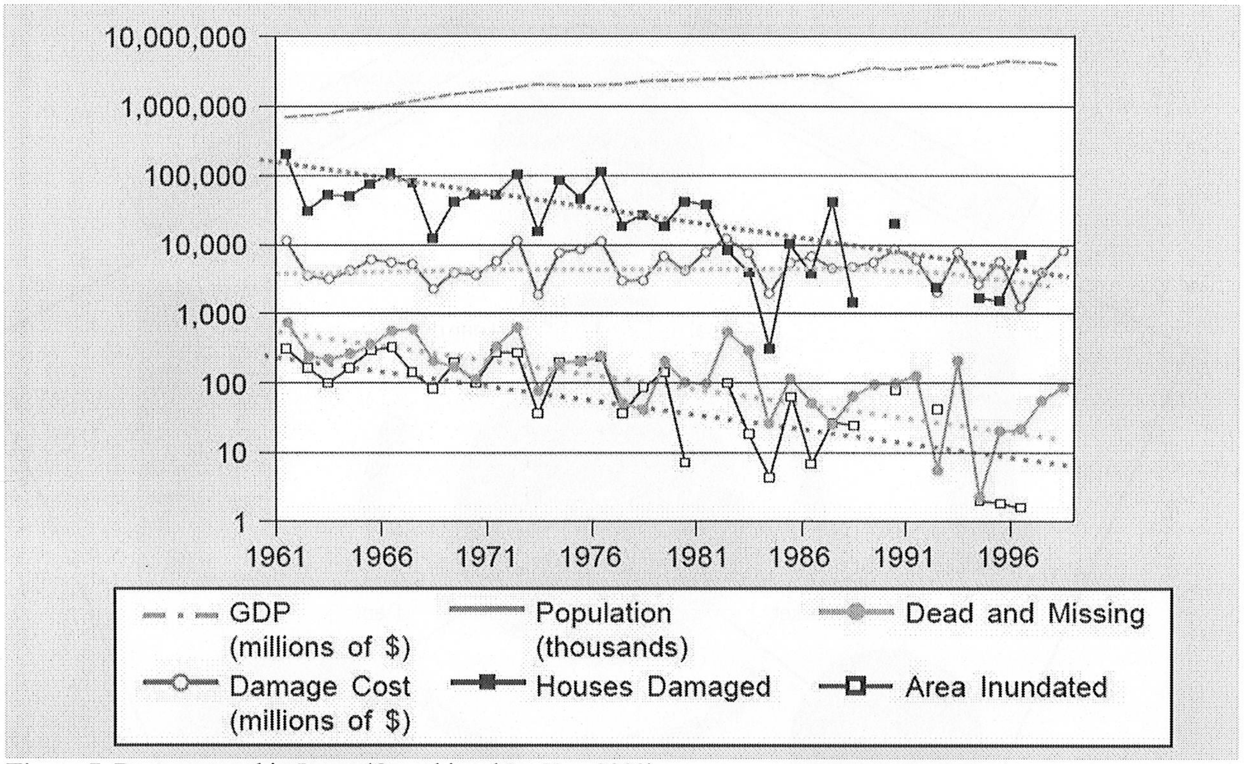


Figure 7. Damage trend in Japan (Omachi and Le-Huu 2003)

Where most countries have experienced increase in index of damage, it has decreased one order since 1961 in Japan (Figure 7). The trend is decreasing for housing and human losses as shown in Figure 8. It should also be noted that the economic damage caused in Japan has not decreased but its impact as a proportion to national impact has decreased. These could be the result of Japan's policy of investing about one percent of GDP on disaster countermeasures. These have led to a significant reduction in annual economic damage due to disasters (ESCAP 2006).

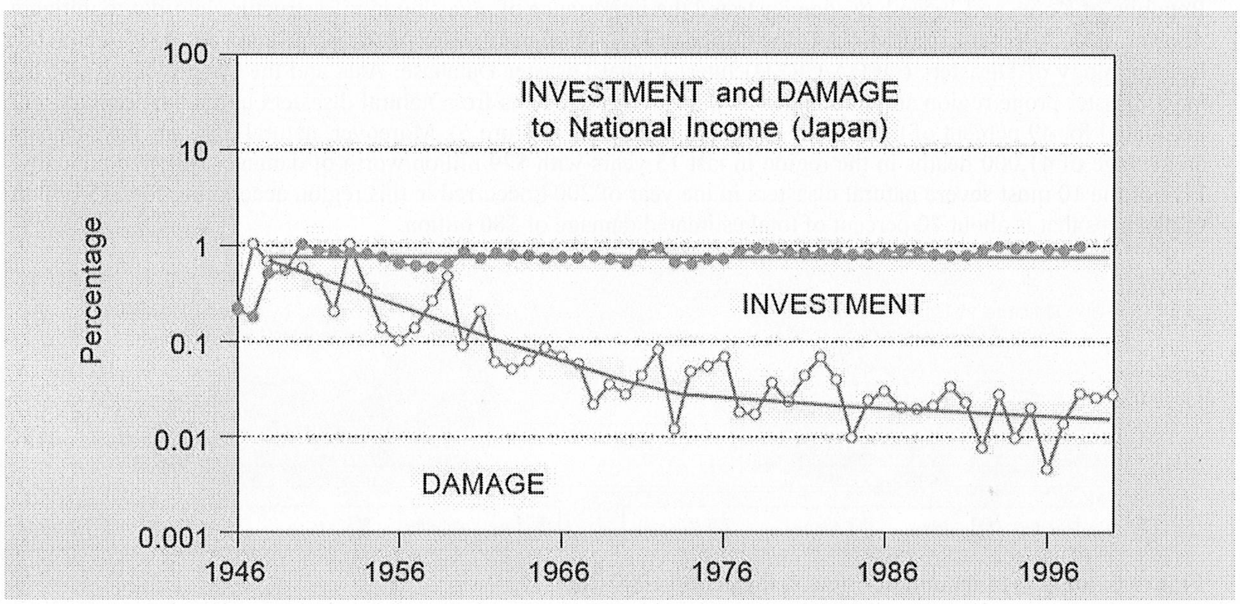


Figure 8. Trends of investment and damage in Japan (Omachi and Le-Huu 2003)

Thus, it is important to realize that making financial strategies to mitigate disaster risks is not the only step in comprehensive disaster risk management strategy. But it is also important to equally focus on other aspects of the strategy such as risk identification and reduction for improved preparedness (Ghesquiere and Mahul 2010). Development of critical infrastructure facilities is essential to improve resiliency, reduce vulnerability and build capacity to recover quickly after disasters. Also, these facilities not only protect citizens and their properties during disasters, and help in recovering faster post disaster, but also contribute to economic development before disaster. Effective disaster risk transfer mechanism and critical infrastructure development would definitely assist to reduce poverty level in low- and middle- income countries (Freeman 1999). While developing countries are facing impediments to raise funds for both disaster losses and infrastructure development, there is a need of a comprehensive strategy that provides them, multilateral agencies and investors an option that encapsulates risks from both these (disaster finance and critical infrastructure development) areas under one common roof so that country can cope with impacts of disasters, sustain certain disaster risks and ensure availability of infrastructure to citizens to boost economic growth in the region. This would benefit all involved parties as critical infrastructure would also reduce damages to their properties and thus disaster risks.

6 Conclusions

Infrastructure plays a major role in disaster risk reduction (DRR) and the economic development of a region. Therefore restoring and improving urban infrastructure is very important for a community. This grand challenge requires that proper emphasis is given in developing tools and techniques for (i) rehabilitating and restoring urban infrastructure, (ii) building infrastructure capacities to enhance resilience against natural disasters, and (iii) develop insurance based instruments that could provide funding necessary to restore and improve urban infrastructure to support a community's economic development and DRR strategies. This paper presented three research areas that could help improve the infrastructure condition under the categories mentioned above.

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Risk for Financial Agencies in Providing Affordable Disaster Insurance to Developing Countries

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ABSTRACT: Under socio economic development practice in Hyogo Framework for Action (HFA) to make the world safer from natural hazards, emphasis is given to protecting and strengthening public infrastructure through proper design, retrofitting and re-building, in order to render them adequately resilient to hazards. Infrastructure facilities are not only important to fortify the nation against disaster risks but they are also crucial for nation's economic development and poverty reduction. While their need is well known to decision makers, they are still short supplied and in poor condition mainly in developing countries. This has caused larger economic losses due to extreme events. This is a result of not only substandard infrastructure but also of increased population and low insurance penetration in the vulnerable urban areas. In order to hedge disaster risks to international capital markets, developing countries have adopted various approaches such as issuing catastrophe (CAT) bonds or creating a pool of funds that are supported by multi-lateral agencies such as the World Bank, Swiss Re, etc. These agencies are also providing risk transfer instruments for financial assistance in emergency situations. Due to restricted budget, most of the developing countries may ignore needs for proper disaster risk reduction and rather divert their funds for development projects. Thus there is a need for a mechanism that would make risk transfer instruments affordable for developing countries so that they do not have to compromise with their spending on development projects. This presentation would discuss the role that multilateral financial agencies could play in establishing such mechanisms through partnerships with governments. It would also discuss the change in their risk profile for financial agencies when they enter into such partnerships.

Keywords: Developing countries, disaster risks, insurance.

1. INTRODUCTION

The economic losses due to natural disaster events have accounted for billions of dollars in both developed and developing countries. While cost of damages has been significantly higher in developed countries, it is much larger as a proportion of GDP in developing countries. This higher cost of damages has interrupted governments' budgets in developing countries. In developed countries, financially well-equipped governments are able to quickly utilize reserve funds or create funds through budget reallocation for immediate post-disaster response and recovery activities. Moreover, well established private insurance market also support governments by covering large portion of losses (World Bank 2011). However, it is difficult for less developed economies to repurpose funds and it is always at the cost of certain other initiatives. Also, the penetration of insurance is comparatively meager in developing countries. This leads to the wide gap between total economic and insured losses that governments have to fill in.

Typically, governments have different options, as shown in Figure 1, which provide funds at different times after catastrophes. Governments require immediate funding for response/relief phase and later for recovery and reconstruction phases after disasters. While financially equipped developed nations ensure availability of funds for disaster response, developing countries mainly depend on humanitarian assistance and financial aid to act in response of events. Figure 1 shows resource requirements and availability of funds from different sources during three post-disaster phases- relief, recovery and reconstruction phases. It should be noted in the figure that, compared to post-disaster financing sources, required funds are processed faster and are made available soon after the event through ex-ante financing sources. It is important for decision makers from all countries to accommodate these requirements and facts while structuring nation's financial protection plan that suits to country's disaster risk portfolio.

To mitigate the risks of catastrophes on governments' budget and to accomplish immediate liquidity needs during emergency, ex-ante financing mechanisms have been exercised in many developing countries. The decision makers have realized importance of advance financial planning after estimating monetary requirements related to vulnerability to disasters (World Bank 2011). Governments, the insurers of last resort, with the support of many international banks and (re)insurance companies, have successfully provided insurance safety net to citizens and protected them against the unexpected losses due to disasters.

In a normal insurance risk transfer chain, people buy insurance and transfer their risks to insurance providers through contracts. Insurance companies retain some of these risks and transfer the rest to reinsurance companies. Whereas, the reinsurance companies transfer some of their risks to retrocessionaire, reinsurer of reinsurer. This horizontal chain is also called the traditional risk transfer chain as shown in Figure 2. Moreover, depending on the magnitude of expected losses, and sequence and level of attachment, insurer and reinsurer distribute risks and returns in specific horizontal or vertical layers (Banks 2005). As shown in Figure 3, in vertical layering, different reinsurer accepts risks of different loss layers. Whereas in horizontal layering, different reinsurers take up risks in the same risk layer. Third example in the figure shows how combination of vertical and horizontal layering can be used in risk layering structure.

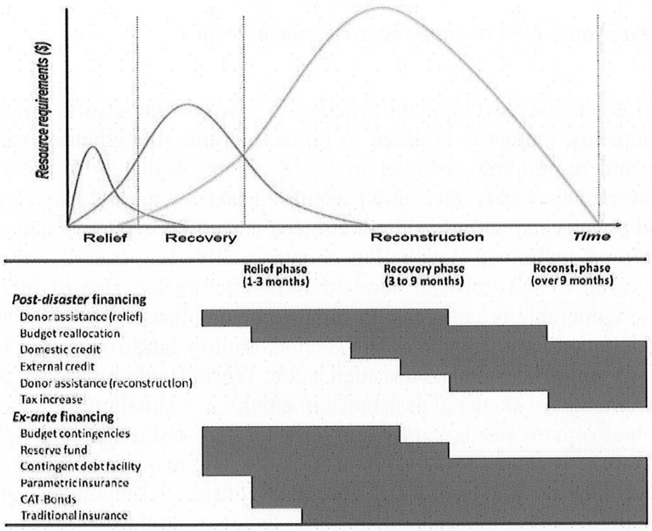

Figure 1. Timeline of resource requirements and availability of different funding sources during post-disaster phases (Ghesquiere and Mahul 2010)

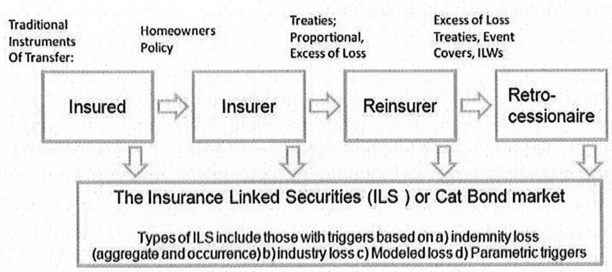

Figure 2. Traditional and new chain of risk transfer in the insurance and Insurance Linked Securities (ILS) markets (Lane 2008)

After hurricane Andrew, a vertical chain to transfer risk was included in the traditional risk transfer chain to hedge risks to capital market as shown in Figure 2. Industries in Florida lost around US$17 billion due to the hurricane Andrew which was more than twice the losses most insurer risk managers had predicted (Swiss Re 2011). It caused a destructive wave of loss claims through the horizontal risk transfer chain, exhausting capital of each party (insurers, reinsurers and retrocessionaires) and forcing several insurers to file bankruptcy. This largely affected the ability and willingness of these firms to provide same coverage after this event. This lead to the innovation of introducing securitization of insurance risks in the risk transfer chain. Its position strengthened in the 2005 hurricane season when hurricanes like Katrina, Rita, Wilma, Ophelia and Dennis contributed for US$80 billion in insured losses.

Insurance linked securities (ILS) provided essential link between global capital market and (re)insurance market. Being a global source of capacity, it helped (re)insurance industry to sustain in the high risk market while provided a diversifying asset for investors (Swiss Re 2011). CAT bonds are most common type of ILS whose coupon and principal payment depend on the non-occurrence of a predefined disaster event scenario. Developing country governments with the support of multilateral banks and reinsurance companies, have hedged their risks using CAT bonds. MultiCAT and CatMex bonds by Mexico government are examples of such type of ILS. A simple structure that incorporates collateralized capital to cover losses from a natural catastrophe is shown in Figure 4. There are three parties involved in the transaction: the ceding company (or sponsor), the special purpose vehicle (or issuer) and the investors (or buyers). Moreover, some other innovative concepts have been introduced in the ILS market to attract investors and build financial capacity. These concepts include overlapping bond coverage by United Services Automobile Association (USAA), the Cafeteria approach by Swiss Re, and multi-country risk pooling (Caribbean Catastrophe Risk Insurance Facility (CCRIF)).

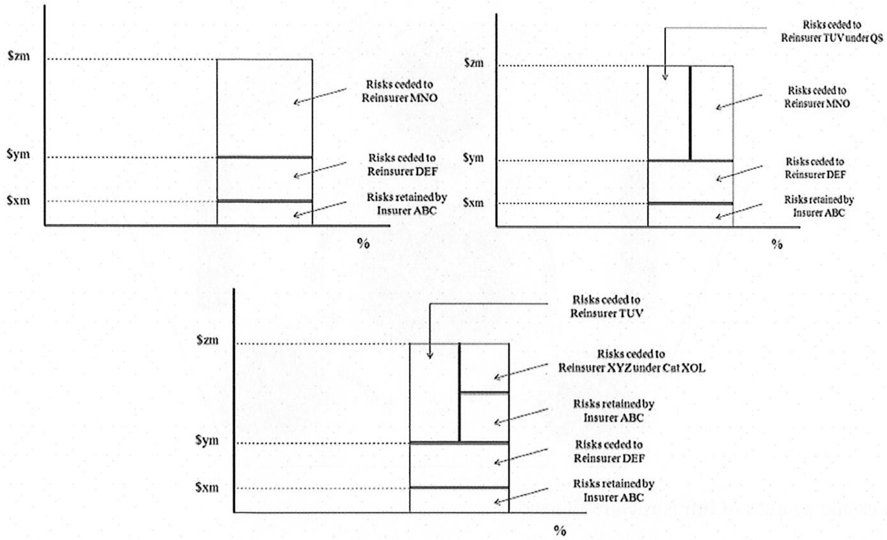

Figure 3. Vertical, horizontal, and combination of vertical and horizontal (re)insurance risk layering structures (Banks 2005)

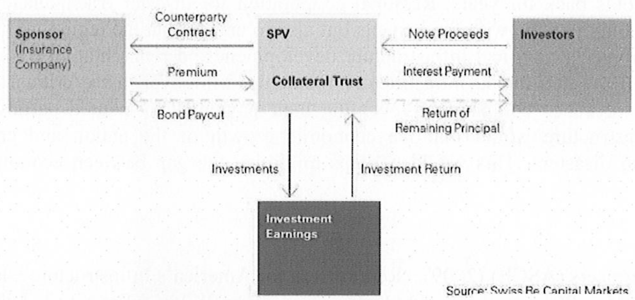

Figure 4. Collateralized capital structure for ILS (Swiss Re 2011)

As mentioned before, infrastructure facilities are essential to reduce vulnerability
or country (UNISDR 2005). Infrastructures are not only important to fortify th
crucial for nation's economic development and reduce poverty (UN 2011). While their need is well known to decision makers, they are still short supplied and in poor condition mainly in developing countries (Briceno-Garmendia et al- 2004). Substantial investments in construction and related spending on operations and maintenance (O&M) are required to improve the quality and provide access to most of the people. This scenario is even found in some of the developed countries like United States of America (USA). The American Society of Civil Engineers (ASCE) has given USA infrastructure a grade of "D" in the year 2009 and USA would require to make an investment of US$2.2 trillion between 2009 and 2014 to improve the condition (ASCE 2009). It is critical to reduce or nullify this finance gap in the current infrastructure system in both developing and developed countries, particularly in areas prone to natural disasters. Figure 5 below shows possible funding sources for a typical infrastructure project.

Moreover, many nations have shown proactive approach in reducing their vulnerability to disaster risks by proper investments in infrastructure. For example, in the Asia and the Pacific region, the countries of the Republic of Korea and Japan have demonstrated the importance of investing in infrastructure in order to mitigate disaster risks. According to EM-DAT, the OFDA/CRED[1] International Disaster Database, Asia and the Pacific being world's most disaster prone region suffered about 91 percent of the deaths from natural disasters in the past century and accounted for 49 percent of the resulting economic damages. Moreover, natural disasters have caused an average of 41,000 deaths in the region in last 15 years with $29 billion worth of damages inflicted annually. Five of the 10 most severe natural disasters in the year of 2004 occurred in this region accounting for $55 billion of damages that is about 70 percent of total estimated damage of $80 billion (Omachi and Le-Huu 2003).

[1] OFDA-Office of U.S. Foreign Disaster Assistance
CRED- *Centre for Research on the Epidemiology of Disasters*

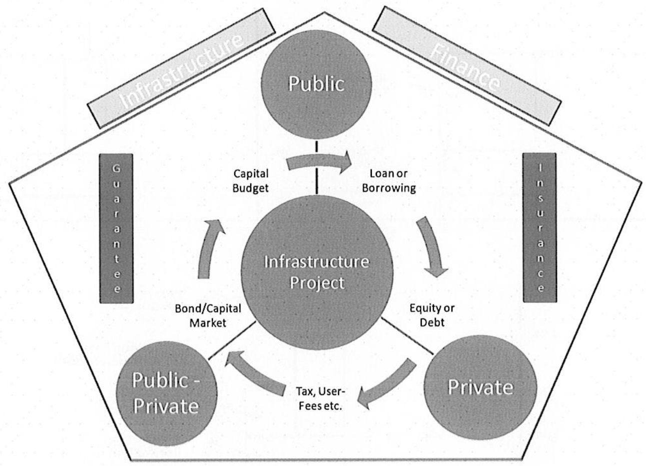

Figure 5. Entities and sources of infrastructure finance

2. ADDED VALUE TO INTEGRATIVE RISK MANAGEMENT

The impact of losses due to natural disasters is significant in developing nations. It would deprive these countries of essential resources which could otherwise be used for economic and social development. The severity of this shock is high enough to push the nations' developmental goals back for years. Regional cooperation for disaster risk management, including infrastructure development, is essential, not only to cope with the impacts but also to ensure that the region sustains its economic growth. This research is expected to contribute into critical infrastructure development and rehabilitation by exploring new sources to fund these projects. This would fill the gap in the infrastructure financing. Moreover, these critical infrastructure facilities would reduce the disaster risks for insurance companies, preventing their payments to insured parties and thus companies' losses. Development of critical infrastructure would improve economic growth of the nation and create an opportunity to build economic/financial capacity to disasters. This would perhaps minimize the gap between economic and insured losses due to disasters.

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