Understanding and Applying the Concept of Community Disaster Resilience: A capital-based approach

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Abstract: Despite the recent popularity and frequent use of the disaster resilience concept in the academic, research, and policy programs, there is a limited theoretical understanding of this concept. For instance, it is not clear how this concept should be operationalized and what its determinant factors are or how they can be measured. Although the recent literatures on hazard and disaster frequently refer to resilience concept as a guiding principle behind an effective hazard risk management, making it operational for policies raises critical challenges in terms of its assessment. This paper is an attempt to develop a conceptual and methodological framework for the analysis, measurement, and mapping of community disaster resilience. The paper specifically intends to archive three objectives. Firstly, it examines the general definitional issues of the concept of resilience with a focus on community disaster resilience. Secondly, it reviews the frameworks that are currently used to measure community resilience. Thirdly, it evaluates the existing methods that are used to develop resilience indices, and based on this review, a methodology on how to measure community disaster resilience is proposed. Finally, it summarizes the limitations and recommendations for further improvement of the methodology.

Key words: Community disaster resilience; Resilience index; Capital domains; Framework; Indicators

1 Introduction

The Indian Tsunami of 2004, Hurricanes Katrina and Rita in 2005, together with the worldwide evidence of global warming illustrate that communities and people are increasingly becoming more vulnerable to natural hazards. It is estimated that in the last ten years, disasters affected more than 3 billion people, killed over 750,000 people, and cost more than US$600 billion (Birkmann, 2006). This trend of loss of human lives and property damage suggests that our communities are not resilient enough to natural disasters. Over the past decade, many authors have underscored the need to accommodate the concept of resilience in research, policy, and disaster risk reduction arenas. And most recently, the concept of disaster resilience has gained a wide interest and has become more popular especially after the adoption of the *Hyogo Framework for Action 2005-2015: Building the resilience of nations and communities to disasters* (Manyena, 2006). Since the adoption of the Hyogo Framework, the main goal of hazard planning and disaster risk reduction has slightly shifted to focusing more on building community resilience rather than only reducing vulnerability. This paper is motivated partly by this current paradigm shift in the vulnerability assessment approach to what the author describes as the *resilience-based approach*.

Despite its popularity and frequent use, there is a limited theoretical understanding of the concept of disaster resilience. For instance, it is not clear how this concept should be assessed, measured, and/or mapped. It seems that making it operational for disaster risk reduction strategies and policies raises critical challenges. The main challenge, for example, is how to define and develop indicators that can adequately measure this concept or, how this concept should be mapped and what unit of analysis should be used. It appears that without a conceptual framework in which indicators can both be defined and measured, this concept will not be useful for disaster risk reduction strategies, nor will it sufficiently inform our disaster risk reduction policies. The main objective of this paper is to develop a conceptual framework

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that can be used to assess and map community disaster resilience, particularly in coastal areas where the risk of weather-related natural hazards is unprecedented.

The paper specifically intends to achieve three objectives. It first examines the general definitional issues of the concept of resilience with a focus on community disaster resilience. Secondly, it reviews the frameworks that are currently used to measure community resilience. Thirdly, it evaluates the existing methods that are used to develop resilience indices and based on this review, it proposes a methodology on how to measure the community disaster resilience. This paper is organized in five main sections; (1) definitional issues, (2) discussion on existing frameworks, (3) proposed framework and methodology, (4) mapping and unit of analysis, and (5) summary and recommendations.

2 Defining the concept of disaster resilience

The term resilience is often used in the same manner as the notion of “bouncing back” that reflects its Latin root *“resiliere”* which means “to jump back” (Klein et al., 2003; Paton & Johnston, 2006). There is an agreement in the literature that the concept of resilience originates from the field of ecology, three decades ago. Holling (1973) is frequently cited as probably the first to both use and define the concept of resilience in the field of ecology after publishing his article entitled “*Resilience and Stability of the Ecological Systems”*. Holling (1973) defined the term resilience for an ecosystem as the measure of the ability of an ecosystem to absorb changes and still persist. He also compared the concept of resilience with the notion of stability which he defined as the ability of a system to return to its equilibrium after a temporary disturbance. That is, the more rapidly the system returns to its equilibrium, the more stable it is. He concluded that resilience and stability are two important properties of an ecological system. Therefore, in this context, a system can be very resilient but still fluctuate greatly; that is low stability. Two decades later, Holling revisited his definition, and redefined the concept of resilience as a buffer capacity or the ability of a system to absorb perturbation, or the magnitude of the disturbance that can be absorbed before a system changes its structure by changing the variables (Holling et al., 1995). Since the work of Holling (1973), many ecological definitions of the concept of resilience have emerged. Table 1 summarizes some of the selected ecological related definitions of the resilience concept.

Table 1: Ecological definitions of resilience

Author	Definition
Holling ,1973	Resilience of an ecosystem is the measure of the ability of an ecosystem to absorb changes and still persist.
Pimm, 1984	Resilience is the speed with which a system returns to its original state following a perturbation.
Holling et al., 1995	It is a buffer capacity or ability of a system to absorb perturbation, or the magnitude of the disturbance that can be absorbed before a system changes its structure by changing the variables and processes that control behavior.
Alwang et al., 2001	Resilience is the ability to resist downwards pressures and to recover from a shock. From the ecological literature – property that allows a system to absorb and use and even benefit change .Where resilience is high; it requires a major disturbance to overcome the limits to qualitative change in a system and allow it to be transformed rapidly into another condition.
Walkers et al., 2002	Resilience is a potential of a system to remain in a particular configuration and to maintain its feedbacks and functions, and involves the ability of the system to reorganize following the disturbance driven change.
Cardona, 2003	The capacity of the damaged ecosystem or community to absorb negative impacts and recover from these.
Resilience Alliance, 2005	Ecosystem resilience is the capacity of an ecosystem to tolerate disturbance without collapsing into a qualitatively different state that is controlled by different set of processes. Thus, a resilient ecosystem can withstand shocks and rebuild itself when necessary. Resilience in social systems has the added capacity of humans to anticipate and plan for the future.

Generally speaking, all ecological definitions place emphasis on the amount of disturbance the system can absorb without a change in its state. It is also clear that they seem to focus more on stability and stress resistance to a disturbance and the speed of return to the equilibrium point. Although there are significant differences in terms of behavior and structures between social and ecological systems (Adger, 2000), the ecological theory on resilience concept can indeed be extended to social systems as a way of conceptualizing hazards and their consequences. This means that a resilient social system should be able to absorb shocks and rebuild so that the community remains on the same functioning state. The social system with high resilience should also be able to reconfigure itself without significant decline in the crucial functions in relation to primary productivity and economic prosperity (Foster, 2006; Pendall et al., 2007).

Since the publication of Holling's work (1973), the concept of resilience has increasingly gained recognition and acceptance and it is now frequently used in many fields, including hazard and disaster. The importance of the notion of resilience is especially growing as a concept for understanding and managing complex linked systems of people and nature (Klein et al., 2003; Walker et al., 2006). Timmerman (1981) is probably the first to use the concept of resilience in relation to hazard and disaster (Klein et al., 2003). Timmerman (1981) defined the term resilience as the measure of a system's or part of the system's capacity to absorb and recover from hazardous event (Klein, 2003). Following the work of Timmerman (1981), many definitions of the concept of resilience have emerged in the hazard and disaster fields. However, despite the many definitions, it appears that there is no consensus among researchers and practitioners on a common definition for this concept. Appendix 1 summarizes a few selected definitions of resilience concept published in the disaster and hazard literatures for the past two decades. As the list indicates, the definitions are diverse, reflecting the complex nature of the concept. McEntire et al. (2002) argue that one of the major challenges that limit the agreement on a common definition is due to the fact that individuals, groups, and communities may each possess different degrees of resilience which vary significantly over time. Hence, finding consensus or common ground on the definition of resilience concept is difficult.

For instance, most authors use the term *capacity/ability* to define the concept of disaster resilience and confine the concept to people, a group of people, a community, or a society. This generally means that, there is an agreement among researchers that the notion of disaster resilience should be associated with the capacity/ability of people, a group of people, a community or a society to cope with disasters. Worth noting also is the wide usage of the term *recovery* in the definitions. Most authors define the concept of disaster resilience in terms of the speed or how quickly people, a group of people, a community or a society can recover from the disaster impacts. From the definitions presented in Appendix 1, the following main conclusions can be drawn.

(1) Some authors adopt the ecological view of the concept of resilience and focus their definitions on a system perspective. That is, the functioning of the system and its self reorganizing capacity. According to Pendall et al. (2007), there are two types of factors of a system (internal and external) that tend to strengthen or stress it. Most of the definitions tend to focus on the internal factors that strengthen the system (Pendall et al., 2007). Additionally, the authors who adopt the ecological view tend to define the con-

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cept of disaster resilience as a process rather than an end or outcome. Generally, the notion of a system perspective is desirable in the sense that once the disaster happens, it facilitates and contributes to the community's recovery process (Klein et al., 2003).

(2) Some definitions tend to take *a long term perspective.* For example, most authors define disaster resilience as a long-term recovery process after a disaster. That is, resilience can be measured in terms of the time it takes to recover or come back to normalcy (equilibrium). A resilient community in this view would be the one that resumes its previous growth trajectory quickly. As Klein et al. (2003) notes, social systems are in continuous state of change. So the notion of bouncing back to original state (equilibrium) after disaster is undesirable as it would leave the system just as vulnerable as before.

(3) Some authors include *the notion of adaptation* in their definitions. When the notion of adaptation is featured in the definition of resilience, especially with respect to a system, it becomes more of a process oriented, which has important implications to policies (Manyena, 2006). This means that a social system can reorganize itself to maintain essential structure and process within a coping and/ or adaptation process. Thus the notion of adaptation is desirable because it increases capacity for learning and coping.

(4) Some authors link the concept of disaster resilience to *the concept of sustainability,* which refers to a long term survival at a non decreasing quality of life. The major feature of sustainability is that it highly depends on natural resources (Smith et al., 2001). The notion of suitability is then desirable because it facilitates more sustainable use of community resources.

(5) In some cases resilience is also understood as *the opposite of vulnerability.* This means that where social vulnerability is high the level of resilience tends to be low, and vice versa. As Klein et al. (2003) noted, the problem of defining resilience in this fashion is that it lends itself into the circular reasoning that a community is vulnerable because it is not resilient and it is not resilient because it is vulnerable. Conceptualizing resilience in this way may not be desirable because it does not add much to our understanding.

The abundance of definitions of disaster resilience and the fact that this concept is shared by many disciplines makes it difficult to have a common definition. Therefore, it is important to set a working definition that will form a basis for discussion in this paper. However, this does not mean that the definitions suggested in the literature are wrong. In this paper the concept of community disaster resilience is referred to as the capacity or ability of a community to anticipate, prepare for, respond to, and recover quickly from impacts of disaster. This means that it is not only the measure of how quickly the community can recover from the disaster impacts, but also the ability to learn, cope with or adapt to hazards. Thus, resilient communities should be organized in such a way that the effects of a disaster are minimal and the recovery process is quick. Figure 1 depicts the hypothetical trajectory of two communities; (1) a more resilient community (solid line), and (2) a less resilient community (doted line).

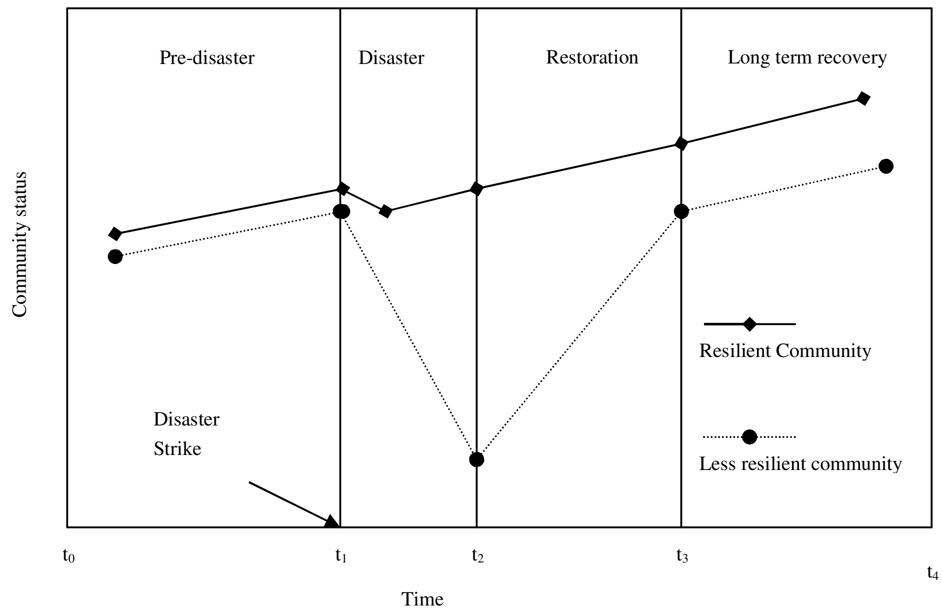

Figure1: A hypothetical trajectory of resilient and less resilient community (Modified from Zhang, 2006).

These two trajectories represent a sequential change of communities over time through four phases, pre-disaster, disaster, restoration, and long-term recovery. The diagram shows that the more resilient community will often experience less disaster impacts, while the less resilient community will experience significant disaster impacts and hence greater fluctuation. It is also clear that the less resilient community will take longer to recover to come back to normal functioning.

3 Frameworks for Analyzing Community Disaster Resilience

Assessing community resilience is a complex process because of the dynamic interactions of people, community, societies, and the environment. There are currently many conceptual frameworks proposed to measure this concept (e.g., Brown & Kulig, 1996-1997; Tobin, 1999; Adger, 2000; Buckle, 2006; Foster, 2006; and Tierney, 2006). Generally, most of these frameworks conceptualize disaster resilience in the same way, in which they all focus on similar factors that could reduce vulnerability and increase community resilience. Such factors include economic resources, assets and skills, information and knowledge, support and supportive networks, access to services, and shared community values. These frameworks seem to focus on what the author describes as a "*community capital*". However, the limitation of most of these frameworks is that they tend to only focus on some or one dimension of disaster resilience and do not adequately take the broader view of the concept. The next section discusses the proposed framework to assess community disaster resilience.

4 Proposed Capital-Based Approach

This paper proposes the use of the capital based approach as a framework to assess community disaster resilience. By building on the foundation laid out by others, this paper extends the social capital approach already suggested in the literature (see for instance Tierney, 2006) to include the five major forms of capital; *Social, Economic, Physical, Human,* and *Natural.* As the literature suggests, the notion of capital aligns very well with the concept of sustainability (Smith et al., 2001), which is related and often linked to the concept of disaster resilience (Mileti, 1999; Tobin, 1999; Brown & Kulig, 1996-1997). The essence of using the capital approach is that, capital consists of those components, which are necessary for development of a sustainable community economy. The conventional wisdom here is that the more the economic opportunities the community has, the more potential it possess for reducing disaster impacts; hence the more resilient the community becomes. The capital based approach is not new in the disaster and hazard fields. It has been widely applied in sustainable development and poverty alleviation programs (see for instance DFID, 1999). Figure 2 depicts the proposed conceptual framework on how the five major forms of capital can contribute to reducing vulnerability and increasing community disaster resilience.

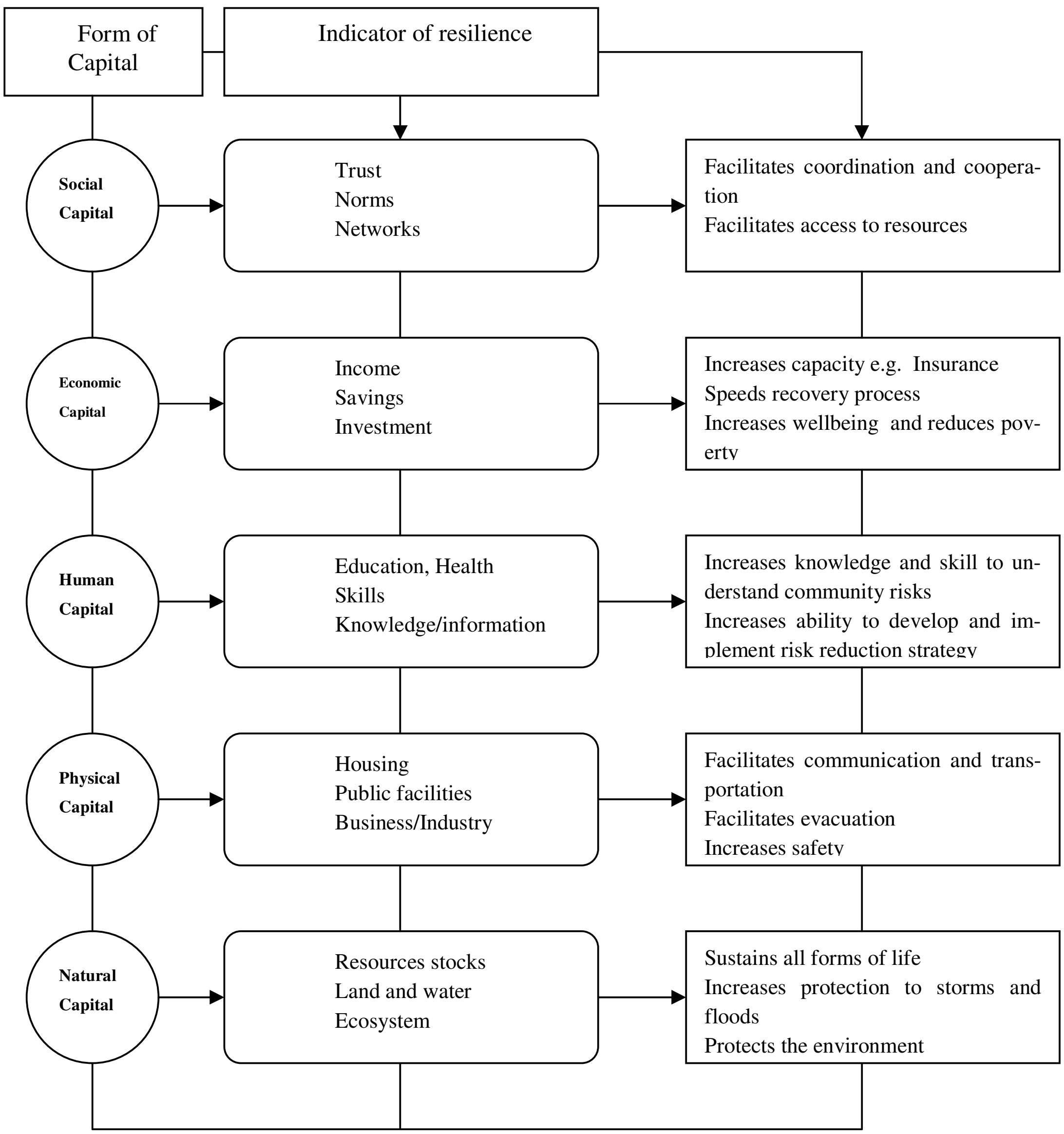

Figure 2: Conceptual framework on the relationship between capital domains and community disaster resilience

The major forms of capital particularly social capital have been recognized as important and useful concepts in hazard and disaster fields (see for example Dynes, 2002). Recent research suggests that the community development theory has demonstrated that success and sustainability depend on the ability of a community to appreciate, access, and utilize the major forms of capital (Beeton, 2006). However, capital as a concept has not been acknowledged, and taken as a central focus in understanding and assessing community disaster resilience. The following section defines and discusses the five major forms of capital and how they may reduce vulnerability and increase community resilience (refer also to figure 2).

(1) *Social capital*

Literature suggests that although social capital has been defined in a variety of ways, there is a common emphasis on the aspect of social structure, trust, norms, and social networks that facilitate collective action (Green & Haines, 2002). Putnam (1995) defines the concept of social capital as features of social organization such as networks, norms, and social trust that facilitate coordination and cooperation for mutual benefit. In the context of community resilience, it reflects the quantity and quality of social cooperation. For instance, community ties and networks are beneficial because they allow individuals to draw on the social resources in their communities and increase the likelihood that such communities will be able to adequately address their collective concerns (Green & Haines, 2002). Community networks can also provide an external resource that may facilitate the developmental process.The concept of social capital is important because it allows citizens to resolve collective problems more easily. The most resilient communities are those that work together toward a common goal (Davidson, 2006). The idea is that, in circumstances where characteristics of a strong community are missing, members of that community tend to have less capacity to cope with disasters. Social capital as a source of community cooperation and efficacy can be measured by the number of non-profit organizations, voluntary associations, religious organizations, voter participation and registration, newspaper readership, and sport and recreational clubs operating in the community. Social capital can thus be measured through the activities such as involvement in public affairs, public meetings, informal sociability and trust.

(2) *Economic capital*

Economic capital denotes financial resources that people use to achieve their livelihoods. It includes savings, income, investments, and credit. The contribution of economic capital to building community resilience is straightforward in the sense that it increases the ability and capacity of individuals, groups, and communities to absorb disaster impacts and speed up the recovery process. It can be used directly to reduce vulnerability, such as through buying insurance and retrofitting homes. Economic capital is an important determinant of community resilience. For example, the capability of a household to gain access to credit is associated with the level of household preparedness and ability to take protective measures. The more stable and growing economy will generally enhance resilience, while an unhealthy or declining economy is an indicator of increasing vulnerability (Buckle, 2001). Among other factors, economic capital can thus be measured through household income, property value, employment, and investments.

(3) *Physical capital*

Physical capital refers to the built environment, which comprises of residential housing, public buildings, business/industry, dams and levees, and shelters. It also includes lifelines such as electricity, water, telephone, and critical infrastructure such as hospitals, schools, fire and police stations, and nursing homes.

Physical capital is one of the most important resources in building capacity of the community to cope with disasters. For example, physical infrastructure such as roads, bridge, dams and levees as well as communication and transportation systems are essential for proper functioning of community, especially during evacuation time. Critical facilities are important to ensure that people have resources and support arrangement during emergencies. In general, lack of physical infrastructure or critical facilities may have direct negative impact on community capacity to cope with disasters. Physical capital can thus be measured by the number, quality, and location of housing units, business/industry, shelters, lifelines, and critical infrastructures.

(4)*Human capital*

Economists define the concept of human capital as the capabilities both innate and derived or accumulated, embodied in the working-age population that allow it to work productively with other forms of capital to sustain the economic production (Smith et al., 2001). More often the human capital is referred to education and includes knowledge and skills that are accumulated through forms of education attainment, training, and experience. Human capital also refers to the health of the working-age population. This means that unless healthy, the population can not be able to harness other forms of capital (Smith et al., 2002). It also applies to any other advantages people have, including disaster experiences, which give them the ability to cope with, adapt to, and recover from disasters. For instance, knowledge and skill of individuals on hazards, hazard history, and hazard risk in their community can be an important resource in building community resilience. Human capital is probably one of the most important determinants of resilience among other forms of capital. Having an adequate, skilled, and trained work force is a prerequisite for economic development and capacity building. This means that the more the human capital available in the community, the more the capacity for building resilience. Human capital can thus be measured through education attainment (e.g., years of schooling), health, population density, population growth, demographic characteristics (e.g., racial and ethnicity), access to transportation services, household characteristics, housing quality, and dependence ratio.

(5)*Natural capital*

The term natural capital refers to natural resources, such as water, minerals and oil, land which provides space on which to live and work, and the ecosystems that maintain clean water, air and a stable climate (Smith et al., 2001). Natural capital is essential in sustaining all forms of life including human life. However, human activities are often responsible for the depletion of the stock and quality of natural capital. The quality of water and land may be degraded through the disposal of wastes from the factories and consumption by households. Emissions of greenhouse gases from factories and cars can change the composition of the air and contribute to global warming. Therefore, recycling of non-renewable resources such as steel and plastics and renewing resources such as forests and fish stocks are essential for future production and hence community sustainability. In the context of disaster resilience, natural resources such as wetland and vegetation cover play an important role in protecting coastal areas from weather-related hazards such as hurricanes and floods. Natural capital can thus be measured through water quality, air quality, soil quality, wetland, forests, and national and local parks.

5 Proposed Community Disaster Resilience Index (CDRi)

Indices have been widely applied in many fields including hazard and disaster fields. They are often applied in poverty and deprivation, social capital, quality of life, human development, social vulnerability, and disaster preparedness (Simpson, 2006). An index is often composed of several different indicators combined using some mathematical formulae to give a single value called an index or rank (Simpson, 2006). Indices are powerful tools because of their ability to summarize more complicated technical data into a simpler way that non-experts can easily understand (Birkmann, 2006). The literature on poverty and deprivation has developed useful methods on how to develop indices, and ways to address problems associated with developing them. The approach and methodology proposed in this paper draws heavily from the poverty and deprivation literatures, particularly from the work of Noble et al. (2004; 2005; 2006).

5.1 Integrating Indicators within the Capital Domains

The capital approach is based on the idea of five major forms of capital though related each with its own contribution to the overall community disaster resilience. Each form of capital is therefore an independent domain that can be measured by a combination of different indicators. Although it seems that there are many methods in the literature that can be used to construct an index, the basic difference is in the summation of the components of the index (Briguglio, 2003). For instance, the indicators of resilience can be measured in different units such as dollars, miles, degrees, and hours. Therefore, a straightforward summation method can not be possible unless these units are normalized in some ways into one standardized unit. There are various methods which can be used to standardize or normalize the indicators to allow an addition or averaging to obtain a score or rank (Briguglio, 2003). A normalization method, which is commonly used, is the one which adjusts the observation to take a value from 0 to 1(Briguglio, 2003). After the normalization process is complete, the next step is to generate and combine the scores into an overall index. Again this is not a straightforward process because the degree of contribution of each indicator may vary depending on its relative importance as a measure to the underlying domain. A method to combine the indicators in such a way as to give more weight to the indicators which have more contribution is critically important. The literature provides a variety of methods that can be used to combine a set of indicators into a single measure. According to Noble et al. (2004; 2005; 2006), the three most frequently used methods in social science research are (1) combining indicators with weights determined from theory, (2) combining indicators with *pseudo empirically* derived weights, and (3) combining indicators with empirically derived weights.

The first method of combining indicators with weights determined from theory is based on the idea that it is possible to assign weights by making some judgment based on informed theoretical argument of the relationship between the various indicators and the concept to be measured. The indicators can then be combined using these weights and the calculated scores. The second method (combining indicators with pseudo empirically derived weights) is based on the idea that it should be possible to assign weights based on the empirical analysis. The third method (combining indicators with empirically derived weights) is

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based on the idea that there are mathematical techniques/methods for identifying weights of the indicators such as Factor Analysis.

However, the Factor Analysis method has often been criticized because of various problems associated with the accurate identification of such an underlying factor (Noble et al., 2004; 2005; 2006). Because of these limitations, this paper suggests that indicators should be combined based on weights determined from the theoretical considerations, and the robustness of the measure can then be examined using a statistical method such as confirmatory analysis based on Cronbach's alpha(Western et al., 2005). The following equation shows a proposed mathematical formula for combining indicators to generate individual indices for each form of capital. For instance, an index for a domain capital *"y"* can be calculated as;

$$y_i = \sum (X_1 w_1 + X_2 w_2 + X_3 w_3 + \dots\dots\dots\dots X_n w_n) \qquad \text{(Eq.1)}$$

Where y_i = Capital index

X = Indicator

w = Weight

n = Number of indicators or weight considered

i = indicator number

5.2 **Developing an overall Community Disaster Resilience Index (CDRi)**

After obtaining scores of each capital domain, these scores need to be transformed to allow cross comparisons among communities. This transformation is important because of the problem of "implicit weights" (Noble et al., 2004; 2005; 2006). When indicators or domains are combined to create an overall measure, some consideration has to be given to their relative importance or weights. These are called the "*explicit weights*". However, the problem of "*implicit weights*" occurs when variables with different distributions are combined into a single score. For instance, in a two variable index where each variable is given an explicitly equal weight of 1, each variable might, in practice, make quite different contributions to the overall score, even if the variables are standardized to a common unit (Noble et al., 2004; 2005; 2006). This is described as implicit weight problem that should be minimized in creating indices. The implicit weights are not desirable in combining indicators or domains because they may introduce unpredicted effects on the overall index such as a "*cancellation effect"*. A cancellation effect is where the high score of one domain of capital is cancelled out by the low score on another. So, it is important that cancellation effects among capital domains be minimized to a certain degree.

There are various methods suggested in the literature that can be used to address the problem of cancellation effect, such as the use of Z-score, untransformed ranks, and exponential transformation. However, it has been argued that Z-score and untransformed ranks methods do not adequately address the problem of cancellation effect (Noble et al., 2004; 2005; 2006). For instance, using the untransformed ranks for each capital domain would solve some problems but would introduce others. The symmetrical nature of ranks and Z-scores of normally distributed data means that a good score on one domain of capital could fully cancel out a bad score on another (Noble et al., 2004; 2005; 2006). For that reason the exponential transformation method is often preferred over the other methods (untransformed ranks and Z-score) because it controls for the effect of cancellation in the overall index. Most importantly, it enables one to determine the desired cancellation effect. This method could transform each capital domain so that they each have a common distribution, the same range, and identical minimum and maximum value so that when the different domains of capital are weighted and combined into an overall single index, the impact of the weight is much clear (Noble et al., 2004; 2005; 2006). For more detailed discussion on the transformation method see Noble et al. (2004; 2005; 2006). For example, the transformed capital domain *"y"* can be represented by the following expression (Noble et al., 2004; 2005; 2006).

$$y = -\theta * \log\{1 - R*[1 - \exp(-100/\theta)]\} \quad \text{(Eq.2)}$$

Where

log = Natural logarithm

exp = Exponential or antilog transformation

θ = Constant that determines the slope of the exponential

5.3 **Assigning Weights to Capital Domains**

How can one attach weights to each of the five major forms of capital? In other words, how can one determine which form of capital is more important than others? As briefly discussed below, there are at least five possible approaches that can be used to assign weights to different domains (Noble et al., 2004; 2005; 2006); *(1)Weights driven by theoretical considerations:* The rationale of the theoretical approach is based on the availability of research evidence on the theoretical model of a concept to be measured (in this case a community disaster resilience) and weights are selected which reflect this theory; *(2)Empirical approaches to weighting:* There are two empirical approaches that can be applied to assign weights; the use of survey to generate weights, and the use of a technique such as Factor Analysis; *(3)Weights determined by policy relevance:* This means that, score of individual domains can be weighted and combined in accordance with the focus of particular policy initiatives; *(4)Weights determined by consensus:* Policy makers and other stakeholders or experts can be interviewed for their views and the results examined for consensus and weights generated; and *(5)Weights that are entirely arbitrary:* Selecting equal weights in the absence of empirical evidence would come into this category. Weighting always takes place when elements are combined together. Thus, if the domains are summed together to create an overall index, this means that they are given equal weight. Therefore, it would be incorrect to assume that items can be combined without weighting (Noble et al., 2004; 2005; 2006).

The literature does not provide much discussion on the advantages and disadvantages of these methods thus suggesting that selection of any of these methods will depend on various factors and situations where the methods are applied. Therefore, there is no straight forward answer of the best method to use. This paper, however, agues that in some cases the combination of more than one method will be more desirable; for instance, the consensus and policy driven weights can be used in combination. The following equation is proposed for integrating the five major domains of capital to generate the overall community disaster index (CDRi).

$$CDR_i = \frac{\sum \left(w_1 SC_i + w_2 EC_i + w_3 HC_i + w_4 PC_i + w_5 NC_i \right)}{n} \quad \text{(Eq.3)}$$

Where

CDR_i = Overall community disaster resilience index

SC_i = Social capital index

EC_i =Economic capital index

HC_i =Human capital index

PC_i = Physical capital index

NC_i =Natural capital index

w = weight

n =Number of capital domains

i = Domain number

5.4 **Mapping and Unit of Analysis**

The capacity and ability of communities to cope with disasters may vary geographically. Therefore, it is important to map the geographical patterns of community resilience to identify the least resilient communities so that the limited resources are directed to those most in need. Spatial information (in terms of maps) is one of the most important decision support tools for planning and management. The generation of such useful maps will require the use of GIS-based technology.

Determining an appropriate unit of analysis for community disaster resilience is critically important but often tricky. This is because resilience can be measured at all levels such as individual, household, group, community, or society level. However, it has been argued that the unit of analysis should be chosen based on where local decisions are invested, that is where community mitigation measures and risk reduction strategies are directed. The unit of analysis can also be chosen based on the fact that such unit will provide both meaningful and adequate disaster resilience information that can influence policy and mitigation measures. For instance, in the United States, a county can be a useful unit of analysis because this is where much of the Federal Emergency Management Agency (FEMA) efforts on disaster mitigation measures are centered.

6 **Summary and Recommendations**

- Although there are many definitions of the concept of disaster resilience suggested in the literature, this concept is still too broad to be used as guidance for policy and disaster mitigation measures. To achieve this goal a more refined common definition is needed.

- It is also clear that the major forms of capital are very complex as they encompass many dimensions some of which can not be directly measured or are difficult to quantify.

- The weakness of most of the current frameworks suggested to measure disaster resilience is that, they tend to focus only on some of the dimensions/aspects of disaster resilience and do not adequately take the broader view of the concept. Thus, it is important that future research focus on the broader view of the concept and not only on a single dimension/aspect.

- The framework proposed in this paper has some potential for measuring disaster resilience as it covers most of the components of the concept in a broader view. Such components include social, economic, psychosocial, and environmental factors. The framework provides a good starting point for developing a more robust methodology to assess community disaster resilience.

- The major challenge of the proposed capital based approach is how to measure adequately each of the five forms of capital. This is because the framework is relatively broad and it is practically not possible to measure all the dimensions/indicators of each type of capital partly because of the limitation of data availability.

- The framework suggested in this paper should be considered as an entry point toward addressing the complex issues of disaster resilience. It generally highlights the key issues that need to be addressed in the future. Moreover, it also points to the direction where the efforts on developing a community disaster resilience index should focus.

- Although it is critically important that both indicators and capital domains be weighted; establishing weights and construction of indices in general are still methodologically very complex processes. Thus, more research is needed to establish much more sophisticated techniques that can address this challenge.

- Finally, it should also be noted that both the framework and the methodology proposed to assess community disaster resilience in this paper are still under development and thus subject to change.

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Appendix 1: Selected definition of disaster resilience[1]

Author	Definition
Timmerman, 1981	Resilience is the measure of a system's or part of the system's capacity to absorb and recover from occurrence of a hazardous event.
Wildavsky, 1988	Resilience is the capacity to cope with unanticipated dangers after they have become manifest, learning to bounce back.
Buckle, 1998	Resilience is the capacity that people or groups may possess to withstand or recover from the emergencies and which can stand as a counterbalance to vulnerability.
EMA, 1998	Resilience is a measure of how quickly a system recovers from failures.
Mileti, 1999	Local resiliency with regard to disasters means that a locale is able to withstand an extreme natural event without suffering devastating losses, damage, diminished productivity, or quality of life without a large amount of assistance from outside the community.
Kulig, 1999	Community resilience is the ability of a community to not only deal with adversity but in doing so reach a high level of functioning.
Comfort, 1999	The capacity to adapt existing resources and skills to new systems and operating conditions.
Adger,2000	Social resilience is the ability of groups or communities to cope with external stresses and disturbances as a result of social, political and environmental change.
Paton et al., 2000	Resilience describes an active process of self-righting, learned resourcefulness and growth — the ability to function psychologically at a level far greater than expected given the individual's capabilities and previous experiences.
Buckle et al., 2000	Quality of people, communities, agencies, and infrastructure that reduce vulnerability. Not just the absence of vulnerability rather the capacity to prevent or mitigate loss and then secondly, if damage does occur to maintain normal condition as far as possible, and thirdly to manage recovery from the impact.
Department of human services, 2000	The capacity of a group or organization to withstand loss or damage or to recover from the impact of an emergency or disaster. The higher the resilience, the less likely damage may be, and the faster and more effective recovery is likely to be.
Alwang et al., 2001	From the sociology literature, resilience is the ability to exploit opportunities and resist and recover from negative shocks.
Pelling, 2003	The ability of an actor to cope with or adapt to hazard stress.
UNISDR, 2005	The capacity of a system, community or society potentially exposed to hazards to adapt, by resisting or changing in order to reach and maintain an acceptable level of functioning and structure. This is determined by the degree to which the social system is capable of organizing itself to increase this capacity for learning from past disasters for better future protection and to improve risk reduction measures.
Paton & Johnston, 2006	Resilience is a measure of how well people and societies can adapt to a changed reality and capitalize on the new possibilities offered.
Plate, 2006	Resilience is the ability of a population to recover after an extreme event. The higher the resilience, the more a society is capable of recovery from disaster.
TISP, 2006	Disaster resilience refers to the capability to prevent or protect against significant multihazard threats and incidents, including terrorist attacks, and to expeditiously recover and reconstitute critical services with minimum damage to public safety and health, the economy, and national security.
Pendall et al., 2007	A person, society, ecosystem, or a city is resilient in the face of shock or stress when it returns to normal (i.e. equilibrium) rapidly afterward or at least does not easily get pushed into a new alternative equilibrium.
Foster, 2006	Regional resilience is the ability of a region to anticipate, prepare for, respond to and recover from a disturbance.

[1] Some of the definitions were adopted from the similar tables in Manyena (2006) and Birkmann (2006)