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The Utility of Structural Approaches for Spatially-Explicit Hazards and Vulnerability Research

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Since the decade of the 1980s, the rise of post-modern and poststructuralist approaches to social research have come to dominate academic thinking about human behavior. As a result of these perspective choices, contingency and agency at the scale of the individual have motivated the majority of research focused on individuals and small group interest and experience at the expense of "systems" and structures at the scale of cities, regions and larger geographical expanses of interest. This has resulted in a theoretical framework of perceptual relativism directed from the largest scale of the effects chain. This phenomenological-based research agenda has developed over the decades with a mixed blessing of perspective benefits but also theoretical and analytical deficits. The purpose of this editorial is not to provide criticism of the poststructuralist perspective but to offer a joint perspective through the mechanism of cross-scale analysis which can make effective use of structural approaches. This serves as a "not only …but also" scenario as suggested by Trevor Barnes for incorporating rigorous quantitative analysis with theoretical approaches not usually perceived as being intrinsically quantitative [1].

As hazards and human system vulnerability studies reach forward into the 21st century, there is an increasing need to extend understanding and analysis across scale of interaction [2,3] as these systems grow increasingly complex and sophisticated. Thirty years of post-structuralism have left theorizing in the social sciences impotent to create generalizable theories and build systematic knowledge that can readily inform policy. While the post-structural approaches have been extremely useful in expanding the stake-holder base and provide an appreciation of the needs of individuals and specific groups, they have only been successful at generating some middle-range theory that does not inform general theory. As such, these approaches have utility for informing specific geographically-limited policies at the scale of observation but are not useful for generalizing at scales covering large-area geographies [4-6]. We do not advocate a Merton versus Parsons type contradiction but rather a combined perspective that is adaptive across scales of analysis that permits the merging of specific observation of the agent decision process with a scale-aggregative framework that is conditioned on scale-dependent structures which may constrain the action and decision sets of groups of actors [3]. This dual approach is particularly useful at the national-level of planning across a variety of hazards and group or site vulnerabilities. This approach can also lend itself much more effectively to analytical approaches that provide quantitative analysis that generates numerical assessments useful in the formulation of government and NGO policies [7].

A mixed methods approach that permits structurally-based hypotheses and employs quantitative, analytical methods for analysis at regional and aggregate scales together with local-scale hypotheses specifying agency characteristics and decision outcomes employing qualitative methods may provide a more complete multi-scale, hierarchical approach to vulnerability analysis and the assessment of community resilience. While most assessments do not consider cross scale indicators when attempting to conduct analysis, they also do not consider the impact of merely aggregating individual scale indicators to the community and beyond for the purpose of delineating vulnerability and resilience.

Structure should provide the framing perspective when the focus of analysis is at the scale of cities or larger. Cities as agents exhibit decision sets that are highly contingent on their infrastructure arrangements, economies, transaction costs, etc. which can be much better modeled and explained in structural context. Groups and individuals, also influenced by structure as constraints on their decision sets, can be represented through a variety of means including systems of representation, stakeholder interests, group valuation frameworks and the context of experience and political perspective – encapsulated in the post-structuralist perspective using qualitative analysis.

Over the course of the last thirty years social science has gradually moved away from grand theorizing in favor of creating middle-range theories that are tractable and coherent with regards to empirical observation [8]. Granted that much of the general theorizing of the past fifty years has been a contest of sorts between functionalism, structuralism and post-structuralism, the activity has produced few good "working" general theories as opposed to perspectives with a few rare exceptions. Nevertheless, this does not mean that social science or, hazards research, should abandon the practice of creating general theories particularly as these frameworks may permit new researchers to generalize across geographies and landscapes in an attempt to isolate a smaller set of behaviors and responses and identify adaptive efficiencies that may otherwise not be deduced. In addition, such frameworks can further the use of quantitative perspectives that are so important for informing policies that may enhance human survivability. This practice may become acutely critical in this century owing to the number and complexity of environmental issues, many of which are human-induced and are tied to systems and structures created by human agency. We do not now have in place a general theoretical framework with which to examine such complex and threatening problems. Only the world-systems perspective stands out as a possible avenue for further general theory-building across scales [9]. The coupled human and natural systems (CHANS) approach can be made structural but in most cases is treated as an agent interaction framework with contingency using simulation methods such as agent-based models [10]. However, agent-based simulation, with very few exceptions, is not inductive analysis.

There are different types of structural approaches that can be considered in vulnerability analysis and resilience assessment all of which may be useful in hazards research. There are purely economic approaches that assume structural frameworks such as market-area analysis and cost-benefit analysis. Marxist and world-systems

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approaches provide frameworks that permit the analysis of political-economic impacts and also provide a hierarchical framework for cross-scale integration of human processes. Regional and state-level governance and intergovernmental approaches may also be employed [11]. Structuration has a comprehensive framework that allows examination of individual and group behavior decisions in a larger, potentially spatially-explicit, political and economic structure without presuming specific types or levels of rationality for the agents [4,5]. Structuration coupled with a world-systems approach may provide an effective and complimentary framework for cross-scale structure-agency analysis as both are spatially-explicit and inherently multi-scalar in perspective. In addition, the two perspectives can be complimentary and afford a level of conceptual interoperability needed for the explicit modeling of structure and agency across scales in spatially-explicit context [5,12]. We exhort hazards researchers to explore new possibilities and combinations that may result in more fruitful analytical and theoretical development potentially giving rise to a fluorescence of hazards research. This is not an undertaking for the faint-hearted as high standards will be necessary for rigor and execution.

Structure, as a process, is deterministic in several mechanisms and effects of hazards research. Structure is present in sensitivity and vulnerability but also in the potential for adaptation and adaptive capacity and mitigation [12,13]. Therefore, to produce the most accurate assessments it is required to evaluate the impact of structure as well as the contingency of agents given the components and types of structure. Similarly, the selection of the scale of the components of structure is critical to accurate vulnerability and adaptive capacity assessment [14]. The critical question then becomes: how do we articulate perspectives and capture the resulting structural and agency components for the integration of the components across scales?

Researchers in hazards disciplines often incorporate structure through data without even realizing the influence on analytical outcomes [15]. A common example is the use of census data that exhibits an explicit spatial organizing principle of sample unit homogeneity. Census sample units are usually hierarchically arranged permitting aggregation from smaller to larger areas. This structural organization can be useful for incorporating local-area qualitative results into larger area urban and regional scale analyses. However, one must be cautious when interpreting scale-dependent results across several scales of observation or aggregation [14].

Structural and structuration approaches can be made rigorous in a variety of ways that also permit the inclusion of results from qualitative studies. Structuration does not rely solely on the perceptions of any particular agent or any level of structure but on the social practices and adaptive responses that are organized across time and space [4,5]. Structuration can thus provide a framework to examine a wide variety of social, economic and political practices useful for vulnerability and community resilience assessments particularly when crossing scales. One potential example is the use of the space-time activity prism developed by Hagerstrand [16] for the analysis of individual travel decisions also employed by Giddens [4] in his delineation of structuration and by Lefebvre in the social creation of space by Harvey [5] in his delineation of spatial practices which, is scale-dependent. The explicit use of space requires the estimation of spatial dependence on spatially-varying outcomes because space fundamentally changes the statistical expectations of the observations – different configurations of space can produce different statistical expectations [17]. This is true with all spatial analysis and vulnerability and resilience assessments are no different. Statistically, the measure of observed dependence produced by a spatial configuration is spatial autocovariance or spatial autocorrelation in standardized form. A variety of measures exist to estimate this configuration effect on observed process (e.g., Moran's I, Geary c, LISA, Geti-Ord statistics, etc. [17,18]. Unfortunately, there are only limited examples, most notably the SERV or Spatially Explicit Resilience and Vulnerability model [3], where spatial dependence of indicators has been applied to vulnerability and/or resilience assessment models. Different structures imposed on a set of observations can similarly produce different results. While inclusion of space can significantly improve assessment and prediction through the computation of spatially-contingent measures, it can also greatly complicate the analysis procedures and make interpretation more difficult for the hazards researcher.

While a structuration approach requires explicit documentation of the role of space and time in the development of human processes and measurement of the effects of these contexts becomes imperative, it is also required to incorporate the effects of time and space on observed data into any models that are used to capture pure structural impacts or structure and agency. Such models become very complex very quickly and transcend simple estimation approaches such as ordinary least squares [17,19]. A variety of single-scale models exist that permit the spatially-explicit testing of structural effects on vulnerability and resilience such as simultaneous autoregressive models (SAR), conditional auto-regressive models (CAR) as well as space-time auto-regressive (STAR) but these models to readily incorporate cross-scale effects. These models also make strong assumptions regarding the stochastic stability of the mean and variance of the observations [17]. Geographically weighted regression (GWR) permits a relaxation of this requirement but does not necessarily aid in the cross-scale problem [20].

Markov random fields can greatly enhance structure capture for studies with sparse information fields as they permit spatial structure to be explicitly modeled from the local dependence arrangement [21]. New types of models that are designed to capture cross-scale structural and qualitative effects must be employed to make full use of the mixed analysis we have suggested. Models such as Bayesian hierarchical models based on Markov random field dyadic structures with cross-scale dependencies can readily capture cross-scale integration of observed phenomenon [18,19]. Models such as these provide great promise for cross-scale structure-agency interaction [22].

- For hazards research to expand and flourish new theoretical approaches are needed in addition to new methodologies that are commensurate with the theoretical frameworks. We argue that explicitly spatial, multi-scale approaches using hybrid theoretical frameworks are most promising. These frameworks will incorporate both phenomenological and structural approaches to provide a more complete delineation of impacts, vulnerabilities and resilience assessments. Deeper consideration of theoretical perspectives and the impact of these perspectives on the use of more sophisticated mixed and integrative methodologies is the recommended path forward for hazards research.

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