Alternative GIS-Based Methodologies for Environmental Exposure Assessment.

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The application of GISs--and spatial methodologies in general--in order to better understand a given population's exposure to technological hazards has increased rapidly over the past decade. One can point to a plethora of studies that have applied GISs to these human-produced hazards at a variety of scales and resolutions, and have applied significantly different spatial methodologies. Unfortunately, the effects of scale, resolution, and methodology are poorly understood. This multiyear project is attempting to unravel some of these vexing problems. Specifically, this paper reports on our research in developing improved GIS-based spatial methodologies for risk assessment.

Geographical Methodology.

Whereas most studies use relatively simple measures for establishing the relationship between hazardous materials and at-risk populations, it is clear that more robust methodologies are needed. For instance, relationships are often based on simplistic measures of proximity--hazardous materials sites falling within a block group with a high percentage of minorities--which can not deal with differential toxicity, actual distance from site, and exact meteorological conditions. While GIS-based buffer analysis provides a better measure of proximity, it is nonetheless problematic in that all buffers are normally generated at the same size. The generation of plumes ameliorates this problem, but assumes that exact meteorological conditions are known ahead of time. Additionally, one needs to think carefully about the statistical significance of the existing distribution. To address these concerns we have utilized both plume dispersion modeling and Monte Carlo simulation.

Plume modeling

Using the plume dispersion model, ALOHA, we have generated a series of simulations of hazardous materials releases--plume modeling represents a significant improvement in measuring potential exposure—and have compared this analysis to a simplistic GIS-based buffer analysis, normally used in these studies. Our results indicate that, while plume modeling provides a better, perhaps much better, estimate of exposure to certain chemicals, such models are difficult to integrate within GISs and require a series of difficult to predict assumptions.

Monte Carlo Simulation

Increasingly, geographers are applying Monte Carlo simulation methods within GISs to enable a comparison between an existing spatial pattern, and a theoretical distribution derived from a repeated randomization—called bootstrapping--of the existing data. This allows researchers to apply what is equivalent to a test of significance in determining where an existing statistic falls in relation to a large number (n normally is well above 1000) of “theoretical” statistics. Our research reports on the application of Monte Carlo methods to create a series of theoretical spatial distributions of Toxic Release Inventory data, and to determine the significance of the existing TRI distribution—when measuring urban poverty--based on the simulations. Our findings indicate that, in terms of measuring the poverty rates “close” to toxic sites, certain, but not all, variables (census data) were significant. For instance, the poverty rates for children under 5 are, in fact, significantly higher in those enumeration units in close proximity to TRI sites. We feel this research represents a very promising approach for addressing the difficult question of what constitutes environmental equity.