# Serendipitous observation leads to research linking physics and urban planning

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In spotting this aerial photo of a city, Franz-Josef Ulm (pictured) made a connection between the patterns of houses and streets and the underlying molecular structure of cement. Credit: Len Rubenstein

Franz-Josef Ulm and a colleague were taking a break from a tough problem one afternoon when they spotted an aerial photograph of a city and had an epiphany. Instantly, they made a connection between the patterns of houses and streets and the underlying molecular structure of cement.

That serendipitous observation has since led to research that is tying together the seemingly disparate disciplines of physics and urban planning. "Ultimately, I believe there's potential for this to become a new field of study," says Ulm, the George Macomber Professor in the Department of Civil and Environmental Engineering, and co-director with Senior Research Scientist Roland Pellenq of the International Joint Unit (UMI) between MIT and CNRS, France's National Center for Scientific Research. "It also could lead to new tools for architects and city planners."

Urban physics, as Ulm calls the new work, views cities as analogous to complex materials. Over the last 50 years, physicists have developed ever-better statistical tools to learn more about materials at the molecular scale. And Ulm himself is a world leader in using them to understand the structure of cement, with the ultimate goal of creating better versions of the material.

Ulm and colleagues are now modifying these tools to explain cities. "Essentially we take a big city and compress it, extracting only the most important statistical information," Ulm says. The end result is computer models that can accurately capture the internal structure of a city with a minimum of data. These models can then be manipulated to explore how a city will respond to phenomena ranging from the intense winds of a hurricane to the higher temperatures associated with global warming.

Just as atoms in a molecule arrange themselves in repetitive structures, researchers have discovered that buildings in a city have an order that, when repeated on a macro scale, gives the city distinct properties. This local order can be computed from physics models that, in turn, incorporate available Geographic Information System (GIS) data, such as the heights of buildings and the distances between them.

So far, the researchers have analyzed 12 cities in the United States. They've found that each has a distinctly different structure: New York resembles a highly ordered crystal, Chicago resembles a less-ordered glass, and Boston resembles an amorphous liquid.

These structures, in turn, determine how a city will likely respond to different stresses. For example, the MIT team has found that cities with a crystal structure absorb and retain more heat than those with less-ordered structures. That particular finding could help urban planners better understand—and mitigate—different cities' responses to global warming.

Initially, other physicists were skeptical of the work, Ulm recalls. "They said, 'You crazy guys, you're jumping 12 orders of magnitude from one field [molecular physics] to another [urban planning].'" But, Ulm says, "as we move forward, we're finding city patterns that are amazing, and we really believe they could have a major impact for 21st-century urban planners."

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