Batman's Gotham City provides test case for community resilience model

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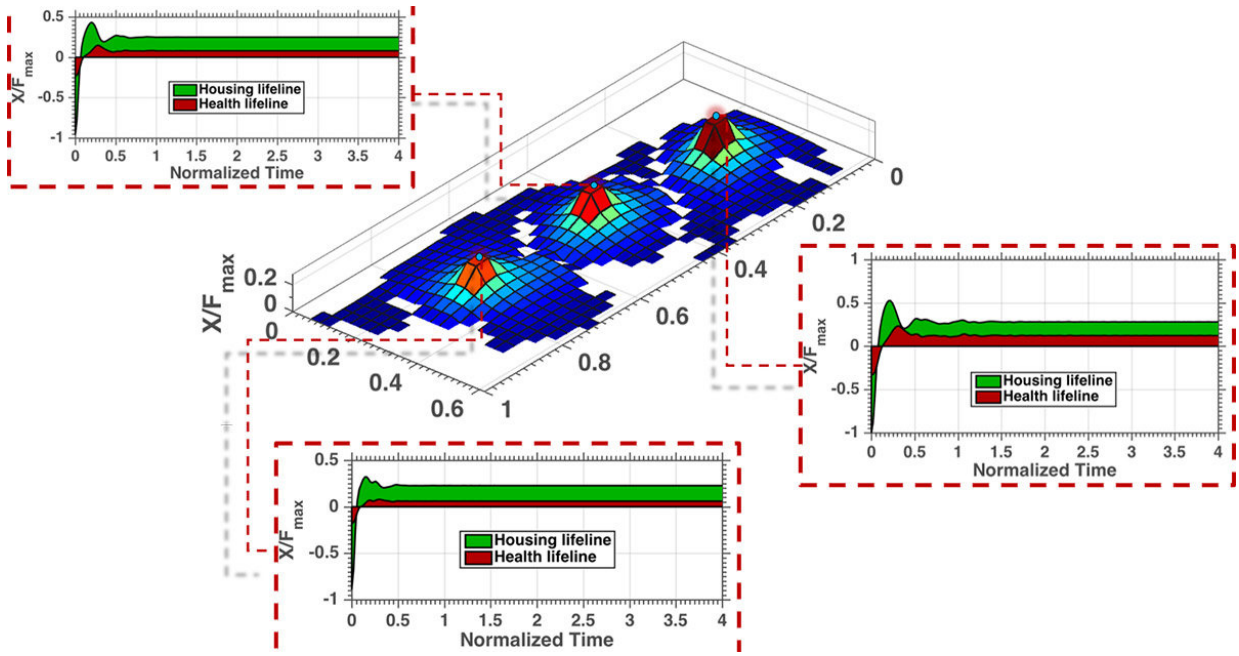

A map of Gotham City is laid out in a Finite Element Analysis grid. The grid shows how stresses to different lifelines affect various parts of the city. Credit: Colorado State University

If a community is resilient, it can withstand and recover from an unanticipated disaster, like an earthquake, fire or flood.

But since every disaster and every community is unique, a uniform measure for defining "resilience" has been hard to come by for engineers

and social scientists.

In a new study, Colorado State University civil engineer Hussam Mahmoud offers an innovative approach to defining resilience that could help communities better prepare for hazards. Integrating a community's infrastructural, social and economic features, Mahmoud's team has created a dynamic mathematical model that quantifies, in space and time, how well a community would withstand a major shakeup – regardless of whether it's a natural disaster like a flood, or a social disruption like the Arab Spring in 2011.

Mahmoud and graduate student co-author Akshat Chulahwat describe their "hazard-agnostic," finite element resilience model in the journal *Computer-Aided Civil and Infrastructure Engineering*.

Finite element analysis is a mathematical tool that engineers use to assess stresses and strain in structural elements, like beams and columns. Mahmoud and Chulahwat's work is built on the principle that a community – be it a town, city or suburb – responds to a disaster very much like a swinging pendulum or vibrating violin string responds to a force.

"Our mathematical formula allows you to cause disruption to a community at any location, and see what that disruption would do to the entire community," said Mahmoud, associate professor of civil engineering.

Batman's home town

To demonstrate the versatility of their model, the team used the fictional city of Batman, Gotham City, as a test bed. They chose a fictional city to provide a proof-of-concept for their model.

Many engineers and social scientists are working to define community resilience. Mahmoud is one of them, as a member of the CSU-led NIST Center for Risk-Based Community Resilience Planning. Typically, resilience is viewed as an engineering, social or economic problem, and individual communities decide which metrics matter most to them. The metrics usually fall into a series of "lifelines," like water, housing, power, health, community and transportation.

In Mahmoud and Chulahwat's approach, recovery of all lifelines is integrated to form a unified resilience metric. The metric combines engineering, social and economic features of the lifelines together, as opposed to selecting only one of them.

Classical mechanics

The approach applies these same lifelines, but simplifies resilience into three classes: social, economic and infrastructure. Using an equation from classical mechanics, the team considered mass to represent social vulnerabilities; damping to represent funds available for recovery; and stiffness to represent robustness of infrastructure

If one or more of these variables experiences a change, the rest of the system follows suit – just like when a violin string is plucked, the force of the plucking affects the time it takes for the string to stop vibrating.

They verified their model using a map of the fictional Batman home city. Dividing Gotham into uptown, midtown and downtown, they recorded the effects of various "disasters," including a jail riot at Arkham Asylum, which is located near uptown Gotham.

Among their observations was that a fast recovery is not necessarily best; if a community bounces back too quickly from a disruption, it can cause instabilities.

Resilience against social uprisings

Mahmoud was inspired to take this approach to defining resilience in part by studying the Arab Spring uprising of 2011 in Egypt and other parts of the Middle East. The widespread demonstrations lasted many weeks and took social and economic tolls on communities for years, but the impact was difficult to measure.

The new hazard-agnostic model provides a framework for better defining how disruptions like the Arab Spring affect communities long term.

"Our model can help us determine what happens to your community, both spatially and temporally, if it's struck by a natural disaster, economic downturn or social disruption," Mahmoud said.

More information: Hussam Mahmoud et al. Spatial and Temporal Quantification of Community Resilience: Gotham City under Attack, *Computer-Aided Civil and Infrastructure Engineering* (2017). DOI: 10.1111/mice.12318

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