# Terrorism Modeling

## Preparing the Worst-Case Scenario

*By John Tedeschi, Krista Ann Lienau, and Peter Cheesman*

**The events of Sept. 11 changed the map of risk forever. For the first time, insurers had to develop models for mass destruction caused not by the vagaries of nature but by the malevolence of other human beings.**

The events of Sept. 11, 2001, have forever changed the world and have left scars on the insurance industry. The attack created an entire new regime of risk that hadn't been contemplated by most risk bearers. In a matter of minutes, a multitude of insurance products were put to the test in a single event: property, business interruption, workers' compensation, general liability, umbrella, automobile, accident and health, life, and medical.

The industry awakened to the possibility that this was not the worse-case scenario. Could nuclear devices be used to expose a major city to some level of radiation, triggering millions in the surrounding impact zone to seek medical attention for an extended period? Could dams be destroyed, flooding properties, eliminating access to water and local electrical generation? Could our growing dependency on the complex cyberworld make us susceptible to cyberterrorism? Insurance companies offer policies protecting against such unthinkable events and, therefore, must diligently manage that risk. Quantifying the economic and human losses resulting from intentional harm is fraught with challenges but is not an insurmountable task.

Prior to Hurricane Andrew and the Northridge earthquake, most insurance operations managed risk and accomplished ratemaking by accumulating basic geographic exposure information such as premium, unit counts, or limits. These devastating events sparked the advent of natural catastrophe computer simulation models during the late 1980s and early 1990s. Over the next decade, these models became firmly established within the industry not only as a means of managing risk but also as a valid approach to ratemaking. Post Sept. 11, several major modeling firms considered leaders in the world of natural catastrophe modeling have responded once again to the ever evolving needs of the insurance industry.

The modeling firms have varying approaches and capabilities for modeling terrorism risk, but most have a multi-tiered approach that involves the same three steps: exposure concentration analysis, generating deterministic (or scenario) loss estimates, and generating probabilistic loss estimates.

**Accumulation Assessment**
Accumulation assessment is the process of identifying and quantifying concentrations of multi-line exposures around potential terrorist targets regardless of their proximity to a target. The accumulation area is often a simple circle based on the damage footprint of a conventional blast event where the center is the highest risk point and the intensity attenuates with distance. The footprints are based on data obtained from a variety of test explosive charges, detonated in a free-field, open environment. As the damage footprints of such blasts are fairly small, the process requires individual building data at a full street address resolution. The address is then used to allocate latitude/longitude coordinates to geographically represent each building location which are, in turn, used by the accumulation algorithms.

Target-based accumulation assessment locates potential targets and aggregates a company's exposures within various distances of the targets (see Figure 1). Accumulation tools can incorporate any singularly selected target or use established lists such as those published by various catastrophe modeling firms. Terrorism target databases are composed of targets of high economic, human, and symbolic value. This includes locations where there are major concentrations of people and business activity, such as trophy buildings and tourist attractions, as well as sites at which an attack could potentially create considerable ancillary losses to the surrounding region, such as major industrial and nuclear facilities. A target-based analysis allows insurers to establish underwriting practices for risks to the targets and their vicinity.

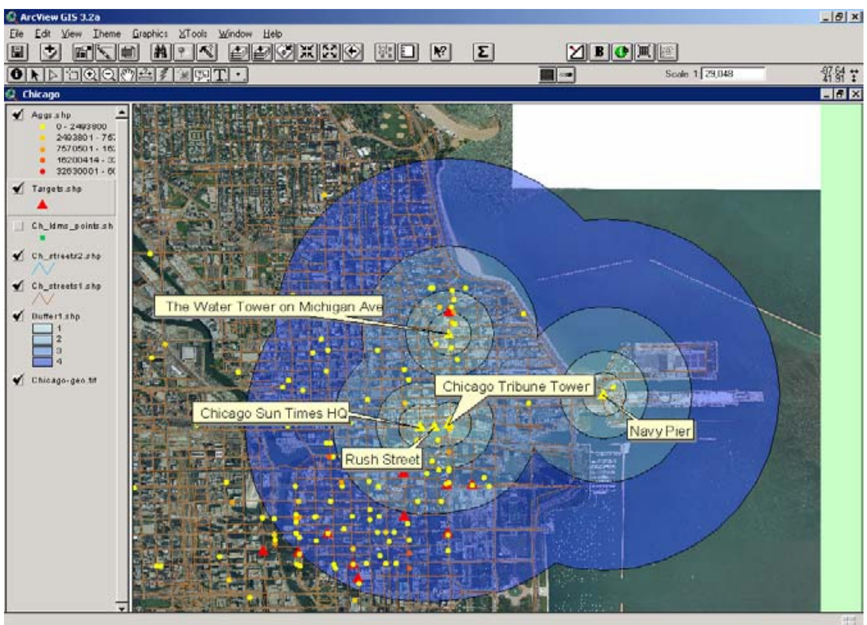


**Figure 1. Accumulation analysis based around selected targets**

To complement the target-based approach, it's also necessary to search for clusters of exposure that exceed an economic threshold within a portfolio, regardless of any perceived targets. Analyzing a portfolio irrespective of identified targets searches for any accumulations that might have been missed using the target-based approach. This compensates for possible omissions in the target list, recognizing that there's some probability of a terrorist attack at any location. This cluster method also allows the analysis of exposure to other catastrophic events such as earthquakes, hurricanes, and wildfires.

More recently, risk measures are being used to describe how concentrated locations are within a set of data. The Pielou Index measures the level of clumping of spatial data. An index close to 1 indicates a random distribution, and values greater than 1 indicate an increasingly clumped distribution. The Pielou Index works by measuring the distance from randomly positioned points to the nearest data point (location of a policy). For example, 500 random points are chosen within a designated boundary such as country, state or city limit. Once the 500 nearest distances have been found, these are used to calculate an average distance, which is used in conjunction with the policy density to calculate the Pielou Index (see Figure 2). Measuring the clusters at different scales indicates the type of hazard to which an insurance portfolio could be susceptible.


**Figure 2. Different cluster values for two sets of data covering the same city area**

Accumulation assessment, whether an examination of target- or non target-based accumulations, and the general level of concentration within a portfolio allows any company to formulate new management practices should it so choose. The identification of large accumulations means that a company can limit the amount of business it writes in that area to try to reduce that accumulation. In reverse, it will also indicate where their accumulated exposures are low, which may highlight potential areas of growth.

**Deterministic Modeling**

Deterministic modeling takes accumulation analysis a step farther. It imposes an event's damage footprint, perhaps a 2-ton bomb or a 1-kg. release of anthrax, at a specified target. Deterministic modeling represents a compromise between the lack of accuracy in an accumulation analysis and the vast uncertainty surrounding probabilistic models.

In accumulation tools where a simple "circle" approach to damage is adopted, there are significant limitations to accurate modeling of the true damage and the loss experienced. By imposing an actual event's damage "footprint" at a specified target, a specific (yet hypothetical) scenario can be analyzed with a fair degree of certainty.

It also eliminates the difficulty that's so difficult to evaluate when contemplating probabilistic terrorism modeling: human intent. Many companies are choosing to manage terrorism risk via deterministic analyses of a specific event happening at a range of targets. This circumvents many of the issues and uncertainties associated with probabilistic modeling without sacrificing accuracy.

Major modeling firms all offer a wide array of deterministic analysis tools for conventional as well as chemical, biological, nuclear, and radiological attacks at target or non-target locations. The benefits of using a refined footprint can easily be understood with the effect of a blast. A simple circle method doesn't include the complex interaction of the blast wave with the urban environment, failing to consider effects such as shielding, focusing, and channeling that will occur in a congested street layout.

It also doesn't account for a blast entering a building through the windows, an effect that may lead to significant additional damage and casualties. It's also true that different cities show markedly different responses to blast. Narrow streets surrounded by high rise buildings found in congested areas such as New York and Chicago have completely different characteristics from a more open, low-rise layout such as Washington, D.C.

One method to obtain a complex event footprint involves a 3-D computer model of the urban cityscape. Any number of device sizes and types are exploded within the cityscape and blast loads are measured at any building. All of the complex effects are incorporated into the blast load results, and a much more accurate picture of the true extent of a bomb's effects can be determined. A typical blast propagation sequence is shown in Figure 3.

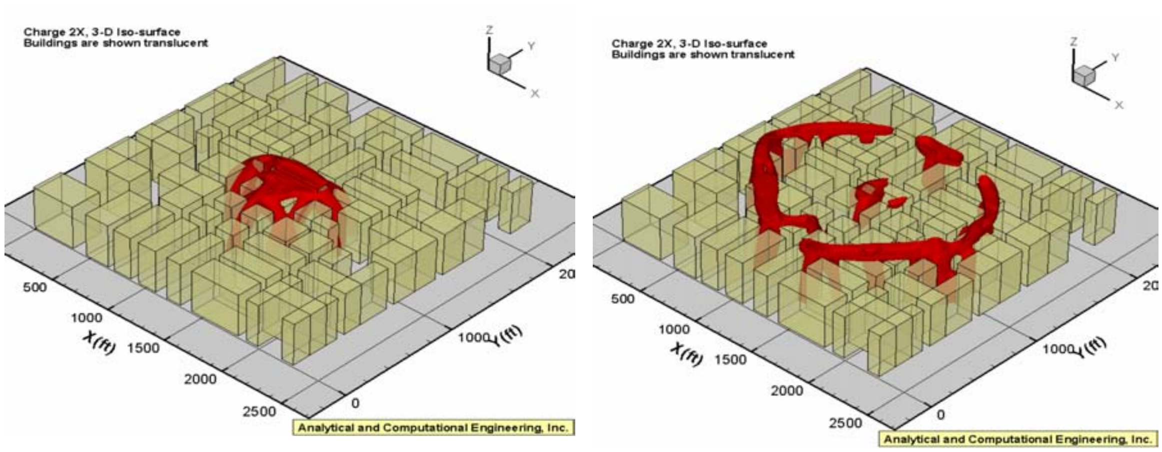


**Figure 3. Typical blast propagation sequence**

A comparison of the variable damage of a 3-D blast and the free-field circle approach can be seen in Figure 4. The red area indicates the projected maximum blast loads experienced by the affected buildings. There are buildings outside the limits of the circle that experience blast loadings greater than the circle would predict. Conversely, some areas of over-prediction occur in the circle method, but clearly the extent of this is limited and impossible to quantify a priori.

The deterministic approach is much more discriminating than the circle approach, both in terms of the effects of the blasts in true urban environments and the damage to buildings within that environment. The 3-D model of the urban landscape can be developed from satellite photographs or other 3-D digital information of building footprints and heights. Any database of information concerning basic structural types (masonry, steel, brick, etc.) completes the required data for the model.

The ease with which explosions can be placed within the environment means that multiple scenarios can be pre-modeled to speed up the accumulation calculations. This allows examination of a range of targets, bomb locations attacking that target, and variations in device type and size.

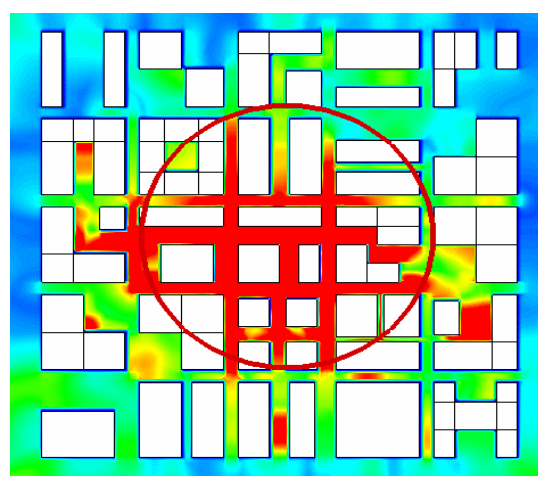

**Figure 4. Circle method compared with blast method**

For high-value areas where there is both a significant likelihood of an attack and significant values of property and occupancy, such a modeling approach becomes very cost-effective in understanding exposures, which could be extensive. The approach is also effective where coarse screening studies show that exposures for an area or event could be high and a more detailed assessment may reduce uncertainties and help decisionmaking.

**Probabilistic Modeling**

There's no question that probabilistic terrorism models are a necessary part of the insurance industry's future management of terrorism risk. There's also no question that building a sound model, let alone convincing industry experts that the model is sound, will be an uphill battle. The deck is stacked against the modeling firms: there is an astounding lack of historical data, an ever changing terrorist attack outlook varying with each new homeland security report, and no direct hotline to Al Qaeda to ask for inside information.

Probabilistic models, whether natural peril or man-made peril, all need to incorporate two basic elements: frequency (how often will an event occur, where it will occur, and what type of event will it be) and severity (once that even occurs, how much damage will be caused). We have the benefit of years upon years of historical data and scientific research when attempting to answer those questions for natural perils. There is no such advantage for the peril of terrorism. While, thankfully, there have been relatively few attacks on U.S. soil, this means that there are few data points for scientific analysis. Additionally, a natural peril doesn't target property and human life, nor does it shift motives and strategies. The uncertainty in a natural peril model is dwarfed by the uncertainty inherent in a probabilistic terrorism model.

However, the modeling firms are working hard to overcome these obstacles. Through creative modeling methodologies such as game theory, the Delphi method, and general expert opinion, the first generation of probabilistic terrorism models has been released into the industry and is on its way to being embraced. Probabilistic loss estimates are needed, uncertain or not, as a risk management tool.

To many, the probabilistic approach is also counterintuitive to the modus operandi of the majority of terrorist organizations. The more likely a target is to be attacked, the less likely it is to be attacked successfully as hardening activities such as access restrictions, improved security, and increased structural defenses make the attack more difficult to undertake.

Model uncertainty aside, the credibility, and therefore the usefulness, of modeled loss estimates hinges heavily on the quality and resolution of an insurance company's data. Natural catastrophe models initially required much more data than companies had historically been capturing. Risk location, type of construction, and policy details have slowly become standard data captured for modeling purposes for property insurance. This evolution in the marketplace has allowed insurers to quantify the trade-offs associated with changing coverage with changes in premium.

Terrorism models have once again forced improved standards in data capture. Given that the footprint of a terrorist attack is typically relatively small compared with a natural peril footprint, exact coordinates (latitude and longitude) of a risk are imperative to capture. In addition, expanding horizons beyond property loss estimates has pushed the envelope. Workers' compensation insurers now capture number of employees by location, shift, and construction of building. Line of business accumulation is no longer adequate, and multi-line insurers now accumulate exposures across all policies exposed in a location.

**The Future**

Terrorism is a global problem, and even though governments, acting in the public interest, are required to attempt to manage the problem, terrorism will never be eliminated. The frequency and intensity of the peril is conditional on the vagaries of those seeking to inflict economic, religious, political and human pain. Even with this daunting task, governments are attempting to provide adequate security in order to allow commerce to continue and therefore allow insurance entities to continue to practice their trade. The advent of terrorism modeling and active management of exposures prone to be tempting targets will allow insurers to proactively safeguard their future.

**This article first appeared in the November/December 2004 issue of *Contingencies* and has been reprinted with permission.**