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RESEARCH ARTICLE

Assessing the Nature and Role of Terrorism Risk Models in the Insurance Sector

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Abstract: Insurance represents an important but often overlooked component to managing and mitigating the impact of terrorism. It plays a key role in enhancing resilience to terrorism especially regarding high intensity terrorist campaigns or high impact terrorist attacks. Extremely little attention however has focused on how the insurance industry assesses and calculates terrorism risk and what the implications may be of this. This research article provides for the first time an overview of the three main terrorism risk-modelling platforms that are used in the insurance market today: Touchstone, RMS Probabilistic Terrorism Mode (PTM), and Sunstone. The article assesses the different approaches to threat and loss calculation that each of the models take. The anlaysis reveals that while the three models all approach the projection of terrorism loss in a broadly similar manner, there are variations in focus, which results in a significant difference in terrorism outlook and projected loss. The discussion concludes by considering some of the implications of these variations as well as potential avenues forward.

Keywords: Terrorism, resilience, modelling, insurance

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Introduction

Terrorism risk modelling tools for insurance began to be developed following the 9/11 attacks of 2001. The extent of loss following the event was unprecedented for a terrorist event and the resulting insurer outlay was enormous – exceeding USD 30 billion across property damage and life insurance lines.[1] The sheer accumulation of value in central Manhattan, as well as the extent to which the Twin Towers were threatened, had not been modelled. The 9/11 attacks resulted in a demand for terrorism risk models that could highlight insured exposures (especially dangerous accumulations of insured values), estimate losses, and assign risk values. There are three terrorism risk models (TRM) that are commonly used in 2021: 1) Sunstone; 2) Risk Management Solutions (RMS) Probabilistic Terrorism Model (PTM); and, 3) the Touchstone Terrorism Model. The following sections will examine the differences between these models and highlight the shortcomings and advantages of each, with a view to identifying key areas for improvement and developing a list of aspirational functionality or inputs that will hone these models.

Data Collection Methodology

This article is a summary compilation of the technical documents for the three TRMs as listed, as part of a wider research initiative into the credibility of these models as an approach to modelling terrorism. All information pertaining to the function of the models was taken from the technical documents themselves[2,3,4] These represent the only reference points for the model descriptions. There is a dearth of academic literature about the efficacy of commercial TRMs, despite the subject of terrorism modelling being explored extensively since 2001. As such, this analysis serves to lay out the function of models as stated by the model manufacturers, as well as their role in pricing terrorism insurance.

Historical Context of Terrorism Risk Models

The economic impact of terrorism can be enormous.[5] It has long been recognised that terrorism can be a remarkably effective low-cost form of conflict. For relatively modest outlays on the part of perpetrators, terrorist violence can inflict disproportionately high economic costs.[6] This asymmetry in terms of impact has long been an attractive characteristic of terrorism for perpetrators.[7]

Further, many terrorists explicitly target economic and commercial targets to augment even further the impact of attacks.[8] Terrorism's asymmetric nature invites attention towards maximising the economic impact of the violence and many ideologies embrace this and flag it as a priority for the cause.[9] Terrorist groups motivated by Islamist-inspired ideologies or nationalist-separatist causes, for example, have strong histories of highlighting the value of targeting economic and commercial targets.[10] Far right and to a degree environmentalist terrorist ideologies also target economic infrastructure to combat the perceived societal and environmental impact of technological and economic development.[11]

Research on the economic impact of terrorism, however, was relatively sparse in the 20th century. That changed to an extent with the unprecedented impact of the 9/11 attacks in 2001.

The scale of the economic impact of those attacks was unparalleled and it provoked some wider interest among researchers and policy makers on the economic consequences of terrorism.[12] Tied to this, policymakers were particularly interested in potential mitigation measures which could limit or mitigate severe economic impacts.[13]

One relatively overlooked element of such mitigation was the role the insurance sector could play.[14] This was not a subject which had attracted much research attention prior to 9/11 and even since then, it has remained a relatively neglected topic. Yet insurance can play a critical (albeit often overlooked) role in the mitigation of the economic impact of terrorism. This was certainly demonstrated in the 1990s in the UK, for example, the response to the Irish Republican Army's (IRA) bombing campaign in London and other major cities in England. In 1992, an IRA bomb detonated close to the Baltic Exchange in the City of London, causing tremendous damage – estimated at around £800 million – and killing three people[15] This was one of a series of high impact bombings carried out by the IRA explicitly designed to inflict major economic costs. The Baltic Exchange bombing certainly achieved this and led to a crisis in the insurance sector. Within months, major European reinsurers had announced that terrorism risk would be excluded from their standard policies starting in January 1993. In November 1992, another large IRA bomb was discovered and successfully defused at Canary Wharf before it could explode. In the aftermath of that attempted attack, the Association of British Insurers (ABI) issued a press statement to say it had advised its members to exclude terrorism from commercial policies in line with the new European policy. During a serious and well organised campaign to target the UK's key financial districts, insurance protection seemed to be evaporating.[16]

In response, the UK government introduced legislation to take on the traditional reinsurance risk for terrorism.[17] Crucially, the UK government effectively agreed to meet 90 percent of future claims made which were not covered by collected insurance premiums, effectively using the insurance sector to spread the risk of future high impact terrorist attacks throughout the national economy. Since this time, in both the UK and for many other countries, the insurance sector has provided an important but often overlooked mitigation for managing the risk of terrorist attacks, absorbing billions of dollars of losses resulting from terrorism since the middle of the 20th century.[18]

Table 1 - Ten Costliest Insured Terrorist Attacks, Millions of 2005 US Dollars[19,20,21,22]

Date	Country	Location	Event	Insured Losses*
9/11/01	USA	NYC, DC	WTC & Pentagon Attacks	$20,953 ($35,600)*
4/24/96	UK	London	Bomb explodes near NatWest tower	$1,000
6/15/96	UK	Manchester	Shopping mall explosion of IRA bomb	$820
2/26/92	USA	New York	World Trade Center garage bomb	$800
4/10/92	UK	London	Bomb explodes in financial district	$740
7/24/01	Sri Lanka	Airport	Rebels damage/destroy 14 aircraft	$439
2/09/96	UK	London	IRA bomb in South Key Docklands	$286
4/19/95	USA	Ok. CITY	Truck bomb attack Oklahoma City	$160
2/21/88	UK	Lockerbie	PanAm Boeing 747 bomb and crash	$152
9/12/70	Jordan	Zerq	3 Aircraft hijacke and dynamited	$140

Insured losses cover only property damage and business interruption losses. The $35,6 billion value for the WTC attack includes all insured losses (such as Workers Compensation)

A key element of this work has revolved around how the insurance sector assesses the risk of terrorist attack for the regions that they cover. The models that are used in this regard have real world implications in terms of the cost of insurance cover and (directly or indirectly) as incentives for the introduction of various target protection and attack mitigation systems and resources. Though clearly important, these models have not been the focus of published academic research to date.

This article represents the first attempt to describe the major terrorism risk models and the data which informs them which are used by the insurance sector. As Johnson and Ackerman recently warned regarding databases on terrorism:

> *"Not all … are of equal quality and uninformed or careless usage of these databases can lead to the drawing of incorrect inferences and thereby to poor policy guidance and specious contributions to our understanding of terrorism."*[23]

The TRMs have remained largely unchanged since their inception, barring minor changes to variable input and calibration. In other words, the fundamental function of the models has remained the same since release, with augmentations added to existing functionality. The TRMs provide 'an answer' to the insurance question and there has yet to be a significant demand for a radical overhaul to the approaches laid out below.

This article then seeks to describe the current range of terrorism risk models in use within the insurance industry, providing insight on how they are used, while remaining cognisant of their separate characteristics, strengths, and limitations.

How Do These Models Work?

A probabilistic analysis in terrorism modelling is, in simple terms, the application of probability to the distribution of deterministic scenarios at pre-selected locations. The locations for these analyses will be informed by a terrorism database, which serves as a set of geographic anchors against which deterministic scenarios are run at different probabilities according to a variety of factors, explored below. The losses generated by the scenarios are then multiplied by the relevant probability of their occurrence, thus generating the loss projection data.

Broadly speaking, each TRM's probabilistic analysis functions in the same way. Each of the TRMs considered here boasts multiple functionalities, including deterministic event modelling, algorithmic accumulation analysis, as well as the probabilistic analysis. Each of these elements is explained in more detail below. Each element serves a separate purpose, and they are used in tandem with one another to generate an overview of the risk to a given portfolio of insured or insurable assets. This is achieved, in turn, by running these analyses with a financial engine, which will apply the various insurance layers that are relevant to each asset in an analysed portfolio.

Financial Engine

A financial engine, in the context of insurance modelling, is a computational functionality that applies financial terms to any analyses that have been carried out. Financial terms like the limits (the maximum loss that can result from an event), deductibles (value retained by the insured), and attachment points (minimum loss before the (re)insurance becomes relevant) are applied through the financial engine to generate the insured losses that will result from the modelled events, rather than the full financial damage caused alone.

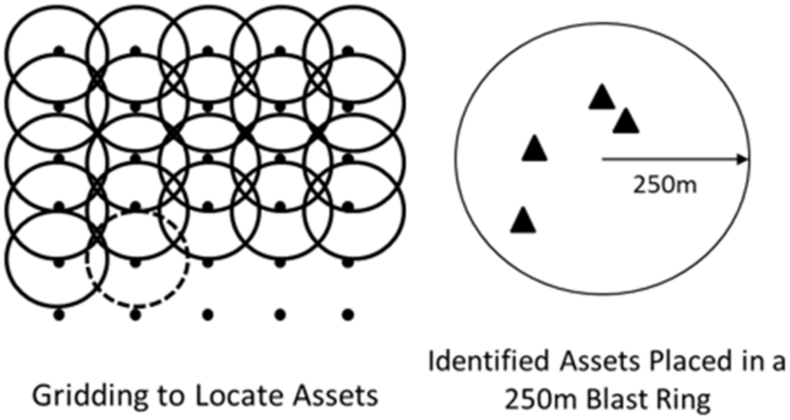
Accumulation Analysis

Accumulation analysis identifies key areas of exposure in a portfolio of assets. Here the TRM will, in conjunction with its financial engine, search for geographic zones which contain the most insured value, rather than the total value of the assets in a geographic zone. Typically, these 'geographic zones' are small enough for them to be relevant to a terrorism analysis – that is, small enough for its totality to be affected by an individual terrorist event. The most common accumulation analysis zone is a ring with a radius of 250m, or a postal (zip) code, although lower resolution (such as city or region constraints) or higher resolution (50m or 100m rings) are used according to the risk appetite of the insurer. While accumulating a portfolio using existing geographic constraints, such as postal codes, is a common functionality across TRM platforms, the ring analyses differ in methodology.

Grid Accumulation Analysis

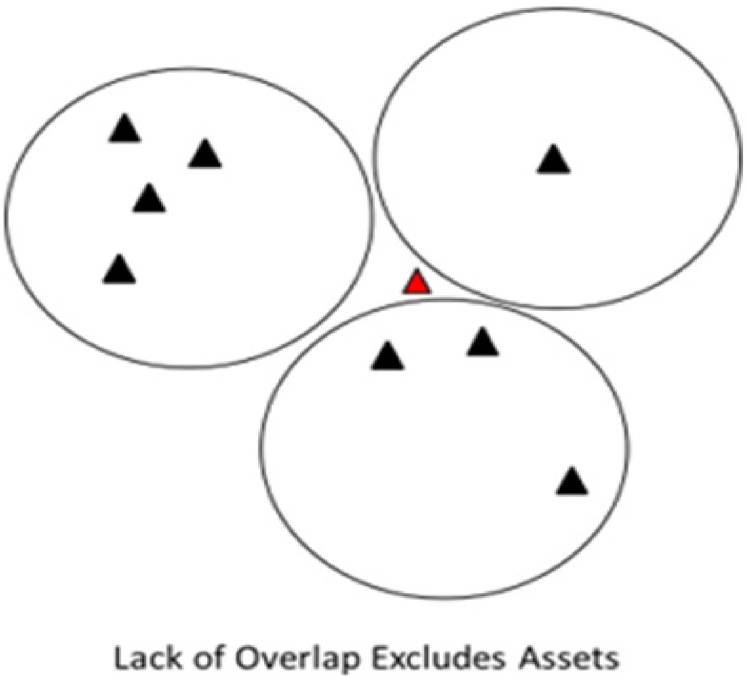
The RMS model includes a grid-based analysis for its accumulations. A grid analysis places multiple rings across the entire portfolio, constrained only by the geographies of the assets themselves. This methodology is primarily used to identify general geographic 'value hotspots'. The system is shown in figure 1 below:

Figure 1. Example Grid Analysis[24]



The system does not allow for overlapping blast radii so it is possible for assets near each other to fall outside a 250m blast ring and therefore run the risk of not being included in accumulation totals:

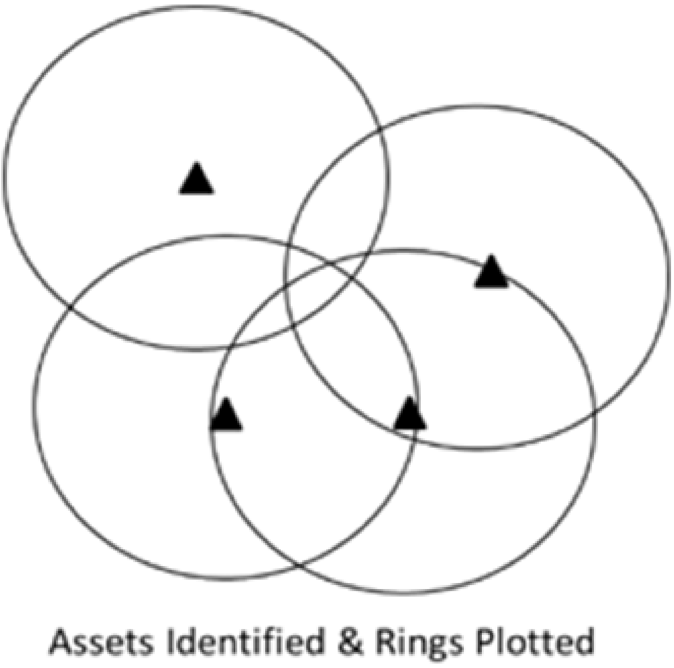
Figure 2: Failure of a grid analysis to capture the full value of a portfolio[25]



Geometric Accumulation Analysis

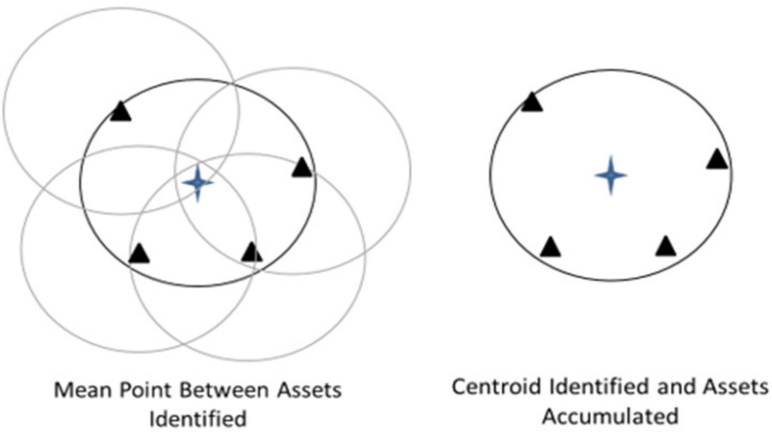
Sunstone and Touchstone TRMs use a different approach to asset location and asset accumulation: assets are located and bounded by 250m blast circles:

Figure 3: Overlapping accumulation of geometric analysis[26]



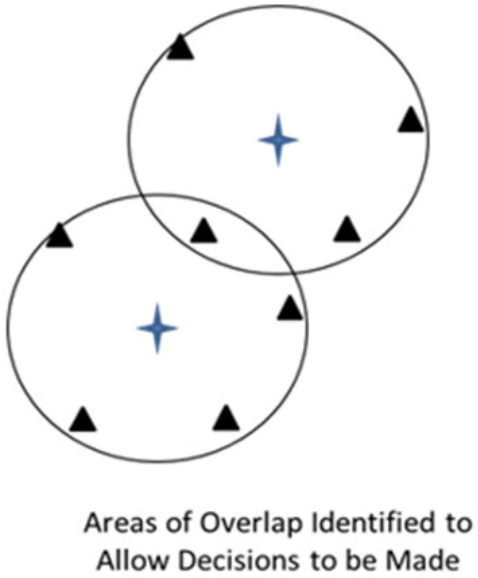
Areas of overlap are then used to locate the mean point between assets and these points are used as centroids for quantification rings. The TRM then automatically identifies areas of significant congestion (accumulation) and places centroids in locations that will allow the maximum number of assets to be incorporated in a ring within agreed maximum limits thereby allowing the maximum risk to be written:

Figure 4: Peak accumulation identification[27]



The system will also allow boundaries to overlap and presents this information to users as areas of greatest value accumulation.

Figure 5: Accumulation exclusive overlaps[28]

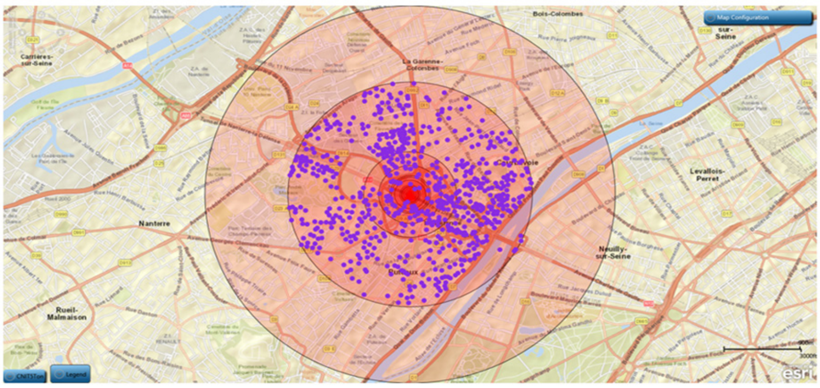


Deterministic Analysis

The deterministic analyses focus on the effects of a prescribed terrorist event against a portfolio of assets. The purpose of this analysis is to answer, 'what if?' questions in the terrorism sphere. For example, one might look to examine the likely impact of an active shooter or truck bomb event at a given target against their own portfolio. These analyses do not account for probability or threat and instead simply examine the likely impact of the events themselves.

The terrorism events that are modelled vary between platforms, but all follow a similar method of loss estimation: concentric impact curves; and for RMS PTM, a variable resolution grid system in addition to a concentric approach. 'Impact curves' refers to the distance-based loss function of an event: a concentric step loss from the centre-point of the event. Each event type, from a small IED to a 9/11 scale airplane impact will emanate concentric rings of damage from its epicentre, which will cause varying levels of loss to assets that fall into the concentric rings themselves. An example is shown in Figure 6 below:

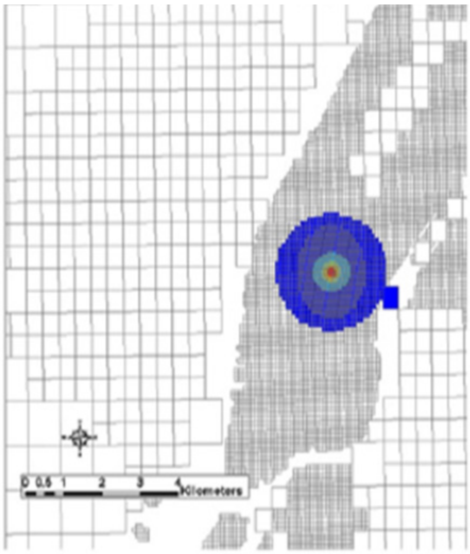
Figure 6: Sunstone concentric ring model, Impact curves of a 5-ton device affecting a large portfolio of assets.[29]



The variable resolution grid used in RMS differs from the concentric ring approach used in

Sunstone or Touchstone. Here, the building density of a given area determines the granularity of the grid. Each conventional attack type will generate decaying impacts from the centre point of the event, which is spread over the relevant grid, for example in Figure 7 below:

Figure 7: A 10 Ton blast in Manhattan – note the grid resolution changes at sea and in central park areas, where building density is low/non-existent.[30]



The impacts vary between models but will accommodate three separate value types – property damage, business interruption, and human injury. Each TRM can perform several different deterministic analyses but not necessarily in the same manner. However, the basis of each probabilistic analysis is the linking of these impact curves to target types across their geographies.

Table 2: Summary Differences

Model	RMS PTM	Sunstone	Touchstone
Accumulation Analysis	Grid-based analysis, may exclude highest possible combination of sites.	Geometric analysis, locations can only be part of one accumulation, identifies the highest accumulation of value	Geometric analysis, locations can only be part of one accumulation, identifies the highest accumulation of value
Deterministic Analysis	Focus on large-scale events with devastating potential impact. Building type and occupancy considered in damage function.	Very wide range of attack types, from small-scale to large. Does not consider building type or occupancy in damage function. Most simplistic approach to loss calculation.	Focus on large-scale events with devastating potential impact. Building type and occupancy considered in damage function.
Probabilistic Analysis	Limited target dataset, only 'important' targets, geographically limited to large cities in North America and Western Europe	Extremely large target dataset, both large and small types of target, no geographical limitations	Large target dataset, restricted to the USA only

As such, whilst the fundamental functioning of each model is similar, their practical ability to model risks varies in terms of geography, damage detail, and approach to probability:

Sunstone:

Strengths: very large geographic coverage, very wide range of attack types, tiered and expansive target dataset.
Weaknesses: lacks damage detail from terrorist events, cannot calculate the net of reinsurance terms, simplistic and somewhat arbitrary approach to probabilities.

RMS PTM:

Strengths: detailed approach to damage calculation, most widely used TRM, considers second-order effects such as fire.
Weaknesses: very limited target dataset, heavy geographical restrictions, limited attack types considered.

Touchstone:

Strengths: detailed approach to damage calculation including city density, considers second-order effects such as fire, extensive target list in considered territory.
Weaknesses: Probabilistic model only for the USA, limited attack types considered.

Attack Types by Model

Each of the TRMs listed uses a different array of attack types to model losses – serving as restraints as to the granularity of the modelled loss for each. The modelled potency of each attack type is, similarly, different across the three platforms. This section will list the attack types deployed by each system and analyse the key differences in the modelled potency of the devices where appropriate.

Conventional Attack Types

Table 3 below lists the attack types that can be simulated on each TRM platform. Each attack type is broken down by the maximum and minimum size of the devices or attack vectors that can be modelled in each platform to demonstrate the difference in the scalability of each platform. All weights are listed as TNT Net Explosive Quantity (NEQ):

Table 3: Attack Types Across the TRM Platforms

Attack Type	Sunstone	RMS PTM	Touchstone
Bombing	<25kg-10,000kg, includes standoff explosive devices such as mortars and grenades.	272kg-10,000kg, consists solely of devices that likely require vehicular delivery	226kg-23,000kg, consists solely of devices that likely require vehicular delivery
Conflagration (Fire)	Limited to 'incendiary' attack type – a catch all for arson attacks.	34,000 litre gasoline truck	N/A
Shooter	Lone shooter – team assault	N/A	N/A
Vehicle as a Weapon	Large explosive aircraft collision, truck collision, ship collision	Large explosive aircraft collision	Large explosive aircraft collision, small airplane collision
Hijack/Hostage (Venue)	Single catch all attack type	Small/medium/large industrial explosion	N/A

All information below pertaining to the function of the models is taken from technical documents Sunstone,[31] Touchstone,[32] and RMS[33].

Neither the RMS PTM nor Touchstone models simulate attacks of <200 kgs, both stating that it is unlikely that attacks of this size could cause catastrophic property losses. Similarly, these models, likely for the same rationale, do not consider non-conventional attacks. Sunstone attempts to capture as wide a range of attack types as possible, to accommodate 'attritional' losses associated with sustained campaigns of low impact, high frequency devices. Indeed, as per the above table, common attack types seen in the West in recent years, such as shooter and truck collision events, are modelled only in Sunstone.

Conventional Attack Type Impacts

The table below breaks down the different approaches between the models. Only the attack types that are common across all platforms will be examined in this table:

Table 4: Conventional Attack Types Across TRMs

Attack Type	Sunstone	RMS PTM	Touchstone
Bombing (Property Damage)	Simple concentric rings – losses range from 100% to 1% at maximum extent. No adjustments for building height, construction or occupancy.	Variable resolution grid emanating from attack centre point. Adjustments for building height, age, construction and occupancy. Building collapse modelled.	Decaying blast curve emanating from attack epicentre distinguished by locations (front, side, rear and interior of a building). Building level property damage is aggregated from damage of every 14 cubic cell that varies by story, construction and occupancy. Building (not contents) totalled modelled. Density of urban environment considered.
Bombing (Business Interruption)	Concentric rings simulating exclusion zones following an explosion, repair to buildings and relevant traffic/pedestrian disruption. Rings reach a different extent to that of property damage.	Variable resolution grid emanating from attack centre point, repair to buildings and relevant traffic/pedestrian disruption. Rings reach a different extent to that of property damage.	As a function of building level property damage and its occupancy.
Bombing (Human Injury)	Concentric ring analysis that applies a decaying rate of death/injury/minor injury. Does not consider construction type or other building characteristics.	Variable resolution grid emanating from attack centre point. Adjustments for building height, age, construction, and occupancy. Masonry failure and collapse accommodated. Losses broken down by medical only, temporary total, permanent partial – minor, permanent partial – major, permanent total, fatal.	Like property damage with additional consideration of cause by collapse. Losses broken down by minor, moderate, major, fatality
Conflagration (Property Damage)	Simple concentric rings – losses range from 100% to 1% at maximum extent. No adjustments for building height, construction or occupancy.	Decay function emanating from attack epicentre. Adjustments for building height, age, construction and occupancy.	Not modelled – fire following is accommodated in nuclear and is built into loss functions.

Conflagration (Business Interruption)	Concentric rings simulating exclusion zones following an explosion, repair to buildings and relevant traffic/pedestrian disruption. Rings reach a different extent to that of property damage.	Losses result from direct damage to structures, as well as relevant exclusion zones imposed by local authorities.	Not modelled – fire following is accommodated in nuclear and is built into loss functions.
Conflagration (Human Injury)	Concentric ring analysis that applies a decaying rate of death/injury/minor injury. Does not consider construction type or other building characteristics.	Death/injury/minor injury calculated by damage to structure and distance from attack epicentre. The model differentiates casualty rates by building construction class and height.	Not modelled – fire following is accommodated in nuclear and is built into loss functions.
Vehicle as a weapon (Property Damage)	Concentric rings for airplane collision as per bombings, no impact curve for truck collision. Does not account for building characteristics.	Decay function emanating from attack epicentre. Does not account for vehicles smaller than airplanes. Adjustments for building height, age, construction and occupancy.	Modelled as an equivalent blast.
Vehicle as a weapon (Business Interruption)	Concentric rings for airplane collision as per bombings, impact curve for truck collision. Does not account for building characteristics.	Losses result from direct damage to structures, as well as relevant exclusion zones imposed by local authorities.	Modelled as an equivalent blast.
Vehicle as a weapon (Human Injury)	Concentric rings for airplane collision as per bombings, impact curve for truck collision. Does not account for building characteristics.	Death/injury/minor injury calculated by damage to structure and distance from attack epicentre. The model differentiates casualty rates by building construction class and height.	Modelled as an equivalent blast.

As per Table 4 above, there is considerable difference between the models with regards to their loss calculation methodologies. The Touchstone model is perhaps the most sophisticated platform, receiving an update in 2021, specifically addressing the impacts of urban density differentials with regards to explosive attacks, with a view to increasing the precision and granularity of the losses generated.[34] Both RMS and Touchstone consider building characteristics and possible structural failure, whilst Sunstone uses a more simplistic approach. This is especially clear with regards to the characteristics of buildings affected by the blast – where RMS and Touchstone adjust their loss calculations based on the construction, height, and occupancy of the buildings, Sunstone makes blanket assumptions. Similarly, Sunstone does not specifically account for structural failure in its calculations of property damage, business interruption, or human injury.

Of the three impact modelling capabilities described here, the Sunstone 2D impact methodology is perhaps the least advanced at the time of writing. The Touchstone system, and to a lesser extent RMS now incorporate systems to estimate portfolio building height and construction type where said data is unknown, based on the industry averages of the considered area.

It is noteworthy that conflagration events in all models do not account for fire spreading, rather that the fires themselves are contained to their immediate target.

Chemical, Biological, Radiological and Nuclear (CBRN) Attacks

The TRMs differ substantially in their approach to the calculations of losses for CBRN events, both in the impacts and the types of attacks modelled:

Table 5: CBRN Attack Types across TRMs

Attack Type	Sunstone	RMS PTM	Touchstone
Chemical	Combines chemical and biological attacks. Differentiates inhalational and ingested releases. Loads range from 'small and sub-optimal' releases to 'Large inhalational/ingestional'. Lethality of the agent is considered. Indoor and outdoor releases considered. Wind assumed to be minimal to maximise concentric impact.	Models sarin gas only. Loads differ between 10kg and 1,000kg release. Different impacts from indoor/outdoor release.	Models sarin/VX gas. Loads differ between 10g and 100kg. same impacts from indoor/outdoor release assumed. Wind is assumed to be minimal to maximise concentric impact.
Biological	As above, non-specific agent	Anthrax and smallpox attacks are modelled. Load sizes range from 1kg to 75kg of slurry.	Anthrax and Smallpox releases considered. Loads range from 10g to 1kg.
Radiological	Single Dirty Bomb scenario – Caesium payload from a 1,500kg explosive device	Dirty bomb sizes range from 1,500 to 15,000 curies of Caesium.	Dirty bombs range from Caesium (low intensity) and Cobalt (high intensity) modelled. Associated explosive force modelled separately.
Nuclear	Explosive loads range from 2kton -10kton. Thermal and blast effects modelled against property – radiological impacts affect human injury.	Explosive loads range from 1kton – 5kton.	Explosive loads range from 1kton – 50kton. Thermal and blast effects are modelled for property losses. Radiological impact modelled for human injury.

The differences in the scale of the attacks between the models is clear, although not regular throughout. Where RMS PTM holds the largest scale chemical, biological, and radiological attacks, Touchstone, and Sunstone hold larger scale explosive loads for nuclear incidents. Critically, it is difficult to adequately justify the scales of the attack types used here – even though there have been mid-scale chemical and biological terrorist attacks in the recent past (1995 Tokyo subway sarin attacks and Amerithrax in 2001). Sunstone is the only platform to model non-lethal and more easily achievable attacks, such as mustard or chlorine gas.

Additional Attack Types

RMS is the only TRM to model direct sabotage attacks on industrial facilities that contain hazardous material. Here the attack vector is not the loss driving impact, but the source of a chemical release or larger explosion. These attack types are necessarily tied to certain locations to an extent that is not replicated in Sunstone or Touchstone.

Target Database Comparisons

All information here is taken from the technical documents of Sunstone,[35] Touchstone,[36] and RMS[37]. The target databases of the three models form the geographical 'anchors' through which the probability matrices and impact curves generate losses against a portfolio of assets. In essence, the targets represent locations that are considered credible locations for attack and, by nature, change to reflect reality. The number of targets that each model contains varies wildly – with each attempting to represent a different modelled reality, as shown in Table 6 below.

Table 6: Target Databases across TRMs

Element	Sunstone	RMS	Touchstone
Number of Targets	~1.3 million	~7,000	~300,000
Countries covered in the model	241	7 (18 countries have targets, but only 7 are useable in the PTM)	USA Only
Number of target categories	40	31	14
Intra-target differentiation	Two tiers, updating to four tiers	5 Tiers, broken down by target type, as opposed to separate tiers of the same target type	Two tiers – standard targets and 'trophy targets'
Associated probability matrices	Annually updated function of historic data and expert opinion	Conditional probability, based on historic data, environmental factors, and active group trends	Function of expert opinion, historic data, and current trends, using the Delphi method

Probabilistic Analysis

All information here pertaining to the probabilistic models is taken from the technical documents of Sunstone[38], Touchstone,[39] and RMS[40]. At a high level, the probabilistic analyses across all three TRMs function in a similar manner. Each is tied to a target database and its associated attack type matrix. The targets are points of interest (POIs) that serve as anchors for the impact curves as described above, which in turn represent the attack types. The models will assign a probability of an attack, or 'rate', at target types and run every applicable attack type at all targets for which the attacks are relevant, taking the loss generated by the attack. They then multiply said loss by the rates to generate an expected loss over a predetermined time period. Typically, the period will be a single year and it is from here that one can scale the losses to determine the size of a 10, 20, 50 year etc. loss to a portfolio. The rates can be, and generally are, geographically distinct, thus creating separate matrices of attack type to target type rate combinations in different geographic areas. In practice, this means that some attack types can be more likely to occur in some areas or against some targets in different parts of the world to reflect reality more effectively.

These models aim to transpose the impact curves, probabilities, and target databases against the modelled portfolio of assets, generating a financial loss summary, thus allowing for a pricing of a risk. Following the application of impacts and rates, losses resulting from the three values – property damage, business interruption, and human injury – are then compared to the relevant insurance structures: policy limits, deductibles, and reinsurance layers are applied by the models' financial engine.

From here, an exceedance probability (EP) curve is derived. The EP curve is used to assess the probability of the portfolio reaching a particular volume of loss in a given year, as per the time period above. There are two types of EP curves. The first, the aggregate exceedance probability (AEP) curve, examines the probability of reaching or exceeding a given volume of loss from an undefined number of events in a given year. The second, the occurrence exceedance probability (OEP) curve, is limited to the probability of a single event exceeding different levels of loss in a year.

All the TRMs listed below form their probability views based on a combination of terrorism incident data (Global Terrorism Database, GTD, for example) and expert opinion. The implementation and influence of the expert opinion are different between all models and raise a pertinent concern with the approach at large: incident data typically shows terrorist attacks that were to some degree successful. Whilst expert opinion may shed light on the rate of interdiction in some territories to an extent, without relevant intelligence clearance in all countries covered, it is unclear how many plots were interdicted and how countries compare. As a result, there remains a speculation within the approach that will be difficult to address without an overhaul of the input methodology.

Differences between the Probabilistic models

Sunstone

Overview derived from Sunstone Technical Document, 2014[41]

Sunstone is a TRM tool that was originally developed by JLT Towers Re and now owned and maintained by Guy Carpenter. The platform is intended to give a more 'realistic' perspective on terrorism than competing models. Others, most notably the RMS PTM, focus on 'macro' events, like truck bombs and airplane collisions in major urban areas, whilst discarding losses in more rural areas and lower HDI countries. Sunstone, instead, models a wide range of attack types – from melee incidents to nuclear events – across all geographies.

Sunstone, like competing models, bases its probabilistic model on three datasets working in tandem – a target database to which terrorist attacks can be allocated, a frequency matrix of attack types to the target types to establish the rates of different attack types at different target types and impact curves to model the effects of attacks at the target locations. These variables are then modelled against portfolios of assets and employees to generate expected losses.

The incorporation of new variables into the Sunstone model is readily achievable and can be approached from several different angles. However, the existing data inputs that impact the frequency calculations are reliant on historical data and qualitative projections, not accounting for geopolitical developments, among other factors, in a quantitative and measurable fashion.

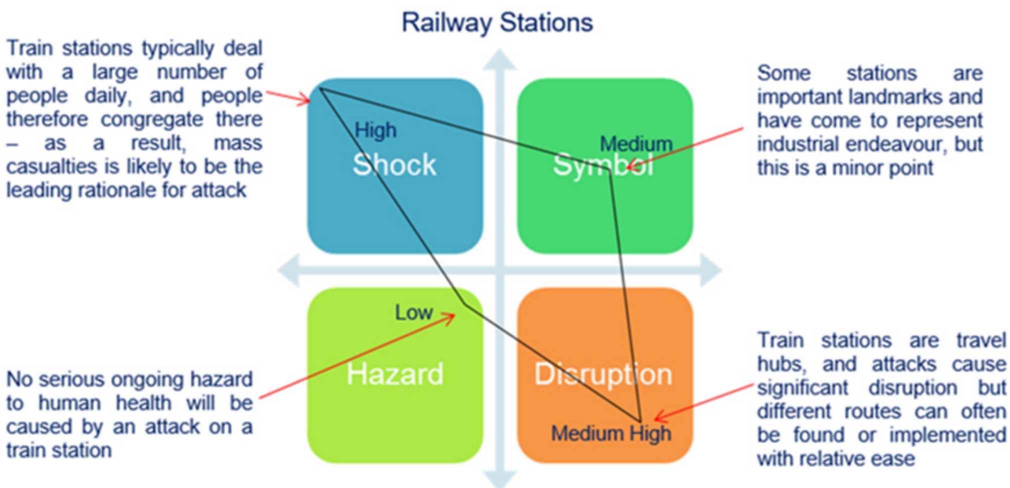
Target Database

With the largest database by far, in both the number and breadth of locations, Sunstone attempts to model global terrorism in as precise detail as possible. The model aims to achieve global coverage, but there remain gaps to date – most notably in Sub-Saharan Africa and Central Asia. The targets themselves are reviewed and audited annually to account for significant changes in target 'realities'. For example, the mass closure of physical bank branches across the West in recent years is reflected in target database updates.

The database contains large, important, and symbolic targets, as well as smaller and perhaps more vulnerable targets. These are differentiated in the 'tier' category of each target – a large and important government facility, such as the UK's Houses of Parliament is a 'tier 1' target, whilst a small council office is a 'tier 4' target.

The process of 'tiering' targets analyses the attractiveness of the targets from four different perspectives: the capacity to cause shock (through death and injury to large numbers of people), its symbolic value, its potential for mass disruption, and finally hazard caused by its destruction or capture. Each target type is given a score for each category of attractiveness – as per below:

Figure 8: Sunstone target tiering methodology



Here, a railway station is given a high shock and disruption score – they are designed to accommodate many people at a given time and are important infrastructure nodes. They have hazard scores since the destruction of a railway station is unlikely to directly result in the release of hazardous material.

As such, the highest tier of railway station requires a large capacity for users, as well as being a particularly important transport hub. An example might be Waterloo or Grand Central Station.

Lower tier targets will invert this – a small rural station, or perhaps an isolated metro station on the periphery of a city.

Where target types have similar attractiveness profiles, tiering is based on similar criteria. Between targets with totally different target profiles, such as industrial facilities and stadia, the relative harm caused by the hazard from attacking said industrial facility will be balanced against the shock of an attack to a stadium, balancing the tiers across all target types.

Probability Calculation

Sunstone holds the largest number of targets and the largest number of attack types of any of the TRMs, with 1.2 million individual target points of interest across 40 different types and 40 different attack types. The attack type and target type matrix are broken down into eight separate geographic areas, dividing the world into the following zones:

- *North America and Australasia*
- *Western Europe*
- *Eastern Europe and Central Asia*
- *East Asia*
- *South and Southeast Asia*
- *Latin America and the Caribbean*
- *Sub- Saharan Africa*
- *Middle East and North Africa*

Each zone holds a different probability matrix, which is updated annually according to changes in the frequency of attacks as shown in the GTD, changes in the qualitative threat outlook in a given territory as well as any updates to the number of targets in a given zone.

Mathematically, this is manifest as an annual rolling review of GTD data, followed by a qualitative inspection of the state of terrorism in a given zone. Each attack type and target type combination will be assigned a 'tier weighting' linking the probability to a target tier. In practice, this allows for a realistic depiction of the threat to a given target type, including the omission of attack type and target type combinations that are unrealistic (boat borne IED against a train station, for example). Some large-scale attack types may be weighted heavily towards small and vulnerable 'low tier' target types. Attack types and target types as listed in the GTD are mapped to their Sunstone equivalents, at which point they are assigned a multiplier of frequency based on the date of the events themselves. These are categorised as follows:

Table 7: Sunstone Attack Frequency Weightings

Time Since the Event	Frequency Weighting
<=5 years	65%
5-10 years	25%
10-25 years	8%
>25 years	2%

In practice, this results in a raw frequency figure for each attack type and target type combination. For example, if a zone had two small IED attacks against police stations in its history, one in 2018 and one in 1990, the total raw frequency associated with this combination would be 0.67 (0.65+0.02). This figure will then make up a percentage of the total prescribed frequency of attacks for a zone, which will be informed by the total number of attacks that have taken place in a given zone in the year before release. Finally, a qualitative assessment will inform a percentage change in the frequency of each attack type/target type combination, to a maximum of a 20 percent movement up or down.

The probability of different attack type/target type combinations can therefore change radically over a year – a steep decline in the year-on-year number of attacks in a zone, perhaps combined with the disarmament of a major terrorist group, will likely see the overall probability of an attack taking place in a zone declining substantially. This was most notable in the 2018 iteration of the probability matrix for Western Europe, which saw not only the decline of terrorist attack frequency, but also the disarmament of ETA in Spain – one of the key drivers of terror in the country (and by extension, the zone) since the 1950s.

Further, the concentration of terrorism losses resulting from the model can vary between years, based on the updated extents of the target database points of interest. All probability is funnelled through the targets themselves, meaning a relative shift in the number of targets away from high-value urban centres can result in losses falling overall – a balance that Sunstone is somewhat unique in attempting to strike. As such, and as with the other TRMs, the fidelity of the target database to reality is a key component in the credibility of the model.

Perhaps the clearest shortcoming in this methodology is that the frequency inputs for the model do not account for the relative security resilience of different countries with regard to preventing terrorist attacks. Indeed, because the only data input here is the GTD – or records of realised terrorism events – it does not account for changes in the likely proportion of planned attacks to successful, non-interdicted attacks in a quantitative manner.

This method can capture the minutiae of changes in terrorism threat and make reasoned and informed predictions as to the likely shape of terrorism given significant changes to the environment of terrorism itself. The key weaknesses lie in the weighting of the historical frequencies and the annual qualitative review – both rely on qualitative assessment that can vary in quality, depending on user-input.

RMS PTM

Overview derived from RMS, Terrorism Model Methodology, 2012[42]

RMS released the PTM in 2003 and has become the most popular TRM in the terrorism insurance market. The PTM is more limited in geographic scope than Sunstone but attempts a more complex and sophisticated projection of losses from a smaller framework: focusing on large urban centres and 'macro-scale' terrorism events. The PTM is updated periodically, with the most recent version, 4.3, released in October 2020.

The RMS PTM refers to the probabilistic functionality, rather than the deterministic capability that is carried out using RMS's Terrorism Scenario Model (TSM).

Probability Calculation

The RMS PTM uses a similar approach to that of Sunstone in calculating the probabilities of attacks – filtering a defined frequency through several factors to arrive at a probability matrix for its attack types and target types. In assigning these frequencies, three factors are considered:

> *"Each attack scenario, composed of a specific combination of target and attack, is assigned a likelihood of occurrence relative to every other attack scenario for that country. This likelihood assumes that a successful terrorist attack occurs, and it is referred to as the conditional probability for that attack scenario. The conditional probability is based on several inputs, including the relative likelihood of:*
>
> *- Successful weapon usage (Attack Mode Likelihood)*
>
> *- Attack for the city in which the target is located (Target City Likelihood)*
>
> *- Attack for each type of target (Target Category Likelihood)"*

The attack mode likelihood is generated separately for conventional and CBRN attacks. Conventional attack types consider the historical frequency of the attacks, their difficulty in execution and their relative interdiction rates. As such, lower impact attacks are favoured in all categories here because they occur more often, have more easily constructed devices and are harder to detect – the opposite is true of larger, more impactful attack types.

The CBRN attack types are calculated somewhat differently, largely due to the dearth of data available. As such, an event-tree is used to estimate frequency of these attacks – accounting for the difficulty in acquiring CBRN materials and construction expertise, political intent of relevant groups and the interdiction capability of local authority. Both the conventional and CBRN attack types consider a risk outlook in addition – reduced risk, standard (unchanged) and increased.

The second factor, target city likelihood, adjusts the frequency weighting for terrorist targets, thus filtering the attack mode likelihood within a country. Larger, more developed, and important cities are favoured here. As per the RMS PTM weighting factor definitions:

> *- City Population—Total population*
> *- Economic Importance— Gross Metropolitan Product (GMP)*
> *- Known Intent to Attack—These are attacks, attempted attacks, appearance on target-lists, or mentions in debriefings by captured operatives*

Other secondary factors considered in the ranking include:

> *- Radical Islamic Activity and Support—the presence of known radical Islamic organisations and movements*
> *- Symbolic Targets—The presence of symbolic targets or association with a symbolic site nearby*
> *- Level of Anti-Terrorism Security—Qualitative assessment and resources allocated in the US Department of Homeland Security disbursal*
> *- Population of the Metropolitan Area—The population of the larger surrounding region rather than the urban boundaries*

The final step is assigning target category likelihood. Here each target type is assigned a tier and an associated likelihood for targeting, thus completing the filter of probability.

Target Database

As of 2021, the targets that make up the RMS PTM are geographically restricted to the major cities and their metropolitan areas in the developed world. As such, the only areas that can be covered by the PTM are in the cities below:

Table 8: RMS Target Locations

Country	Cities	PTM
United States	All Cities	X
Australia	Canberrra, Brisbane, Sydney	
Belgium	Brussels	
Canada	Montreal, Toronto	X
China	Hong Kong	
Denmark	Copenhagen	X
France	Paris	
Germany	Berlin, Frankfurt, Munich	
Greece	Athens	
Great Britain	London	X
Ireland	Dublin	X
Italy	Vatican, Milan, Rome	X
Japan	Tokyo	
Philippines	Manila	
Singapore	Singapore	
Spain	Madrid	
Switzerland	Geneva, Zurich	
Turkey	Ankara, Istanbul	X

RMS Targets, 2012[43]

The RMS target selection methodology is more exclusive than that of Sunstone's approach. According to the PMS methodology documentation:

> *"Targets are defined as geographic locations, buildings, or structures that, if attacked by terrorists, would result in significant property damage, economic interruption, or loss of human life, and would also have a high symbolic impact."*[44]

The targets must be qualified against their peer group to be among the most attractive locations for terrorists to attack. The criteria for this assessment are broken down into four categories:

- *The likely total financial damage and total loss of life that could result from an attack at the location*
- *The possible disruption and resulting economic loss that would result from an attack*
- *The total 'symbolic' value of the target to the cause of the terrorist's grievance*
- *The political significance of the city where the target is located*

Whilst these selection characteristics resemble those of Sunstone above, they entirely focus on high profile targets, against which large-scale attack methodologies would be appropriate for terrorists. For example, a 1,000 kg TNT NEQ device would be wasted against a rural bus stop, a possibility that is considered in Sunstone. Another difference is the geographic restriction of the targets themselves: where the 'broad net' of Sunstone targets naturally cluster in large cities, RMS PTM requires its targets to be in cities of significance, thus excluding areas of possible value that are outside of cities from analysis.

The tiering system used by RMS is based on the target preference for terrorist groups using historic data, rather than assigning different threat values to different types of the same target, as per Sunstone. Here, the target preference for worldwide attacks is accounted for by the frequency by which they are targeted over a given period. For example, government buildings occupy a separate tier to that of industrial facilities and military sites because they have a distinct threat profile, based on the number of times that they have been attacked over a given period.

Touchstone

Overview derived from AIR Terrorism Model, 2016[45]

The Touchstone terrorism model is the second most popular TRM deployed in the insurance market. Whilst the deterministic capability of the model is global, the probabilistic functionality is geographically limited to the USA. Like RMS PTM, Touchstone also focuses on catastrophic events, rather than including the attritional loss effects of smaller, more common attack types.

Probability Calculation

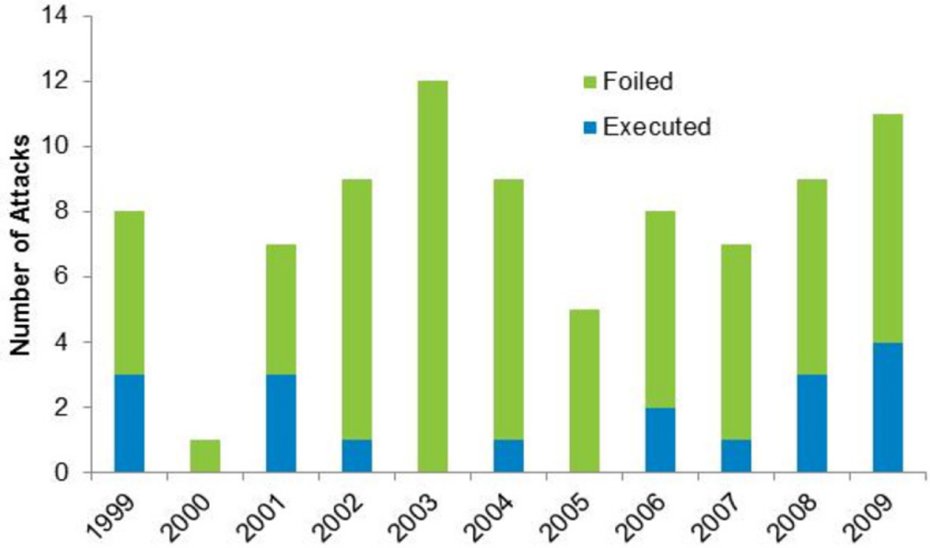
The Touchstone model uses the Delphi Method to determine its attack type frequencies:

> *"The Delphi method is a well-known and accepted approach for developing probability distributions from expert opinion. Developed by the RAND Corporation at the start of the cold war, the Delphi method has been used to generate forecasts in many subjects including inter-continental warfare and technological change."* [46]

This method blends the use of historical data – such as the GTD, FBI data, and US State Department data – and expert or operational opinion to project the effect of historical trends and changes to technology to project future terrorist outcomes. In contrast to Sunstone, this approach accommodates some information to the rate at which attacks are foiled.[47] The expert or operational opinion is drawn from counter-terrorism community in the FBI, CIA, Department of Defense, and Department of Energy. The teams are tasked as such:

- *Team members perform social network analysis and probabilistic plot analysis of the steps required to conduct a successful terrorist operation.*
- *The exercise is performed for each terrorist group type and each type of weapon being considered. Each step in each plot is quantified by resources, skill, time, and probability of success.*
- *The outcome is the estimated overall likelihood of success for the attack type, given that it is chosen by the terrorist group.*

Figure 9: Number of terrorist attacks against US targets.[48,49]



An analysis is then carried out to determine the frequency of attack types to target types in different locales. The possibility of "swarm" events – coordinated attacks that are part of the same plot, using the same weapons type are considered. The access of groups to weaponry, general resources, and the overall impact of counterterrorism activities are all considered in line with the groups' objectives.

This process is more detailed and structured than that of Sunstone, which focuses on key geo-political developments, rather than group specific developments, to drive the forward-looking trend. The Touchstone model considers three types of terrorist organisation – Islamist extremists, state-sponsored groups, and domestic (USA) terrorists. Each of these groups is given a prediction as to the following considerations:

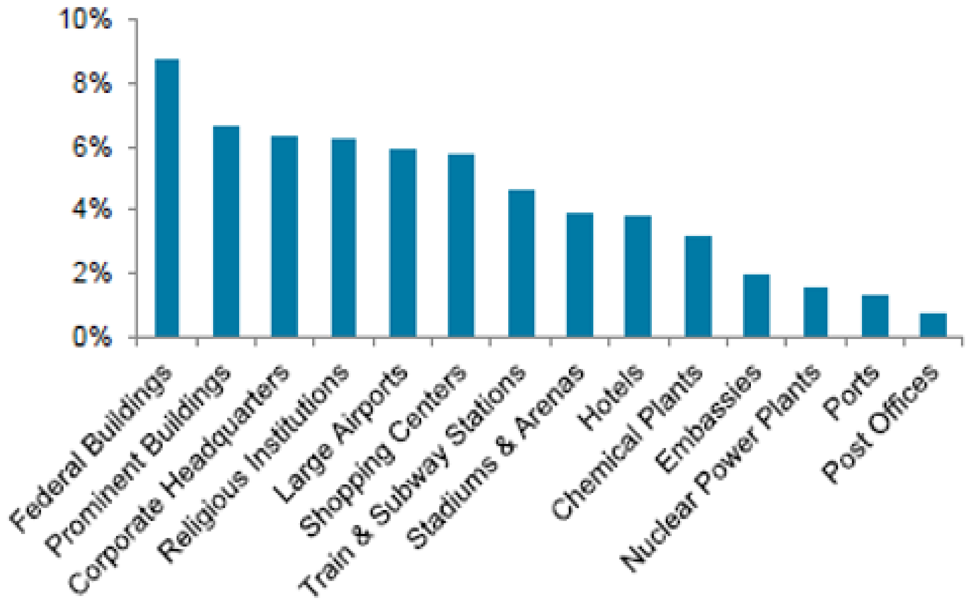
- *Its likely choice of weaponry*
- *How likely it is to commit to 'swarm' events*
- *The likely choice of targets given the likely choice of weapons*
- *The likely location of the attacks (by specific urban area)*

The combination of the above allows for the model to differentiate risk zones within the geographic constraints of the model – directly opposed to Sunstone, which can only differentiate the level of threat within a geographic zone by the density of the target database in a given area.

Target Database

The Touchstone model's probabilistic capability is constrained to the USA. All the approximately 300,000 targets are in the USA. The target types that are used represent all the target types that have been attacked in the USA, and the total of which is distributed as probability drivers for the target categories themselves.

Figure 10: Likelihood of attacks on targets[50]



Targets are broken down further in two ways. The first is the designation of 'trophy' targets, or targets that are "usually heavily crowded or may be symbolically or culturally important to a particular... a preferred site for an attack." These targets are more attractive to terrorists and are therefore considered to be a greater source of threat.

The second differentiation is manifest in the geographic location of the targets across the United States. A list of 274 metropolitan areas is broken down into 5 tiers, with Tier 1 representing the most threatened areas, and Tier 5 the least. These urban areas broadly correspond to the economic and political importance of the cities themselves.

Discussion

There are significant implications of the differences between these models. Most obviously, differences in projected losses to a portfolio result in two entirely different insurance pricing prescriptions. Further, the types of attacks that are generating losses in the modelled portfolio will have implications for the sorts of cover that might provide resilience. For example, a model that lacks specific but common attack types, like events that cause high business interruption but limited property damage, is unable to realise these losses where they are appropriate and impactful for the insurance coverage required. In essence, differences in the approaches to loss projection are themselves a source of uncertainty. This uncertainty can precipitate a lack of confidence in the ability of these models to present terrorism 'realistically' and thus higher prices for coverage ensue.

To contribute to financial resilience to terrorism, the use of these models must lead to a clarification of terrorism threat for those using them, allowing them to offer coverage more efficiently. None of the models can reasonably claim to be the most credible in all categories of risk projection. As it stands, there is no great demand for an overhaul of the modelling approaches laid out here within the insurance industry itself – it appears that the results provided by the models is 'good enough' for insurers to use. To speculate, this is because there is limited understanding of the peril itself within the insurance market and a dearth of significant loss events since 9/11.

The models described in this article differ substantially in their scope and detail, but they do function in a similar way to one another. Sunstone stands out for its breadth and depth of targets and attack types but is less sophisticated in its approach to loss modelling to that of Touchstone and RMS. Crucially, Touchstone and RMS focus exclusively on the catastrophic 'higher end' of terrorist outcomes within a limited geographic sphere. Sunstone alone models smaller events and accommodates their probability as an outcome, rather than acknowledging them as a contributory factor in the determination of more damaging attack types. This design allows for a potentially more precise examination of future losses for large portfolios of assets for the first layer of insurance – the losses suffered by portfolios before reinsurance layers of cover are added, which will typically not suffer loss from small-scale events.

Regardless, the vulnerability factors that are in play with both RMS and Touchstone provide a framework for greater levels of precision in the losses resulting from large-scale events, a feature that is critically lacking in the Sunstone platform. The shielding and channelling effects that urban areas can have on the distribution of explosive load, as well as the vulnerability of buildings based on their construction type is overlooked entirely in Sunstone. Despite this, the models themselves all suffer from the generalisation of effects to an extent – concentric rings and assumed urban density result in the possibility of over or underestimation of projected loss, both of which can lead to inefficient insurance coverage decision making on a deterministic level.

Another common shortcoming of all the models is their reliance on qualitative input and interpretation for their modelled frequencies. Sunstone is perhaps the most simplistic in this regard, not accounting for regional resilience or capability in anything other than a broad stroke fashion. Instead, alternative approaches to frequency calculation should be considered. The question remains as to whether the probability calculation methodologies are adequate for forward projection; it is a combination of precise impact and probability modelling that will allow for the models to project realistic outcomes, after all. The methodologies used here are broadly similar – using a combination of historic data and, to varying extents, expert opinion.

The following research aims to practical steps that would assist in increasing the fidelity of the TRMs to reality:

- *The deployment of more precise blast and weapons effects modelling in the place of concentric analysis. This may include the construction of 3D models of cities which contain information as to the construction type of the constituent buildings.*
- *Exploration of alternative approaches to probability calculation – the existing methodology blending expert opinion and terrorist incident data is necessarily limited by the quality of the experts and their foresight. A robust quantitative calculation approach may be more effective here, if yet to be realised.*
- *Honing these elements of the TRMs allows for more accurate, and therefore efficient, insurance pricing – a societal benefit where terrorism insurance is overwhelmingly*

provided by competing private companies, as well as potentially serving as a useful contributory methodology for assessing terrorism likelihood and geographical distribution on a strategic level.
- The next stage here is to run the models on a standardised portfolio to assess the differences in output. From here, a discussion of the tangible differences in output can be discussed with reference to the respective methodologies described above. Further along this study, the losses will be compared to realised losses where applicable, against which further probability testing can take place.

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Endnotes

1 Makinen, G. (2002, September). The economic effects of 9/11: A retrospective assessment. Library of Congress Washington DC Congressional Research Service.

2 AIR Worldwide (2021), AIR Terrorism Model, [Accessed Online] https://www.air-worldwide.com/models/Terrorism/

3 Risk Management Solutions, Inc.(2012). Terrorism Model Methodology, RMS PTM 3.1 RiskLink 11.0, [Accessed Online] http://support.rms.com.

4 Meng, Fei, (2014), Sunstone Technical Document v1.1, JLT Towers Re, Unpublished.

5 Buesa, Mikel, and Thomas Baumert (2019). 'The economic impact of terrorism.' In Routledge Handbook of Terrorism And Counterterrorism (pp. 185-194). New York: Routledge.

6 Bardwell, Harrison, and Mohib Iqbal (2021). "The economic impact of terrorism from 2000 to 2018." Peace Economics, Peace Science and Public Policy 27, no. 2: 227-261.

7 Drake, Charles (1998). Terrorists' target selection. New York: Springer.

8 Drake, Charles JM. "The role of ideology in terrorists' target selection." In Insurgent Terrorism, pp. 437-469. Routledge, 2017.

9 Silke, Andrew. (2012). 'Understanding terrorist target selection.' In Terrorism and the Olympics (pp.49-71). New York: Routledge.

10 Silke, Andrew. How terrorists think about the economic impact of attacks. Pool Reinsurance (PoolRe).

11 Macklin, Graham. "The extreme right, climate change and terrorism." *Terrorism and political violence* 34, no. 5 (2022): 979-996.

12 For example, Dixon, Lloyd S., Lloyd Dixon, and Rachel Kaganoff Stern (2004). Compensation for Losses from the 9/11 Attacks. Vol. 264. Santa Monica: Rand Corporation;

13 For example, Little, Richard G. (2007). "Cost-effective strategies to address urban terrorism: A risk management approach." The economic costs and consequences of terrorism (pp. 98-115); Stewart, Mark G. (2010). "Risk-informed decision support for assessing the costs and benefits of counter-terrorism protective measures for infrastructure." *International Journal of Critical Infrastructure Protection* 3, no. 1: 29-40.

14 Lakdawalla, Darius, and George Zanjani. "Insurance, self-protection, and the economics of terrorism." *Journal of Public Economics* 89, no. 9-10 (2005): 1891-1905.

15 McGladdery, Gary. (2006).The Provisional IRA in England: the bombing campaign, 1973-1997. Dublin: Irish Academic Press.

16 Coaffee, Jon (2016). Terrorism, risk and the global city: Towards urban resilience. New York: Routledge.

17 Walker, Clive, and Martina McGuinness (2013). "Commercial risk, political violence and policing the City of London." In Crime and insecurity, pp. 246-271. Willan.

18 Jaffee, Dwight M., and Thomas Russell. "Terrorism Insurance: Rethinking the Government's Role." *Issues in Legal Scholarship* 6, no. 3 (2007).

19 Jaffee and Russell, *Issues in Legal Scholarship* 6, no. 3 (2007), p.5.

20 Swiss, Re. "Terrorism-dealing with the new spectre." Focus report, Zurich (2002).

21 Re, Swiss. "Natural catastrophes and manmade disasters 2005: high earthquake casualties, new dimension in windstorm losses, *Sigma Series* No 2, 2006." (2006).

22 Hartwig, Robert (2006), Insurance Information Institute, September 2006, https://www.iii.org/sites/default/files/docs/pdf/September%252011%2520Anniversary.pdf.

23 Johnson, Stephen and Gary A. Ackerman (2023). Terrorism databases: Problems and solutions. In Lara Frumkin, John Morrison and Andrew Silke (Eds.), A Research Agenda for Terrorism Studies (pp.159-176). Cheltenham: Edward Elgar Publishing.

24 *Meng, 2014, Sunstone Technical Document, p.21.*

25 *Meng, 2014, Sunstone Technical Document, p.21*

26 *Meng, 2014, Sunstone Technical Document, p.21*

27 *Meng, 2014, Sunstone Technical Document, p.21*

28 *Meng, 2014, Sunstone Technical Document, p.21*

29 *Meng, 2014, Sunstone Technical Document, p.25*

30 *RMS, 2012, Terrorism Model Methodology, p.52*

31 Meng, Fei, (2014), Sunstone Technical Document v1.1 Appendix 1 – Attack Types, JLT Towers Re, Unpublished.

32 AIR Worldwide (2021), AIR Terrorism Model, p.40-100.

33 Risk Management Solutions, Inc.(2012). Terrorism Model Methodology, RMS PTM 3.1 RiskLink 11.0. p29-31.

34 AIR, 2021, The AIR Model for Terrorism, Accessed 2 September 2023, https://www.air-worldwide.com/siteassets/Publications/Brochures/documents/AIR-Terrorism-Model-Brochure.

35 Meng, Fei, (2014), Sunstone Technical Document v1.1 Appendix 2 – Target List, JLT Towers Re, Unpublished.

36 AIR Worldwide (2021), AIR Terrorism Model, p.24-40.

37 Risk Management Solutions, Inc.(2012). Terrorism Model Methodology, RMS PTM 3.1 RiskLink 11.0. p.11-17.

38 Meng, 2014, Sunstone Technical Document, p.3-25.

39 AIR Worldwide (2021), AIR Terrorism Model, p.24-101.

40 Risk Management Solutions, Inc.(2012). Terrorism Model Methodology, RMS PTM 3.1 RiskLink 11.0. p.37-48

41 Meng, 2014, Sunstone Technical Document.

42 Risk Management Solutions, Inc.(2012). Terrorism Model Methodology, RMS PTM 3.1 RiskLink 11.0.

43 Risk Management Solutions, Inc.(2012). Terrorism Model Methodology, RMS PTM 3.1 RiskLink 11.0 p.18

44 Risk Management Solutions, Inc.(2012). Terrorism Model Methodology, RMS PTM 3.1 RiskLink 11.0 p.11.

45 AIR Worldwide (2021), AIR Terrorism Model.

46 AIR Worldwide (2016), AIR Terrorism Model, p.19.

47 Strom, K., Hollywood, J., Pope, M., Weintraub, G., Daye, C. and Gemeinhardt, D., 2010. Building on clues: Examining successes and failures in detecting US terrorist plots, 1999–2009. Institute for Homeland Security Solutions, pp.621-48.

48 Strom, K., Hollywood, J., Pope, M., Weintraub, G., Daye, C. and Gemeinhardt, D., 2010. Building on clues: Examining successes and failures in detecting US terrorist plots, 1999–2009. Institute for Homeland Security Solutions, pp.621-48.

49 AIR Worldwide (2021), AIR Terrorism Model, p.16.

50 AIR Worldwide (2021), AIR Terrorism Model, p.29

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