Institute of Actuaries of Australia

Terrorism Catastrophe Models

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Terrorism Catastrophe Models – Will Gardner

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Abstract

This paper outlines the Australian Terrorism Insurance Act 2003 and the issues insurers need to consider regarding the Act. It outlines the reasons why models for terrorism differ from models for natural perils and identifies model components where similar methodologies can be applied. Finally, it explains ways in which results of models for terrorism can be used to improve management of terrorism risk.

Keywords

Terrorism; Catastrophe Model; Probabilistic; Event; Terrorism Insurance Act 2003

Introduction

The Australian Terrorism Insurance Act 2003 (the "Act") enacted at 1 July 2003 sets in place the Australian Reinsurance Pool Corporation (the "Pool") that provides a basis for cover for acts of terrorism on Australian soil. The Bill requires insurers to provide cover to commercial insureds on a compulsory basis wherever cover has been provided for property or business interruption.

Insurers may join a pooling scheme which will act as reinsurance for insurers writing terrorism cover. The Pool is funded through contributions from insurers where contributions are based on written premiums at rates that vary by postcode. The rates, assuming no event happens, are 2% for rural postcodes, 4% in major cities and 12% in the Central Business Districts, each contribution rate tripling post-event.

If a terrorism event occurs, as defined by the Act, insurers will retain a maximum of $1m per insurer or $10m for the industry. Above this amount, the Pool will pay claims, up to its total balance, which is expected to grow at around $100m per year to $300m. Above this, $1bn of commercial loan facilities and $9bn of government backed loan facilities are in place to take the total event remuneration from the scheme to a maximum of $10.3bn. The design of the Pool is shown graphically in Figure 1.

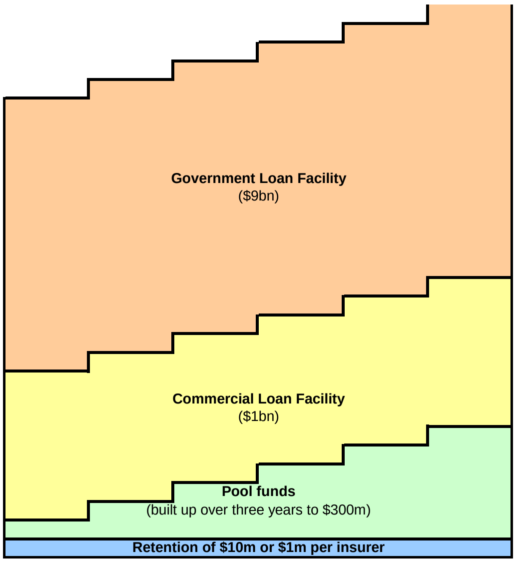

Figure 1 – Structure of Australian Terrorism Reinsurance Pool

The government has stated that the aim of the Pool is to provide a facility for terrorism risk to be transferred until the insurance industry becomes able to insure this risk.

However, there are a number of issues an insurer must consider

- Insurers must provide the cover if they write commercial business
- Insurers are required to retain the first $1 million of any terrorism event
- Insurers are required to fund the scheme through contributions that are a function of written premium, varying by postcode, so this data needs to be collected and maintained

- The terrorism premium to be charged to the insureds is not defined (although it can be assumed that the Pool contribution rates could be a suitable base rate)
- Insurers are not required to be members of the Pool
- The Pool does not operate as a full risk transfer, as loss amounts above the Pool funds are simply loans

Quantification of the terrorism risk is beneficial to insurers in order to determine

- How their relative risk of terrorism compares to their peers
- What is the maximum event loss for an insurer
- How much to charge for the retention
- Whether to retain the risk or not
- Whether or not to be in the Pool or use reinsurance instead

Models

APRA Guidance Note GGN 110.5 – Concentration Risk Capital Charge requires insurers to determine Minimum Capital Requirements (MCR) based on catastrophe modelling. The Maximum Event Retention (MER) should be set as the largest loss to which an insurer would be exposed after reinsurance recoveries and reinstatement premiums, where a return period of 1 in 250 years should be used.

GGN 110.5 states "APRA will expect the insurer to be able to demonstrate an understanding of the model used in estimating the MER.", including but not limited to "the methodology used to incorporate the data and assumptions into the model..". In the author's experience, the task of understanding the models is usually undertaken by or supervised by an actuary. Therefore, actuaries should strive to learn either how the commercial black-box models for natural and man-made perils work, or build their own models for any perils that can cause an MER, not a simple task.

At the time of writing, the providers of commercial modelling software to the insurance industry, US-based companies RMS, EQE and AIR, have simulation models for the terrorism peril for the United States only. It is unlikely they will expand these models to Australia in at least the next three years. However, Aon's catastrophe modelling division, Impact Forecasting LLC, whose models are available exclusively to Aon's clients, has expanded its model to include potential terrorism targets and terrorism events in Australia.

The remainder of this paper describes the workings of the Aon Re Australia Terrorism Model "the model" and gives examples of how the model can be used by a sample insurer (Company XYZ) to understand and manage their terrorism risk.

Natural versus Man-made Disasters

Natural disasters can include tropical cyclones (also known as hurricanes and typhoons), earthquakes, floods, hail, bushfires, tsunami, meteor strikes, drought, ice storms, windstorms and landslides.

Man-made disasters can include large fires, building collapses, oil-spills, landscape modification causing landslides, floods and earthquakes, gas leaks, large scale theft or heist, transportation accidents, explosions and terrorism.

For the majority of the events listed above, the cause of such is accidental. The major differentiator of terrorism from natural perils is that not only is terrorism a man-made peril, but that events are also intentional.

Occurrence-based probabilistic models involve the development of a database of potential events, each such event having a given probability of occurrence. A similar approach can be taken for terrorism, but the determination of event probability is difficult, due to the fact that human decision-making processes are not random.

A model can be thought of having three components: the "where", the "what" and the "when". As shown in Table 1, the where and what can be defined in a similar way to those for a model of natural perils.

	Tropical Cyclone	**Terrorism**
Where?	Category 5 hurricane crosses over Philippines	Two ton truck bomb detonated at United Nations
What?	Wind speeds at each distance from eye cause given levels of damage, leading to financial and human loss	Shock waves and fire cause damage at each distance, leading to financial and human loss
When?	Based on historic records and scientific analysis, this event is expected once every 250 years	??? Human behaviour ???

Table 1 – Where/What/When of modelling

However, the when cannot easily be estimated for a number of reasons.

First, there is not a statistically significant amount of historic terrorism data available to accurately estimate parameters and identify trends. Although in the last twenty years there have been on average more than 400 terrorism events globally each year, there have not been significant numbers in the countries and regions of the world where attacks are now taking place or may take place, such as in the United States or Australia.

Secondly, terrorism is an intentional event. This means that terrorists will seek to attack at the most vulnerable location and time, and will aim in many cases to cause maximum damage and casualties. Although Mother Nature can be deadly, she is not known for being spiteful.

Thirdly, due to terrorism being intentional, it is not to model appropriate the occurrence of an event using a Poisson process. A Poisson distribution (which is often used to the model the occurrence of natural peril events) assumes that

- Events are independent of each other
- Only one event can occur at any instant
- The probability of an event is proportional to the length of a time period

It is normally assumed for the third criteria that the probability remains constant over short time periods.

As none of these three criteria are met by the process that defines terrorism attacks, a Poisson approach cannot be used.

Although there are difficulties in determining probabilities of terrorism attacks, estimates can be made in order to complete an analysis and/or determine the effects of changes in probability on other metrics.

Modelling the Where

The database of potential terrorism targets used in Aon's terrorism model is a selection of locations relating to a wide variety of industries and uses. There are forty target types in five major categories, listed in Table 2.

Commercial	**Infrastructure**	**Government**	**Transport/Education**	**Public**
Business Districts	Dams	Aerospace Installations	Airports	Amusement Venues
Financial Institutions	Medical Facilities	Embassies/Consulates	Bridges	Casinos
Industrial Facilities/Mines/Factories	Oil Refineries	Government Buildings	Bus Stations	Cinemas
Listed Companies in Australia	Oil/Gas Production	Military Installations	Educational Facilities	Indoor/Outdoor Venues
Luxury Hotels & Resorts	Post Offices	Police Headquarters	Museums	Night Club Districts
Media Company Locations	Power Plants	Prisons	Ports	Places of Worship
Shopping Malls	Telecommunication Towers	Scientific Installations	Railway Stations	Sports Venues
Skyscrapers (All)	Water treatment facilities	US Interests	Tunnels	Theatres and Concert Halls

Table 2 – Terrorism Target database

Although in theory every building and location in Australia is a potential target, there needs to be a realistic set of potential targets in terms of modelling. Many locations that could be attacked would not be, as terrorists do not have limitless resources and need to ration their capabilities to attack only prime targets.

The number of targets in the database, 2107, has been selected so that there are enough targets to obtain convergence in spatial and modelling terms, while few enough so that analysis can be performed on the database allowing for model run-time. The targets are mapped below in Figure 2.

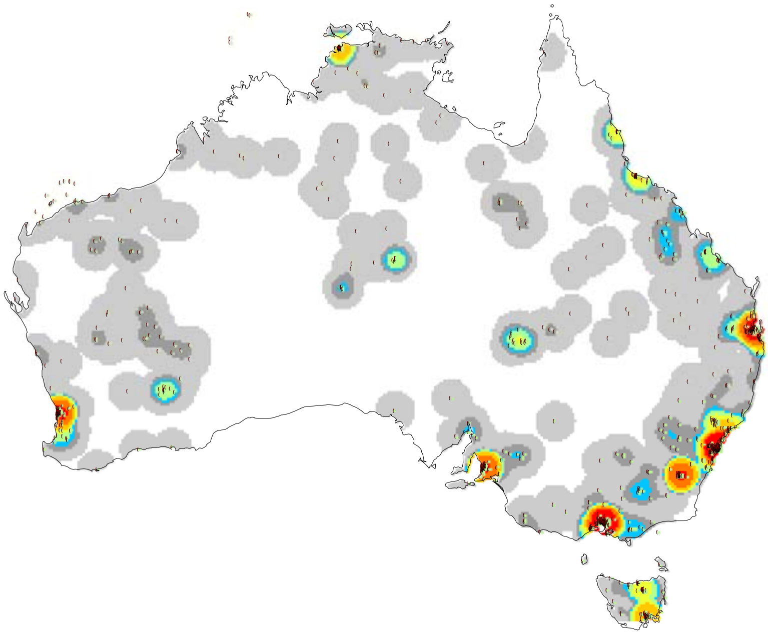

Figure 2 – Terrorism Risk Database Density

Following selection of the database of potential targets, the locations were geo-coded, determining the longitude and latitude of each potential target.

There is some debate regarding the benefit of geo-coding of exposures in modelling to the longitude/latitude level, as opposed to simply clumping all locations in a postcode to the centre of each postcode. For natural perils such as tropical cyclone, there is little difference in results due to the fact that cyclones are large, covering a wide range of postcodes, and the wind speeds recorded within a postcode would not vary to a great degree. However, geo-coding of targets and company is extremely important in the modelling of terrorism as terrorism events such as car bombs are much smaller and the difference of a few metres can make the difference between life and death.

The terrorism database can be used to determine a number of measures for a company's exposure, such as the distribution of company exposure relative to terrorism targets versus a typical industry exposure, as shown in Figure 3.

This figure shows the proportion of total exposure for the company and the industry at each distance from major skyscrapers. In this example, Company XYZ has a slightly higher concentration near targets than the industry over the first eight kilometres from each potential target.

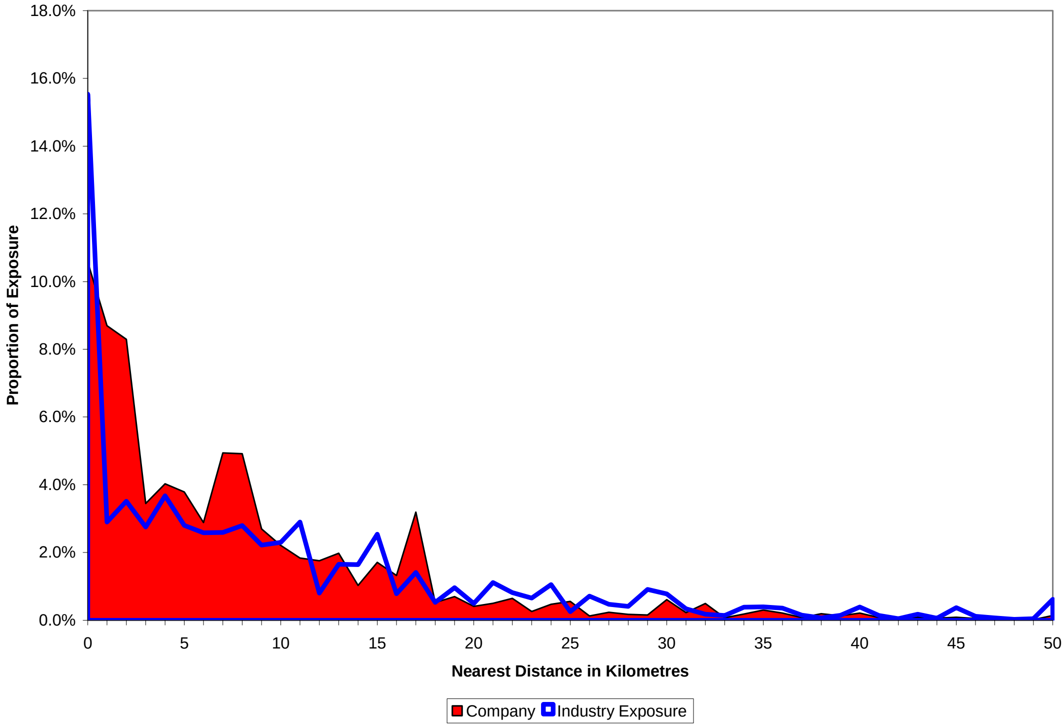

Figure 3 – Company Target Relativity Comparison – Major Skyscrapers

The company exposure can be shown versus industry exposure for each of the 40 categories of terrorism target.

The weighted average distance to each category of target can be used to determine a single measure for each target category, and an average for the portfolio to all targets.

The Terrorism Risk Index (TRI) is defined as one hundred times the average distance to nearest target weighted by industry exposure divided by the average distance to nearest target weighted by company exposure.

Figure 4 - Company Target Relativity Comparison – Terrorism Risk Indices

The weighting system may be based purely on physical distance, or may take into account the relativity of risk at closer distances by using exponentially modified weights, applying much greater importance to company risks located within the first few kilometres from targets.

Modelling the What

24 different attack types are simulated at each of the 2107 targets. The 24 attack types are shown in Table 3.

4	**7**	**7**	**3**	**3**
Nuclear	**Conventional**	**Radiological**	**Biological**	**Chemical**
100 kiloton	Cruise missile	Cruise missile	Large event	Large event
20 kiloton	Multiple aircraft	Multiple aircraft	Medium event	Medium event
10 kiloton	Single aircraft	Single aircraft	Small event	Small event
1 kiloton	Large truck bomb	Large truck bomb		
	Small truck bomb	Small truck bomb		
	Car bomb	Car bomb		
	Human bomb	Human bomb		

Total attack types = 24

Table 3 – Attack Types

The four sizes of nuclear weapon represent a realistic range of potential TNT-equivalent explosiveness for transportable nuclear weapons that are realistic scenarios for international or domestic terrorists.

For conventional weapons, the potential attack types represent a realistic range that has been experienced across the globe in recent years.

The radiological weapon sizes are equivalent to the conventional attack types, although it is assumed that radiological material and dispersion agents are used to spread the radioactive material in the most effective way.

There is much uncertainty involved when modelling chemical or biological weapons. For chemical weapons, among the many factors that must be considered are wind speed and direction, humidity and changes in humidity, terrain and topography, vegetation, air temperature and time of day. As biological weapons may be transported long distances by human “carriers”, a detailed model would be required to incorporate complex interactions between people riding on planes, landing in other cities and allowing for medical reaction to the spread of any contagious threat.

Because of the complexity of modelling biological and chemical weapons, it was decided to simply model three realistic scenarios for each attack type, ie. Small, medium and large, and allow for their likelihood in the treatment of probability for chemical and biological weapons. The largest of the chemical attack scenarios causes injury as far as twenty kilometres from the target.

For each event, the distance is calculated from the target to the locations of insured risk. This distance is used to determine the distribution of potential damage to buildings and contents, the distribution of potential loss of occupancy or business interruption and the distribution of probability of injury and death to humans at each location. Sample damage functions for human injuries and deaths are shown for a conventional large truck bomb in Figure 5.

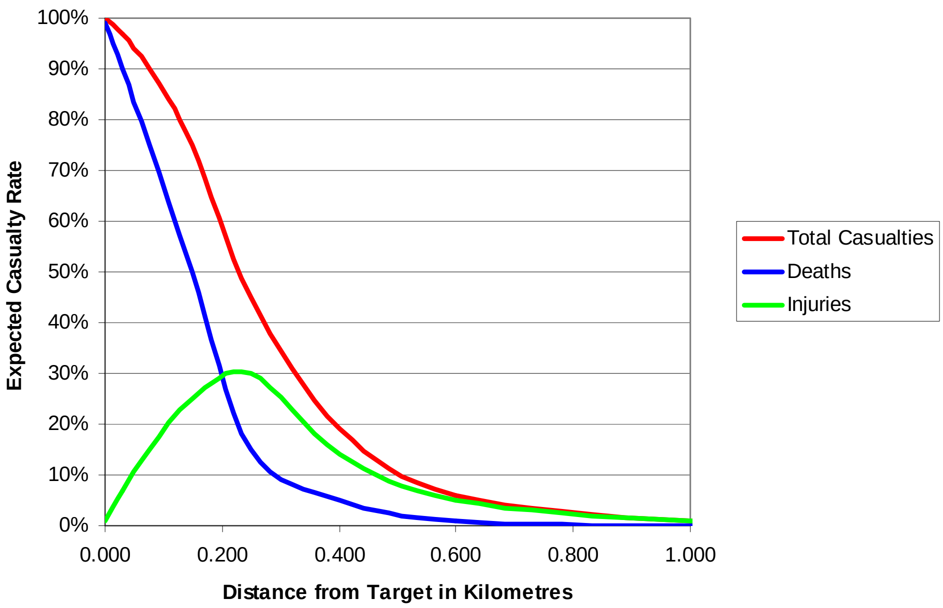

Figure 5 – Mean Casualty Rates - Conventional Weapons – Large Truck Bomb

Much research has been undertaken into effects of various explosives, due to the use of such tools in construction and as weapons in war over the last few centuries. There are many sources of information relating to damage distributions which were used in the construction of this model.

The damage distributions in this model were determined and peer reviewed by certified engineers following discussion and interaction with experts from Impact Forecasting LLC in Chicago, Illinois, Shirmer Engineering in Deerfield, Illinois, Aon Special Risk Team in London, UK, members of British Intelligence located in Chicago, Illinois, and a small selection of ex-Navy Seals and ex-military personnel. Additional references are listed below.

For each damage distribution, the uncertainty around a mean loss rate can be used for determining costs of loss above insurance excesses and/or losses up to insured limits. This is more important when modelling commercial property policies, the form of insurance likely to be effected by terrorist attacks.

The mean loss from simulated events for each attack type at a given target is shown for Company XYZ in Table 4.

	Target Number	27
	Name	Reserve Bank Of Australia - Adelaide
	Address	182 Victoria Square
	City	Adelaide
	State	SA

Attack Index	Attack Type	Expected Loss
1	Nuclear - 200 Kiloton	226,501,088
2	Nuclear - 20 Kiloton	174,723,559
3	Nuclear - 10 Kiloton	112,523,093
4	Nuclear - 1 Kiloton	83,752,385
5	Conventional - Cruise Missile Attack	4,037,915
6	Conventional - Multiple Aircraft	5,177,315
7	Conventional - Single Aircraft	3,145,328
8	Conventional - Large Truck Bomb	1,506,309
9	Conventional - Small Truck Bomb	800,224
10	Conventional - Car Bomb	444,037
11	Conventional - Human Bomb	13,320
12	Radiological - Cruise Missile Attack	7,358,117
13	Radiological - Multiple Aircraft	7,424,596
14	Radiological - Single Aircraft	4,141,269
15	Radiological - Large Truck Bomb	3,129,070
16	Radiological - Small Truck Bomb	2,550,403
17	Radiological - Car Bomb	1,866,027
18	Radiological - Human Bomb	1,282,064
19	Biological - Large Attack	8,875,172
20	Biological - Medium Attack	1,452,493
21	Biological - Small Attack	256,539
22	Chemical - Large Attack	16,312,988
23	Chemical - Medium Attack	2,536,491
24	Chemical - Small Attack	304,646

Table 4 – Expected Loss by Attack Type

Definition of terrorism

The Macquarie Dictionary defines terrorism as “The use of terrorising methods; the state of fear and submission so produced; a method of resisting a government or of governing by deliberate acts of armed violence”

The key points of definition in the Terrorism Insurance Act are:
- “action or threat of action” …
- “intention of advancing a political, religious or ideological cause”
- “intention of coercing or influencing by intimidation” … or
- “intimidating the public or a section of the public”

According the Act, in order for an event to be declared a “terrorism event”, the Minister, after consulting the Attorney General, must declare it so.

The US Terrorism Act has a similar method of definition, but requires the agreement of the Treasury Secretary, the Secretary of State and the Attorney General. It also specifies that events must be international rather than domestic acts.

In most cases, losses of Australian insurers would be ceded to the Pool. However, terrorism events must be clearly defined, as the Act would not apply for losses below the minimum retention, for classes of business not covered by the Act and for insurers who choose not to join the Pool, selecting instead international reinsurance.

Modelling the When

As previously mentioned, the determination of the frequency of terrorism attacks, or the "when" of the model, is not a simple process. In order to perform an analysis similar to a probabilistic study of a natural peril, assumptions are required to be made for

- the annual frequency of events;
- the conditional probability of an attack at each target or target type given an event occurs; and
- the conditional probability of an attack of each form given an event occurs.

Although credibility of any estimates must be taken into account, there are a number of ways in which frequencies can be derived for use in a model. Three approaches can be used to estimate frequencies :

- Statistical
- Opinion-based
- Reinsurance rate implied frequencies

Statistical pricing implies the use of past experience. For regions such as the Middle East, where historical frequencies have been relatively high, there is more credibility in any past data. In regions such as the United States and Australia, there have fortunately not been enough attacks to provide credibility to any statistics.

The US Department of State year 2000 report "Patterns of Global Terrorism", updated in 2002 to include 2001 events, provides statistics on international terrorism frequency. Figures 6 and 7 show respectively the total number of international terrorism attacks from 1981 to 2001 and the total number of international attacks by region from 1985 to 2001.

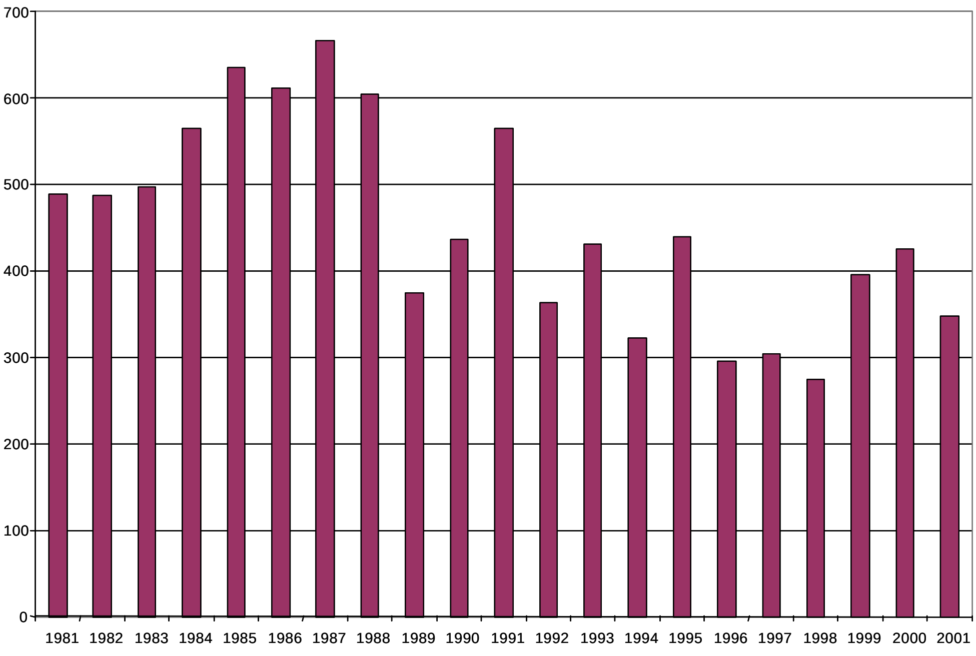

Figure 6 – Total International Terrorism Attacks by Year

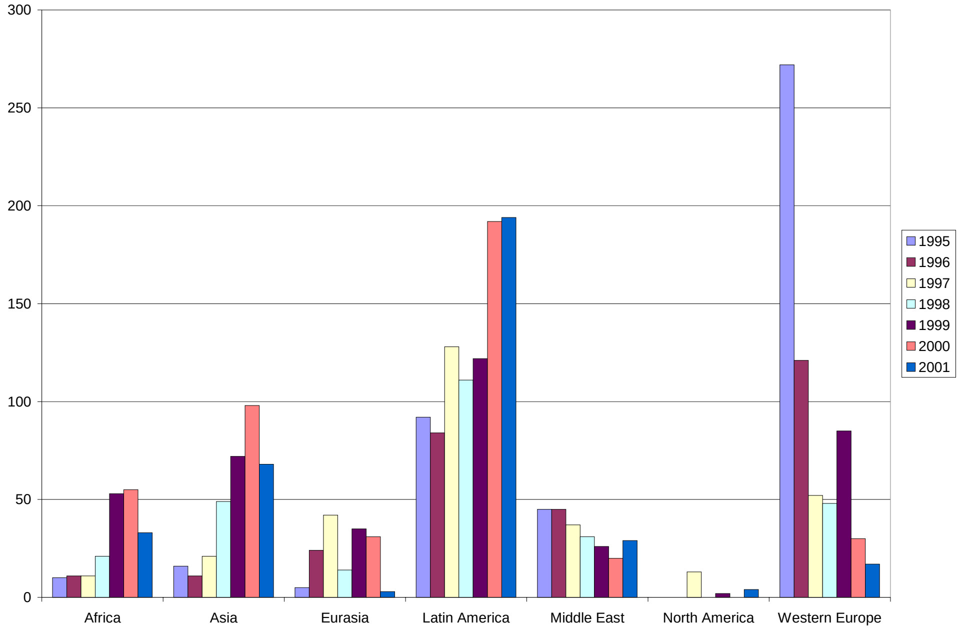

Figure 7 – Total International Attacks by Region

The U.S. Department of Justice Federal Bureau of Investigation report Terrorism in the United States 1999 shows statistics on different types of terrorism attacks. Table 5 shows the comparative figures by target type from the two reports. Figures 8 and 9 show respectively the proportion of terrorism attacks by target type and the proportion of terror attacks by event type from the FBI report.

Year	Business	Diplomat	Government	Military	Other
			Department of State		
1995	338	22	20	4	126
1996	235	24	12	6	90
1997	327	30	11	4	80
1998	282	35	10	4	67
1999	276	59	27	17	95
2000	384	30	17	13	113
Total	67%	7%	4%	2%	21%
			Federal Bureau of Investigation		
1980-1999	232	61	101	13	7
Total	56%	15%	24%	3%	2%

Table 5 – Attacks by Target Type

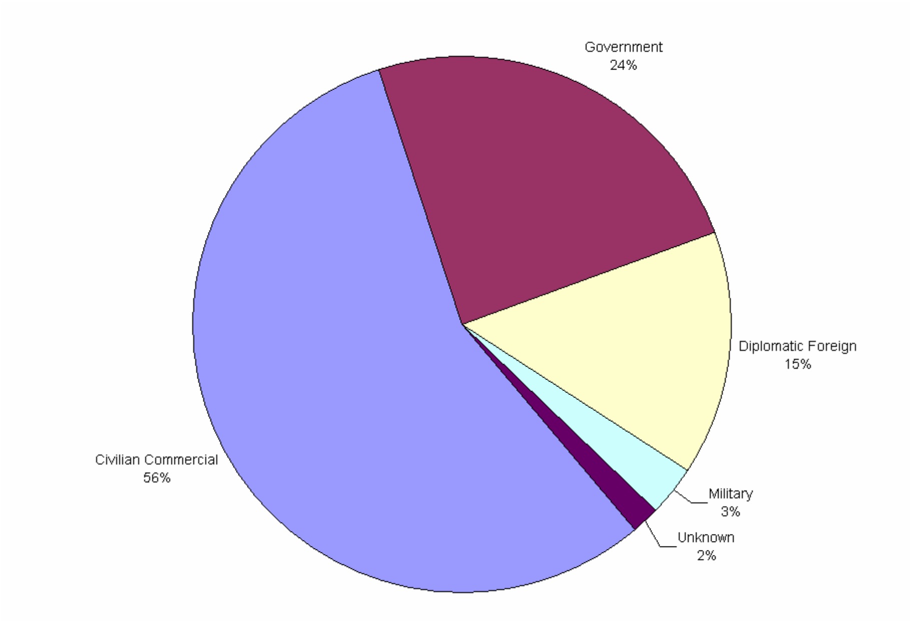

Figure 8 – Terrorism by Target

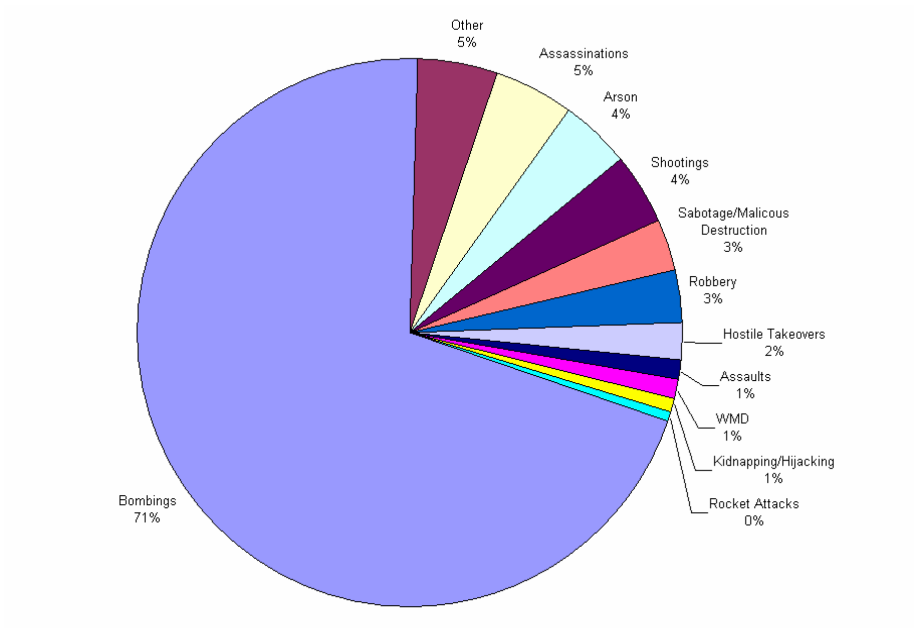

Figure 9 – Terrorism by Event Type

As limited data is available for the region of interest, opinion based frequencies may be used as an alternative. Techniques such as the Delphi Method (developed by the Rand Corporation during the Cold War) can be used to give weights to each of the expert opinions, based on the credibility and estimated accuracy of each expert's opinion.

Although many people are involved in the global fight against terrorism and have been concentrating on Al Qaeda and the terrorism risk in recent years, human behaviour is difficult to predict with any real certainty. Opinion based frequencies are only credible to the extent of the expertise of the experts providing such an opinion, so unless the actual terrorists are the ones providing the opinions, it is difficult to see how anyone can make accurate predictions of what the terrorists may do.

As the opinion-based approach provides such a high level of uncertainty it should therefore only be used when no other approaches are available.

Reinsurance-based estimates can be made for such uses as allocation of cost and estimates of expected losses on retentions on reinsurance policies, when an estimated or actual market price has been set for an excess of loss reinsurance contract on terrorism risk.

This approach starts with an analysis of potential losses by target and attack and type, as outlined above. Estimates must be made of the conditional probabilities of attack by target and attack type, conditional on an event occurring. The estimated or actual market premium for the reinsurance contract, adjusted for an estimated profit margin, can be compared to the estimated model losses in the range of reinsurance market price to determine the implied annual frequency used in the reinsurance pricing. This frequency can then be used to price other layers of cover or the retention below where the reinsurance contract attaches.

The draw-back of this method is that the reinsurance profit margin in the current environment, due to the wide range of uncertainty in terrorism modelling and pricing, makes up the majority of any terrorism reinsurance price. For some actual contracts on natural perils at high layers, for return periods of, say, greater than 250 years, the quoted price of an excess of loss layer may contain a margin equivalent to more than ten or twenty times the expected loss in that layer. Terrorism quotes, due to the higher uncertainty and the use by many reinsurers of minimum Rates-on-Line, may contain margins many times higher. This means that the estimation of the implied expected loss has a wider error margin.

The lack of certainty in each of these approaches demonstrates how difficult it is to estimate frequencies in terrorism modelling.

Using the results

Once the model assumptions have been made, it is possible to calculate a number of metrics from the analysis:

- Premium rates can be estimated from the annual expected cost of terrorism attacks at each geographic location or postcode. (Figure 10)

- PMLs may be used for risk management through the determination of reinsurance purchasing requirements and the pricing of such contracts.

- Reinsurance costs can be allocated to underlying policies using the losses in each reinsurance contract attributable to each location or policy.

- Retention pricing can allow insurers to estimate their expected losses below any reinsurance contract or participation in the Pool and allocate this cost accordingly.

- Maximum industry event losses and the probability distributions of such losses may be estimated and used by regulators to determine the security of the industry and exposure to the terrorism peril (Table 6)

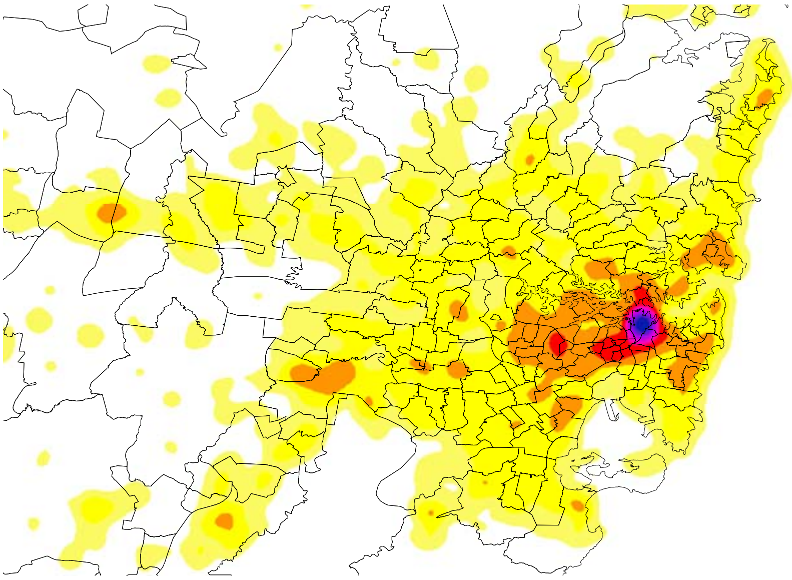

Figure 10 – Relative Terrorism Risk by Location - Sydney

Potential losses on a sample portfolio indicative of the total insurance industry are shown in Table 6. It can be seen that attacks from the larger attack forms at the given target would produce industry losses that would exhaust any funds in the Pool and exhaust each of the commercial and government loan facilities. Multiple events would cost even greater losses.

Target	1
Name	Sydney CBD
Address	500 George St
City	Sydney
State	NSW
Postcode	2000
Longitude	151.207098
Latitude	-33.872113

Attack Type	Property Insurance Commercial	Property Insurance Residential	Deaths	Life Insurance Cost (* $300K)	Injuries and Deaths	Workers Compensation Cost (* $250K)	TOTAL
1 Nuclear - 200 Kiloton	27,721,277,294	47,339,274,491	677,893	203,367,900,000	589,547	147,386,750,000	425,815,201,785
2 Nuclear - 20 Kiloton	24,912,877,120	36,880,980,650	552,733	165,819,900,000	530,805	132,701,250,000	360,315,007,770
3 Nuclear - 10 Kiloton	21,480,625,032	24,583,199,619	277,023	83,106,900,000	313,322	78,330,500,000	207,501,224,651
4 Nuclear - 1 Kiloton	19,274,212,792	18,909,018,347	196,154	58,846,200,000	184,627	46,156,750,000	143,186,181,139
5 Conventional - Cruise Missile Attack	5,991,149,504	1,369,702,017	17,373	5,211,900,000	6,226	1,556,500,000	14,129,251,521
6 Conventional - Multiple Aircraft	7,153,426,632	1,710,975,488	24,528	7,358,400,000	9,747	2,436,750,000	18,659,552,120
7 Conventional - Single Aircraft	3,955,715,013	884,285,754	16,904	5,071,200,000	6,864	1,716,000,000	11,627,200,767
8 Conventional - Large Truck Bomb	1,435,660,991	320,118,103	7,017	2,105,100,000	4,270	1,067,500,000	4,928,379,094
9 Conventional - Small Truck Bomb	448,795,413	100,070,655	5,158	1,547,400,000	3,506	876,500,000	2,972,766,068
10 Conventional - Car Bomb	256,050,901	57,093,234	72	21,600,000	397	99,250,000	433,994,135
11 Conventional - Human Bomb	-	-	-	-	19	4,750,000	4,750,000
12 Radiological - Cruise Missile Attack	13,042,651,037	3,489,753,500	18,657	5,597,100,000	6,966	1,741,500,000	23,871,004,537
13 Radiological - Multiple Aircraft	12,334,091,755	3,241,577,348	24,937	7,481,100,000	11,051	2,762,750,000	25,819,519,103
14 Radiological - Single Aircraft	8,823,234,581	1,987,964,028	18,297	5,489,100,000	7,743	1,935,750,000	18,236,048,609
15 Radiological - Large Truck Bomb	4,449,751,627	996,907,374	7,689	2,306,700,000	4,884	1,221,000,000	8,974,359,001
16 Radiological - Small Truck Bomb	2,520,143,710	562,495,793	5,758	1,727,400,000	3,891	972,750,000	5,782,789,503
17 Radiological - Car Bomb	1,481,438,600	330,889,368	372	111,600,000	679	169,750,000	2,093,677,968
18 Radiological - Human Bomb	1,958,057,623	436,600,071	-	-	100	25,000,000	2,419,657,694
19 Biological - Large Attack	8,565,088,291	2,980,978,803	54,580	16,374,000,000	57,423	14,355,750,000	42,275,817,094
20 Biological - Medium Attack	2,211,527,782	532,518,628	17,591	5,277,300,000	15,407	3,851,750,000	11,873,096,410
21 Biological - Small Attack	283,472,773	63,771,608	1,859	557,700,000	1,458	364,500,000	1,269,444,381
22 Chemical - Large Attack	12,047,377,821	5,036,740,166	91,061	27,318,300,000	102,095	25,523,750,000	69,926,167,987
23 Chemical - Medium Attack	3,641,599,269	958,260,072	29,645	8,893,500,000	30,193	7,548,250,000	21,041,609,341
24 Chemical - Small Attack	334,609,731	75,455,905	2,231	669,300,000	1,665	416,250,000	1,495,615,636

Table 6 – Estimated industry loss from specified event

The model losses outlined in this paper have focused on losses at the time of the event at the risks physically located in the vicinity of the attack. Although business interruption losses are modelled for the locations physically affected by the attacks, economic losses to companies and industries can reach beyond the vicinity of any attack form. For example, the bomb blasts in Bali in 2002 have led to a wide reduction in tourism to the whole of South East Asia and beyond. Extent of losses beyond both the geographical locations modelled and classes of insurance modelled should be considered in any assessment of terrorism risk.

Conclusions

In summary, it is possible to model terrorism in a similar manner to the approach taken for the modelling of natural perils. However, the probabilistic component of any model presents the greatest difficulty due to uncertainty surrounding the modelling of human behaviour.

Terrorism needs to be modelled and models need to be understood and accepted if the risk is eventually to be passed from the Australian Government to the insurance industry.

References

Weapons, Updated Edition, The Diagram Group, 1990

Explosion in Air, Baker, W.E. University of Texas Press 1973

Introduction to Structural Dynamics, John M. Biggs, MIT, 1964

Explosives and Demolitions, Field Manual 5-25, Headquarters, Department of the Army, 1986

US Navy Seal Combat Manual, Special Warfare Training Handbook, Lancer, 1974

Chemical and Biological Warfare, Eric Croddy, Springer-Verlag, 2002

How to Make War, Third Edition, James F. Dunnigan, 1993

Patterns of Global Terrorism, The Department of State, 2000

Terrorism in the United States, The U.S. Department of Justice Federal Bureau of Investigation, 1999

Power and Weakness, Robert Kagan, Policy Review No.113, Hoover Institution, Stanford University