Workers' Compensation Risk Assessment California Terrorism

Report Prepared For:

Workers' Compensation Insurance Rating Bureau of California
October 2018

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Executive Summary

RMS conducted a California terrorism risk assessment for the Workers' Compensation Insurance Rating Bureau (WCIRB) to determine the proportion of workers' compensation loss payable that is covered by insurers, the US government, and retained by the policyholders under the US Terrorism Risk Insurance Program Reauthorization Act (TRIPRA) for calendar year 2019. RMS quantified total workers' compensation losses using an analysis of exposure data from member companies of the WCIRB.

Key highlights from this study are described below.

Exposure Overview and Assumptions

Terrorism risk is very concentrated in nature and often varies significantly over small geographic areas. The resolution of address data is therefore very important in determining a location's proximity to targets, hazard level, and financial impact, given a terrorist attack occurs. The quantification of terrorism risk, as a result, is greatly dependent on the detail and positional accuracy of the underlying exposure data.

To ensure consistency with the corresponding WCIRB Earthquake Casualty Risk Assessment conducted in December 2017, RMS utilized the same exposure dataset and assumptions, as summarized below:

- The WCIRB portfolio contains 11.4 million full-time equivalent (FTE*) employees across 543,502 distinct locations in California, with a total payroll of $544 billion. The portfolio is structured so that each record consists of a location's data grouped by occupation class, resulting in a total of 993,123 records in the dataset.
- For 98% of the exposure, RMS was able to achieve a high level of positional accuracy (street address or better).
- Building attributes, such as number of stories or construction class, were not available. RMS was able to backfill this data for locations that geocoded to a building centroid. For the remaining locations, RMS utilized regional building stock to infer the building density mix based on the provided ZIP code.
- When evaluating workers' compensation losses for terrorism risk, in addition to considering the geographic location of exposure, the number of employees exposed to any particular attack must also be accounted for. Employees are only insured while working. The model attempts to capture the correct exposure by taking into consideration any available shift data. In the absence of such data, RMS utilizes an average industry distribution by occupation class to determine the FTE exposed at the time of an attack.
- When modeling terrorist attacks, RMS identifies likely terrorist targets that have a high symbolic value or the potential to cause significant economic damage or mass casualties. These include categories such as government buildings, stadiums, skyscrapers, tourist attractions. When modeling mobile exposure such as workers' compensation line of business, one needs to determine where people are located throughout the day to calculate potential losses from an attack. For this study, RMS chose 11 a.m. on a weekday to estimate the number of employees exposed as it represents the peak occupancy levels for most occupations.

*FTE: the equivalent number of employees who work 40 hours/week.

Cost Severities

RMS estimates the average cost (medical and indemnity) expected from a given injury state using a simulation approach that accounts for legal, regulatory, demographic, and medical treatment information on a U.S. state-level basis.

RMS caps the indemnity death benefit to a maximum of $320,000, corresponding to the maximum benefit for employees with three or more dependents. On WCIRB's request, RMS revised this death benefit to assume a maximum benefit of $290,000, reflecting the maximum benefit for employees with only two dependents. After re-running the simulation with this revision, the overall state-level death benefit reduced from $282,000 to $274,000.

Table 1 provides the modified cost severities for California using the new simulation with only two dependents per worker. This is the same cost severity scheme as was used for the 2017 WCIRB Earthquake Casualty Risk Assessment.

Table 1: Workers' compensation cost severities in California

Cost component	Medical only	Temporary total	Permanent partial-minor	Permanent partial-major	Permanent total	Fatal
Medical	$1,440	$10,300	$73,000	$365,000	$2,000,000	$120,000
Indemnity	$0	$7,300	$47,200	$194,000	$1,658,000	$274,000
Total	$1,440	$17,600	$120,200	$559,000	$3,658,000	$394,000

Loss Modeling

Table 2 illustrates the probabilities of activation for the program cap, program trigger, and deductible associated with the 2019 TRIPRA program. The WCIRB effective deductible is the portion of the TRIPRA deductible that is retained by WCIRB-member companies.

Based on an attack catalog drawing from approximately 60,000 terrorism events, RMS analysis suggests that there is a 9.5% probability of triggering the TRIPRA program (or exceeding $180 million for all TRIPRA eligible lines of business). This should not be interpreted as a 1-in-10 chance of terrorist attack. Instead, it indicates that the methodology used to generate the exceedance probability curve considers events which are very severe but unlikely due to pervasive counter-security measures. Because there are relatively few points on the exceedance probability curve that correspond to the lower return periods (i.e. <100 years), a mathematical interpolation is used to infer losses.

Using this interpolation, the likelihood of reaching the TRIPRA threshold ($180M) is 9.5%. RMS analysis also suggests there is a 0.26% probability (corresponding to a 391-year return period) that the workers' compensation losses will exceed the WCIRB effective deductible of $1.9 billion. Of the workers' compensation losses that exceed the WCIRB effective deductible and are below the program cap adjusted for workers' compensation line of business, the government retains 81%. The remaining 19% along with the deductible is covered by the WCIRB-member companies. Please refer to the "TRIPRA Overview" section for additional details.

Table 2: Probability of TRIPRA Program Activation

Program Structure	Value	Return Period	Critical Probability
Program CAP	$100,000,000,000	15,173	0.0066%
TRIPRA Deductible Activation	$31,069,998,200	2,524	0.0396%
WCIRB Effective Deductible Activation	$1,918,099,004	391	0.2557%
Program Trigger	$180,000,000	10	9.5867%

The workers' compensation loss retained by the WCIRB-member companies under the TRIPRA Program is referred to as *Net-Insured Retained*. Key metrics in respect to the net-insured retained losses are listed below:

- 1-in-10,000-year net-insured retained loss of $5.0 billion
- 1-in-5,000-year net-insured retained loss of $3.8 billion
- 1-in-500-year net-insured retained loss of $2.0 billion
- An average net-insured retained loss per year of $21 million, with an average loss rate per FTE of $1.85 and an average loss rate per $100 payroll of $0.0039

Central business districts (CBD) and skyscrapers are the top loss-causing target categories. Without the TRIPRA program, they incur an average annual loss of $14.8 million and $9.1 million, respectively. Under the TRIPRA Program, each comprises of an average net-insured loss of $8.6 million per year.

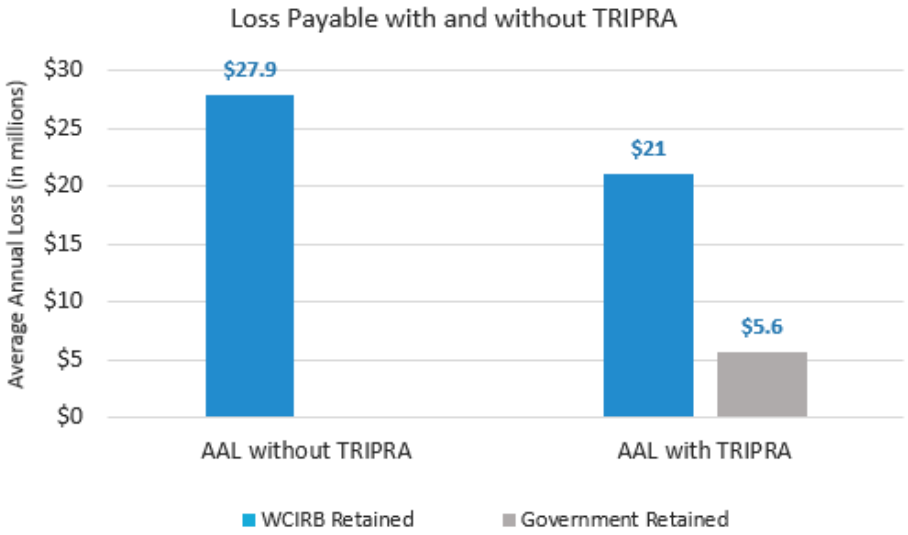
Biological anthrax attacks account for the highest average annual losses to the WCIRB portfolio without TRIPRA. When factoring in the 2019 TRIPRA structure, however, it is the 600 lb. bomb that results in the largest net-insured retained average annual losses, with a value of $8.9 million.

Although Los Angeles has the most exposure, San Francisco generates the highest loss, with an average annual loss of $16.7 million to the WCIRB portfolio without TRIPRA and $12.2 million in net-insured loss payable with the 2019 TRIPRA Program. This is due to the high density of exposure and potential terrorist targets in San Francisco.

TRIPRA Effect on Loss Payable

Figure 1 depicts the average annual loss (AAL) payable by WCIRB-member companies and by the government with and without the 2019 TRIPRA Program.

Figure 1: WCIRB Loss payable with and without TRIPRA



Without TRIPRA, the WCIRB average annual loss payable is $27.9 million. With TRIPRA, $1.3 million of this loss lies above the program cap. The remaining loss of $26.6 million is shared between the government and WCIRB. $5.6 million is retained by the government, and $21 million is retained by WCIRB-member companies, reducing their loss payable by 25% due to the TRIPRA program.

Analysis Settings and Assumptions

This risk assessment was conducted using Version 4.2.18 of the RMS Probabilistic Terrorism Model (PTM), released in the summer of 2018. This model incorporates updates to reflect recent trends in the terrorism risk landscape, including an update of the global target database. The model only considers macro attacks that can potentially result in huge economic losses (in excess of US$1 billion) or casualties of more than 20 fatalities and/or 100 injuries.

The model uses an attack catalog of 66,365 events across the United States. All attack modes were incorporated in this analysis, including conventional and chemical, biological, radiological, and nuclear (CBRN) attacks. Results were modeled using a standard risk outlook, which represents the best assessment of the risk of macro-scale terrorism loss for the current parametrization.

Details of the model methodology can be found in the “Model Methodology” section.

Exposure Summary

Exposure Summary

The WCIRB provided exposure data represented by aggregate payroll and the number of FTE by occupation class. The dataset consisted of 993,123 records in the state of California with coordinate and street-level address information by employer for each member company. RMS utilized the FTE data and street-level address information for each location and occupation type.

As done in the WCIRB Earthquake Casualty Risk Assessment, RMS geocoded the dataset using the street-level address information, resulting in 98% of the exposure corresponding to a high-resolution geocode match (street level or better). Table 3 provides a breakdown of the WCIRB portfolio by geocode resolution.

Table 3: Total FTE and total payroll by geocode resolution

Geocode resolution	Number of records	Total FTE*	Total payroll (in millions)	% of total FTE	% of total payroll	Description of resolution
Building	30,386	630,290	$37,498	5.6%	6.9%	Geocodes to the exact center of the building footprint.
Parcel	713,817	8,210,299	$390,324	72.3%	71.8%	Geocodes to the exact center of the parcel boundaries for street address match.
Street	234,057	2,328,739	$107,157	20.5%	19.7%	Geocoder achieves a fine level of positional accuracy by interpolating the location of the property along a street segment.
Street name	4,108	59,156	$2,645	0.5%	0.5%	Geocoder achieves a level of positional accuracy based on the centroid along a set of street segments representing the street and an enclosing geography, such as the postal code.
Postal code	10,755	127,369	$5,966	1.1%	1.1%	Geocoder places the location on the centroid of the postal code (e.g., U.S. zip code) in which it falls. Postal-code centroids are exposure and population weighted to provide a better representation of exposure. Population-weighted centroids and geographic centroids are not usually the same place.
Total	993,123	11,355,852	$543,586	100%	100%	

* The FTE has been rounded to 0 decimal places for presentation purposes only. The model itself captures the fractional employees.

Note: Employees of temporary staffing firms are allocated to their estimated places of employment.

Exposure by RMS Employee Occupation Classification

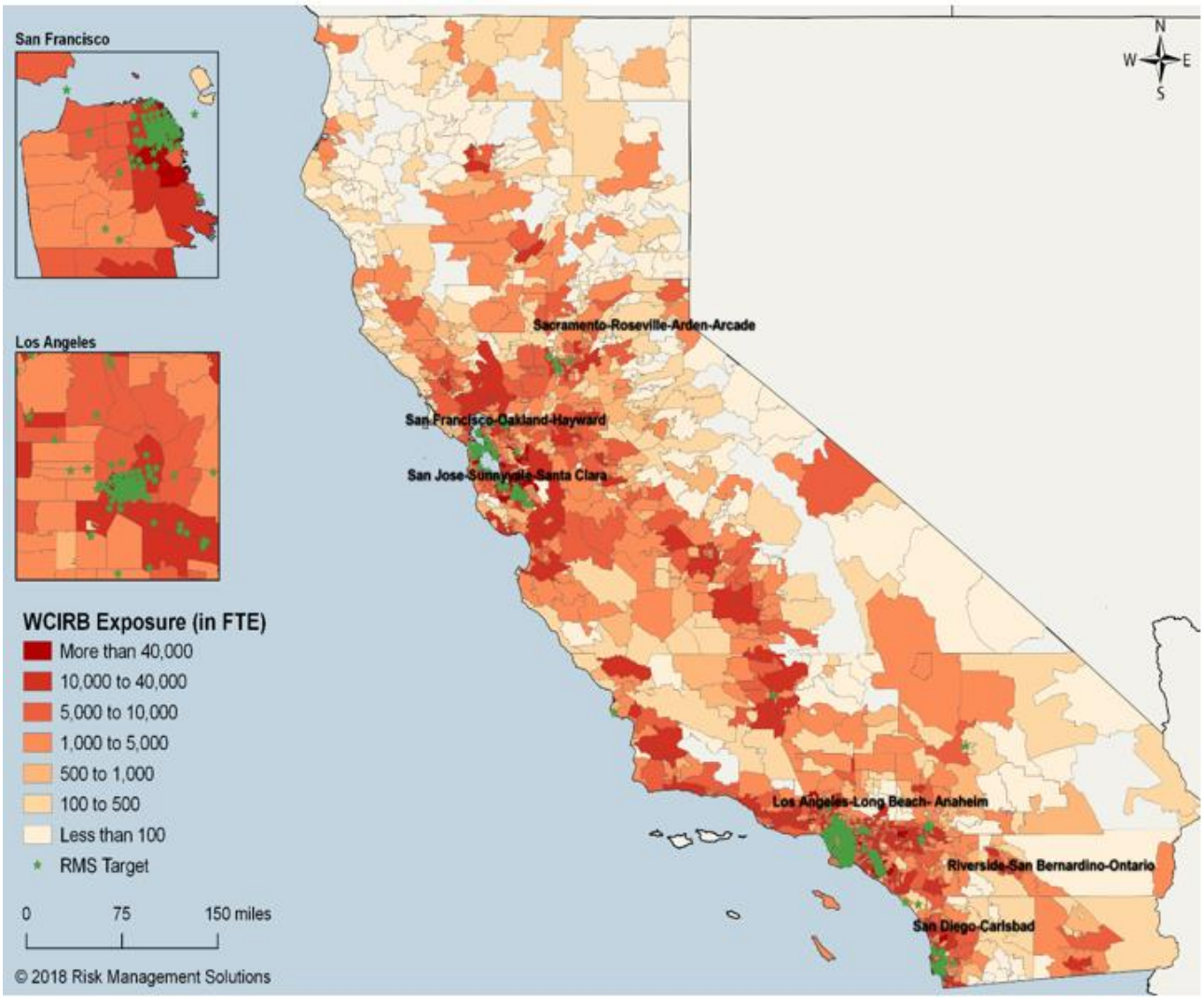
RMS utilized the employee descriptions provided by WCIRB to map each FTE's occupation to the RMS workers' compensation occupation classification (WCOCC) scheme, as used by our model. Table 4 depicts how the data is classified by occupation with the time-of-day adjustments made to each occupation class.

Table 4: Total FTE and total payroll by RMS occupation classification

RMS workers' compensation occupation classification	Total FTE	Total payroll (in millions)	% of total FTE	% of total payroll	Time-of-day adjustment (11 a.m.)
1 – Office	6,157,080	$362,477	54%	67%	75%
3 - Heavy and other manufacturing	1,356,548	$55,647	12%	10%	73%
5 - Retail trade	1,365,352	$46,049	12%	8%	62%
6 – Restaurant	708,933	$17,475	6%	3%	52%
2 - Light manufacturing	633,819	$17,670	6%	3%	70%
4 - Wholesale trade	365,066	$12,719	3%	2%	75%
13 – Construction	348,623	$13,637	3%	3%	82%
14 – Medical	348,028	$15,043	3%	3%	70%
8 - Hotel/Motel	72,403	$2,869	1%	1%	53%
Total	11,355,852	$543,586	100%	100%	

Exposure Distribution

Figure 2: FTE Exposure Map



Exposure by Metropolitan Statistical Area (MSA)

Figure 2 depicts the exposure from the WCIRB portfolio relative to the location of RMS-identified targets. As illustrated by both this map and Table 5, exposure is highest in the Los Angeles-Long Beach-Anaheim MSA, accounting for about 35% of the portfolio's total FTE. The San Francisco-Oakland-Hayward MSA and the San Jose- Sunnyvale-Santa Clara MSA consist of 17% and 11%, respectively, of the portfolio's exposure. Together, these three metropolitan areas make up about 63% of WCIRB's exposure. As the map suggests, these MSAs also have large concentrations of RMS Targets, indicating that the WCIRB exposure lies in high-risk areas.

Table 5: Exposure by MSA

Metropolitan Statistical Area (MSA)	Total FTE	% of total FTE
Los Angeles-Long Beach-Anaheim	3,979,403	35%
San Francisco-Oakland-Hayward	1,897,708	17%
San Jose-Sunnyvale-Santa Clara	1,265,768	11%
San Diego-Carlsbad	1,013,942	9%
Riverside-San Bernardino-Ontario	761,999	7%
Sacramento-Roseville-Arden-Arcade	483,936	4%
All Remaining Exposure	1,953,096	17%
Total	11,355,852	100%

Within these MSAs, there are a few cities where exposure is highly concentrated. Table 6 lists the top ten cities in California, ranked by FTE. These top ten cities alone consist of 30% of the WCIRB portfolio's exposure. In addition to having the largest exposure, San Francisco and Los Angeles have the highest concentration of RMS Targets, signifying a greater risk of terrorist attacks.

Table 6: Top ten cities by exposure (FTE)

City	Total FTE	% of total FTE
Los Angeles	674,031	6%
San Francisco	607,137	5%
San Diego	595,795	5%
San Jose	381,469	3%
Irvine	269,434	2%
Mountain View	209,819	2%
Sacramento	188,022	2%
Santa Clara	183,797	2%
Fresno	138,305	1%
Palo Alto	131,347	1%
All Others	7,976,696	70%
Total	11,355,852	100%

Exposure Accumulation

Terrorism is an urban risk, predominantly in areas where there are large concentrations of people and business activity. Therefore, in addition to identifying the cities with the highest exposure, it is crucial to identify areas that have the most concentrated exposure, as it is the attacks in these areas that are likely to cause significant losses.

The RMS Terrorism Model incorporates two categories of attack modes: conventional attacks and chemical, biological, radiological, and nuclear (CBRN) attacks also called non-conventional attacks.

For conventional attacks, which are more likely to occur than CBRN attacks, the majority of the damage and human injury occurs within a 400-meter radius. RMS conducted an accumulation analysis on the WCIRB portfolio, using a 400-meter radius, to determine the areas that have the largest concentrations of exposure. This type of analysis helps in understanding where the highest potential loss could occur to the WCIRB portfolio.

Although Los Angeles has the highest overall exposure, the largest concentration of exposure for a 400-meter radius lies in the main central business district (CBD) in San Francisco, also known as the financial district, as indicated by Table 7. This accumulation area has the potential to impact 168,951 employees. This is in contrast with Los Angeles's highest exposure accumulation for a 400-meter radius (ranked number 3 in Table 7), which has the potential to impact 54,138 employees. This corresponds to Los Angeles' financial district. Given the concentrated nature of terrorism risk, even small attacks in high-accumulation areas such as these have the potential to result in large losses.

Table 7: Top 10 Exposure Accumulations in WCIRB portfolio for a 400-meter radius

Rank	City, Postal Code	Centroid Location	Total FTE
1	San Francisco, 94111	Within a CBD*: (Montgomery St. and California St.)	168,951
2	Mountain View, 94043	Googleplex (Google's largest global headquarters)	139,357
3	Los Angeles, 90071	CBD: Hope Pl and S Grand Ave	54,138
4	San Francisco, 94103	Jessie Square: 3rd St. and Mission St.	48,829
5	Los Angeles, 90067	Century Woods Drive	44,121
6	Cupertino, 95014	Apple Headquarters	37,072
7	Palo Alto, 94304	Stanford Hospital	32,286
8	San Jose, 95134	Samsung Semiconductor	31,330
9	San Francisco, 94108	Wentworth Pl. and Jackson St.	30,784
10	Los Angeles, 90017	Multiple CBDs and skyscrapers	30,126

*RMS-defined central business district (CBD) targets are locations that are part of the central district of a city, usually characterized by a high concentration of retail and office buildings.

TRIPRA Overview

- TRIPRA Overview

-2019 TRIPRA Structure

-Effective Workers' Compensation Deductible Calculation

TRIPRA Overview

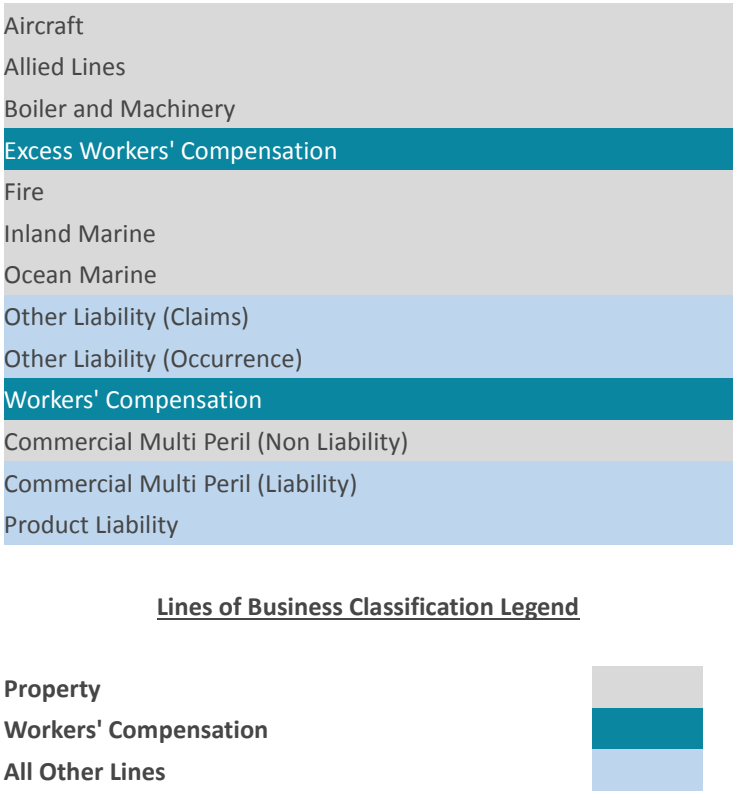
On January 12, 2015, President Obama signed into law the Terrorism Risk Insurance Program Reauthorization Act (TRIPRA), which extends the Terrorism Risk Insurance Act, commonly known as TRIA, through December 31st, 2020. The act serves to reduce the level of federal coverage of insured terrorism losses through 2020 by incrementally increasing the program trigger and the insurer's co-participation percentage on a yearly basis. Culminating in 2020, the government share under TRIPRA will cover between 80 to 85% of the insured losses, depending on the calendar year. The program trigger will increase by $20 million each year until 2020, when the program trigger will reach $200 million. The program cap for each year will be $100 billion in aggregate industry losses. Please refer to Table 8 below for a breakdown of the TRIPRA structure by year from 2015 to 2020.

Table 8: TRIPRA Structure Changes from 2015-2020

Calendar Year	Minimum Attack Size (i.e. Program Trigger)	Percent Covered by Government	Percent Covered by insurance Industry
2015	$100 million	85%	15%
2016	$120 million	84%	16%
2017	$140 million	83%	17%
2018	$160 million	82%	18%
2019	$180 million	81%	19%
2020	$200 million	80%	20%

As per TRIPRA, each primary insurer's deductible will be 20% of its prior calendar-year direct earned premium (DEP) for all TRIPRA-eligible lines. Figure 3 lists these TRIPRA-eligible lines of business, classified as either property, workers' compensation, or all other lines of business.

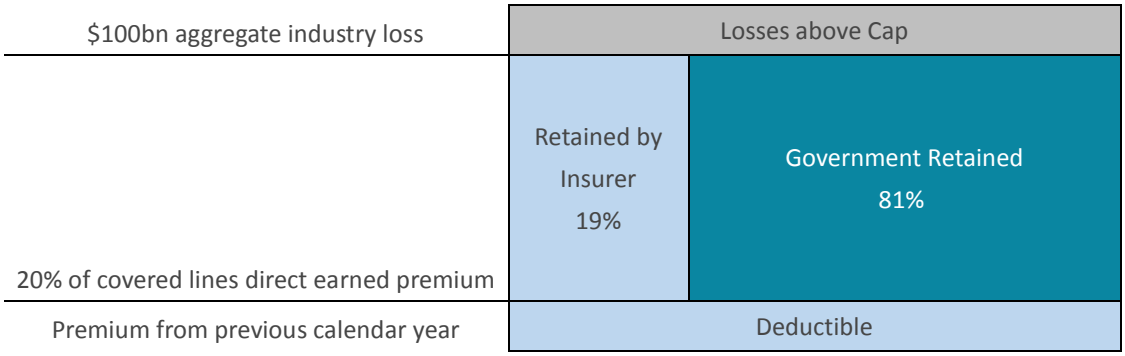
Figure 3: TRIPRA-eligible Lines of Business



2019 TRIPRA Structure:

For this analysis, RMS used the 2019 TRIPRA structure, as illustrated in the figure below. In order for the program to trigger, the minimum attack loss must be $180 million. Losses retained by the government are in excess of the deductible, less the insured participation of 19%, adjusted to the $100 billion program cap for the entire insurance industry. The deductible and the remaining 19% share will be covered by the insurance companies (net-insured retained).

Figure 4: 2019 TRIPRA Program Structure



TRIPRA: Effective Workers' Compensation Deductible Calculation

To obtain the national TRIPRA deductible value, RMS gathered 2017 nationwide Direct Earned Premium (DEP) statistics by insurer for all TRIPRA-eligible lines of business using S&P Global Market intelligence data (SNL.com). 2017 was the most up to date information available in SNL. The national TRIPRA deductible across all insurers in California summed up to $31 billion across all TRIPRA-eligible lines of business.

To calculate WCIRB's share of the deductible, which only corresponds to the workers' compensation (WC) line of business, RMS disaggregated the total TRIPRA deductible based on the three broad groups – WC, property, and all other lines, as outlined in Figure 3. Based on the 9/11 attack, RMS assumes 10% of the TRIPRA deductible is allotted to "all other lines".

The remaining deductible is distributed between the workers' compensation and property lines of business based on their expected proportion of average annual loss resulting from terrorist attacks in California. To determine this ratio, RMS modeled losses using its proprietary 2018 Industry Exposure Databases for property and workers' compensation exposure. This resulted in 87% of the remaining deductible to be covered by the property line of business, and 13% to be covered by the workers' compensation line of business.

Since not all insurers will be impacted by a terrorist attack, RMS assumes insurers that have a higher workers' compensation market share would more likely be affected; consequently, they would have a higher probability of paying out the workers' compensation deductible. RMS used each insurer's share of workers' compensation DEP in California as a proxy for their market share. The top twenty-five workers' compensation insurers make up 90.8% of the total DEP in California. The workers' compensation deductible for each group (the top 25 insurers and the remaining) is weighed by their respective market share. The resulting deductible is referred to as the *Effective Deductible* and is incurred by the entire workers' compensation industry in California.

To capture WCIRB's share of the effective deductible, RMS weighed the effective deductible by the ratio of WCIRB's expected loss with respect to the industry's expected WC loss. The subsequent WCIRB deductible was calculated to be $1.9 billion.

Loss Summary

-Loss Overview

-Exceedance Probability Analysis

-Loss Analysis

Loss Overview

Terrorist attacks are executed with the intention of inflicting maximum loss, whether it be in the form of economic loss or number of casualties. As such, workers' compensation losses will be maximized when the highest number of employees are exposed. Because human exposure is mobile, the number of employees exposed varies depending on the time of day and day of week. Based on industry averages across occupations, 11 a.m. is expected to be the peak time at which the maximum number of employees are present at work, Therefore, for this study, RMS uses 11 a.m. on a weekday to estimate terrorism casualties.

TRIPRA Program Activation

RMS analysis uses an attack catalog of about 66,000 terrorism events with 11 a.m. peak exposure adjustment option and a standard risk outlook.

The analysis suggests that there is a 9.5% probability of triggering the TRIPRA program. However, this does not imply a 1-in-10 chance of a terrorist attack exceeding the TRIPRA trigger. This merely implies the methodology used to generate the exceedance probability curve considers events which are very severe but unlikely to occur due to the counter-terrorism measures. Consequently, there are very few points on the exceedance probability curve corresponding to the lower return period. A mathematical interpolation is used to measure the losses at shorter return periods. Using this interpolation, the likelihood of reaching the TRIPRA threshold ($180M) is 9.5%.

Additionally, the probability of losses reaching the WCIRB effective deductible of 1.9 billion is 0.26%. The probability of exhausting the TRIPRA program with the cap of $100 billion is 0.006%, corresponding to a 15,173-year return period.

Exceedance Probability Analysis

Table 9 illustrates the probability of losses exceeding various thresholds due to one or more attacks in a given year for the peak exposure adjustment (11 a.m.) scenario.

RMS analysis suggests that there is a 0.1% probability (corresponding to a 1000-year return period) that one or more terrorist attacks will cause at least $2.3 billion in net-insured losses under TRIPRA.

Without TRIPRA, the average annual WCIRB loss is $27.9 million. Adjusted for the TRIPRA program cap, the average annual WCIRB loss becomes $26.6 million of which $21 million is retained by the WCIRB and $5.6 million is retained by the government. This implies the average annual loss payable by WCIRB is reduced by 25% under TRIPRA.

Despite only having a participation rate of 19%, the WCIRB retains a majority of the average annual loss, in part, because the higher likelihood events are those attacks that have losses below the deductible, as illustrated by the low probability of exceeding the WCIRB effective deductible (0.26%). WCIRB covers all losses until this deductible is reached.

$13.8 million or 66% of the $21 million net-insured average annual loss lies below the WCIRB effective deductible and hence is entirely retained by the WCIRB. The remaining 34% lies above the deductible and is shared proportionately between WCIRB and the government based on their respective participation rate (19% for WCIRB and 81% for the government).

With TRIPRA, the net-insured will sustain an average loss of $1.85 per FTE and an average loss rate per $100 payroll of $0.0039.

Table 9: Key Return Period Losses

Critical probability	Return period (years)	WCIRB AEP Loss (in millions)			
		WCIRB Loss Without TRIPRA	WCIRB Losses - Adjusted for TRIPRA Program Cap**	Net-Insured Retained Loss	Government Retained WCIRB Loss
0.0020%	50,000	$77,278	$39,482	$9,055	$30,427
0.0040%	25,000	$36,352	$25,928	$6,480	$19,448
0.0100%	10,000	$18,104	$18,104	$4,993	$13,111
0.0200%	5,000	$11,758	$11,758	$3,788	$7,970
0.0400%	2,500	$8,075	$8,075	$3,088	$4,987
0.1000%	1,000	$4,142	$4,142	$2,341	$1,802
0.2000%	500	$2,354	$2,354	$2,001	$353
1.0000%	100	$332	$332	$332	$0
Average loss per year*		**$27.9**	**$26.6**	**$21.0**	**$5.6**
Average loss rate per $100		$0.0051	$0.0039		
Average loss rate per FTE		$2.4553	$1.8499		

*Average annual loss represents the loss averaged over all aggregate exceedance probability (AEP) levels.

**WCIRB adjusted losses account for the allocation of the loss to WCIRB after the program cap is applied.

Loss Analysis

Top Losses

Table 10 lists the five most severe terrorist attacks that impact the WCIRB portfolio without the TRIPRA program. All these attacks are extreme cases – chemical, biological, radiological or nuclear (CBRN) attacks – and most of them occur in central business districts in San Francisco due to large outdoor attacks.

Table 10: Top 5 Attacks by WCIRB Losses (in millions) without TRIPRA

Rank	Target Name	Target Type	Method of Attack*	WCIRB Loss Without TRIPRA	WCIRB Loss Adjusted for Program Cap	With TRIPRA	
						Net-Insured Retained AAL	Government Retained WCIRB AAL
1	California St. and Montgomery St.	Central Business District	Nuclear Bomb Large	$100,764	$39,718	$9,100	$30,618
2	Stevenson St. and 6th St.	Central Business District	Biological - Anthrax Large, Outdoors (SE)	$97,155	$26,191	$6,530	$19,661
3	California St. and Montgomery St.	Central Business District	Biological - Anthrax Large, Outdoors (SE)	$91,288	$25,668	$6,431	$19,237
4	Green St. and Jones St.	Central Business District	Biological - Anthrax Large, Outdoors (SE)	$91,181	$25,663	$6,430	$19,233
5	The Embarcadero and Bryant St.	Central Business District	Biological - Anthrax Large, Outdoors (SE)	$85,376	$25,181	$6,338	$18,843

*Outdoor attacks include wind direction

Given that the top five attacks are almost all caused by the same method of attack, Table 11 provides more insight on the maximum loss value (without the TRIPRA program) per attack mode. Ranked by maximum loss incurred by WCIRB without TRIPRA, the table illustrates losses with different magnitudes, resulting in a total of thirty-five attack modes. The table shows that losses from large smallpox, arson, dirty bombs, nuclear plant sabotage, hazmat, industrial explosions, toxic releases, and small sarin gas attacks do not exceed the deductible value of $1.9 billion, leading WCIRB to retain all of their associated losses.

Moreover, small and medium smallpox attacks, apart from the genetically engineered versions, cause losses below the 2019 TRIPRA Program trigger; consequently, losses from these attacks are also entirely covered by the WCIRB.

Table 11: Maximum WCIRB Loss (in millions) Without TRIPRA Per Attack Mode

						With TRIPRA	
Method of Attack	**Target Name**	**Target Type**	**City**	**WCIRB Attack Loss without TRIPRA**	**WCIRB Loss Adjusted for Program Cap**	**Net-Insured Retained Loss**	**Government Retained WCIRB Loss**
Large Nuclear Bomb	California St and Montgomery St	Central Business District	San Francisco	$100,764	$39,718	$9,100	$30,618
Large Biological Attack - Anthrax	Stevenson St and 6th St	Central Business District	San Francisco	$97,155	$26,191	$6,530	$19,661
Indoor Chemical Attack - Sarin Gas	Google	HQ of Fortune 100 Company	Mountain View	$80,042	$26,672	$6,621	$20,051
Small Nuclear Bomb	California St and Montgomery St	Central Business District	San Francisco	$64,868	$33,742	$7,965	$25,777
Medium Biological Attack - Anthrax	Green St and Jones St	Central Business District	San Francisco	$40,076	$19,489	$5,257	$14,232
Indoor Biological Attack - Anthrax	Google	HQ of Fortune 100 Company	Mountain View	$38,951	$31,182	$7,478	$23,704
Small Biological Attack - Anthrax	Stevenson St and 6th St	Central Business District	San Francisco	$21,866	$15,349	$4,470	$10,879
10 Ton Bomb	California St and Montgomery St	Central Business District	San Francisco	$10,984	$10,532	$3,555	$6,977
5 Ton Bomb	California St and Montgomery St	Central Business District	San Francisco	$9,066	$8,835	$3,232	$5,603
2 Ton Bomb	California St and Montgomery St	Central Business District	San Francisco	$6,762	$6,622	$2,812	$3,810
1 Ton Bomb	California St and Montgomery St	Central Business District	San Francisco	$5,421	$5,341	$2,568	$2,773
Large Biological - Genetically Engineered Smallpox	San Francisco City Center	Smallpox Epicenter	San Francisco	$5,209	$2,379	$2,006	$373
Aircraft Impact	Spear Tower	Skyscraper	San Francisco	$5,082	$5,066	$2,516	$2,550
Large Chemical Attack - Sarin Gas	Montgomery St and Gold St	Central Business District	San Francisco	$4,803	$4,598	$2,427	$2,171
Medium Chemical Attack - Sarin Gas	Montgomery St and Gold St	Central Business District	San Francisco	$2,442	$2,437	$2,017	$420
600 lb. Bomb	Wells Fargo	HQ of Fortune 100 Company	San Francisco	$2,375	$2,371	$2,004	$367
Large Biological Attack - Smallpox	San Francisco City Center	Smallpox Epicenter	San Francisco	$1,742	$1,317	$1,317	$0
Arson (conflagration)	Wells Fargo	HQ of Fortune 100 Company	San Francisco	$1,717	$1,608	$1,608	$0
Large Dirty Bomb	California St and Montgomery St	Central Business District	San Francisco	$1,321	$1,285	$1,285	$0
Nuclear Plant Sabotage	San Onofre	Nuclear Power Plant	Camp Pendleton	$1,066	$432	$432	$0
Sabotage – Industrial Toxic Release - Large	Witco Corp Allied Kelite Div	Industrial Facility	Los Angeles	$877	$877	$877	$0
Small Dirty Bomb	California St and Montgomery St	Central Business District	San Francisco	$736	$730	$730	$0

Table 11: Maximum WCIRB Loss (in millions) Without TRIPRA Per Attack Mode (continued)

						With TRIPRA	
Method of Attack	**Target Name**	**Target Type**	**City**	**WCIRB Attack Loss without TRIPRA**	**WCIRB Loss Adjusted for Program Cap**	**Net-Insured Retained Loss**	**Government Retained WCIRB Loss**
Hazmat Transportation	Los Angeles Hazmat (1)	Hazmat Transportation	Los Angeles	$672	$672	$672	$0
Sabotage - Industrial Explosion- Large	Ciba-Geigy Corp Furane Produc	Industrial Facility	Los Angeles	$637	$637	$637	$0
Medium Biological Genetically Engineered Smallpox	San Francisco City Center	Smallpox Epicenter	San Francisco	$531	$516	$516	$0
Sabotage -Industrial Explosion- Medium	Ciba-Geigy Corp Furane Produc	Industrial Facility	Los Angeles	$393	$393	$393	$0
Sabotage - Industrial - Explosion + Release - Large	Bp Chemicals Inc.	Industrial Facility	Hawthorne	$384	$384	$384	$0
Sabotage - Industrial Explosion - Small	Exxon Company Usa	Oil Refinery	Benicia	$317	$317	$317	$0
Small Chemical Attack - Sarin Gas	California St and Montgomery St	Central Business District	San Francisco	$309	$309	$309	$0
Sabotage – Industrial Toxic Release -Medium	Alta Photographic Inc	Industrial Facility	San Diego	$261	$261	$261	$0
Sabotage - Industrial Explosion + Release -Medium	Merck & Co Inc Kelco Div	Industrial Facility	San Diego	$290	$290	$290	$0
Sabotage - Industrial Explosion + Release -Small	Merck & Co Inc Kelco Div	Industrial Facility	San Diego	$192	$192	$192	$0
Medium Biological Attack - Smallpox*	San Francisco City Center	Smallpox Epicenter	San Francisco	$147	$147	$147	$0
Small Biological Attack - Smallpox*	San Francisco City Center	Smallpox Epicenter	San Francisco	$20	$20	$20	$0
Sabotage – Industrial Toxic Release – Small**	Gallade Chemical Inc. Dba Oran	Industrial Facility	Santa Ana	$18	$18	$18	$0

*Indicates events that do not exceed the 2019 TRIPRA Program trigger of $180 million.

**When accounting for all TRIPRA covered lines of business, loss from small industrial toxic release attacks exceed the TRIPRA program trigger.

While the top attacks described in Tables 10 and 11 are high in severity, they have a low relative likelihood of occurring. This is because of the difficulty associated with the execution of these attacks – requiring specialized skills, dozens of terrorist personnel, months to years of planning, and heavy financial backing. Moreover, the possibility of detection for these attacks by counter terrorist forces is very high. As a result, the large CBRN attacks that make up the highest overall attack losses are not actually driving the highest average annual losses.

Instead, the highest average annual loss-causing attack, as portrayed by Table 12, results from a 600 lb. bomb. Although attacks from 600 lb. bombs have a relatively low severity, they are more likely to occur due to the comparatively fewer resources and less time needed for a successful attack. Thus, conventional attacks such as those from 600 lb. bombs play a more significant role in driving average annual loss payable.

Table 12: Maximum WCIRB Average Annual Loss (without TRIPRA) by Attack Mode

						With TRIPRA	
Attack Mode	**Target Name**	**Target Type**	**City**	**WCIRB AAL Without TRIPRA**	**WCIRB Loss Adjusted for Program Cap**	**Net-Insured Retained AAL**	**Government Retained WCIRB AAL**
600 lb. Bomb	California St and Montgomery St	Central Business District	San Francisco	$1,159,258	$1,157,487	$985,871	$171,616
Small Biological Attack - Anthrax	Union St and Castle St	Central Business District	San Francisco	$236,023	$174,618	$52,837	$121,781
Aircraft Impact	Spear Tower	Skyscraper	San Francisco	$195,850	$195,218	$96,963	$98,255
1 Ton Bomb	California St and Montgomery St	Central Business District	San Francisco	$131,649	$129,718	$62,380	$67,338
Small Nuclear Bomb	California St and Montgomery St	Central Business District	San Francisco	$81,101	$42,186	$9,958	$32,228
2 Ton Bomb	California St and Montgomery St	Central Business District	San Francisco	$41,637	$40,775	$17,313	$23,462
Arson* (conflagration)	California St and Montgomery St	Central Business District	San Francisco	$40,784	$38,364	$38,364	$0
5 Ton Bomb	Transamerica Pyramid	Skyscraper	San Francisco	$25,798	$25,033	$10,690	$14,343
Industrial Sabotage - Explosion + Release - Small	Bp Chemicals Inc	Industrial Facility	Hawthorne	$20,405	$20,405	$20,405	$0
Medium Biological Attack - Anthrax	Elm Ave and E Seaside Way	Central Business District	Long Beach	$20,371	$13,591	$4,509	$9,082
Hazmat Transportation	Los Angeles Hazmat (1)	Hazmat Transportation	Los Angeles	$12,304	$12,304	$12,304	$0
Large Nuclear Bomb	California St and Montgomery St	Central Business District	San Francisco	$10,243	$40,037	$925	$3,112
Small Dirty Bomb	California St and Montgomery St	Central Business District	San Francisco	$8,319	$8,015	$8,015	$0
10 Ton Bomb	US Security Bureau	Government Building	San Francisco	$8,100	$7,660	$2,920	$4,740
Indoor Chemical Attack - Sarin Gas	Bank America Ctr - Cal St	Skyscraper	San Francisco	$5,328	$5,328	$2,972	$2,356
Sabotage-Industrial Explosion -Small	Ciba - Geigy Corp Furane Produc	Industrial Facility	Los Angeles	$5,017	$5,017	$5,017	$0
Medium Chemical Attack - Sarin Gas	Montgomery St and Gold St	Central Business District	San Francisco	$4,513	$4,502	$3,726	$776
Indoor Biological Attack - Anthrax	Bank America Ctr - Cal St	Skyscraper	San Francisco	$4,309	$4,308	$4,075	$233
Large Dirty Bomb	California St and Montgomery St	Central Business District	San Francisco	$3,794	$3,144	$3,144	$0
Nuclear Plant Sabotage	San Onofre	Nuclear Power Plant	Camp Pendleton	$3,667	$1,486	$1,486	$0
Sabotage-Industrial Explosion – Medium	Ciba - Geigy Corp Furane Produc	Industrial Facility	Los Angeles	$3,542	$3,542	$3,542	$0
Large Biological Attack - Anthrax	Central Ave and Magnolia Ave	Central Business District	Riverside	$3,447	$1,376	$387	$989

Table 12: Maximum WCIRB Average Annual Loss (without TRIPRA) by Attack Mode (continued)

						With TRIPRA	
Attack Mode	**Target Name**	**Target Type**	**City**	**WCIRB AAL Without TRIPRA**	**WCIRB Loss Adjusted for Program Cap**	**Net-Insured Retained AAL**	**Government Retained WCIRB AAL**
Sabotage –Industrial Explosion + Release - Medium	Bp Chemicals, Inc.	Industrial Facility	Hawthorne	$2,375	$2,375	$2,375	$0
Small Biological Attack - Smallpox	San Francisco City Center	Smallpox Epicenter	San Francisco	$1,885	$1,885	$1,885	$0
Sabotage-Industrial Explosion – Large	Ciba - Geigy Corp Furane Produc	Industrial Facility	Los Angeles	$1,355	$1,355	$1,355	$0
Medium Biological Attack - Smallpox	San Francisco City Center	Smallpox Epicenter	San Francisco	$1,020	$1,020	$1,020	$0
Large - Genetically Engineered Smallpox	San Francisco City Center	Smallpox Epicenter	San Francisco	$992	$453	$382	$71
Small Chemical Attack - Sarin Gas	Bank America Ctr - Cal St	Skyscraper	San Francisco	$785	$785	$785	$0
Medium Genetically Engineered Smallpox	San Francisco City Center	Smallpox Epicenter	San Francisco	$539	$524	$524	$0
Large Chemical Attack - Sarin Gas	The Embarcadero and Pier 19	Central Business District	San Francisco	$965	$886	$493	$393
Sabotage –Industrial Explosion + Release - Large	Bp Chemicals, Inc.	Industrial Facility	Hawthorne	$404	$404	$404	$0
Large Biological Attack - Smallpox	San Francisco City Center	Smallpox Epicenter	San Francisco	$394	$298	$298	$0
Industrial Sabotage - Toxic Release - Medium	Courtaulds Aerospace Inc Chem	Industrial Facility	Glendale	$288	$288	$288	$0
Industrial Sabotage - Toxic Release - Small	Spraylat Corp LA Div	Industrial Facility	Los Angeles	$265	$265	$265	$0
Industrial Sabotage - Toxic Release - Large	Witco Corp Allied Kelite Div	Industrial Facility	Los Angeles	$132	$132	$132	$0

Loss Drivers

To understand what is driving these losses, RMS investigated the components that are typically considered by terrorists to maximize the utility of an attack. This includes target location, target category, and the choice of attack mode.

Targets are chosen depending on the potential symbolic value or consequential economic loss and number of casualties they can cause. In terms of choosing an attack mode, a judgement must be made based on a comparative assessment between the level of difficulty in utilizing a mode of attack versus the role that attack mode can have in generating losses.

Outlined below are the key attack characteristics in terms of target locations, target categories, and attack modes that are driving the average annual losses for the WCIRB portfolio.

Losses by Geography

Over the past decade, terrorism attacks worldwide have demonstrated that there is an overall tendency for terrorist groups to concentrate their macro-attacks on major and popular cities. Table 13 ranks the top ten cities that generate the highest average annual losses to the WCIRB portfolio.

Table 13: Top Ten Cities by WCIRB Average Annual Loss (in millions) without TRIPRA

City	WCIRB AAL without TRIPRA	WCIRB AAL Adjusted for Program Cap	With TRIPRA	
			Net-Insured Retained AAL	Government Retained WCIRB AAL
San Francisco	$16.70	$15.81	$12.18	$3.63
Los Angeles	$6.43	$6.29	$5.31	$0.98
Oakland	$1.68	$1.58	$1.06	$0.52
Long Beach	$0.91	$0.89	$0.79	$0.10
San Diego	$0.90	$0.89	$0.78	$0.11
San Jose	$0.50	$0.46	$0.31	$0.15
Burbank	$0.11	$0.11	$0.11	$0.00
Irvine	$0.11	$0.08	$0.04	$0.04
Santa Ana	$0.10	$0.08	$0.04	$0.04
Anaheim	$0.10	$0.08	$0.05	$0.03
All Others	$0.35	$0.34	$0.33	$0.01
Total AAL	**$27.9**	**$26.6**	**$21.0**	**$5.6**

As illustrated in Table 13, the top average annual loss-causing cities for the WCIRB portfolio consist of San Francisco, Los Angeles, Oakland, Long Beach, and San Diego, making up 95% of the average annual WCIRB losses with and without TRIPRA.

San Francisco is the primary loss driver, generating 60% of the WCIRB average annual losses payable without TRIPRA and 58% with TRIPRA. As seen in Tables 10, 11, and 12, most severe attacks occur in San Francisco. This, along with the presence of highly concentrated exposure, contributes to San Francisco's large losses.

The top loss-driving cities are consistent with the top loss-causing MSAs, as highlighted in Figure 5 and Table 14, with San Francisco-Oakland-Hayward retaining 66% of the average annual WCIRB losses without TRIPRA and 63% of their losses with TRIPRA

Figure 5: Top 3 Metro Areas by WCIRB Average Annual Loss

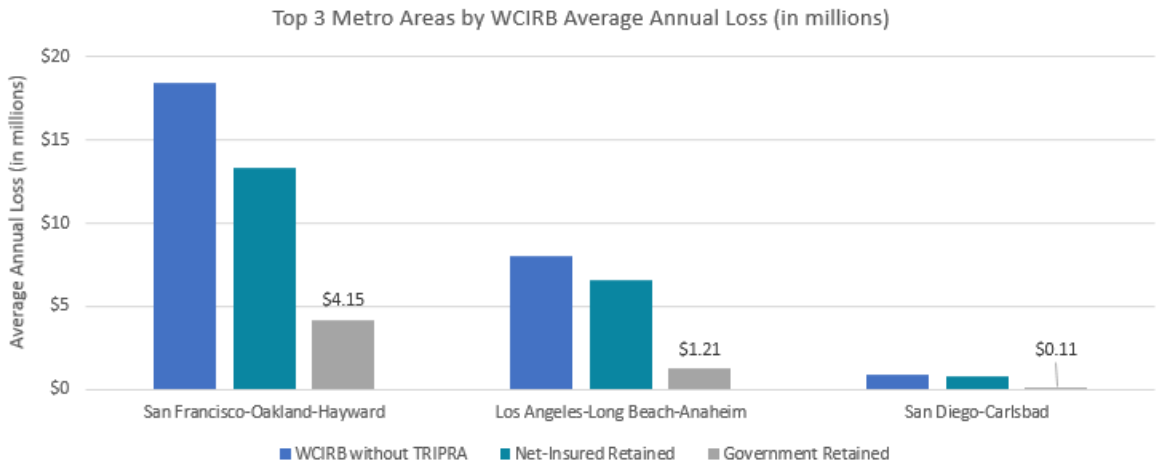


Table 14: Average Annual Loss (in $) to WCIRB Portfolio By MSA

			With TRIPRA	
Metropolitan Statistical Area (MSA)	**WCIRB AAL without TRIPRA**	**WCIRB AAL Adjusted for Program Cap**	**Net-Insured Retained AAL**	**Government Retained WCIRB AAL**
San Francisco-Oakland-Hayward	$18,371,899	$17,396,645	$13,245,770	$4,150,875
Los Angeles-Long Beach-Anaheim	$7,996,978	$7,773,879	$6,566,789	$1,207,090
San Diego-Carlsbad	$902,935	$895,814	$783,738	$112,076
San Jose-Sunnyvale-Santa Clara	$499,969	$460,449	$310,022	$150,427
Sacramento-Roseville-Arden-Arcade	$57,590	$57,567	$55,677	$1,890
Riverside-San Bernardino-Ontario	$46,766	$43,353	$39,405	$3,948
Others	$4,948	$5,947	$5,947	$0
Total Loss	**$27,881,085**	**$26,633,654**	**$21,007,348**	**$5,626,306**

Target Categories

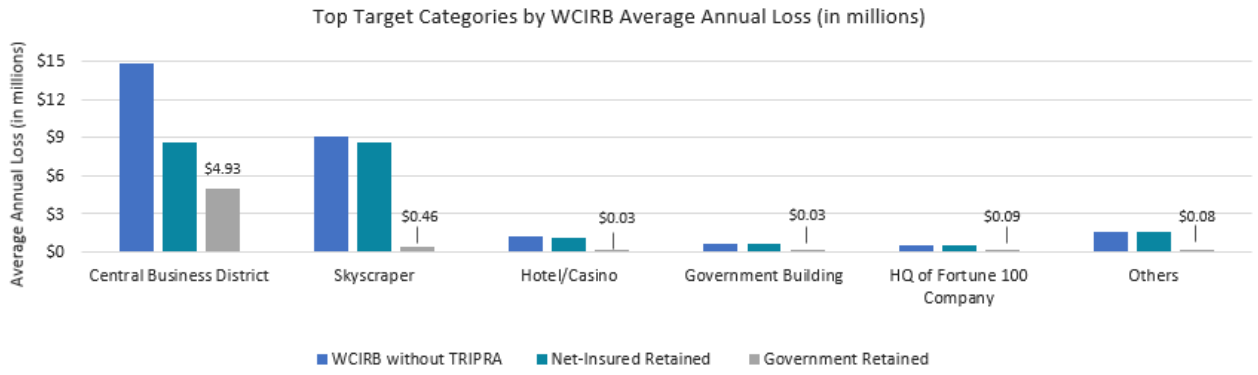
Within these cities and metropolitan areas, there are zones and structures that are more vulnerable to terrorism risk. Buildings gain validity as targets if they are symbolic of political and economic power. For example, within a sizeable city such as San Francisco, a wide variety of targets exist, ranging from government offices to skyscrapers, hotels, and economic power houses.

RMS has developed its own proprietary target database that includes potential targets - buildings or structures that, if attacked, would result in significant property damage, economic interruption, loss of human life or have a high symbolic impact. These high-risk areas typically consist of central business districts, revered buildings,

corporate headquarters, major industrial or nuclear facilities, and skyscrapers.

As depicted in Figure 6, the targets that sustain the highest average annual losses for the WCIRB portfolio include RMS-defined central business districts, skyscrapers, hotels and casinos, government buildings, and headquarters of Fortune 100 companies. These five categories alone generate 94% of all WCIRB average annual losses and 93% of their net-insured retained average annual losses with TRIPRA.

Figure 6: WCIRB Average Annual Loss by Top Target Categories



Amongst all target categories, central business districts account for about $14.8 million or 53% of the overall WCIRB average annual losses without TRIPRA. Characterized as areas of highest commercial activity within a city, central business districts were created by RMS to capture locations that might be more vulnerable to terrorist attacks due to the presence of multiple high-profile targets (office and retail buildings).

Apart from central business districts, skyscrapers are the second highest loss-causing target category, making up 33% of the overall WCIRB average annual losses without the TRIPRA program.

Under TRIPRA, both central business districts and skyscrapers are the primary loss drivers for the WCIRB portfolio, each accounting for 41%, or $8.6 million, of the average annual net-insured retained losses.

Attack Methods

The RMS Terrorism Model takes into consideration eleven primary modes of attack, categorized into non-conventional-CBRN or conventional attacks. For select attack modes, RMS models multiple magnitudes, providing different vulnerabilities given a small, medium, or large attack. For example, conventional bombs modeled by RMS range from 600 lb. to 10 tons. Additionally, the model accounts for a range of potential outcomes by incorporating climactic conditions such as wind speed and direction and considering whether the attack occurs indoors or outdoors.

Table 15 depicts average annual WCIRB losses by attack mode and illustrates the breakdown of total losses between the two broad attack mode categories: CBRN or conventional. Tables 10 and 11 portrayed how CBRN attacks cause the most severe losses. Table 12 provided us with the insight that a 600 lb. bomb attack causes the maximum average annual loss to the WCIRB portfolio. Consistent with this finding, apart from anthrax

attacks, Table 15 shows that conventional attacks are the primary average annual loss drivers. In fact, with a net-insured retained loss of $8.9 million, the 600 lb. bomb is the primary loss-causing attack mode for the net-insured, accounting for 43% of their total average annual losses.

Amongst the CBRN modes of attack, biological anthrax attacks are the most likely weapon of choice due to the relatively lower cost of production and skills needed to develop it. Compared to conventional attacks, anthrax attacks still cause significantly more damage in terms of the number of fatalities due to their high-severity nature. Hence, they rank high as a contributor to WCIRB average annual losses.

Table 15: Average Annual Loss (in $) by Attack Mode

			With TRIPRA	
Attack Methods	**WCIRB AAL without TRIPRA**	**WCIRB AAL Adjusted for Program Cap**	**Net-Insured Retained AAL**	**Government Retained WCIRB AAL**
Biological – Anthrax	$10,869,478	$9,857,105	$5,524,802	$4,332,303
Nuclear Bomb	$644,286	$445,753	$153,845	$291,908
Chemical Sarin Gas	$246,959	$245,754	$224,379	$21,375
Sabotage - Industrial - Explosion	$163,580	$163,580	$163,580	$0
Dirty Bomb	$158,769	$154,561	$154,561	$0
Sabotage – Hazmat	$40,115	$40,115	$40,115	$0
Sabotage - Industrial - Toxic	$18,513	$18,513	$18,513	$0
Biological – Smallpox	$16,172	$15,294	$15,223	$71
Sabotage - Nuclear Plant	$5,486	$3,056	$3,056	$0
Total CBRN	**$12,163,358**	**$10.943,731**	**$6,298,074**	**$4,645,657**
600 lb. Bomb	$9,199,660	$9,196,971	$8,945,273	$251,698
Aircraft Impact	$1,977,789	$1,977,106	$1,805,067	$172,039
1 Ton Bomb	$1,773,744	$1,770,594	$1,640,853	$129,741
Conflagration	$1,044,348	$1,035,272	$1,035,272	$0
2 Ton Bomb	$784,436	$782,617	$683,543	$99,074
5 Ton Bomb	$725,881	$719,651	$477,905	$241,746
10 Ton Bomb	$211,869	$207,712	$121,362	$86,350
Total Conventional	**$15,717,727**	**$15,689,923**	**$14,709,275**	**$980,648**
Total Average Annual Loss	$27,881,085	$26,633,654	$21,007,349	$5,626,305

Due to the comparably low-severity nature of conventional attacks, they might not cause losses over the $1.9 billion deductible, leading the WCIRB-member companies or the insured to retain all or a majority of the losses. As a result, the insured retain a greater proportion of losses from conventional attacks than they do from CBRN attacks.

Without TRIPRA, the WCIRB-member companies have an average annual loss payable of $12.2 million from CBRN attacks.

Table 16 shows that with the TRIPRA 2019 program, the government retains 42% of the program-cap adjusted CBRN average annual losses. This amounts to a decrease of 48% in net-insured average annual loss payable to only $6.3 million.

By contrast, the government retains only 6% of the program-cap adjusted average annual losses for conventional attacks under TRIPRA and only 3% of the loss caused by 600 lb. bombs. The net-insured, as a result, retain 94% of all conventional and 97% of all 600 lb. bombs program-cap adjusted average annual losses. Due to this high retention by the net-insured, attacks by 600 lb. bombs play a much more significant role in driving the net- insured losses as opposed to anthrax attacks, which have a net-insured retention of only 56%.

Overall, with TRIPRA, the government retains 21% of the total WCIRB average annual losses under the program cap and above the deductible, causing a 25% decrease in average annual loss payable by WCIRB-member companies.

Table 16: Average Annual Loss Retention Percentages with TRIPRA per Attack Mode

Attack Mode	% Net-Insured Retained	% Government Retained	% Decrease in WCIRB AAL Payable with TRIPRA
CBRN	**58%**	**42%**	**-48%**
Conventional	**94%**	**6%**	**-6%**
Major Components			
Biological – Anthrax	**56%**	**44%**	**-49%**
600 lb. Bomb	**97%**	**3%**	**-3%**
Total Average Annual Loss	**79%**	**21%**	**-25%**

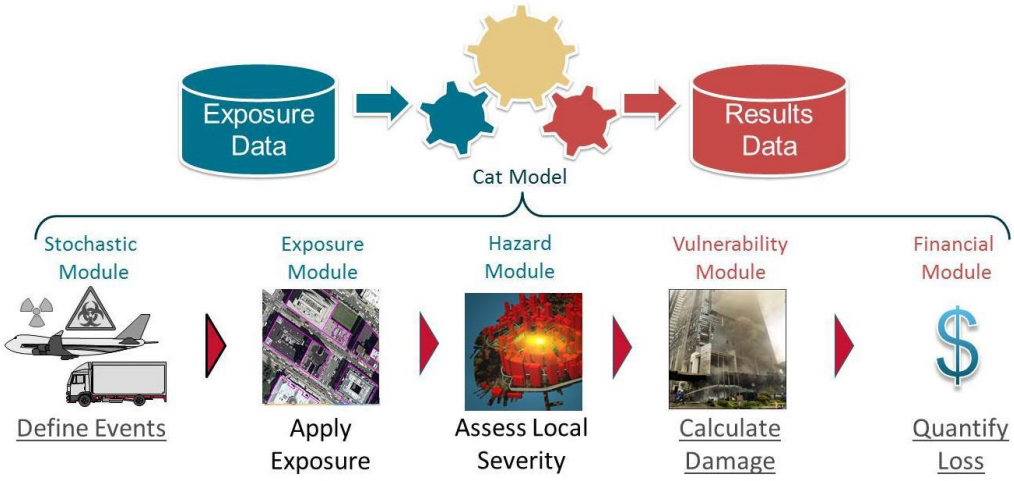
Model Methodology

Model Methodology

Terrorism Scope

RMS defines the scope of terrorism modeled in this study as terrorism directed at the United States. The focus is on macro-terrorist attacks which will lead to massive economic losses, large losses of life, and/or destruction of symbolic targets. Foreign groups including Al-Qaida, Islamic State, and the global Salafi-jihadi movement are representative of the terrorist threat analyzed.

Figure 7: Model Composition



The RMS terrorism models are comprised of five modules as depicted in Figure 7 are described below:

- **Stochastic Events Module**: This contains the set of target/attack pairings that define scenario events for which losses are calculated along with the relative likelihood of different attacks, multiplicity, and the overall frequency of attacks
- **Exposure Module:** Exposure at risk is identified in terms of number of employees at risk for workers' compensation line of business and buildings, contents and business interruption as part of property line of business. Exposure must include high-resolution address information.
- **Hazard Module:** This module quantifies the hazard from each attack scenario in the event set at each location with exposure. The measure of hazard depends on the type of attack ranging from pressure waves for bomb blasts to contaminant dispersal for biological attacks. It takes into consideration the local building and environmental conditions.
- **Vulnerability Module:** It calculates the impact of an attack, in terms of injuries/fatalities to people and damage to property, as a function of hazard, building attributes, and geographic characteristics. This module provides the parameters for loss distribution in terms of a mean and standard deviation that accounts for secondary uncertainty associated with the losses from an event.
- **Financial Analysis Module:** The physical damage to buildings, their contents, and business interruption and their impacts on human exposure are translated into financial losses after applying financial structures such as policy limits, deductibles, and reinsurance treaties. The exceedance probability curve and average annual loss (AAL) is influenced by the risk outlook chosen (Standard, Increased, Reduced).

Stochastic Events Module

The stochastic events module defines the event set used to generate losses. Terrorism events are defined by a combination of targets, attack modes, and multiplicity. Targets are selected for inclusion in the RMS Target Database from a large inventory of potential locations based on a combination of quantitative value assessments and specialists' expert opinions. Attack modes include both conventional and CBRN attacks. Multiplicity accounts for the potential for swarm attacks (a coordinated event consisting of multiple attacks). Event rates for terrorism are calculated using a game theory engine which considers the utility of an attack, the logistical cost of an attack, and target hardening and security.

Identifying Targets

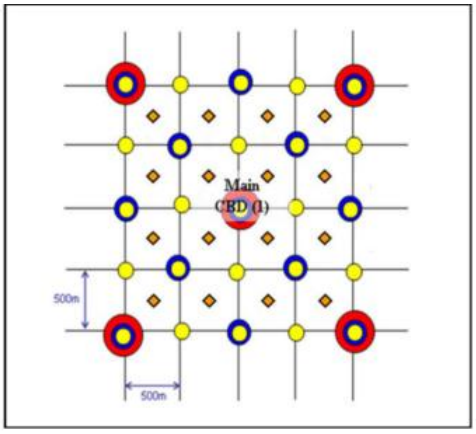
Targets are defined as geographic locations, buildings, or structures that, if attacked by terrorists, would result in significant property damage, economic interruption, or loss of human life, and would also have a high symbolic impact. RMS identifies the most likely terrorist targets for each modeled country. This includes locations with major concentrations of people and business activity, trophy buildings, and tourist attractions, as well as sites at which a terrorist attack could create considerable ancillary losses to the surrounding region, such as major nuclear and industrial facilities. The potential terrorist targets are selected and prioritized from the perspective of a terrorist seeking to maximize the utility of an attack. RMS targets are selected from a large inventory of potential targets based on quantitative value assessments along with specialists' expert opinions on likely target categories, locations, and methods of terrorist attack.

Creation of RMS-defined Central Business Districts

Central business district (CBD) targets are locations that are part of the central district of a city, usually characterized by a high concentration of retail and office buildings. Each CBD is identified using aerial photography with land use/land cover data, commercial property values, and employee counts. Additional target points are created using a consistent and predictable grid/numbering system so that the primary business district is covered. Average spacing between major points of the grid is 500 meters. Some CBD areas include intermediate points for improved resolution.

Figure 8 provides a visual illustration of how the CBD targets are located and the attack modes that correspond to each CBD target.

Figure 8: CBD Target Locations and Corresponding Attack Modes



Descriptions for the colors in Figure 8 follow:

- Yellow = 600 lb., 1-ton, 2-ton, and 5-ton bombs, conflagration, small dirty bombs, chemical-outdoor attacks
- Blue = large dirty bombs, small biological-outdoor anthrax attacks, small nuclear bombs
- Red = medium and large biological-outdoor anthrax attacks, large nuclear bombs
- Orange = 600 lb., 1-ton and 2-ton bombs, conflagration

Attack Modes

RMS defines attack mode scenarios by considering the relevant attack modes for each of the targets. Eleven primary attack modes including both conventional and CBRN (chemical, biological, radiological, and nuclear) Some of these have different magnitudes and/or consider climatic conditions, such as wind speed and wind direction to account for a range of potential outcomes. Each attack mode is described in the following tables.

Table 17: Conventional Attacks

Attack Mode	Magnitude	Other Details
Bomb – 600 lb.	600 lb. TNT equivalent	Passenger auto (sedan) size bomb
Bomb – 1 Ton	1 ton TNT equivalent	Minivan size bomb
Bomb – 2 Ton	2 ton TNT equivalent	Box van size bomb
Bomb – 5 Ton	5 ton TNT equivalent	Large van or moving truck size bomb
Bomb – 10 Ton	10 ton TNT equivalent	Semi tractor-trailer size bomb
Aircraft Impact	747 Commercial Airliner	September 11 type attack
Conflagration	9000-gasoline tanker	
Industrial Sabotage	Explosion, Explosion + Release, Release Only	Sabotage of a chemical or industrial facility resulting in a chemical explosion only

Table 18: CBRN Attacks

Attack Mode	Magnitude	Other Details
Chemical	Small - 10kg, Medium - 300kg, Large - 1,000kg Sarin Gas outdoors; 10kg Sarin gas indoors	Indoor and outdoor considered; 8 wind directions
Biological	1kg, 10kg, 75kg and Anthrax outdoors; 40kg Anthrax indoors Smallpox: Small (10 people infected); Medium (100 people infected); Large (1,000 people infected); Two levels of genetically engineered modeled (Medium and Large)	Indoor and outdoor Anthrax considered; eight wind directions
Radiological	Small - 1,500 curies; Large - 15,00 curies of Cesium 137	Also known as Dirty Bomb; 4 wind directions
Nuclear Bomb	Small - 1 kiloton; Large - 5 kiloton yield	
Nuclear Plant Sabotage	3 magnitudes of radioactive release	Attack on nuclear power plant; 8
Hazmat Transportation Sabotage	Release of 90 tons of liquid chlorine gas	Eight wind directions

Determination of Attack Scenario Probabilities

Each attack scenario, consisting 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 is based on the assumption that a successful terrorist attack occurs and is referred to as the *conditional probability*, which is required to generate probabilistic results. The conditional probability is based on a number of inputs including the relative likelihood of mode of attack, a relative likelihood of attack for each type of target, a relative likelihood of attack for the city in which the target is located, and weather statistics such as wind direction that may affect plume events.

- Relative likelihood of attack mode chosen: conventional bombs are easier to plan for and execute than CBRN attacks
- Relative likelihood of attack for each type of target: locations having high symbolic or economic importance are more likely to be targeted
- Relative likelihood of attack for the city in which the target is located (i.e. target city likelihood): As validated by the experiences in the last decade, major attacks are likely to be focused on major cities to maximize the political agenda of the terrorist.

Multiplicity

Terrorist organizations plan on executing multiple synchronous attacks to inflict maximum loss. Multiplicity in attacks are basically coordinated attacks committed by the same group within a given time frame. A synchronous attack involves two or more targets that are struck within 24 hours. Success is still claimable even if some of the synchronous attacks fail, as demonstrated by what happened on 9/11.

Exposure Module

The most critical elements of exposure for modeling workers' compensation due to terrorism are – the geographical resolution of the data, the number of employees, attributes of the building like construction and height and occupation of employees.

For terrorism analyses, data resolution is extremely important due to the concentrated nature of terrorism risk. Exposures geocoded at the lower resolutions like zip code level or worse can lead to inaccurate loss results. Building construction and height are the primary building attributes that impact vulnerability and losses are sensitive to these two attributes. In the case where building attributes are not known, regional building inventory averages are used.

Occupation information is important for casualty modeling because it determines the percentage of people that will be subject to a terrorist attack. For example, if an attack is modeled at 11 a.m. on a weekday, the percentage of office workers at work will be different than the percentage of restaurant workers at work. If occupation information is not available, the model will use building occupancy to infer the occupation of the employee.

To quantify occupation exposure, RMS recommends using the peak time of day, or 11 a.m. on a weekday. This expresses the worst-case scenario where terrorists maximize the utility of their attack by obtaining the highest number of total exposed lives across occupations.

Hazard Module

Hazard is a way of defining the physical characteristics of a terrorist attack.

Terrorism hazard is primarily determined by distance from an attack. The measure of hazard differs by attack mode as the hazard from a bomb blast is measured in pressure waves while the hazard from a biological or chemical attack is measured in dosage/deposition of contaminant.

In addition to varying by attack mode, terrorism hazard also differs by building characteristics (construction, height), target environment (for instance, sarin gas release inside or outside a building), and the size of the attack (. 1-versus 5-ton bomb).

Simulation of Attack Scenarios

Given a set of exposures, RMS performs a simulation of each attack scenario. RMS models scenarios by overlaying a hazard footprint at each target location. Hazard data is pre-compiled by variable resolution grids (VRG), which are as small as 50 meters by 50 meters in dense urban areas. Losses are determined based on the hazard level at each exposure location falling within the footprint.

Vulnerability Module

In both the casualty and property terrorism models, vulnerability represents the relationship between the level of hazard and casualties or hazard and mean damage. The casualty rate is defined as the number of people injured in each of the six injury classes described in Table 19 to the total number of people exposed to an event. Vulnerability for both the property and casualty terrorism model is primarily a function of building construction and building height. For terrorism, there are vulnerability curves for thirty different combinations of building construction and height. These curves translate the hazards from various types of terrorist attacks to casualty rates or mean damage ratios, which are then used to assign loss or compensation values.

Table 19: Injury Classes

Injury state	Description
No injury*	No bodily harm.
Medical only	Minor injury that can be easily treated and will not cause any permanent impairment. Examples include abrasions, lacerations, strains, sprains, contusions.
Temporary total	Injury that results in an individual's inability to work but from which the individual can fully recover within a reasonably short period of time. Examples include simple broken bones, loss of consciousness, serious strains, and sprains.
Permanent partial-minor	A permanent injury that results in ongoing partial disability. Examples include complicated fractures, serious joint injury, concussions, or minor crush injury.
Permanent partial-major	A permanent injury that results in a disability level greater than 25%, but less than total disability with no return to work. Examples include massive organ injury, heart laceration, loss of limb(s), or crushed extremities.
Permanent total	The most severe type of non-fatal injury. Results in a total disability state where the individual is unable to work again. Examples include spinal cord syndrome, crush syndrome, and massive head injury. These injuries require extended hospitalization.
Fatal	Immediate death or fatal injuries resulting in death.

* No loss is associated with the "no injury" classification, so there is no modeled output for this injury state

Causes of Injuries

The causes of injuries depend on the attack mode being modeled. For conventional bombs, injuries can result from three major sources:

- Damage from blast effects
- Flying fragment items (e.g., glass shards)
- Falling debris

For attack modes involving release of CBRN agents (e.g., sarin or anthrax), the injuries (quantity and severity) depend on the level of exposure to these agents, efficiency of detection (including time until infection treatment begins and ends), and available medical treatment programs during the immediate aftermath of an attack.

Another important consideration is that, typically, human casualty lines of business exposure is mostly indoors. This necessitates the consideration of how a particular attack outdoors would ultimately affect people indoors. For example, in the case of a bomb attack, flying glass or building debris are major causes of injuries, and the level of protection afforded varies according to building height, construction type, and construction quality. On the other hand, for the attacks involving the release of substances outdoors, buildings provide substantial shielding, thereby reducing the severity and number of injuries for people indoors. In this case, the infiltration ratio of indoor concentration to outdoor concentration is used to estimate indoor casualties.

Finally, for all attacks, the proportion of people outdoors and indoors is used to obtain a weighted average of outdoor and indoor casualties. The casualty rate is averaged across the building. This proportion is based on studies conducted by agencies responsible for health protection, on activity patterns of populations, with the objective of characterizing exposure to outdoor pollution.

Financial Module

Physical damage to buildings, their contents, and business interruption, and impacts on human exposure are translated into financial losses after applying relevant financial structures such as policy limits, deductibles, and reinsurance treaties applied by the financial module. Also, the exceedance probability (EP) loss curve and average annual loss is influenced by the risk outlook chosen (Standard, Increased, or Reduced).

Risk Outlooks

RMS provides three different risk outlooks to enable clients to carry out sensitivity analyses of how their risk management decisions might be affected if alternative views were taken into consideration. The three outlooks consist of:

- **Standard Risk Outlook:** This outlook represents the best assessment of the risk of macro-scale terrorism loss in each country for the current parameterization, resulting from the most active terrorism threat groups. The probability of attack is higher, but improved security measures have also reduced the chances of attacks succeeding. Medium-scale conventional attack modes predominate, multiple synchronous attacks are still likely, and the chance of a CBRN attack is small.

- **Increased Risk Outlook:** This risk outlook represents pessimistic interpretations of the available information and trends that would lead to increased risk of attempted attacks. During the year, there is a potential for a relaxation of security measures or events to take place that would provoke terrorist attacks at a higher level than those

incorporated in the RMS Standard threat assessment.

- **Reduced Risk Outlook:** This outlook incorporates optimistic interpretations of available intelligence and extrapolation of trends that would lead to a decreased view of terrorism risk. During the year, increasing counter-terrorism gains and improving security levels everywhere could produce a safer environment than that incorporated in the RMS Standard Risk Outlook.

Modeling Uncertainty in Losses

There are several sources of uncertainty in modeling the losses from a terrorist attack. RMS' Probabilistic Terrorism Model divides the uncertainty in two parts—the primary uncertainty arising from uncertainty in location of the attack with respect to the exposed employees, severity, and probability of occurrence of an attack; and the secondary uncertainty arising from the impact on the people from the attack. Both primary and secondary uncertainty are modeled separately for different classes of attacks.

Primary Uncertainty

Primary uncertainty is the uncertainty around whether an attack will occur, and if an attack does occur, which attack it will be. For terrorism, primary uncertainty is defined for each attack/target pair within the probabilistic model. The model considers the relative probability that a certain kind of attack will be carried out against a certain target. Attacks with conventional bombs are easier to plan for and execute than anthrax releases. Also, given a capability to carry out a specific attack, locations having high symbolic or economic importance are much more likely to be targeted.

In addition to relative likelihood of occurrence of a successful terrorist attack at different target/attack combinations, the frequency of successful attacks is modeled separately for each country. The occurrence of successful macro terror attacks is the outcome of a stochastic control process generated by the dynamics of the confrontation between the forces of terrorism and counter-terrorism. Due to the controlling actions of counter-terrorism following a successful attack, the distribution of successful macro terror attacks is non-Poissonian, based on the principle that countermeasures will be ramped up after any successful attack. In statistical terms, this implies that attacks subsequent to an initial attack cannot be treated as being statistically independent, and their probability of occurrence has to be modeled accordingly. The RMS threat model for macro-terror attacks depends on modeling three input parameters:

- Number of attempted attacks in a year
- Distribution of success rate of attempted attacks
- Suppression factor that is based on government response to an attack

Finally, the uncertainty in number of individual incidents that comprise a terrorist attack (e.g., 9/11) is considered by assigning likelihood for multiplicity of attacks. Attack multiplicity distributions are determined based on historical attack pattern, target type defense, weapon availability, terrorists' capabilities and resources, and the overall chance of detection. The probabilistic methodology takes into account the probabilities of varying numbers of simultaneous attacks launched as part of a single terrorist operation.

Secondary Uncertainty

Secondary uncertainty is the uncertainty in the size of loss, given that a specific attack has occurred. The size of loss can be a range of possible values, some of which are more likely than others. For all attacks involving conventional explosions, secondary uncertainty is modeled through simulations involving bomb explosions, performed through the proprietary Autodyn software.

An additional source of secondary uncertainty in modeling U.S. workers compensation comes from the casualties that occurred. The random nature of terrorism attacks combined with the uncertainty of where people are located at that time gives rise to significant uncertainty in the number of casualties and resulting losses. As a result, there is considerable uncertainty in financial payouts for injuries and deaths. Different members of the population can be expected to have varying levels of coverage; furthermore, regulations governing payouts by injury level also vary from state to state. This source of uncertainty is modeled through the RMS cost severities for casualty models.

Workers' Compensation Cost Severities

A catastrophe model such as the RMS Terrorism Model produces an injury severity distribution, or the number of injuries expected for different injury states. The nature of workers' compensation coverage is such that there is no pre-defined or specified limit of insurance coverage. The amount for which an insurer is ultimately liable depends on many components, including the severity of injuries, the extent of physical impairment, and the duration over which benefits will be paid.

Catastrophic impact is quantified in terms of the expected loss amount by applying mean cost severities that capture statutory indemnity benefits and the cost of medical treatment.

The development of RMS cost severities considers many different factors, or cost components. Each of these cost components, as well as other considerations in estimating ultimate cost, is explained in greater detail in this section.

Medical Costs

All statutory workers' compensation laws provide for the full coverage of medical costs arising from the treatment of injuries and lifesaving procedures.

Generally, injuries result in two forms of medical treatment: acute and maintenance. Acute care is provided to immediately treat the injury but may last for a longer period of time depending on how long it takes to stabilize the injured employee. Beyond acute care, there are maintenance costs. For minor injuries, medical treatment may consist of only acute care, but permanent injuries may require regular maintenance in the form of check-ups, medication, physical therapy, at-home care, nursing care, or a combination of these. Because there is no limit on the medical component covered by workers' compensation insurance, medical inflation is of concern.

Indemnity Costs

Typically, indemnity benefits refer to the benefits that an injured employee receives to compensate for lost wages. RMS has interpreted indemnity costs more broadly to include not only traditional indemnity benefits, but also legal fees, vocational rehabilitation, and funeral costs.

- **Indemnity benefits:** Injured employees are compensated for lost wages. Although they vary by state,

indemnity benefits are typically two-thirds (2/3) of the injured employee's average weekly wage. The indemnity component is highly regulated, and almost every state imposes a maximum and minimum to which the benefit is subject. Many states also have a maximum benefit. Indemnity benefits begin after an initial injury period that varies by state but is between three and seven days. If the employee misses a greater amount of work, then that employee is usually entitled to indemnity benefits for the entire period for the entire duration of the injury. In the case of a permanent disability, this means that indemnity benefits would last for the life of the injured employee unless the state's workers' compensation laws limit the amount or duration of benefits.

- **Survivor benefits:** For fatality claims under workers' compensation, the surviving spouse and/or dependents are awarded benefits according to state law. These have been included as part of the fatal injury indemnity benefits.
- **Legal fees:** Many severe workers' compensation claims involve mediation, arbitration, or, in some cases, court trials. Most states allow the injured employee to recover these fees as part of their workers' compensation coverage. These legal costs have been factored into the RMS cost severities for permanent partial and permanent total disability claims.
- **Vocational rehabilitation:** Workers' compensation insurance in most states also includes a provision to retrain employees who sustain permanent injuries if they can no longer perform their job but are capable of performing a different job. These vocational rehabilitation costs have also been factored into the RMS cost severities for permanent partial disability claims.
- **Funeral and burial costs:** Each state includes a workers' compensation funeral benefit provision to assist the family of a deceased employee to cover the funeral and burial costs. RMS has included each state's specific funeral benefits as part of the overall indemnity cost.

Glossary

Aggregate Exceedance Probability (AEP)

AEP measures the probability of exceeding a specified loss threshold from one or more occurrences in a given Year.

Average Annual loss (AAL)

The expected annual loss on a long-term average basis. Mathematically, it is the expected value of the aggregate loss distribution, or alternatively, the area under the AEP Curve.

CBRN attacks

Chemical, biological, radiological, and nuclear attacks. These attacks are high-severity and low frequency attacks due to the extensive time and resources needed to be successfully executed.

Conventional attacks

Bomb, aircraft impact, conflagration, or industrial attacks. These attacks are lower in severity, and high frequency attacks due to the comparably less resources and time needed to be successfully executed.

Effective workers' compensation deductible

The WCIRB portion of the workers' compensation share of the TRIPRA deductible.

Government retained

The loss payable by the government with the 2019 TRIPRA Program.

Macro-Terrorism Attacks

Attacks that can potentially have the following consequences:

(1) Economic losses in excess of US$1 billion;

(2) Casualties of more than 20 dead and/or 100 injured; (3) Massively symbolic damage

Net-insured retained (NIR)

The loss retained by the WCIRB-member companies with the 2019 TRIPRA Program.

Peak exposure adjustment scenario

An exposure time adjustment used by RMS to estimate exposure at a specific time of day and day of the week. For this analysis, 11 a.m. on a weekday was used.

Program Cap-Adjusted Losses

The allocation of loss to WCIRB after the TRIPRA program cap is applied.

Standard Risk Outlook

The best assessment of terrorism risk given the current 2019 parameterization.

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