23rd January 2018
Advisory Board 2018 Research Showcase

Applications of Corporate Risk Profiling

Centre for
Risk Studies

UNIVERSITY OF CAMBRIDGE
Judge Business School

Andy Skelton
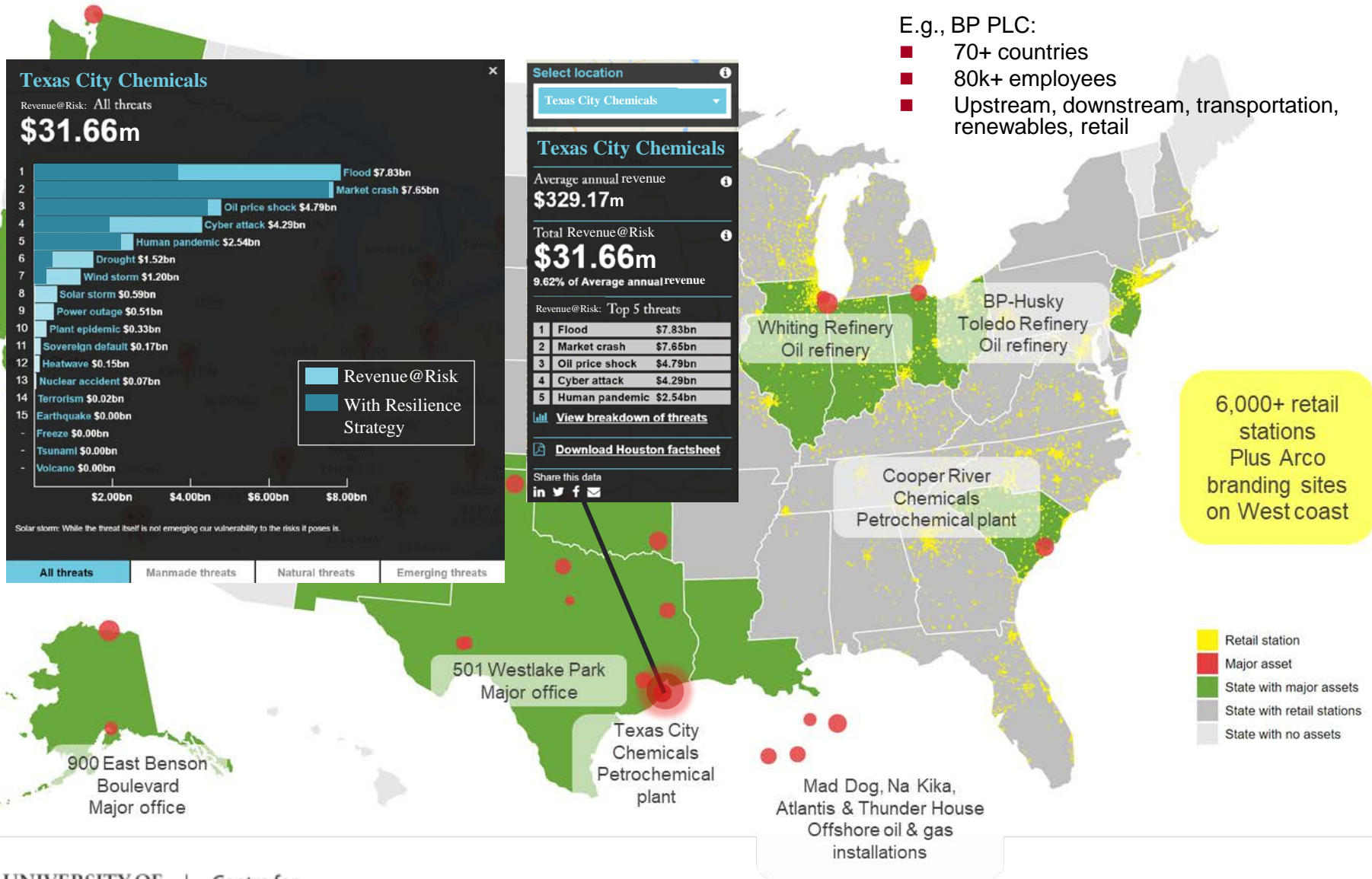Senior Risk Researcher
Cambridge Centre for Risk Studies

Why Focus on Corporate Risk Profiling?

Corporate Long-Term Viability

- **Increasing external requirements**
  - A 'Long Term Viability Statement' is now an annual reporting requirement in the UK
  - A qualitative 'Significant Risks' section is now a SEC 10K requirement in the US
    - Proposal for additional quantitative disclosures on how these risks are assessed and mitigated

- **Growing trend toward improved internal risk reporting**
  - Some companies starting to report 1-in-100 year risks
  - Executives increasingly concerned about accountability to shareholders
  - Many companies already defining their own risk registers and conducting scenario planning exercises

- **But internal risk registers may be too narrow, short-term, or biased toward the probable**
  - An holistic view is needed that combines company-specific risk registers with a more comprehensive view of the external threat landscape
  - This requires a unified and quantified framework

- **Corporates can put in place a wide range of strategies to improve their resilience to severe shocks from both internal and external threats**
 - Quantitative tools are needed to help support trade-off decision making

UNIVERSITY OF CAMBRIDGE
Judge Business School

Centre for
Risk Studies

What Should a Corporate Resilience Strategy Support Tool Do?

1. Compare Risk Profile of Corporate Locations Under Different Resilience Strategies

Texas City Chemicals

Revenue@Risk: All threats

$31.66m

1	Flood	$7.83bn
2	Market crash	$7.65bn
3	Oil price shock	$4.79bn
4	Cyber attack	$4.29bn
5	Human pandemic	$2.54bn
6	Drought	$1.52bn
7	Wind storm	$1.20bn
8	Solar storm	$0.59bn
9	Power outage	$0.51bn
10	Plant epidemic	$0.33bn
11	Sovereign default	$0.17bn
12	Heatwave	$0.15bn
13	Nuclear accident	$0.07bn
14	Terrorism	$0.02bn
15	Earthquake	$0.00bn
-	Freeze	$0.00bn
-	Tsunami	$0.00bn
-	Volcano	$0.00bn

Legend:
- Revenue@Risk
- With Resilience Strategy

x-axis: $2.00bn $4.00bn $6.00bn $8.00bn

Solar storm: While the threat itself is not emerging our vulnerability to the risks it poses is.

| All threats | Manmade threats | Natural threats | Emerging threats |

Select location

Texas City Chemicals ▼

Texas City Chemicals

Average annual revenue

$329.17m

Total Revenue@Risk

$31.66m

9.62% of Average annual revenue

Revenue@Risk: Top 5 threats

1	Flood	$7.83bn
2	Market crash	$7.65bn
3	Oil price shock	$4.79bn
4	Cyber attack	$4.29bn
5	Human pandemic	$2.54bn

📊 View breakdown of threats

📄 Download Houston factsheet

Share this data

E.g., BP PLC:
- 70+ countries
- 80k+ employees
- Upstream, downstream, transportation, renewables, retail

BP-Husky Toledo Refinery
Oil refinery

Whiting Refinery
Oil refinery

6,000+ retail stations
Plus Arco branding sites on West coast

Cooper River Chemicals
Petrochemical plant

501 Westlake Park
Major office

Texas City Chemicals Petrochemical plant

900 East Benson Boulevard
Major office

Mad Dog, Na Kika, Atlantis & Thunder House
Offshore oil & gas installations

Legend:
- 🟨 Retail station
- 🔴 Major asset
- 🟩 State with major assets
- ⬜ State with retail stations
- ⬜ State with no assets

2. Construct Overall Corporate Exceedance Probability Curves and Show Impact of Resilience Strategies

- An established concept in the insurance industry – can they be adopted in the corporate sector?
- Can help identify scenarios that could result in a loss level of concern and be used to benchmark more details stress tests
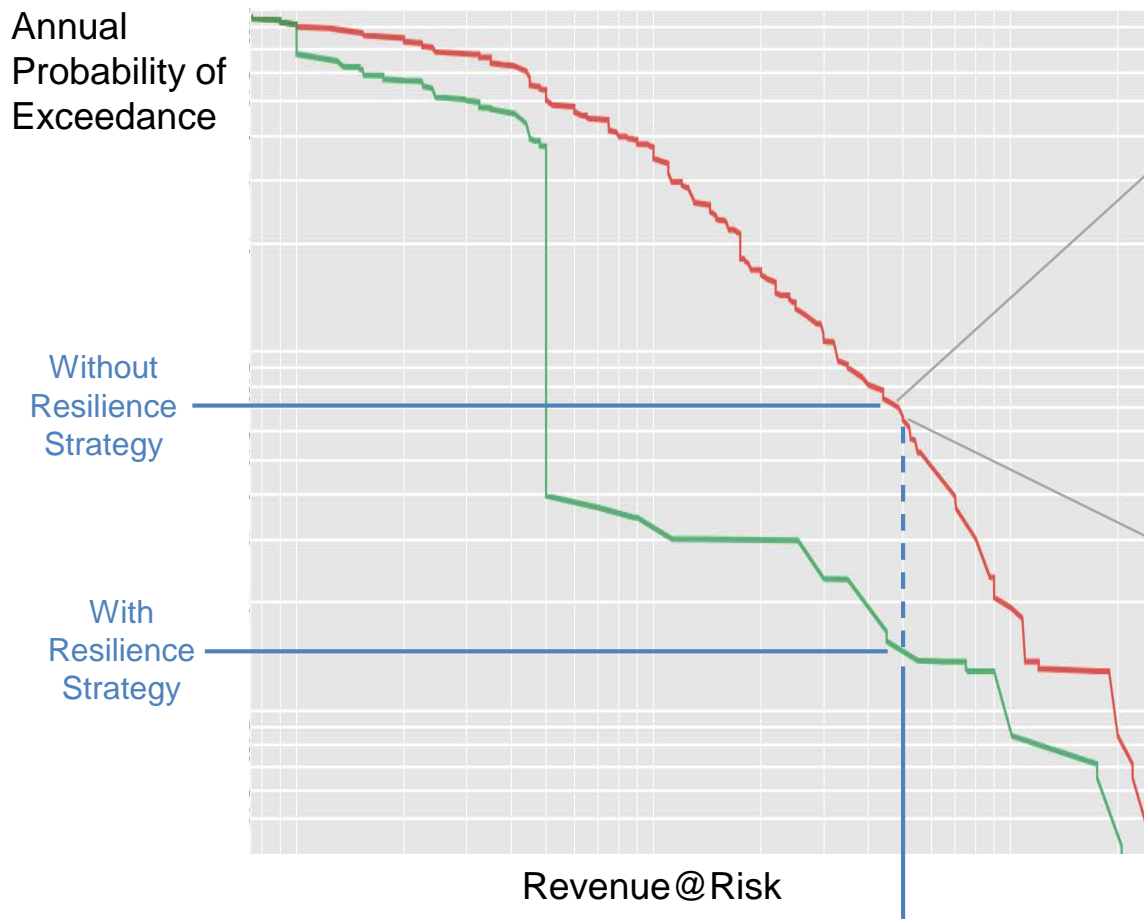
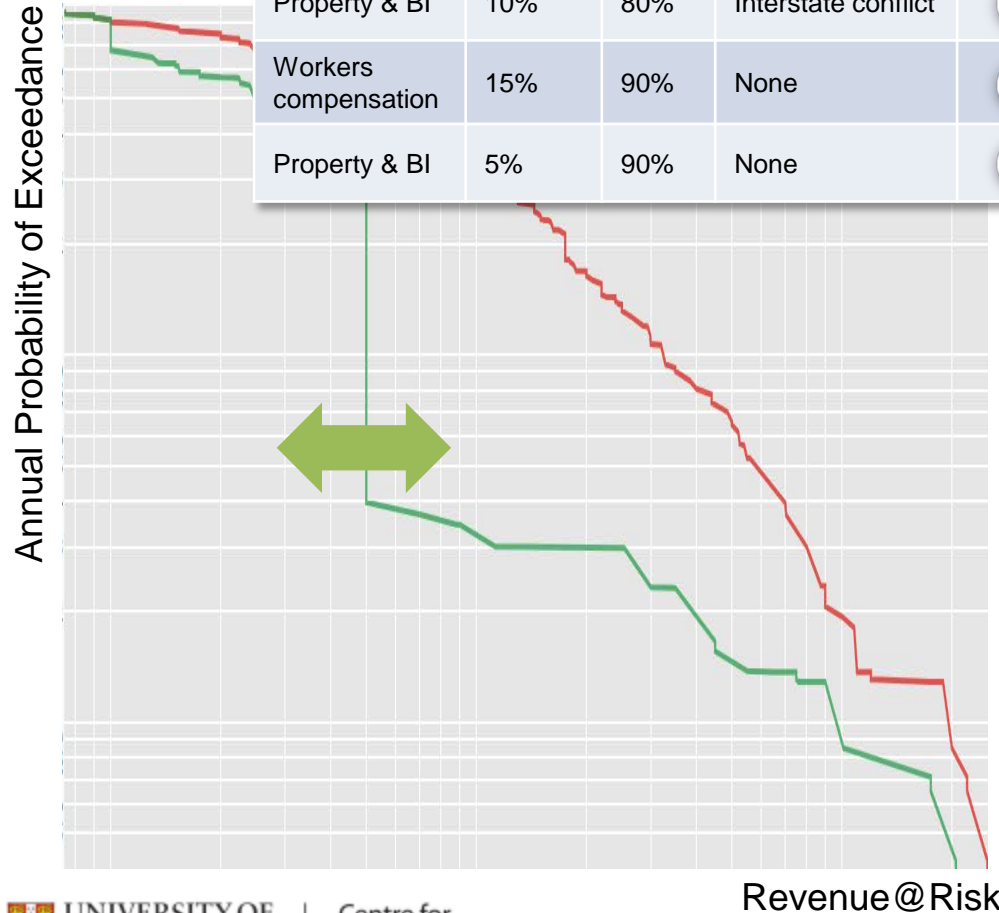FL2 (flood 3m depth, moderate velocity water) scenario at Texas City Chemicals location
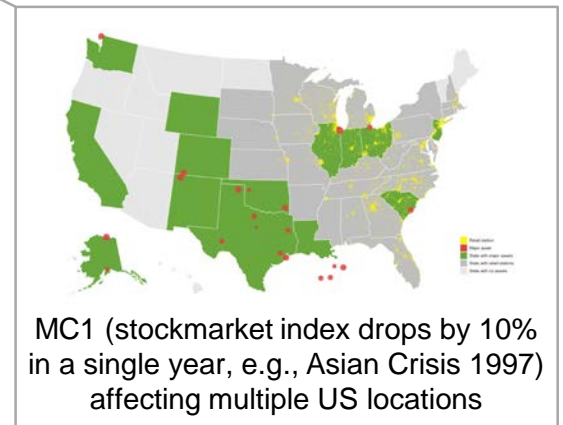
MC1 (stockmarket index drops by 10% in a single year, e.g., Asian Crisis 1997) affecting multiple US locations

Annual Probability of Exceedance

Without Resilience Strategy

With Resilience Strategy

Revenue@Risk

E.g., Risk of corporate distress

UNIVERSITY OF CAMBRIDGE
Judge Business School

Centre for **Risk Studies**

6

3. Explore Impact of and Fine Tune Alternative Resilience Strategies

Insurance product	Deduct.	Limit	Threat exclusions	Active		Whiting Refinery	Cherry Point Refinery	BP-Husky Toledo Refinery	Texas City Chemicals	Cooper River Chemicals
Property & BI	5%	90%	Interstate conflict	🟢		●	●	●	●	●
Property & BI	10%	80%	Interstate conflict	🔴		○	○	●	●	●
Workers compensation	15%	90%	None	🟢		●	●	●	○	○
Property & BI	5%	90%	None	🔴		●	●	●	●	●

Annual Probability of Exceedance — *Revenue @ Risk*

- Allow a user to better understand and test the impact of:
  - Adding new resilience strategies
  - Removing an existing strategies
  - Changing strategy parameters, e.g., policy terms and exclusions of an insurance product
  - Change the company locations to which a strategy applies

- Impacts would be observed in the shape of the EP curve and location results

UNIVERSITY OF CAMBRIDGE
Judge Business School

Centre for
Risk Studies

4. Account for the 'Organograph'
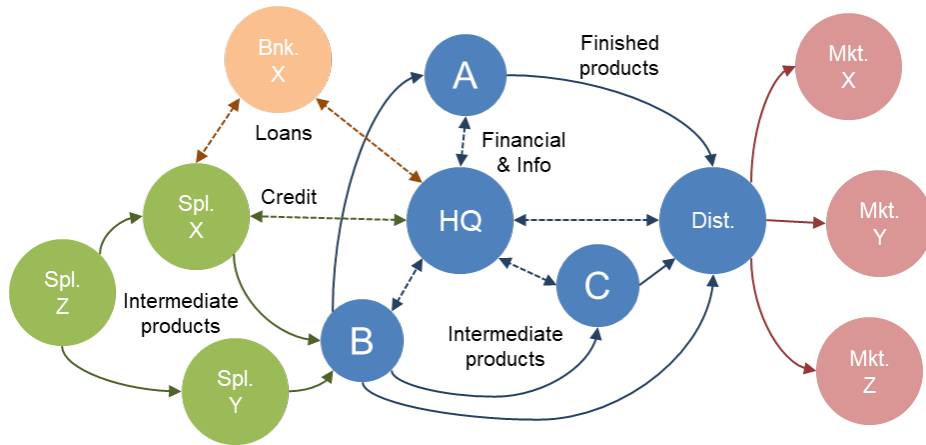
E.g., BP PLC:
- 1,000+ subsidiaries
- Spanning 70+ jurisdictions

- An organograph details location interdependency along with supply, distribution & demand networks

- Map physical assets to legal and financial perspectives of a business

- Assess contagion risks through internal corporate structures and with external counterparties

- Find a balance between granularity and practicality

UNIVERSITY OF CAMBRIDGE
Judge Business School

Centre for **Risk Studies**
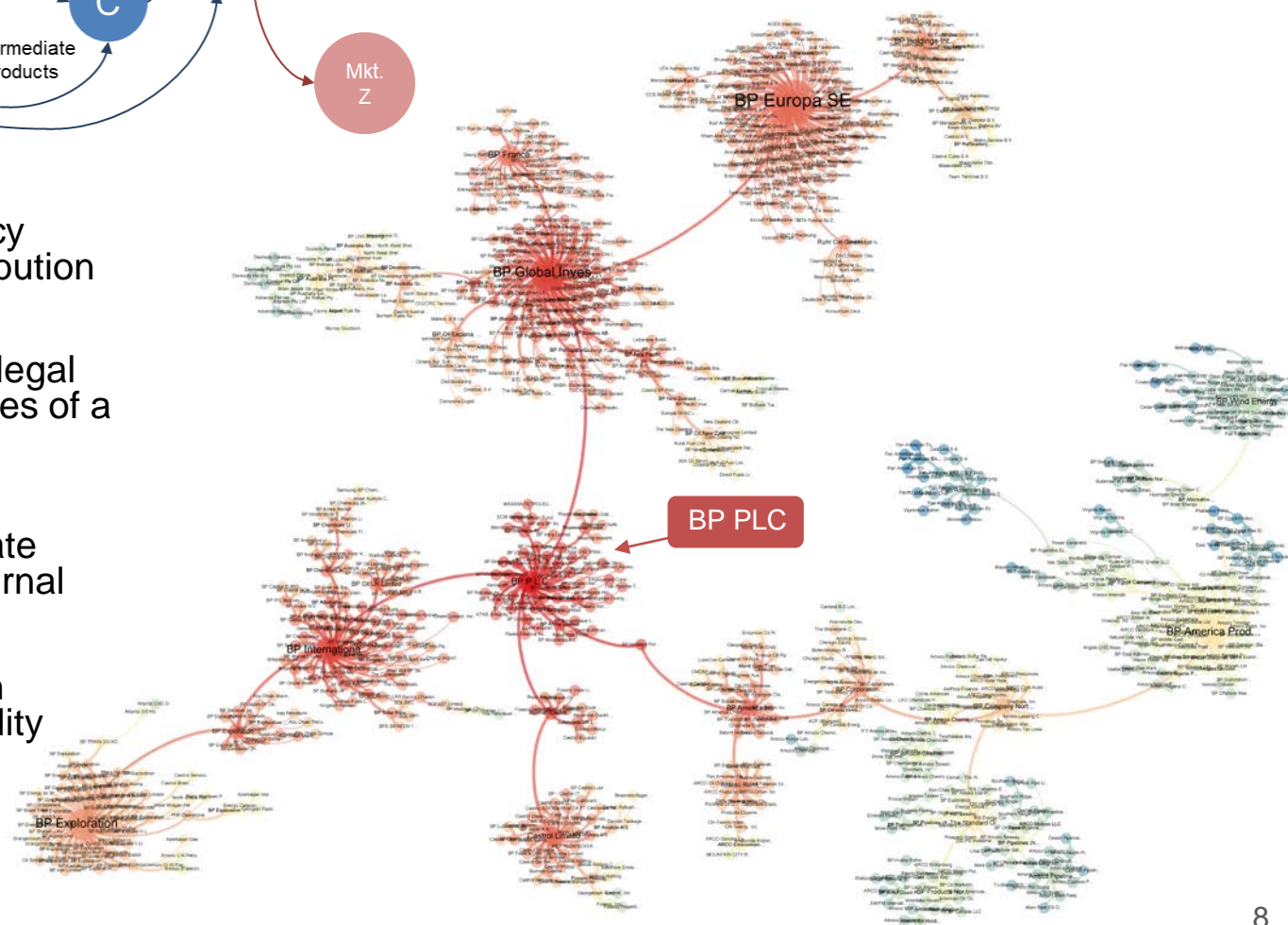
Key Objectives

- Develop an analytical process for defining types and likelihoods of events that will cause severe loss to a company
  - Process should be generalisable to the large majority of companies

- Must account for corporate resilience strategy & be able to adjust losses accordingly

- Analysis may be used directly by a corporate or by an advisor/broker to help a client company optimise strategy and improve its resilience to severe shock

- Necessarily a 1st-order approach
  - Aim to derive initial estimates for all threats rather than try to be more detailed in any particular one
  - Use the existing Cambridge Risk Framework as a starting point

UNIVERSITY OF CAMBRIDGE Judge Business School | Centre for **Risk Studies**

Cambridge Risk Framework – Global Economy

- Cambridge Risk Framework is our analytics platform for global catastrophes
- We model 22 threat types
  - Over 12,000 localised shock scenarios for major cities all over the world
  - Over 3,000 scenarios of systemic shocks to the global economy
- Each view of risk supported by networks of subject matter specialists

Finance, Economics and Trade
Market Crash · Sovereign Crisis · Commodity Prices

Geopolitics and Security
Interstate Conflict · Terrorism · Separatism Conflict · Social Unrest
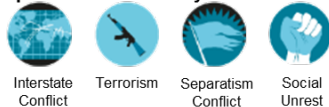
Natural Catastrophe and Climate
Earthquake · Tropical Windstorm · Temperate Windstorm · Tsunami · Flood
Volcanic Eruption · Drought · Freeze · Heatwave

Technology and Space
Nuclear Accident · Power Outage · Cyber Attack · Solar Storm

Health and Humanity
Human Pandemic · Plant Epidemic

- **$1tr** events have an 8 year return period
- **$10tr** events have an 47 year return period
- $16tr events have a **100 year** return period
- $22tr events have a **200 year** return period

Return Period (Years)

- Mt Fuji Eruption at VEI VII
- Worst case hurricane season NE USA
- Solar storm impacting North America & Europe
- Major global market crash
- Global virulent pandemic
- Level 4 interstate conflict between China & India

Legend:
- Finance, Economics & Trade Risks
- Geopolitics & Security
- Technology & Space
- Natural Catastrophe & Climate
- Health & Humanity

$US trillion

UNIVERSITY OF CAMBRIDGE
Judge Business School
Centre for Risk Studies

10

Blueprint for a Corporate Resilience Strategy Support Tool
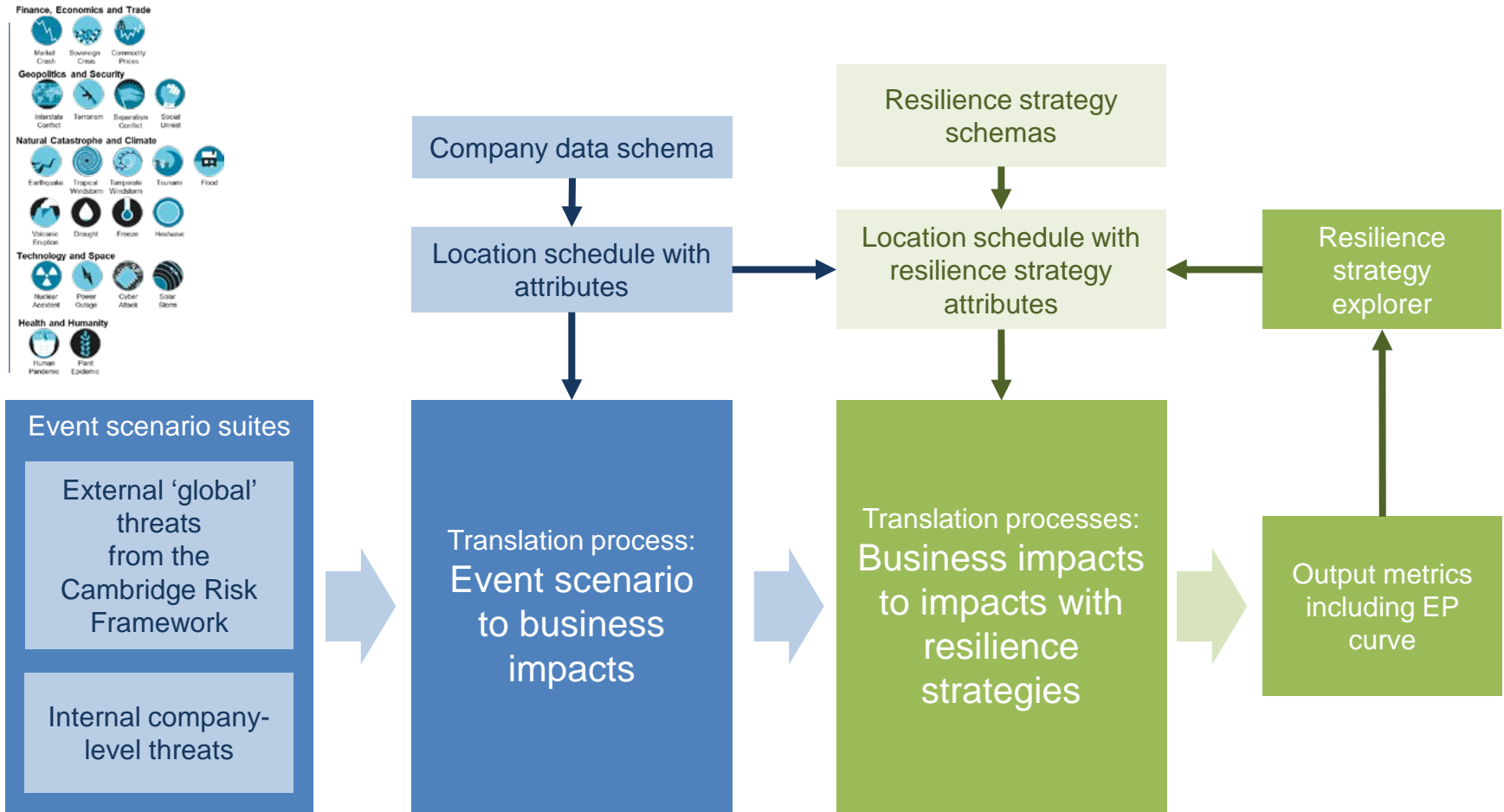
- Insurance strategies with be informed by Global Exposure Accumulation Clash (GEAC) project in collaboration with RMS and a consortium of clients
- Collaborating with IRM to develop understanding of broader resilience strategies

UNIVERSITY OF CAMBRIDGE
Judge Business School
Centre for **Risk Studies**

Calibration Example of Translating Event Scenarios to Business Impacts

Calibrating Asset Types:
Example of Merak PTA Plant in Indonesia

Jakarta
GDP@Risk: All threats
$48.23bn

Rank	Threat	Value
1	Sovereign default	$7.99bn
2	Human pandemic	$7.74bn
3	Market crash	$6.01bn
4	Earthquake	$5.41bn
5	Terrorism	$4.27bn
6	Volcano	$4.09bn
7	Flood	$3.26bn
8	Drought	$3.17bn
9	Plant epidemic	$2.09bn
10	Cyber attack	$1.60bn
11	Tsunami	$0.87bn
12	Power outage	$0.79bn
13	Solar storm	$0.53bn
14	Wind storm	$0.42bn
15	Freeze	$0.00bn
-	Heatwave	$0.00bn
-	Nuclear accident	$0.00bn
-	Oil price shock	$0.00bn

Solar storm: While the threat itself is not emerging our vulnerability to the risks it poses is.

Jakarta
Average annual GDP
$342.41bn

Total GDP@Risk
$48.23bn
14.09% of Average annual GDP

GDP@Risk: Top 5 threats
1	Sovereign default	$7.99bn
2	Human pandemic	$7.74bn
3	Market crash	$6.01bn
4	Earthquake	$5.41bn
5	Terrorism	$4.27bn

View breakdown of threats

Download Jakarta factsheet

Share this data

UNIVERSITY OF CAMBRIDGE
Judge Business School
Centre for **Risk Studies**

13

Localised Impact Scenario Assessment

- Assume that Plant Capital Cost is $100m

- It has 500 personnel, working in shifts (200 on site at any one time)

- It produces 530,000 tons a year of PTA (Raw materials for polyester)

- Represents 7% of BP's PTA Output

- If the following scenarios occur…

Potential Outage for BP Marek, Indonesia, Facility

Threat Type	Scenario	Exceedance Probability	Exceedance Return Period	Days of Outage
1.7 Tsunami	Tsunami 6m runup	0.0009	1,075	1800
3.1 Interstate War	Strategic bombing destroys facilities	0.0012	869	1800
6.1 Accidental Fire	Accidental Large Explosion	0.0012	826	720
1.2 Volcano	1m Ash layer	0.0013	752	360
1.7 Tsunami	Tsunami 3m run-up	0.0043	231	320
1.5 Flood	Flood 6m depth, highly polluted waters	0.0045	221	300
3.3 Terrorism	Major Weapon/WMD Terrorist Attack	0.0046	220	300
1.1 Earthquake	MMI X	0.0046	217	270
6.1 Accidental Fire	Accidental Explosion (PML)	0.0050	198	180
1.5 Flood	Flood 3m depth, Moderate velocity water	0.0057	176	120
1.1 Earthquake	MMI IX	0.0060	166	90
3.2 Civil War and Separatism	Civil war heavy weaponry fighting	0.0064	155	80
1.3 Wind Storm	Cat 5 Hurricane	0.0067	150	75
4.2 Cyber	Cyber attacks on power grid	0.0070	143	75
1.2 Volcano	5cm Ash layer	0.0076	131	60
4.2 Cyber	Cyber-Physical Attack	0.0094	106	50
5.1 Human Pandemics	Pandemic with high fatality disease	0.0101	99	48
3.2 Civil War and Separatism	Sectarian fighting between private militias	0.0113	89	40
3.4 Social Unrest	Strikes prevent workers attending	0.0148	68	36
1.1 Earthquake	MMI VII	0.0154	65	30
4.3 Solar Storm	SS3	0.0160	62	30
5.1 Human Pandemics	Pandemic influenza infects 43% of pop	0.0183	55	28
4.2 Cyber	Cyber breach - major data exfiltration	0.0363	28	25
2.2 Sovereign Default	Country defaults	0.0382	26	24
1.3 Wind Storm	Cat 3 Hurricane	0.0396	25	21
3.1 Interstate War	Missile attack or aerial bombardment	0.0400	25	21
3.2 Civil War and Separatism	Civil Unrest riots and protests	0.0400	25	20
4.1 Electrical power outage	All power lost for 10 days	0.0412	24	20
6.1 Accidental Fire	Accidental Fire (EML)	0.0562	18	20
1.5 Flood	Flood 1m depth, low velocity water	0.0581	17	14
5.1 Human Pandemics	Localized epidemic of new emergent disease (e.g. SARS)	0.0587	17	14
1.3 Wind Storm	Cat 1 Hurricane	0.0639	16	10
3.3 Terrorism	2 ton truck bomb Terrorist attacks	0.0679	15	10

External event probabilities benchmarked off nearest CRF city in the first instance – more granular threat layers would follow

Expert and evidence-based judgements

Exceedance Probability Curve of Business Outage

Business Outage Exceedance Probability Merak Facility

Annual Probability of Exceedance

- 3 week outage = 1 in 25 yrs
- 3 month outage = 1 in 167 yrs
- Probability = 1 in 230
- Effectively permanently decommissioned

Number of Days Outage

UNIVERSITY OF CAMBRIDGE
Judge Business School

Centre for **Risk Studies**
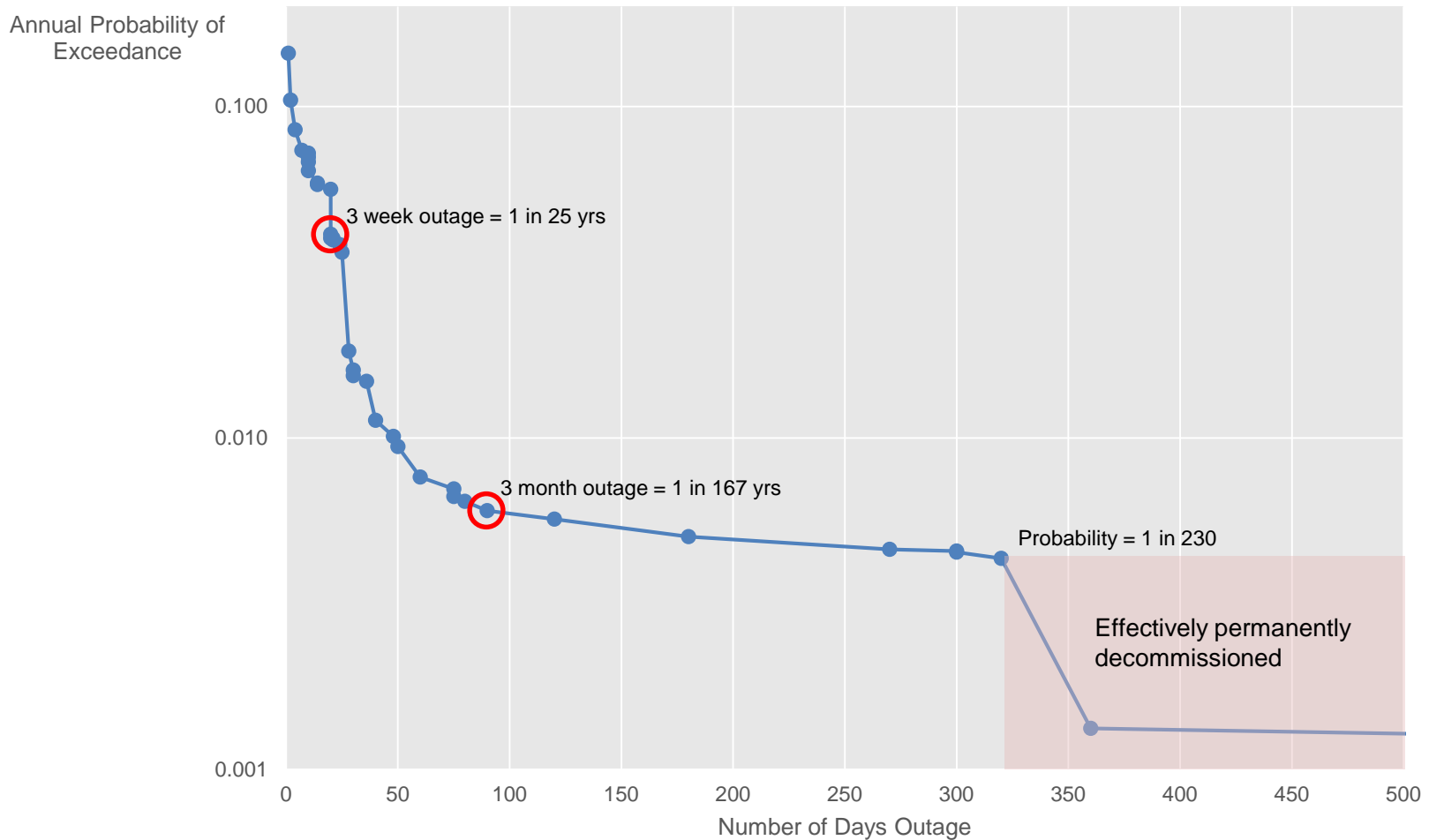
- ■ Financial models can be used to further translate days of outage in annual revenue loss for example

Physical Damage for BP Marek, Indonesia, Facility

Threat Type	Scenario	Exceedance Probability	Exceedance Return Period	% Repair Cost of Facility
1.7 Tsunami	Tsunami 6m runup	0.0009	1,075	100%
3.1 Interstate War	Strategic bombing destroys facilities	0.0012	869	100%
3.3 Terrorism	Major Weapon/WMD Terrorist Attack	0.0012	847	90%
1.7 Tsunami	Tsunami 3m run-up	0.0042	239	50%
1.5 Flood	Flood 6m depth, highly polluted waters	0.0044	229	50%
1.1 Earthquake	MMI X	0.0044	226	35%
3.2 Civil War and Separatism	Civil war heavy weaponry fighting	0.0048	207	30%
● 6.1 Accidental Fire	Accidental Large Explosion	0.0049	205	20%
3.2 Civil War and Separatism	Sectarian fighting between private militias	0.0061	164	18%
1.5 Flood	Flood 3m depth, Moderate velocity water	0.0067	148	15%
● 6.1 Accidental Fire	Accidental Explosion (PML)	0.0072	140	10%
1.1 Earthquake	MMI IX	0.0075	133	8%
1.3 Wind Storm	Cat 5 Hurricane	0.0077	129	8%
1.2 Volcano	1m Ash layer	0.0078	127	5%
4.2 Cyber	Cyber-Physical Attack	0.0096	104	5%
3.3 Terrorism	2 ton truck bomb Terrorist attacks	0.0136	73	5%
3.1 Interstate War	Missile attack or aerial bombardment	0.0141	71	3%
1.3 Wind Storm	Cat 3 Hurricane	0.0154	65	2%
● 6.1 Accidental Fire	Accidental Fire (EML)	0.0304	33	2%
1.1 Earthquake	MMI VII	0.0311	32	1%
1.5 Flood	Flood 1m depth, low velocity water	0.0330	30	1%

■ Note that some threats are unlikely to lead to any physical damage, e.g., Human Pandemic

Exceedance Probability Curve of Physical Damage

Physical Damage Exceedance Probability Merak Facility

Annual Probability of Exceedance

0.5% RCR = 1 in 25 yrs

5% RCR = 1 in 73 yrs

20% RCR = 1 in 200 yrs

90% RCR = 1 in 850 yrs

Repair Cost as Ratio of Capital Cost
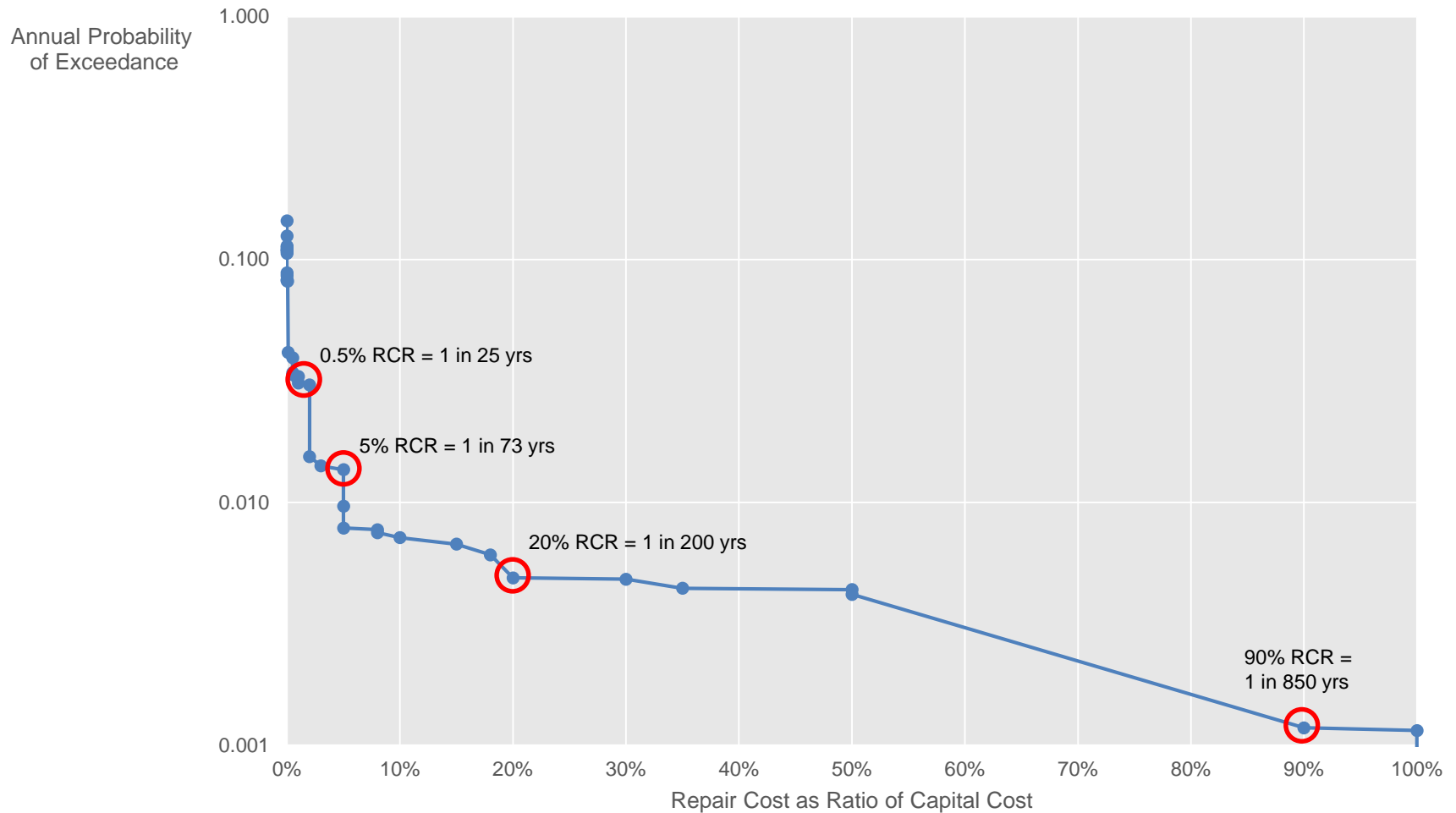
Exceedance Probability Curve of Physical Damage: With Example Resilience Strategy

Physical Damage Exceedance Probability Merak Facility

Annual Probability of Exceedance

0.5% RCR = 1 in 25 yrs

5% RCR = 1 in 73 yrs

20% RCR = 1 in 200 yrs

90% RCR = 1 in 850 yrs

Cost to company after insurance recovery

Repair Cost as Ratio of Capital Cost
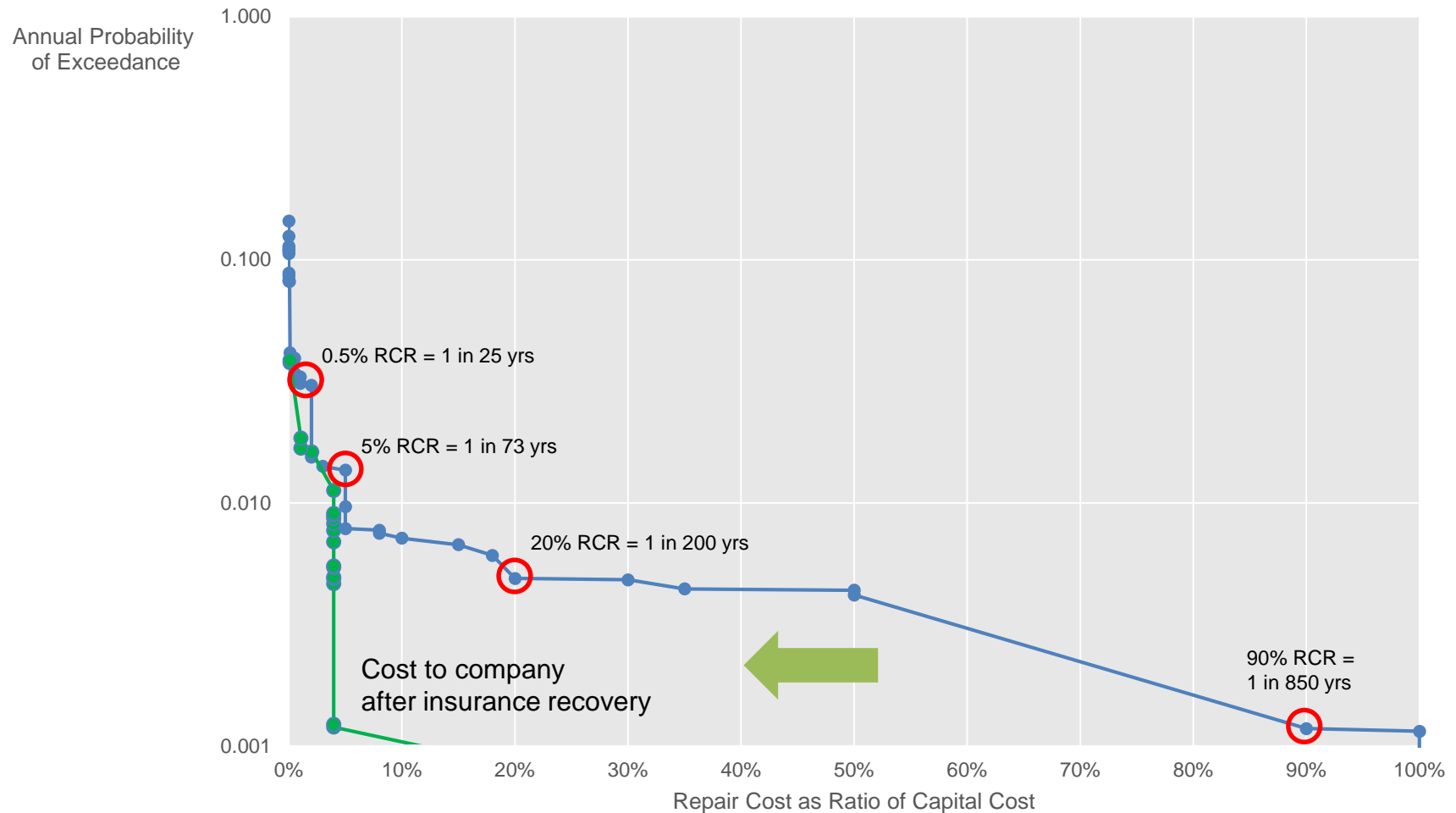
Preview of Prototype Application

Preview of Prototype Application:
Upload, Edit, and Download Company Location Data

- Make live edits in the app and rerun threat analysis
- View locations on interactive map, sized by key attributes
- View and edit underlying model calibration parameters in the Advanced tab

Preview of Prototype Application:
Identify Locations Most at Risk from Different Threats
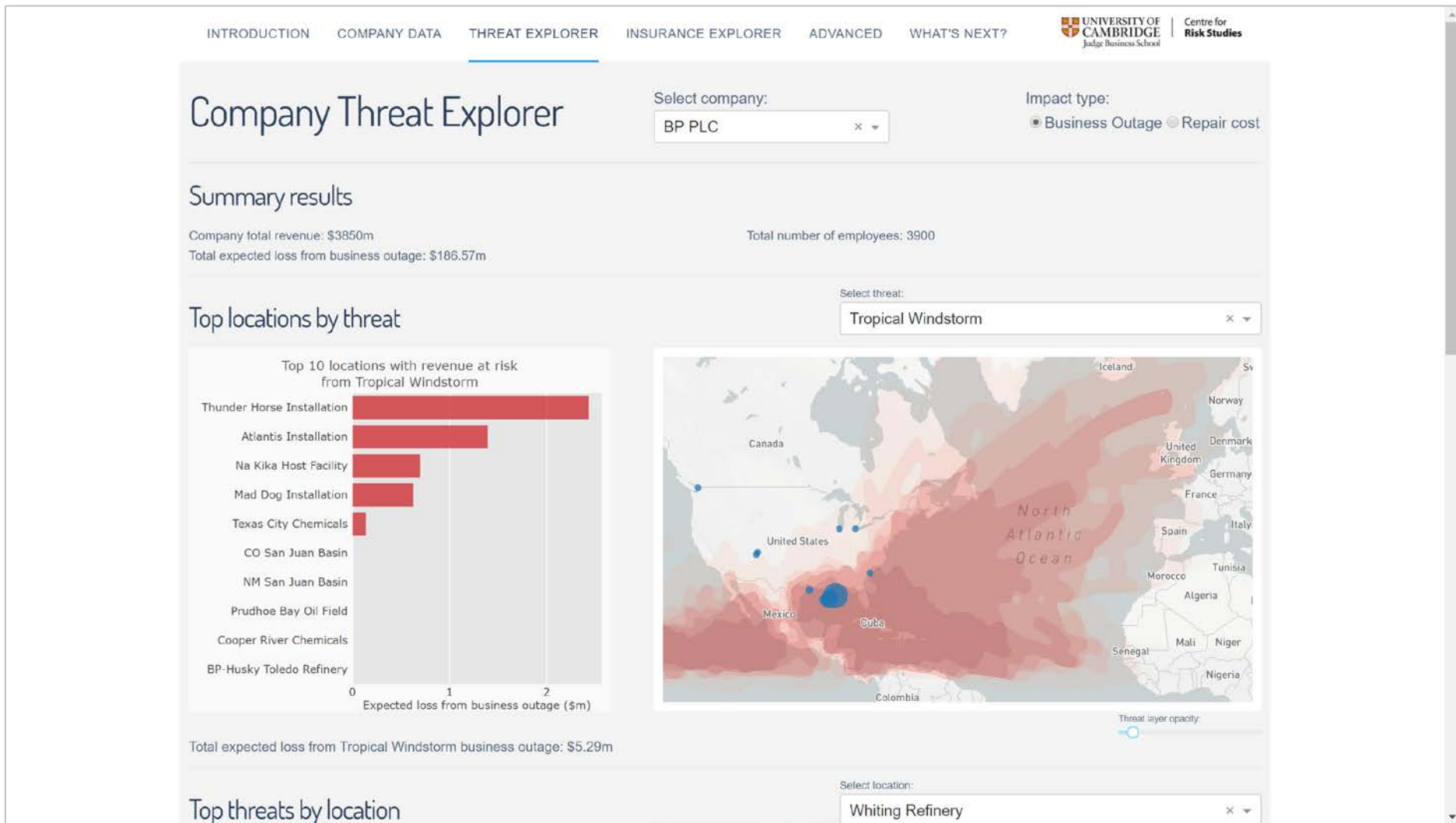
- View results for different impact types, e.g., business outage or repair costs
- View locations on map overlaid with threat layers and sized by expected loss

Preview of Prototype Application:
Identify Threats Posing Greatest Risk to Different Locations
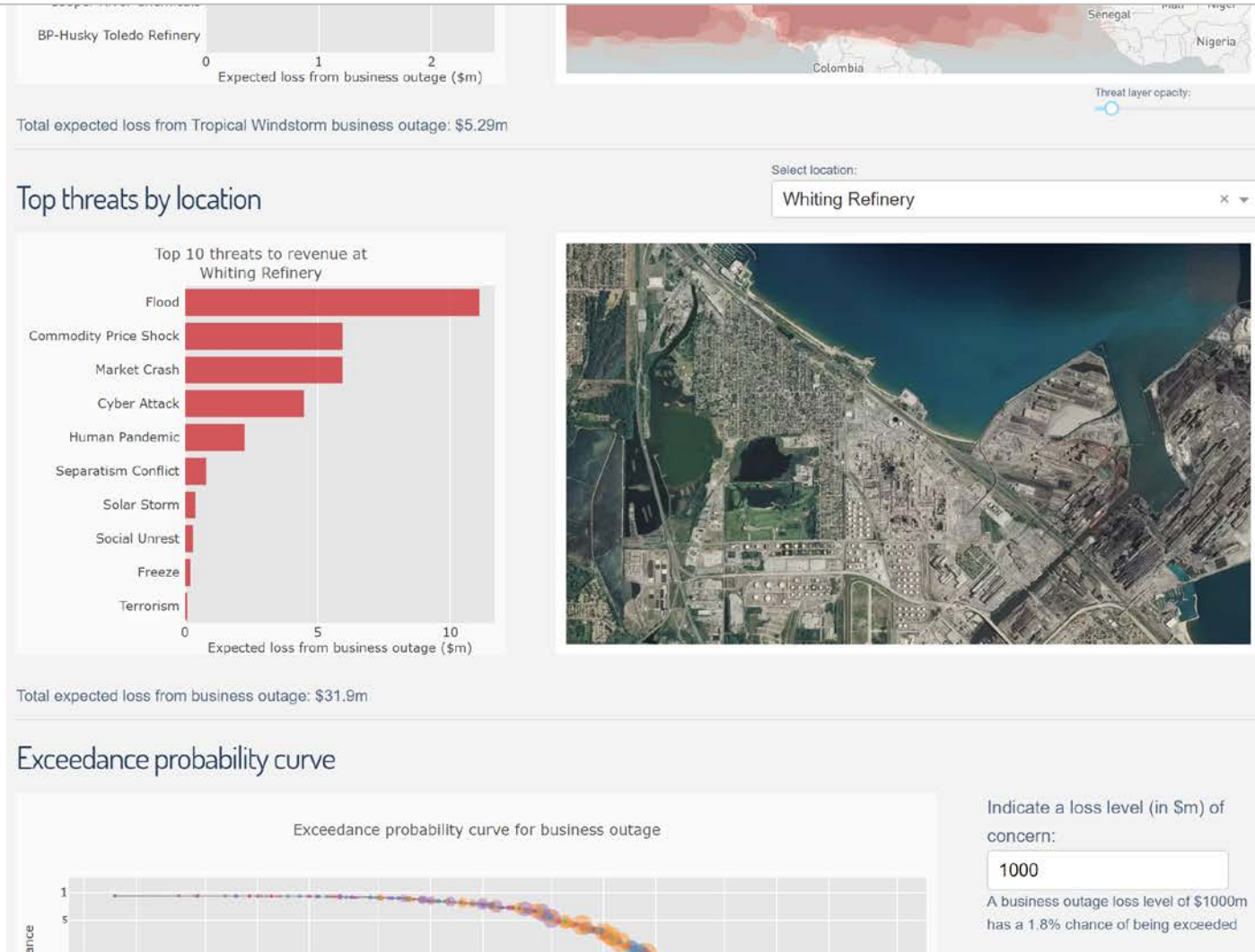
- View satellite map of each location to help validate threat assessments

UNIVERSITY OF CAMBRIDGE
Judge Business School

Centre for **Risk Studies**

Preview of Prototype Application:
View Overall Corporate EP Curve
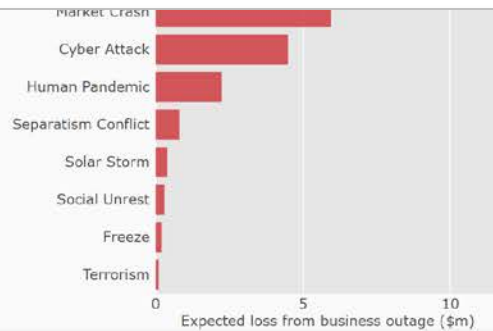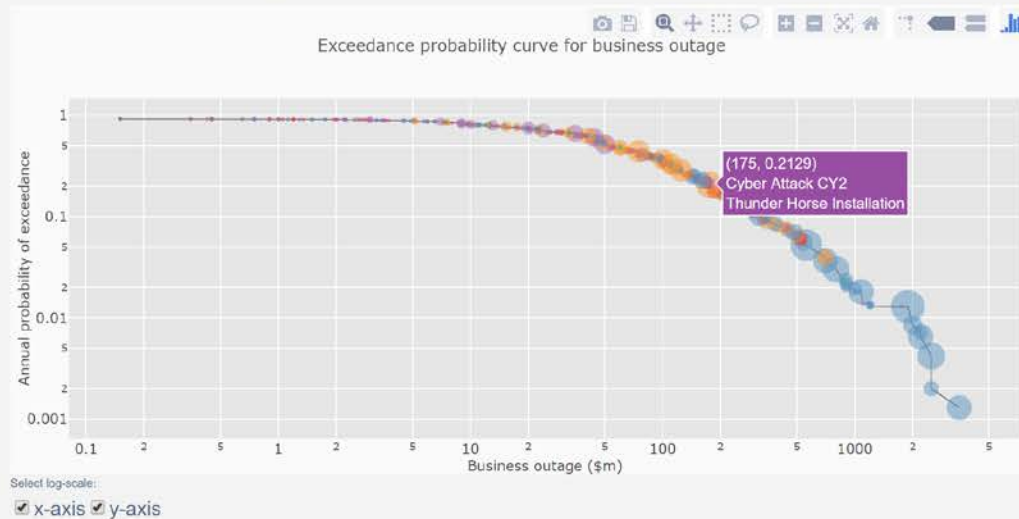
■ Identify probability of exceeding a given loss threshold, and vice versa

■ Identify representative scenarios at loss levels or exceedance probabilities of interest

UNIVERSITY OF
CAMBRIDGE
Judge Business School

Centre for
Risk Studies

# Preview of Prototype Application: Represent Corporate Resilience Strategies

- Construct a simple corporate profile of insurance products and rerun threat analysis
- Set limits, deductibles, exclusions and select which locations a product is applied

Preview of Prototype Application:
Compare EP Curves With and Without Resilience Strategy
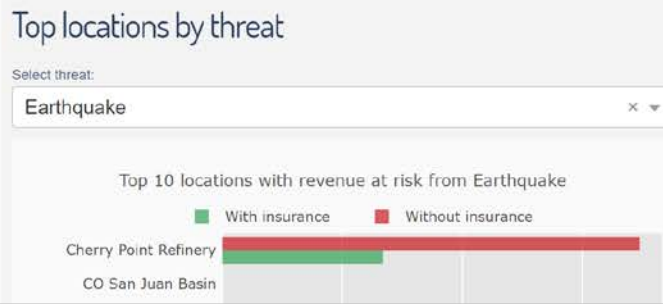
- Identify impact of strategy on the probability of exceeding a given loss threshold, and vice versa
- Identify new representative scenarios at loss levels or exceedance probabilities of interest

Preview of Prototype Application:
Identify New Key Threats and Locations Given Resilience Strategy
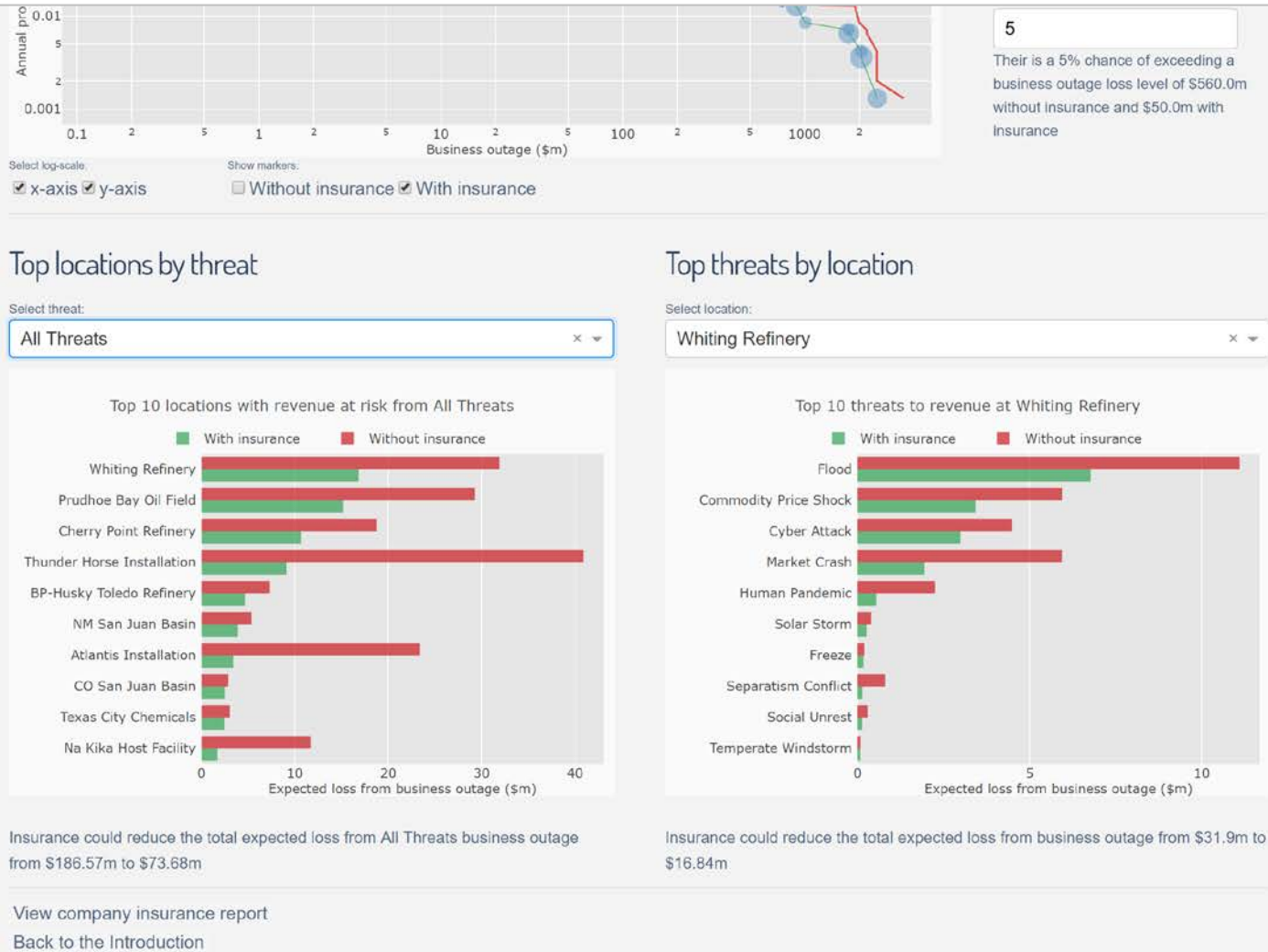
- Compare expected loss results by threat and location for scenarios with and without corporate insurance profile applied
- Identify impact of insurance profile on expected loss

Centre for
Risk Studies

UNIVERSITY OF
CAMBRIDGE
Judge Business School