



TEXAS A&M UNIVERSITY

Zachry Department of
Civil & Environmental Engineering



CROSS-BORDER THREAT SCREENING
AND SUPPLY CHAIN DEFENSE

A Department of Homeland Security Center of Excellence



Stochastic
Geomechanics
Laboratory

"What is Past is Prologue: Improving Regional Decision-Making through Bayesian Risk Networks

Zenon Medina-Cetina

04/09/2025

Relationship between Hazard & Consequences

Risk

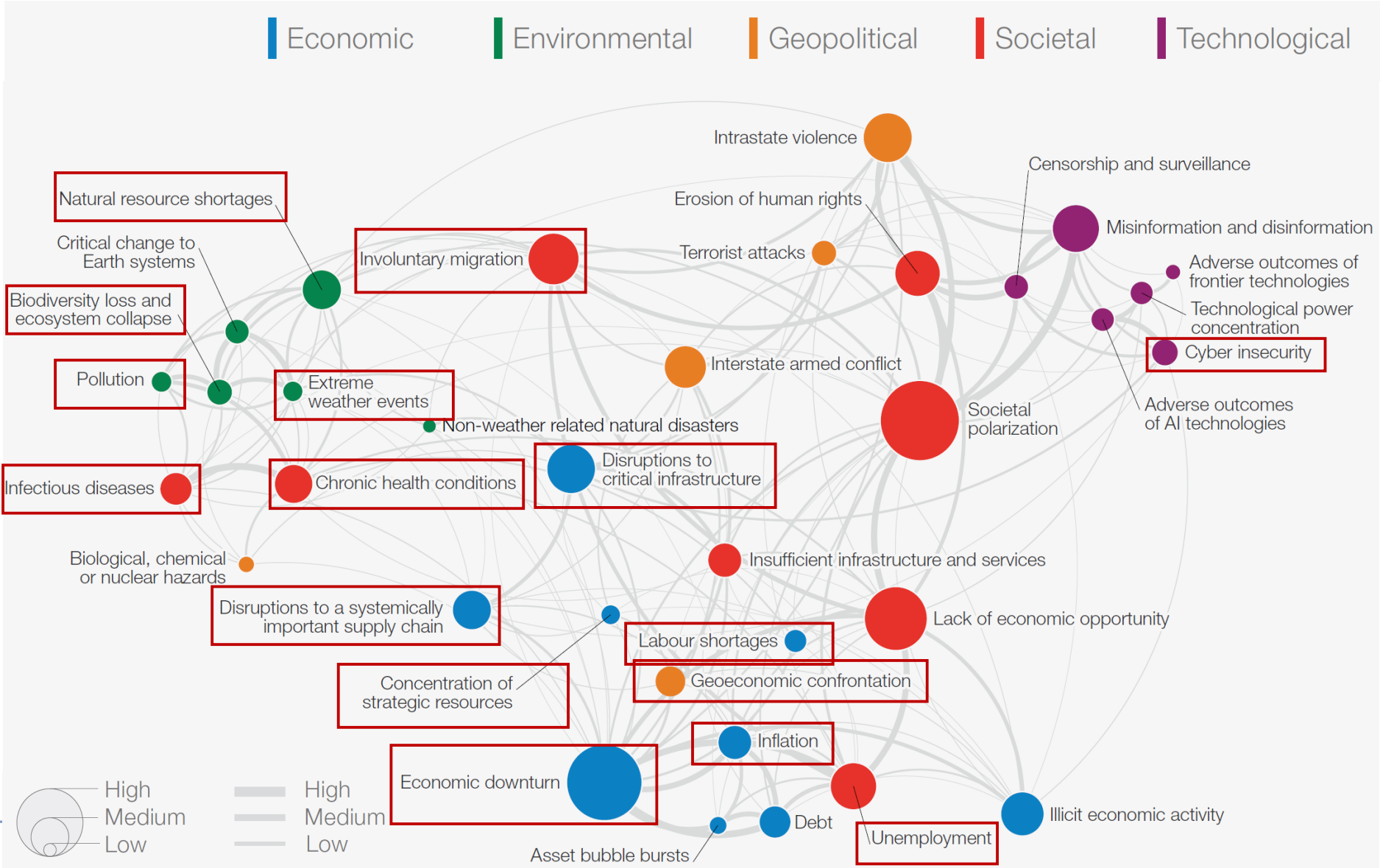
=

Hazard

x

Consequences

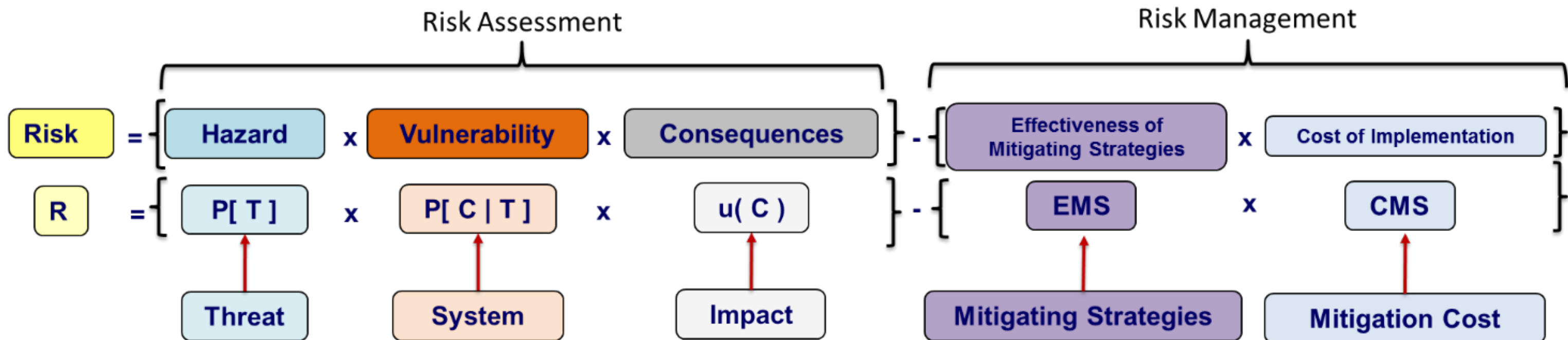
World Economic Forum
Global Risk Perception
Survey 2023 – 2024



1049 respondents were asked to identify relationships between 'Hazards' and 'Consequences'.

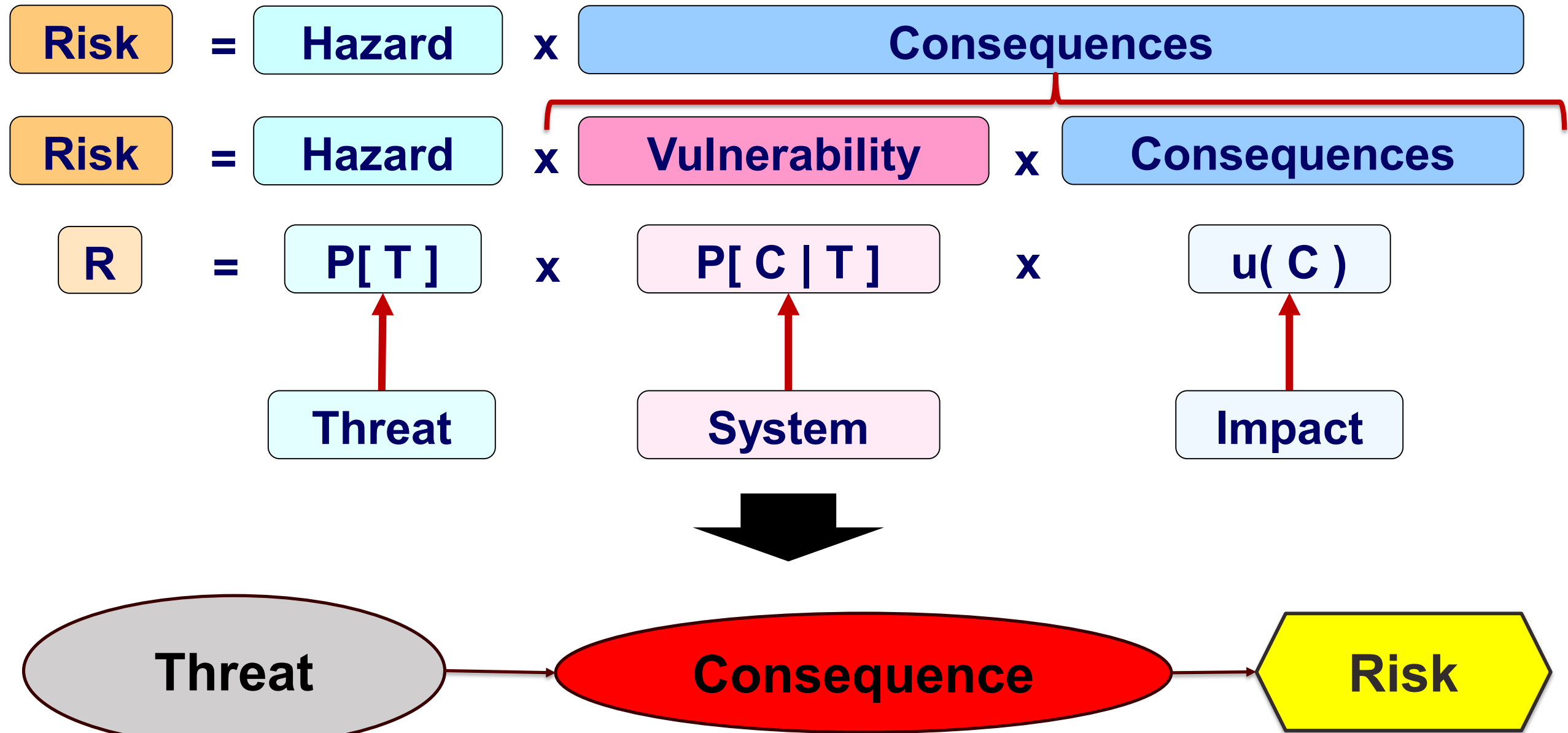


Risk Assessment & Management Framework



T = Threat Intensity
C = Value of Consequences
R = State of Risk

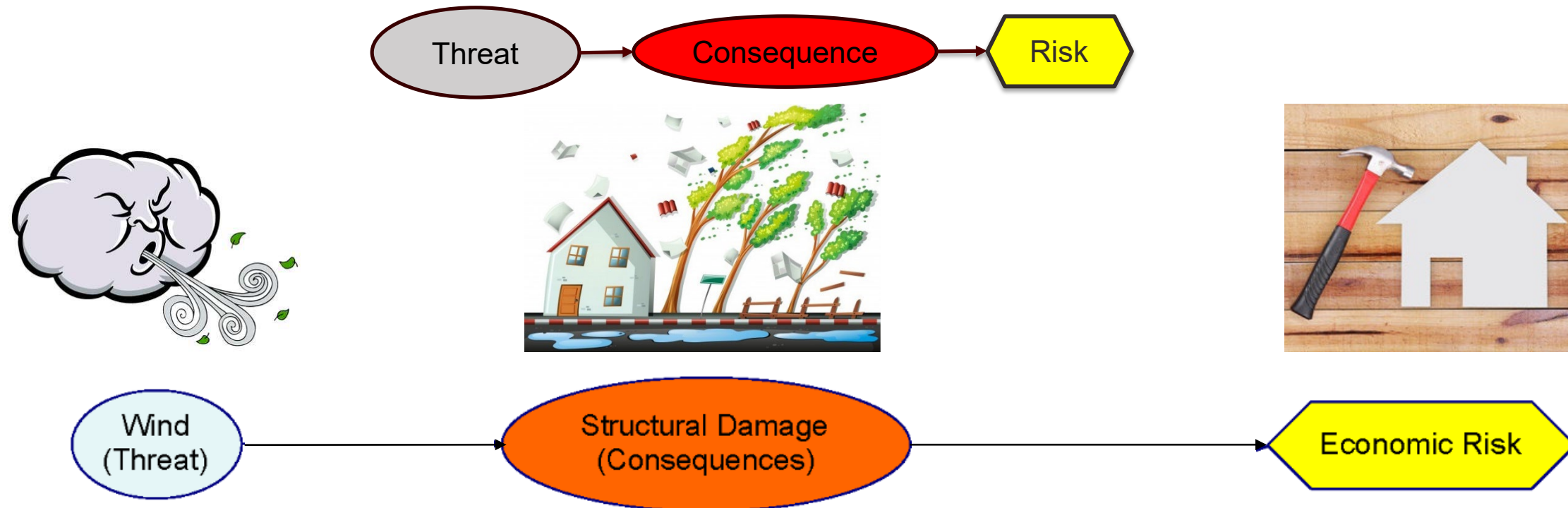
Bayesian Risk Framework



Bayesian Network (BN) – Prognosis Analysis

Case Study 1: House 'System'

(Single Threat, Single Vulnerability, Single Consequence)

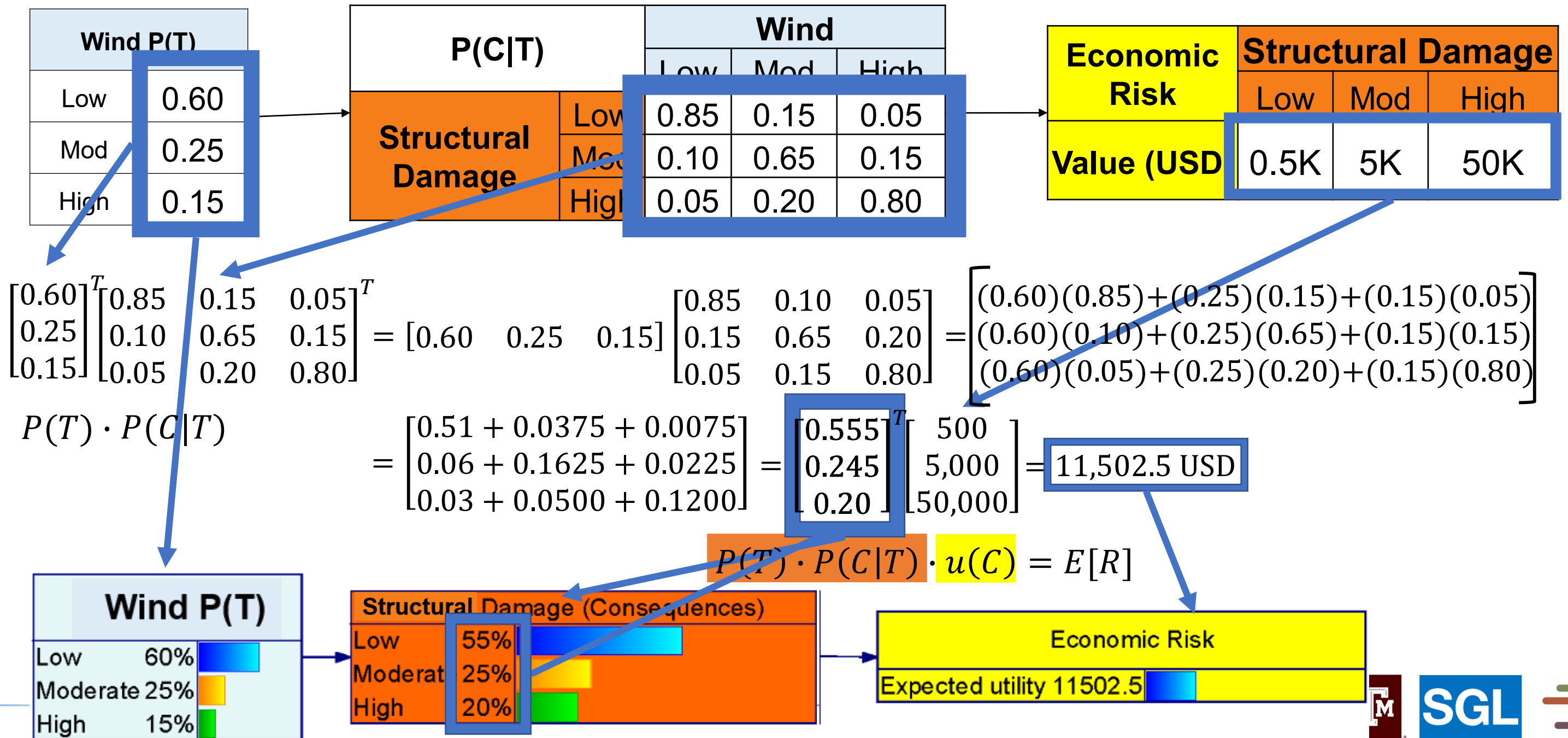


Wind P(T)	
Low	0.60
Mod	0.25
High	0.15

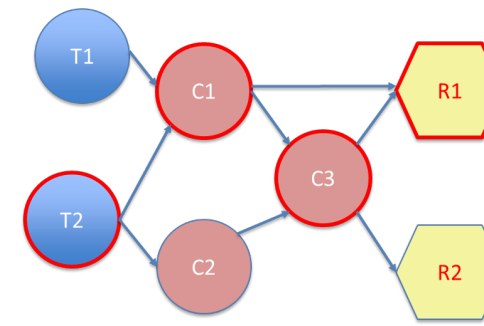
P(C T)		Wind		
		Low	Mod	High
Structural Damage	Low	0.85	0.15	0.05
	Mod	0.10	0.65	0.15
	High	0.05	0.20	0.80

Economic Risk	Structural Damage		
	Low	Mod	High
Value (USD)	0.5K	5K	50K

Bayesian Network (BN) – Prognosis Analysis



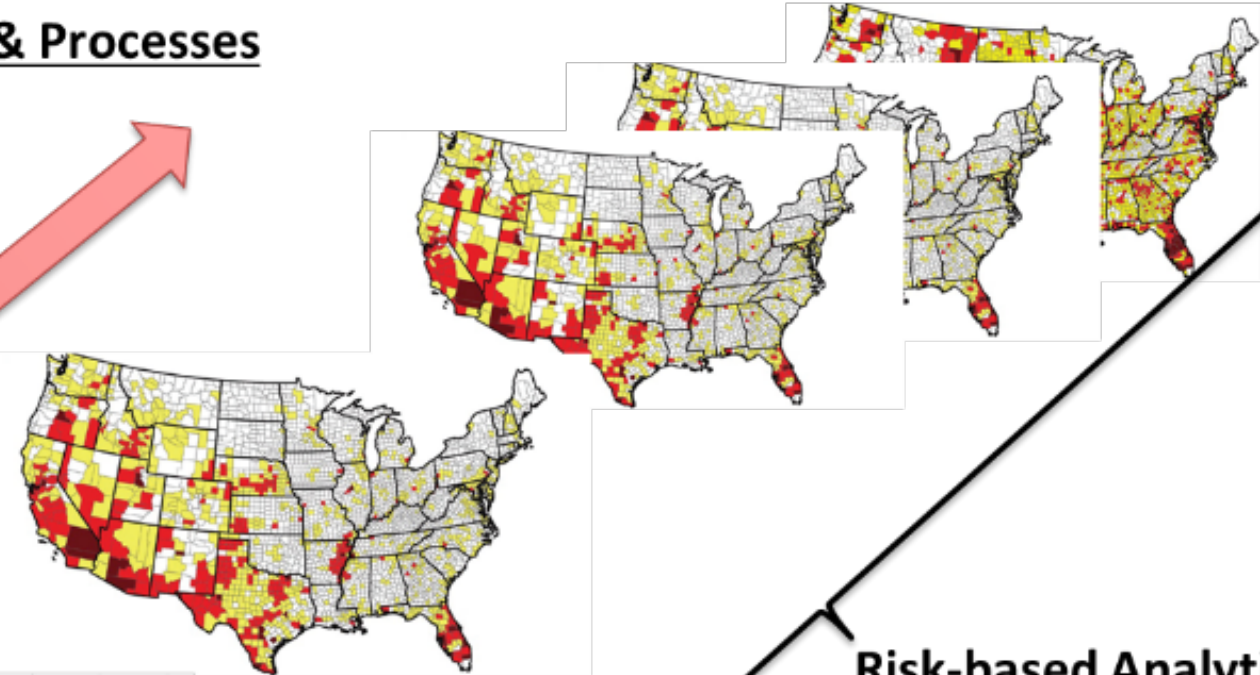
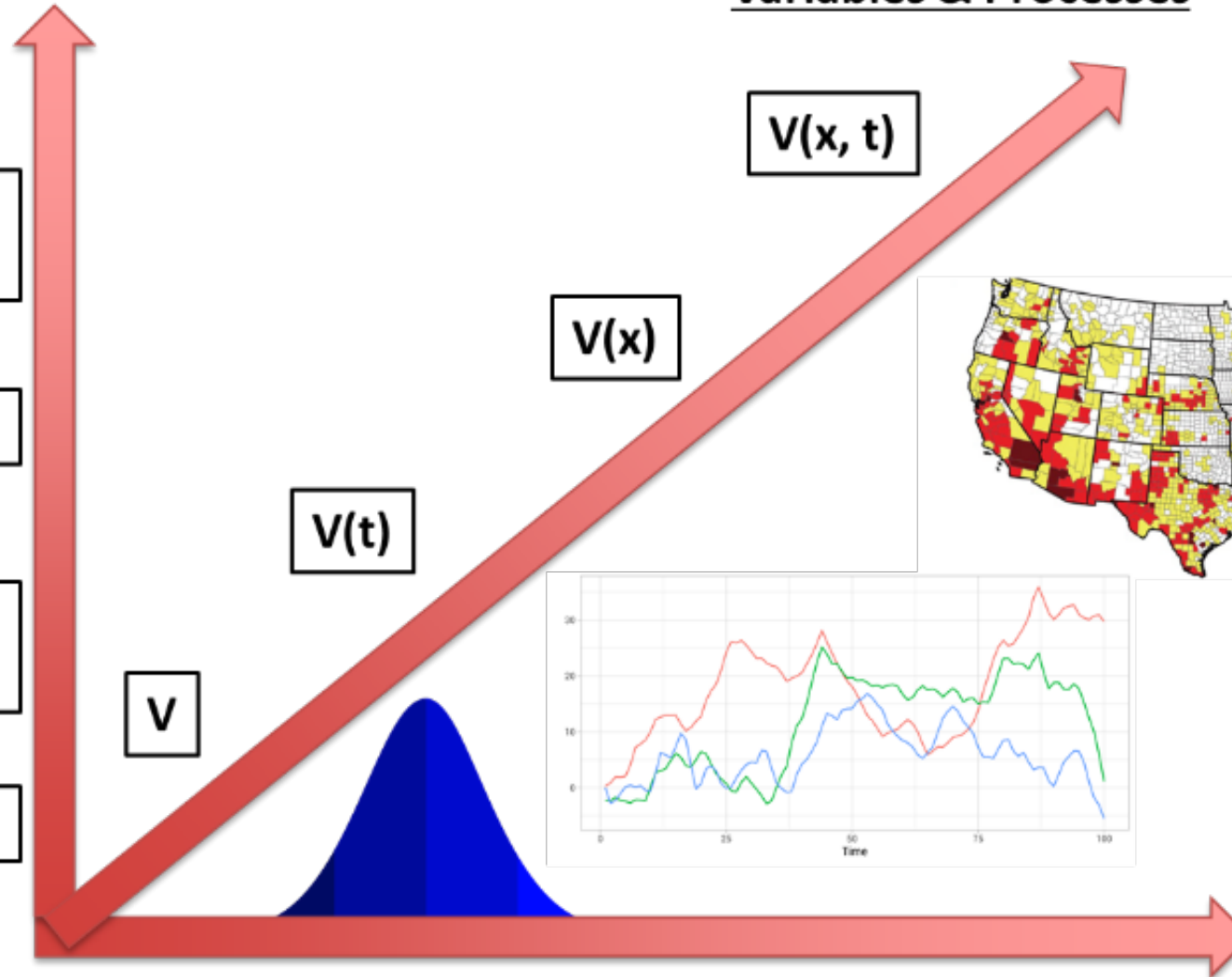
Variable Classification



Geographical Region

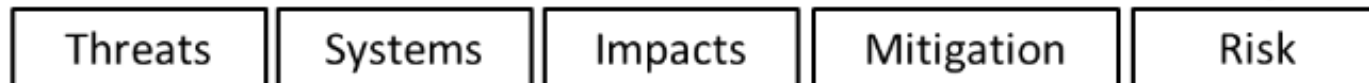
- United States of America
- Mexico
- Binational (U.S.-Mexico)
- Worldwide

Variables & Processes

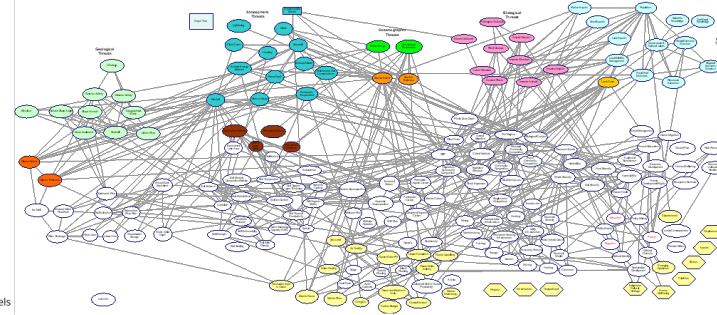
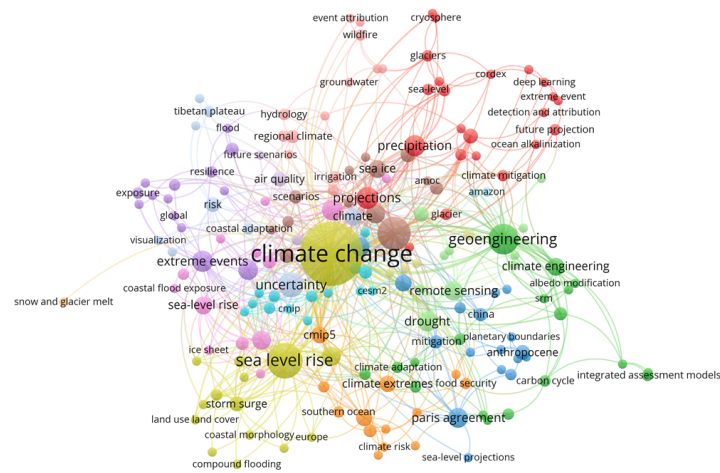
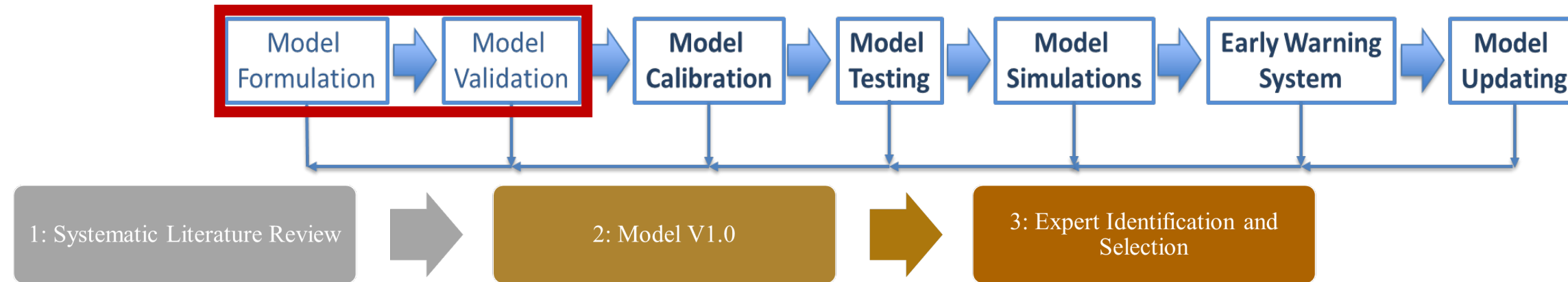


Risk-based Analytics

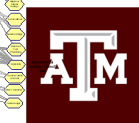
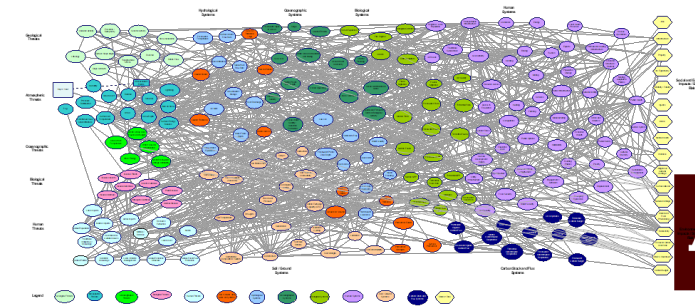
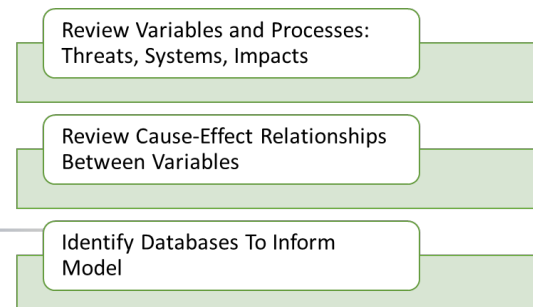
Risk Components



Mathematical Model Lifecycle – Formulation & Validation



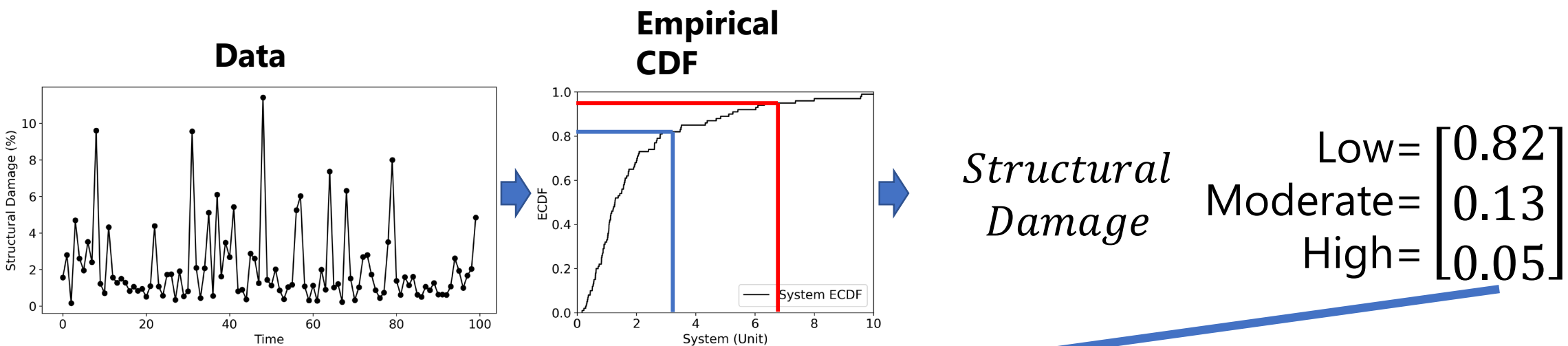
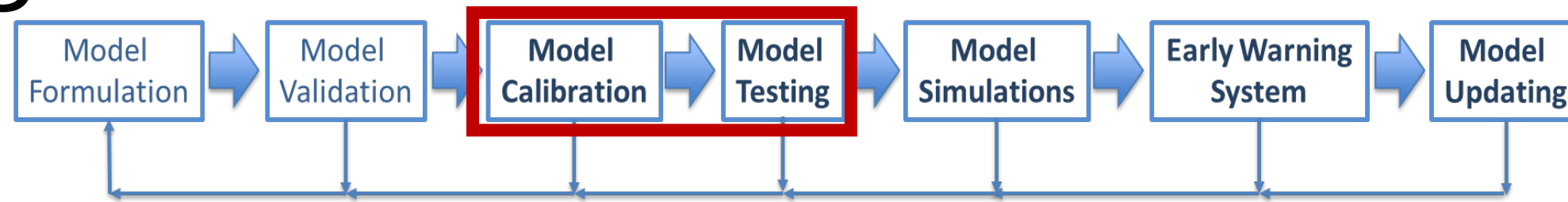
Expert Model Elicitation



Subject Matter Experts (SMEs)



Mathematical Model Lifecycle – Calibration & Testing



Wind P(T)	
Low	0.60
Mod	0.25
High	0.15

P(C T)		Wind		
		Low	Mod	High
Structural Damage	Low	$P(C_1 T_1)$	$P(C_1 T_2)$	$P(C_1 T_3)$
	Mod	$P(C_2 T_1)$	$P(C_2 T_2)$	$P(C_2 T_3)$
	High	$P(C_3 T_1)$	$P(C_3 T_2)$	$P(C_3 T_3)$

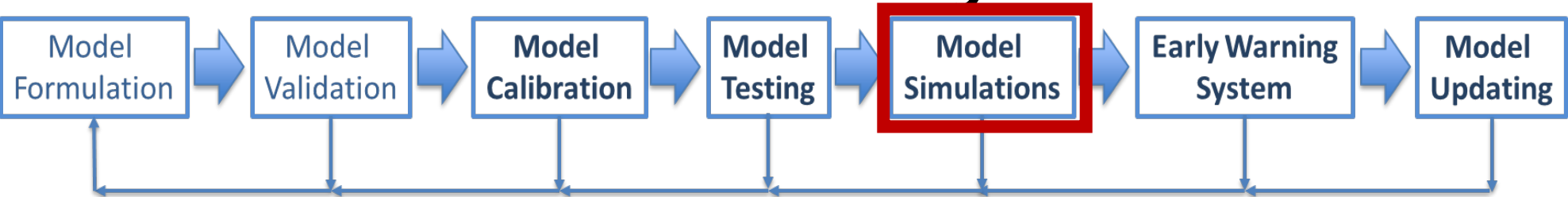
Conditional Probability Table

Economic Risk	Structural Damage		
	Low	Mod	High
Value (USD)	0.5K	5K	50K

Goal: Estimate the parameter of probability values in Conditional Probability Table



Mathematical Model Lifecycle – Simulation



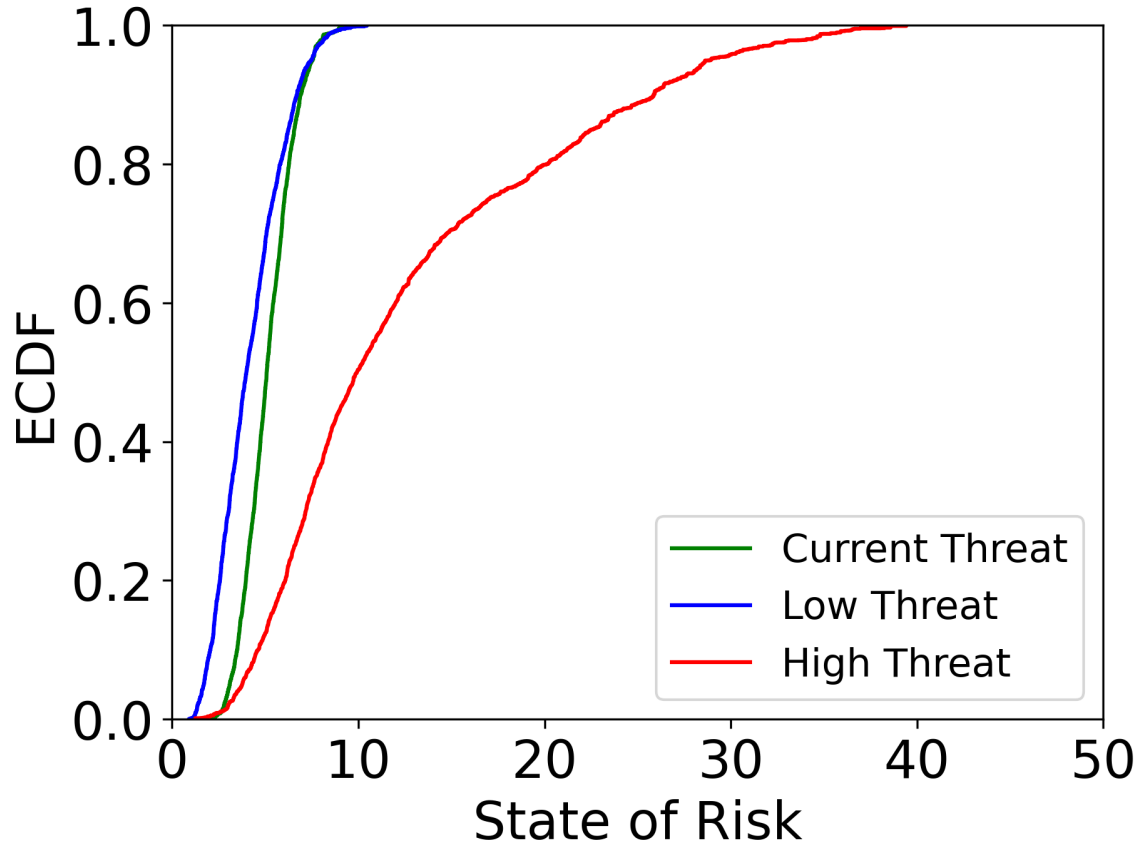
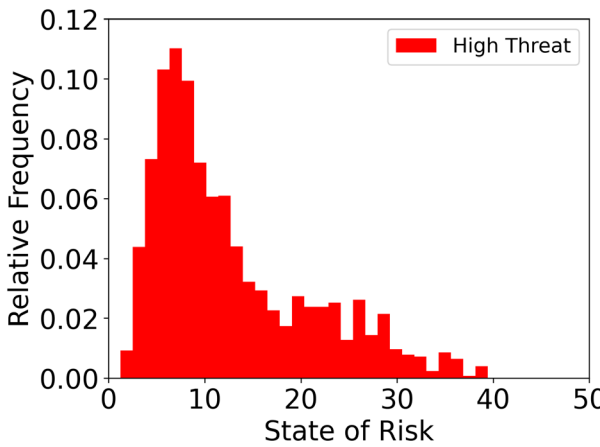
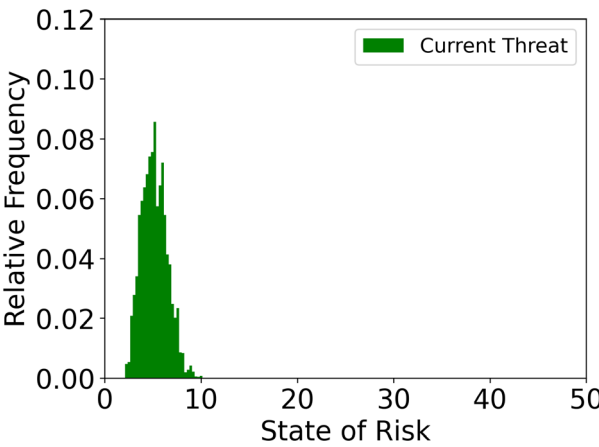
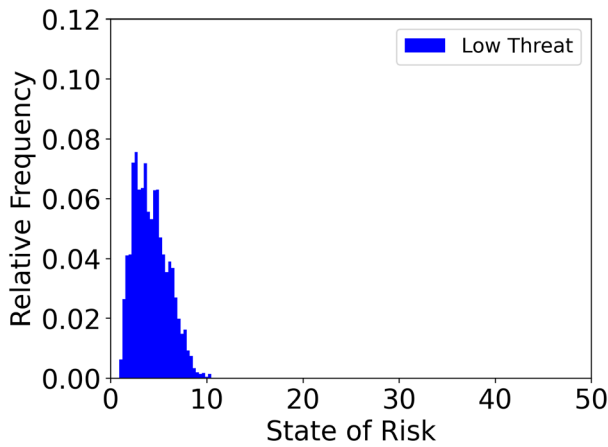
We can change the **level of threat** to simulate **different risk scenarios**

Level of Wind Threat

Low = $\begin{bmatrix} 1 \\ 0 \\ 0 \end{bmatrix}$
Moderate = $\begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}$
High = $\begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}$

Low = $\begin{bmatrix} 0.60 \\ 0.25 \\ 0.15 \end{bmatrix}$
Moderate = $\begin{bmatrix} 0.25 \\ 0.25 \\ 0.15 \end{bmatrix}$
High = $\begin{bmatrix} 0.15 \\ 0.25 \\ 0.15 \end{bmatrix}$

Low = $\begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix}$
Moderate = $\begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix}$
High = $\begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix}$



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Low	0.60
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P(C T)		Wind		
		Low	Mod	High
Structural Damage	Low	$P(C_1 T_1)$	$P(C_1 T_2)$	$P(C_1 T_3)$
	Mod	$P(C_2 T_1)$	$P(C_2 T_2)$	$P(C_2 T_3)$
	High	$P(C_3 T_1)$	$P(C_3 T_2)$	$P(C_3 T_3)$

Economic Risk	Structural Damage		
	Low	Mod	High
Value (USD)	0.5K	5K	50K

$= E[R]$



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Thank you!

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