Using Precursor Analysis to Prevent Low-Frequency, High-Impact Events, Including Fatalities

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Northwest Construction Consumer Council
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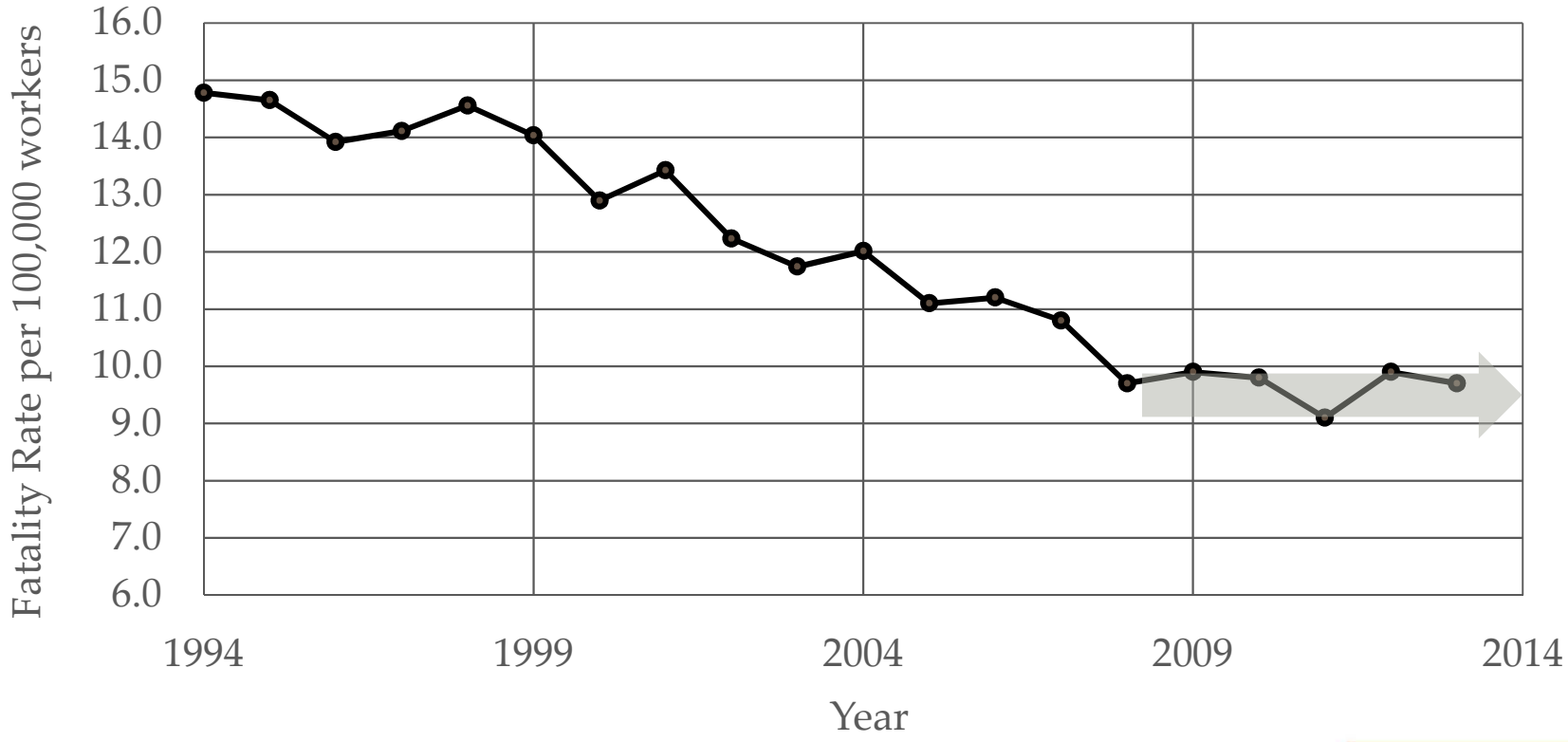
Co-Investigator:
Dr. Matthew Hallowell, University of Colorado at Boulder

Research Question: How can we (further) improve construction safety?



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Antecedent Question: Why do accidents (still) occur?

Source: CII, EM160-21, 2006

Safety Culture/Climate

Risk and Reliability

Risk and Reward

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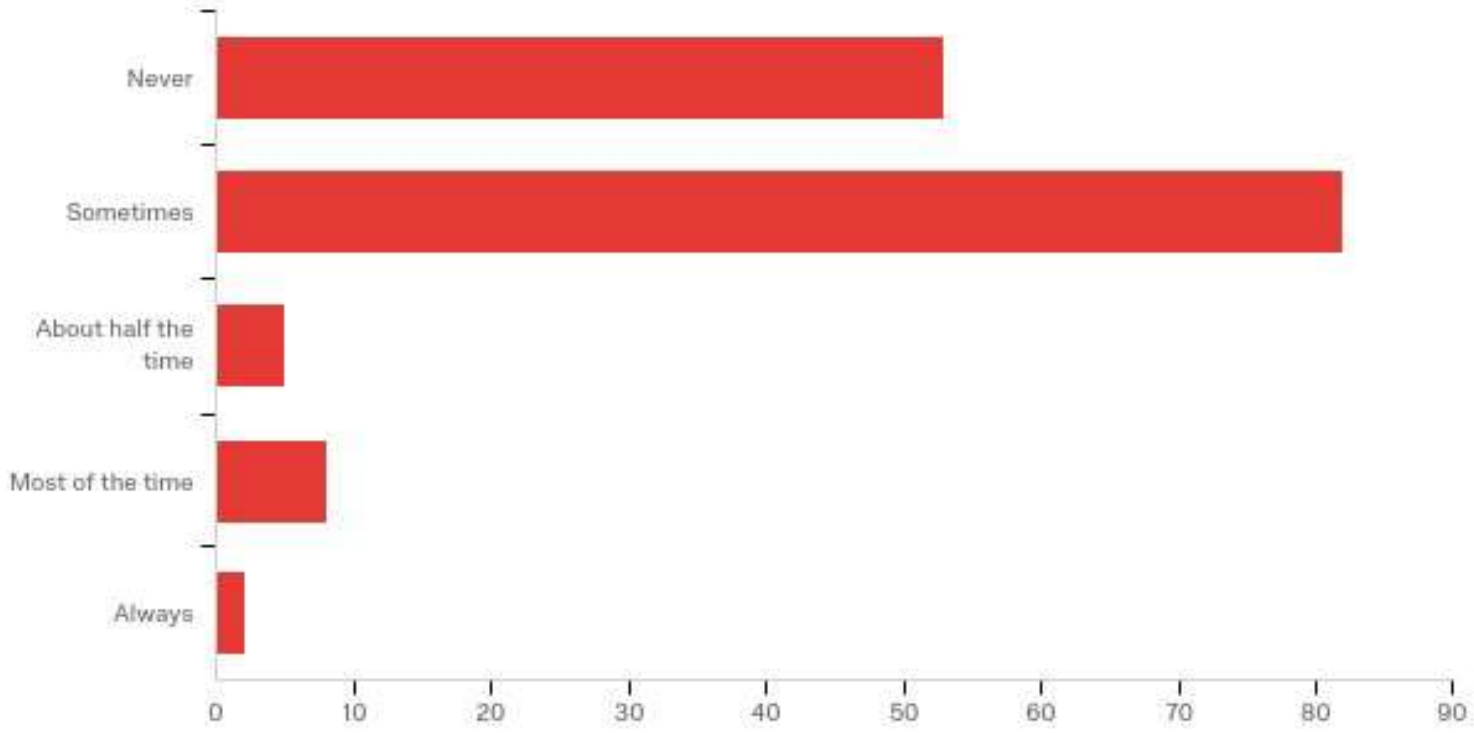
Risk and Reward – Survey Question

- How often do you knowingly take a calculated risk even though it is against your training/work safety plan?



Number of Responses (n = 150)

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Hazard Assessment, Risk Projection, and Decision-making

Behavior of ALL employees!

Potential Root Causes of Accidents	Human Behavior
Mistake / error	Unintentional
Absent-minded / forgetful	Unintentional
Uncaring / indifferent / giving other goals higher priority	Willful
Ignorance	Unintentional
Poor risk management	Willful
High risk tolerance	Willful
Other (e.g., Act of God)	Unrelated

To be effective, a safety program should:

- Address ALL potential root causes
- Address different types of behavior differently

Additional Considerations

- Risk normalization
- Normalization of deviance
- Uncertainty
- Distractions

- Chronic unease

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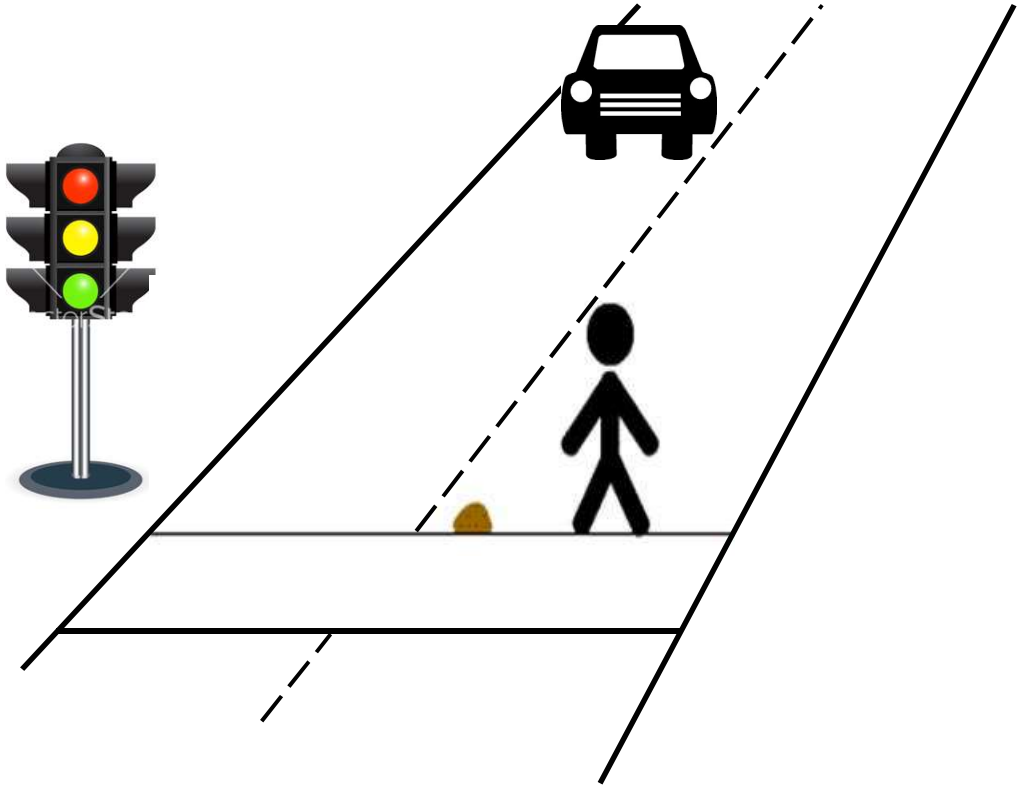
Everyday Life Question: What do you think about when deciding whether to cross a street?



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CII RT-321

- Using Precursor Analysis to Prevent Low Frequency/High-Impact Events (including fatalities)

Dillon Alexander,
University of Colorado at Boulder
John Barry, *SABIC Innovative Plastics*
Matthew Bedrich, *Shell*
Jim Duncan, *Jacobs*
Shane Farrah, *JV Driver*
John Gambatese,
Oregon State University
Larry Green, *British Petroleum*
Matthew Hallowell,
University of Colorado at Boulder
John Hogan, *SNC Lavalin*
Anthony Littlefair, *Enbridge Pipelines*
Donna Parry, *Procter and Gamble*
Gregg Slintak,
Consolidated Edison Co. of New York
Irvin Tyler, *Shell*
Shawn Xu, *Conoco Philips*
Rick Zellen, *Zurich*

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CII RT-321: Key Definitions

Serious injury or fatality (SIF) event:

An event that results in or has the potential to result in a fatality or life-altering injury or illnesses. HILF = high impact, low frequency event

Precursor*:

Reasonably detectable event, condition, or action that serves as a warning sign of an event, i.e., an anomaly

*Different than a leading indicator

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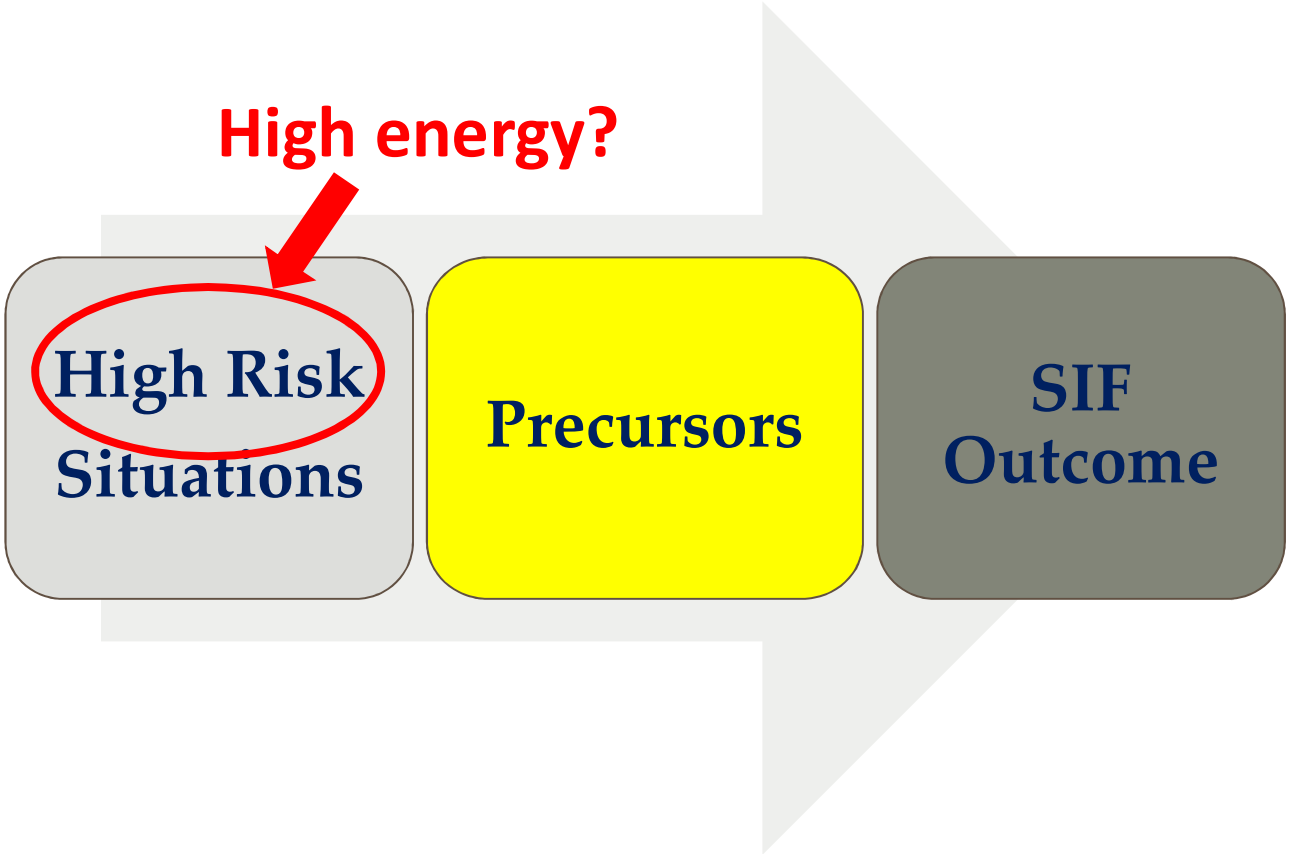
When should we use precursor analysis?



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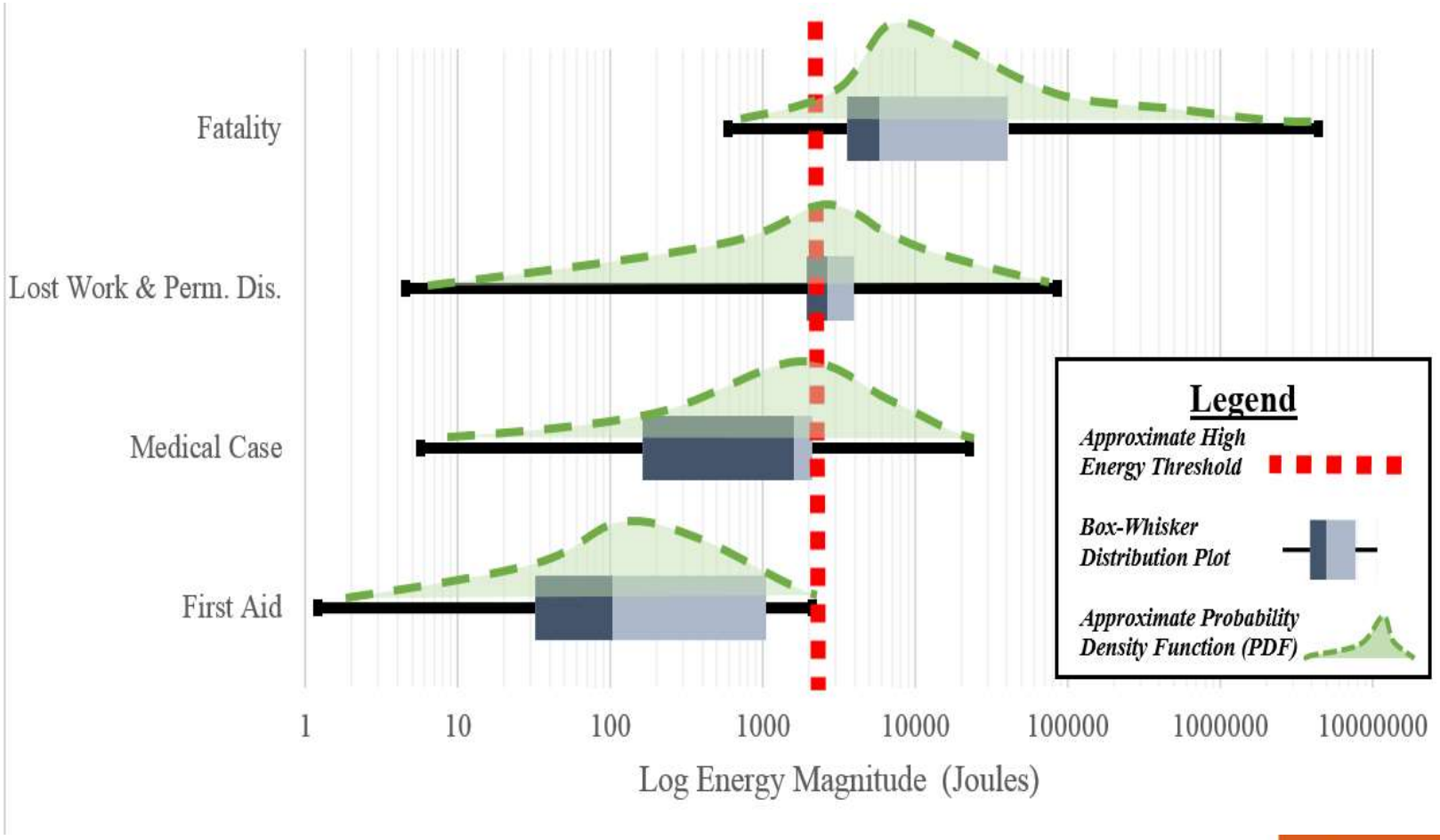
Does energy magnitude predict injury severity?



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Precursor Analysis Process

Is this a "high energy" situation? → **Are precursors are present?** → **Should the work proceed?**

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Identify Precursors → Experiment to Test Precursors → Validate with Multiple Groups → Objective Statistics

NIOSH Fatality Assessment and Control Evaluations (FACE)

Work-Safe BC Reports

Reports from Research Team

Team reviews cases and produces list of factors; plus additional factors added from outside experts

List of Factors

- X
- X
- X
- X
- X
- X

Investigation Form

- ?????????
- ?????????
- ?????????
- ?????????

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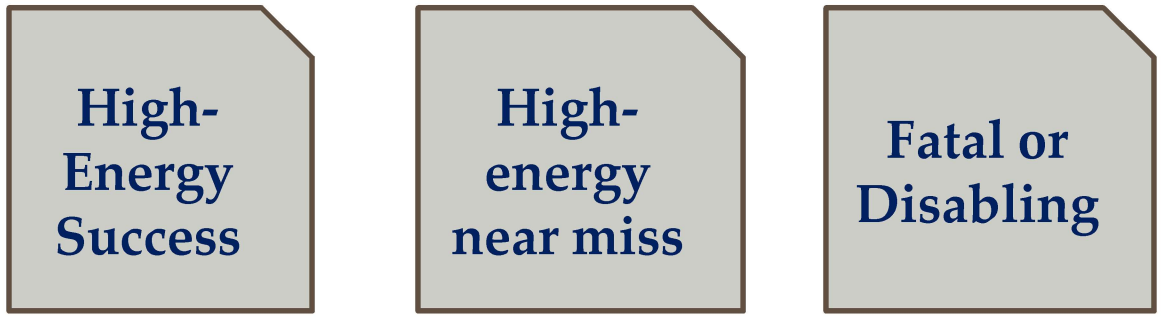

RATIO: (3) (1) (1)

Use precursor investigation form to collect LEADING data for three types of cases

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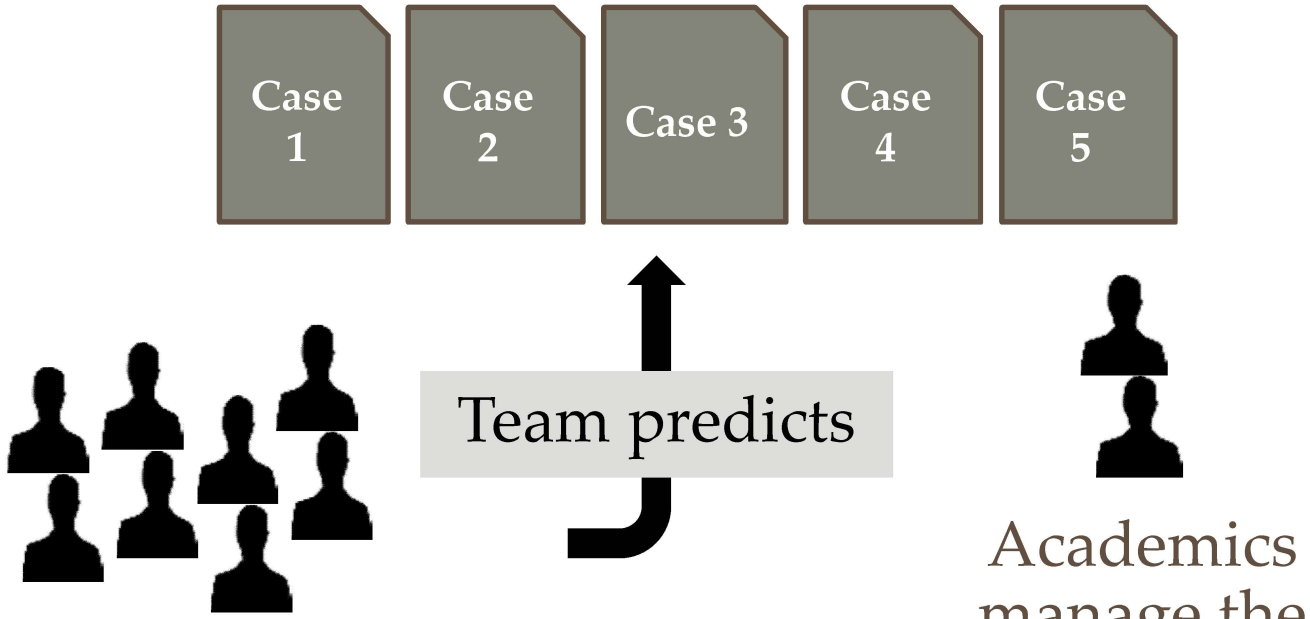

Conduct experiment round

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Round 1	Success	Near Miss	Success	Success	Fatal	3/5 (60%)
Round 2	Success	Success	Success	HILF	HILF	5/5 (100%)
Round 3	HILF	Success	HILF	HILF	Success	4/5 (80%)
Round 4	HILF	Success	HILF	Success		4/4 (100%)

Results from research team trials

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Identify Precursors → Experiment to Test Precursors → Validate with Multiple Groups → Objective Statistics

Typical Professionals

Demographic Information	
# of Participants:	13
Median Age:	53
Median Years of Experience:	20

Inexperienced Students

Demographic Information	
# of Participants:	10
Median Age:	29
Median Years of Experience:	2

Repeat experiment with diverse groups of people

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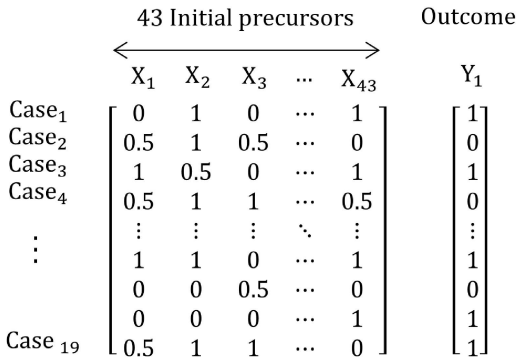
Identify Precursors → Experiment to Test Precursors → Validate with Multiple Groups → Objective Statistics



Simple data structure

→ **Principal Components Analysis (PCA)**

Groups like precursors together

Reduces the number of variables

→ **Generalized Linear Modeling**

Creates an equation that predicts the probability of HILF based on precursor presence

Find an equation for the probability of an event

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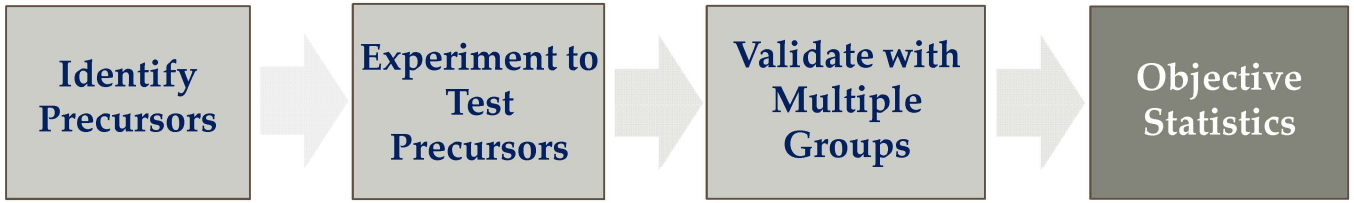
Identify Precursors → Experiment to Test Precursors → Validate with Multiple Groups → Objective Statistics

$$Probability = \frac{e^{(-1+0.20*X_1+0.56*X_2+0.46*X_3+0.24*X_4)}}{e^{(-1+0.20*X_1+0.56*X_2+0.46*X_3+0.24*X_4)}+1}$$

Reduce complexity for ease of use

Poor Work Planning	Factor Presence	Weight	Weighted Score
Crew Members are Unaware of Work Procedure		x1	
No/Poor Plan to Address Work Changes		x1	
No/Poor Pre-Task Plan or Discussion Specific to Work		x1	
Productivity Dominated Culture	**Factor Presence**	**Weight**	**Weighted Score**
Crew Members are NOT Active in Safety		x2	
Fatigue		x2	
Schedule/Productivity Pressure		x2	
Significant Overtime		x2	
Prior Safety Performance is Poor		x2	
Vulnerability to High Energy	**Factor Presence**	**Weight**	**Weighted Score**
Lack of Control Barrier and/or Visual Warning		x2	
Line of Fire is Uncontrolled		x2	
Improvisation		x2	
Outside Safety Influences	**Factor Presence**	**Weight**	**Weighted Score**
Congested Workspace/Crowding		x1	
Distracted Workers		x1	
Limited Safety Supervision		x1	
Poor Quality or Inexperienced Foreman		x1	
Working Alone		x1	
Total Score (if score equal to or greater than 4, HILF is Predicted)			



Case #	Regression Model Probability	Regression Model Skill	Precursor Assessment Rubric Score	Precursor Assessment Rubric Skill
22	73.3%	Correct	7.5	Correct
20	54.3%	Correct	5	Correct
29	62.4%	Correct	6	Correct
27	36.3%	Correct	2	Correct
21	58.1%	Correct	5	Correct
23	76.3%	Correct	8	Correct
24	71.6%	Correct	8	Correct
25	56.1%	Correct	4.5	Correct
26	78.4%	Correct	8.5	Correct
28	65.5%	Correct	6	Correct

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Predicting with the Precursor Analysis Scorecard

Step 1: Enter presence of each factor:

- 0 → 'Not Present'
- ½ → 'Partially Present'
- 1 → 'Present'

1 2 3

Poor Work Planning	Factor Presence	Weight	Weighted Score
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Working Alone		x1	
Total Score (if score equal to or greater than 4, HILF is Predicted)			

Step 2: Multiply each factor by the weight

Step 3: Sum the weighted score

Step 4: Total exceeds 4?

HILF event is more likely than not if total exceeds 4

4

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Let's give it a try.

1. Watch video of construction site interview
2. Complete the Precursor Analysis Scorecard

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The actual outcome?

Potentially fatal, near miss.

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Conclusions and Next Steps

- Despite strong safety programs, fatalities impact even top performing organizations
- Precursor analysis augments a strong safety program
  - But, it cannot serve as a replacement for other program elements
- This is a starting point; more data will allow others to build on the results and methodology
  - To facilitate progress, need to address the barriers that presently impede the flow of information
- We welcome further collaboration and research!

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Looking to the Future

- Resilient Infrastructure and Safety Research Lab

- $1,000,000 seed funding from MDU Construction Services Group

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New OSU Safety Research Lab: Inter-connected Virtual/ Augmented Reality

Driving simulator

Immersive virtual environment

Motion capture/ tracking

Truck/ Equipment simulator

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Working Together to Improve Safety

- Construction Safety Research Partnership (CSRP)
  - Explore and develop new ways to improve safety
  - Leverage collective knowledge and resources
  - Safety leadership for the construction industry

New Partners Welcome!

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- Thank you for your interest!
- Questions? Comments?
- For more information:

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