Patterns of Event Causality Suggest More Effective Corrective Actions

Abstract: The Occurrence Reporting and Processing System (ORPS) has used a consistent causal evaluation process and causal analysis tree for over six years. More than 5,000 events have been reported with at least one causal factor identified. An evaluation of statistically valid differences in patterns of causality suggest potential directions for more effective corrective actions. This discussion will highlight differences in causal factor pattern effects on severity and variance by major reporting types and facility and activity types. Suggested applications to annual analysis and corrective action processes are provided.

Acknowledgement: I wish to thank Carl Everatt and DEO-SR for their support and sponsorship of this research.

Sam K. Formby, ABD
PhD Candidate
Management Science Department
Moore School of Business
University of South Carolina
Columbia, SC 29208
samuel_formby@moore.sc.edu

Bio: Sam has master's degrees in physics and electrical engineering from Georgia Tech and worked at Savannah River Site for 28 years before retirement. Sam is currently working on a PhD in Operations Management at the University of South Carolina Moore School and in partnership with DOE-SR is doing his dissertation research on the topic of accident causality in operations. The findings presented here are just a few of the observations being evaluated in his dissertation research.

Outline

- Searching for patterns of causality
- Evaluation data and methods
- Summary observations based on individual Causal Analysis Tree factors.
- A systems view: simultaneous causal factor evaluation, and the search for significant causal factor interactions.
- Conclusions: Potential implications for assessment and corrective action programs
- Next steps

Searching for Patterns of Causality

- Are certain causal factors more prevalent in higher severity accidents than low?
- What are the most influential causal factors affecting severity?
- What are the most influential causal factors associated with different accident types, facility functions, and activity types?
- Operations processes are complex. Does the way causal factors interact influence accident severity?

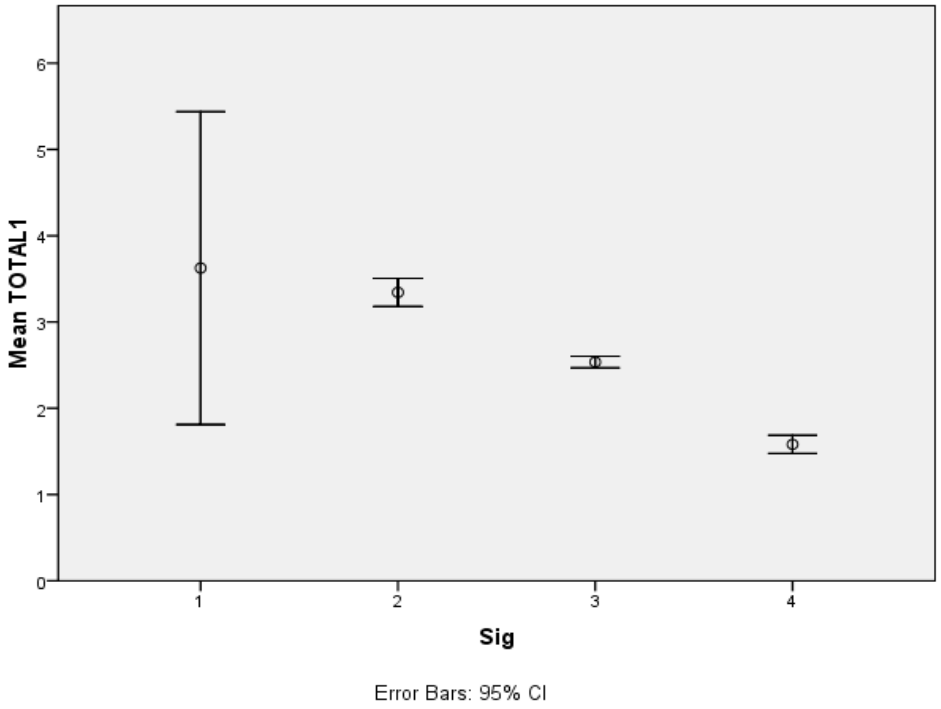
Department of Energy Occurrence Reporting and Processing System (ORPS) database, 2003-2008

- This data base has recorded 1000+ events per year for the last five years covering safety and operational events in administrative, common industrial to high hazard facilities. Each event is consistently evaluated and reported on based on a common set of procedures and classification criteria led by trained professionals.
- 41 fields of data are captured, including Facility Function (27 types), Significance Category (6 levels), Activity Category (14 types), Causal Factors (167 in 3 level event tree format), Reporting Codes (81 in 3 tier format), Corrective Actions, and other event details including dates, times, conditions, and personnel involvement.
- Content analysis and event study methodology are used to extract metrics suitable for statistical analysis. Since almost all of the information extracted is categorical and mostly binomial significant challenges exist in application of statistical analytic methods.

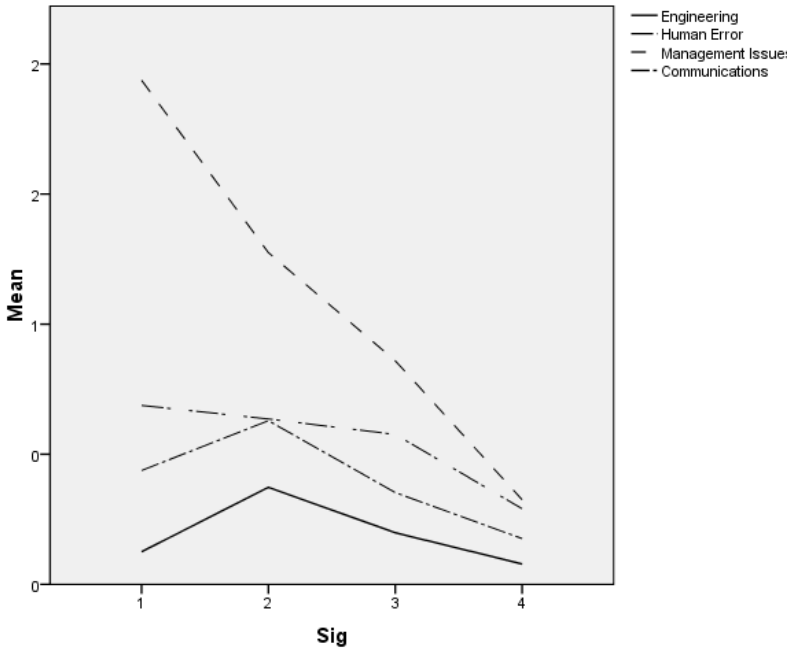
Simple Statistical Observations Indicate Real Differences

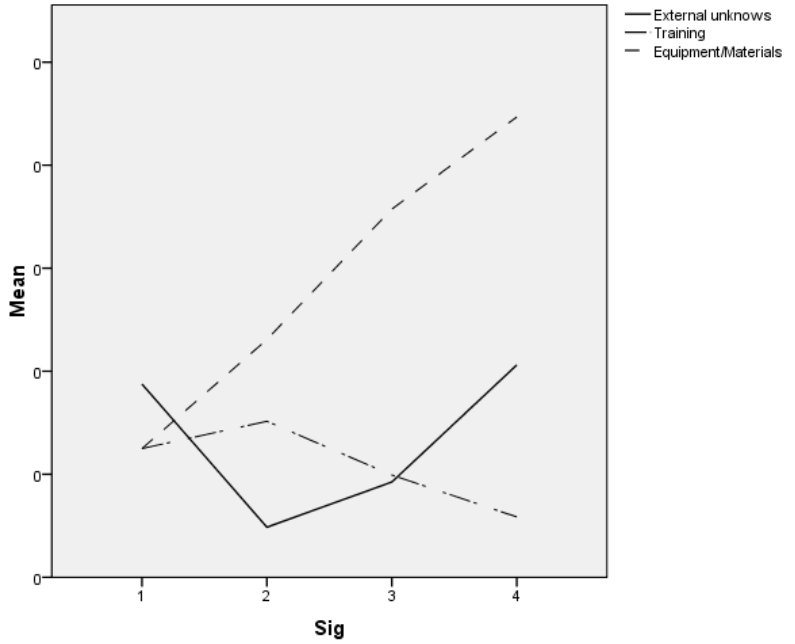
- The mean number of causal factors (all three tiers) per event differ by severity level.
- The mean severity level of events by contextual factors such as reporting category, facility function, and activity type also differ.
- Therefore, patterns of causal factors and context are predictors of reportable events.
- Focusing assessment and improvement actions on these causal factor patterns should result in improved performance.

Severity or Significance is related to the number of causal factors identified.



Severity is also related to type (A1-A7) of causal factors.

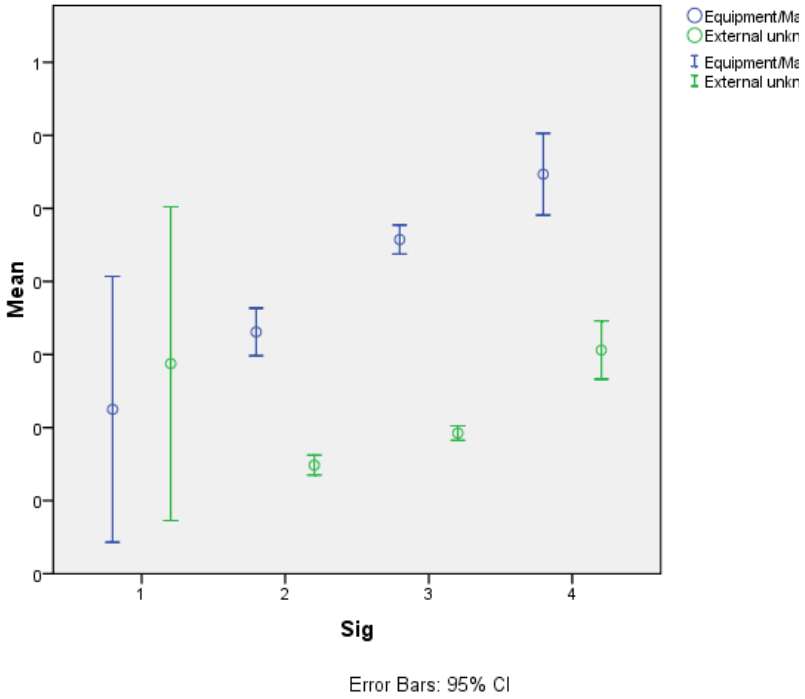


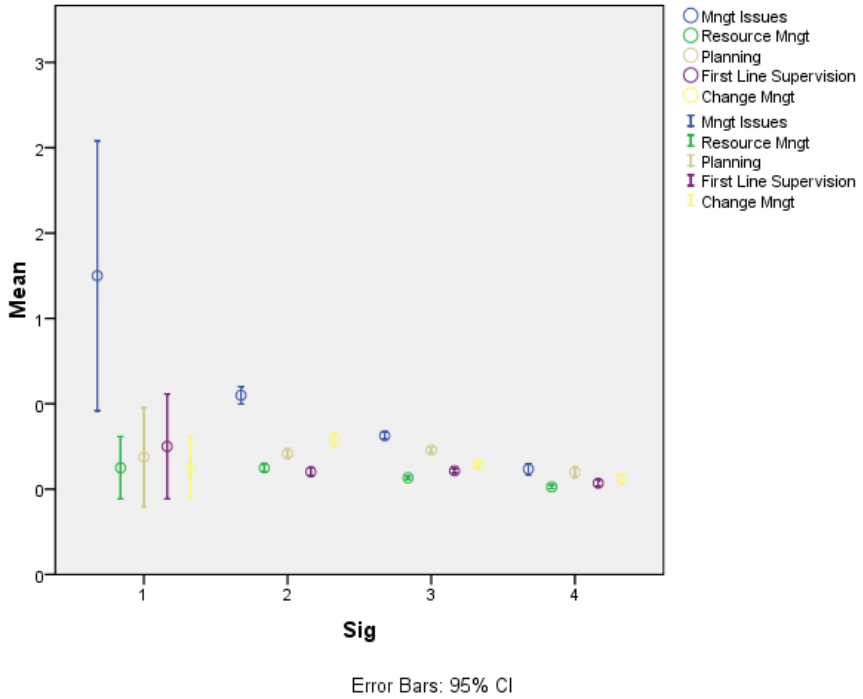


The mean number of Management, Engineering, Communications and Human Performance causal factors appear to increase with severity. Equipment/ Materials, External Phenomena and Training factors appear to stay even or decrease with severity. Management Problems appear to be the greatest indicator of severity.
Note: The small sample size for Sig 1, results in large confidence interval overlaps. The primary significance is in the 4-3-2 trends.

Low severity is dominated by Equipment/Material Problems and External Phenomena.

Drilling down into management tier 2 and 3 factors we find that A4B1C01 – Management policy guidance/expectations not well-defined, is dominant.





Operations are complex, so causal factor interactions are also important.

The following output is from multinomial logistic regression and only intended to highlight the issue that interactions between causal factors can be more influential predictors than individual causal factors.

	Direct Effects: Exp(B) values						
Severity Level	A1- Engineering	A2-Equipment/ Materials	A3-Human Performance	A4- Management Problems	A5- Communications	A6- Training	A7- External Phenomena
1				3.12++			
2	7.00++	.75++	1.59++	2.88++	2.35++		.57++
3	3.40++	1.21+	1.99++	2.13++	1.55++		
	Interaction Effects: Exp(B) values						
	A3*A7	A3*A5	A4*A5	A1*A3	A2*A3	A3*A4	A1*A4
1						.78+	4.03++
2				.38++		.77++	
3	6.71+			.44++		.80++	1.75+
Note: ++ = p < .05 and + = p <.1; All blank cells NS.							

Interpretation: If engineering and management causal factors are identified together in a single event, the event is 4.03 times more likely to be significance level 1 than 4. If human performance and external factors are identified together, the event is 6.7 time more likely to be a significance level 3 than 4.

Contextual factors also aid in event prediction.

Evaluating causal patterns relative to activity, facility function and reporting category can provide greater predictive specificity.

For example: Compare the top two most influential tier 3 causal factors in injuries and illnesses in site utilities to injuries and illnesses in research laboratories. Interpretation: finding problems in these specific areas are very strong predictors of reportable injuries occuring.

Injuries & Illnesses in Site Utilities		
CC	Exp(B)	Description
A1B5C03	38.624	Natural Environment LTA
A6B2C03	27.603	Refresher Training LTA

Injuries & Illnesses in R&D Facilities		
CC	Exp(B)	Description
A3B4C01	103.709	Individual's capability to perform work LTA.
A3B2C01	63.349	Strong rule incorrectly chosen over other rules

Other contextual comparisons can also be made. For example, between: contractors, facilities, time of day, day of week, season of year.

Conclusions: Implications for Assessment and Corrective Action Programs

- Determination of the most significant and influential causal factors and their interactions in given contexts may can point to more specific areas of improvement focus.
  - This information could be used to prioritize assessments, management activities, and corrective action strategies.
  - Example, refer to the table: Analyses have potential to explain much variability in accident severity. % Variance explained relates to predictive capability.

Independent Variables (DV is Significance level)	Potential % Variability Explained
Total causal factors identified	6.90%
A1-A7	13.00%
A1B1 - A7B2	21.20%
A1B1C01 - A7B2C02	31.30%
Activity Type	4.30%
Facility Type	9.30%
Reporting Type (top tier)	48.70%

Next Steps?

- Can these methods improve the annual assessment process?
- Can we link the ORPS data to man-hours per year per major site and find accident frequency differences that lead to quantitative assessment of best practices in operations management? By site, by contractor, by type work?
- From the data, can we demonstrate valid path models of accident causality that more effectively identify dominant linkages and interactions in operations processes that influence accident type, frequency and severity?
- Can we find underlying causal commonalities in similar facility and activity types that could be used to improve safety strategies?
- Can we correlate corrective action (CA) responses with causal factors and patterns and find changes in trends by sites or over years, thus evaluating effectiveness of CA programs?
- From both of these last two questions, can we further focus assessment and corrective action efforts to reduce frequency and severity of accidents?