



Analysis of Nuclear Safety Reports Using **NLP**

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“There are many lessons that we must all take away from the accident at Fukushima, but some of the most valuable **extend beyond the technical aspects** and are embedded in human and organizational behaviors. **Among these is safety culture**”

- NRC Chairman Dr. Allison M. Macfarlane



Diablo Canyon Power Plant, California

Problem Statement

- Most of Nuclear and Aviation incidents are caused by safety culture problems.
- Safety reports are too lengthy (900+ pages).
- NLP techniques are needed to extract valuable information.

Primary Data Sources

**Diablo Canyon Independent Safety Committee
Thirty-Second Annual Report on the Safety of Diablo Canyon Nuclear
Power Plant Operations
July 1, 2021—June 30, 2022**



Robert J. Budnitz, Chair
Per F. Peterson, Vice-Chair
Peter Lam, Member

Approved: September 28, 2022

932 pages!

*Pocket Guide
to INPO 12-012:*
**Traits of a
Healthy Nuclear
Safety Culture**

INPO®

The Safety Traits:

1. Personal Accountability
2. Questioning Attitude
3. Effective Safety Communication
4. Leadership Safety Values and Actions
5. Decision-Making
6. Respectful Work Environment
7. Continuous Learning
8. Problem Identification and Resolution
9. Environment for Raising Concerns
10. Work Processes

Sample of Data from Report:

DCISC 24th Annual Report (2014)



Electric flashovers are electric discharges (arcs) from an energized component to ground or to another object that is normally insulated from the component that is the source of the arc. This flashover results from deterioration in the insulated path between the source of the arc and the object that is on the receiving end of the arc. In the case of DCPD the source of the arc was a 500kV system. The first of the flashover events occurred in October 2012, during a light rain, when visible arcing was noted on the Unit 2 A and B Phase Main Bank Transformer (MBT) Coupling Capacitive Voltage Transformers (CCVTs). Soon afterward, the A phase MBT CCVT flashed over to ground, causing a single-line-to-ground fault, which in turn caused the 500kV tie-line differential relay to actuate, resulting in a Unit 2 Turbine Trip and Reactor Trip. The root cause of this trip was eventually determined to be that the insulator's minimum creepage distance (i.e. the distance between two conductive parts) was too small and not consistent with industry codes and standards for the contaminant levels in its operating environment.

The somewhat similar Unit 2 reactor trip occurred in July 2013 during a periodic hot washing of the 500 kV insulators for Unit 2, after having performed the hot wash for Unit 1. These hot washings have been conducted about every six weeks since about 1996. Their purpose is to remove contaminants. The root cause of this event was determined to be inadequate controls for oversight of supplemental PG&E transmission line personnel and for on-line risk analysis that resulted in a conductive overspray, which induced an external arc around the lightning arrester insulation resulting in a flashover.

During the period after the second flashover event, which occurred in July 2013, DCPD developed organization measures aimed at minimizing the likelihood of events that might result from high and very high-risk work activities. These measures, summarized below, appear to be reasonable, and the following are some of the key elements that were put in place to help ensure organizationally that such high-risk activities could be performed without negatively impacting the plant or personnel safety. Some of the key measures are as follows:

- Convening a Risk Readiness Review Board (RRB) with all key stakeholders to scrutinize the actual work documents that will govern the work

Page 779

Station Director, Site Vice President, and the Chief Nuclear Officer of the results review prior to conducting the planned work

voltage to plant engineering safety features following a limiting transmission system contingency.

- A licensing basis change on the 230kV offsite power system was not accompanied by a review for whether the change might create an unreviewed safety question, which would have required prior approval by the NRC.

The RCE Team's review resulted in the development of a 150-page report that was approved on November 7, 2012. Their review included the following activities:

- Analysis of the above four violations and of fourteen additional events with decision-making aspects dating back to September 2008
- Survey of station management and individual contributors in Operations, Engineering, and Regulatory Services to determine the station's "technical conscience" and organizational behaviors
- Interviews with station leadership and the NRC Senior Resident Inspector
- Additional analysis to validate the findings of the above Process Analysis and of the interviews and surveys conducted as part of this effort
- Examination of industry standards and expectations in this area compared to DCPD standards and processes

The Root Cause identified by the Team was as follows: "Leaders are not consistently setting, modeling, and reinforcing clear standards and expectations for conservative decision-making, resulting in a station culture that favors production-oriented interpretation of the license basis."

Contributing Causes identified by the Team were the following:

- Procedures contained inconsistent guidance for conservative decision-making.
- Previous cause analyses in some cases led only to correction of the conditions. Although decision-making aspects were recognized as a weakness, these aspects were sometimes not addressed.
- Station leadership had not effectively used performance metrics for self-identifying early indication, tracking, and resolution of safety culture performance

Page 489



Project Objectives

1. Automatically extract valuable paragraphs from DCISC reports.
2. Classify the extracted paragraphs to their associated safety traits.

Example: The Root Cause identified by the Team was as follows: “Leaders are not consistently setting, modeling, and reinforcing clear standards and expectations for conservative decision-making, resulting in a station culture that favors production-oriented interpretation of the license basis.”

Source: DCISC 24th Annual Report (2014)

Page: 489

Safety Traits: Leadership Safety Values and Actions, Decision-Making, Work Processes

“Gold standard” Dataset



Task: Manually reading, analyzing, and extracting valuable paragraphs from different DCISC reports and labeling them with the most relevant safety traits. This will be used to evaluate the model's performance.

- **Input Reports:** 24th (2014), and 32nd (2022)
- **Output:** ~65 paragraphs have been labelled
- **Labelling Method:** Reading the INPO booklet, summarizing, and using keywords.
- **Verification Methods:** Multiple reviewers

Report: DCISC-24th-Annual-Report

1. Three Station Level Human Performance Event Clock Resets occurred during the fourth quarter of 2013, causing the station's 18-month indicator for such Resets to become Yellow (deficient). Two of these three events involved Operations personnel. Operations performance with respect to human error rate has been Red (Unsatisfactory) since July 2013. Component mispositioning appears to continue to be a contributor.

Page: 8 / 150

Tags: Personal Accountability, Continuous Learning, Work Processes

2. Equipment problems due to aging have led to an increasingly negative trend in the station's Deficient Critical Component Backlog Orders. DCP's performance on reducing or eliminating Safety System Functional Failures has not improved despite implementation of a corrective action plan.

Page: 12

Tags: Work Processes, Problem Identification and Resolution

3. The DCP knowledge transfer program, "Passport to Knowledge" appears well designed but full implementation has taken a back seat to higher priority items such as outage planning and outages. The DCISC encourages DCP to move forward with this program to not lose valuable job knowledge as employees retire.

Page: 154

Tags: Continuous Learning, Decision-Making

4. RC1: The process for evaluating both the risk of outage emergent work on outage protected equipment and the potential impacts to the operating unit is not formal and does not include prerequisites for adequate analysis, review, and approval prior to making a decision to work on protected equipment.

Page: 121

Tags: Problem Identification and Resolution, Decision-Making



Exploration of Algorithms

Semi-Supervised

Idea: To iterate over the cycle of training and labelling using the trained BERT model.

Issues:

- Lack of an accurately-labeled seed dataset.
- Overfitting to training data.
- Catastrophic forgetting encountered in later iterations.

Prioritized approach

Rule-Based

Lbl2Vec Text Classification

Topic Modelling (SVD, LDA)

Unsupervised

Idea: Use rules to extract aspect-adj pairs. Classify aspects to traits by computing cosine similarity between each aspect and the list of seed words.

Issues: Defining many rules, multi-word aspects.

Idea: Classify sentences to traits with the help of seed words (label vectors). Classify based on similarity with each label vectors.

Issues: Does not allow overlap between classes.

Idea: Use probabilistic text clustering algorithm (ex: Latent Dirichlet Allocation) to classify negative sentences to multiple traits. Guided by seed words.

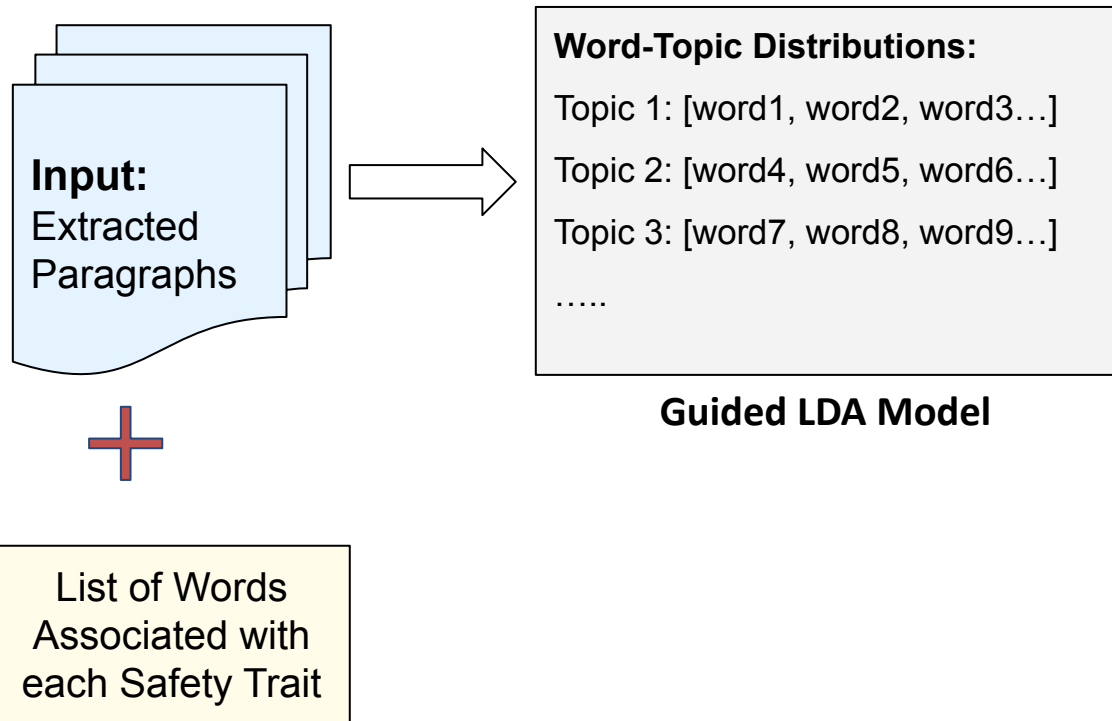
Issues: Properly defining seed words, defining classification thresholds.

Overview of Guided LDA

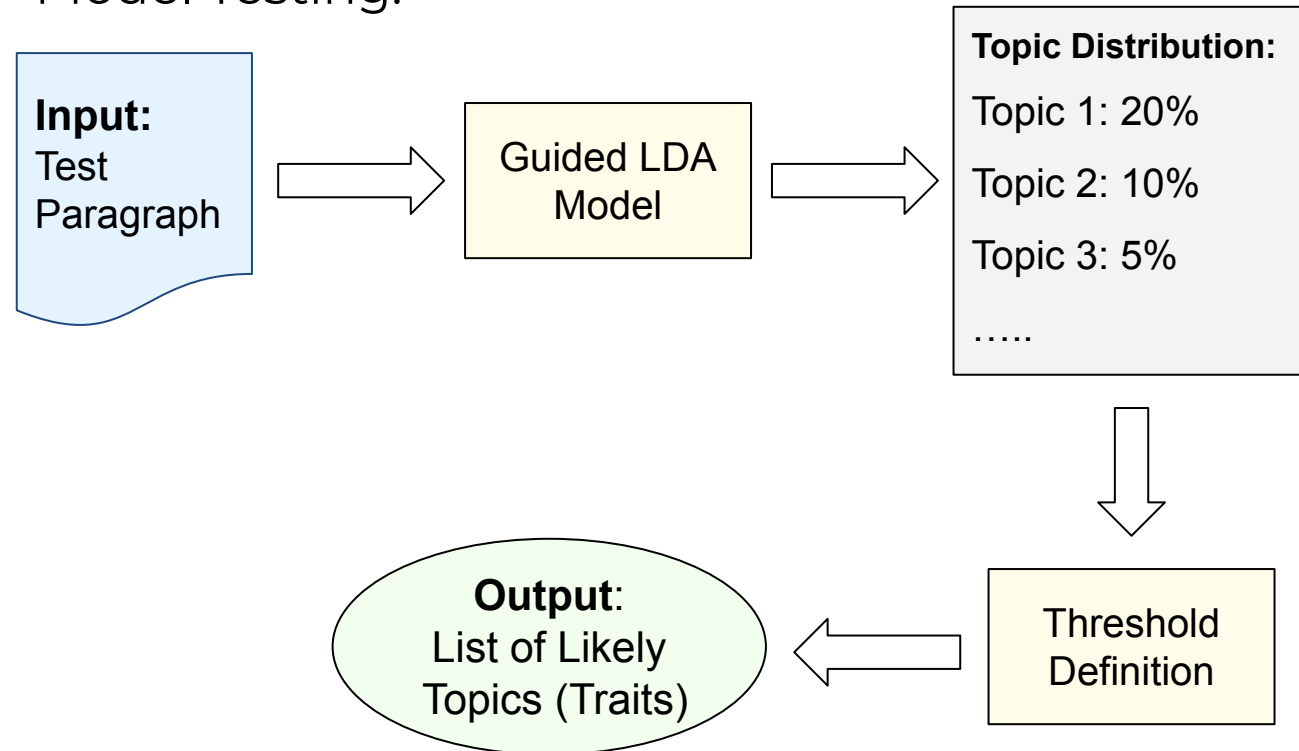


Description: A generative statistical model that is used to identify topics discussed in a given document or text (Probabilistic text clustering algorithm).

Model Training:



Model Testing:





Initial Results (Sample output)

Text: CCI: The troubleshooting procedure lacks specificity and formality and was implemented informally.

Aggregated Probabilities:

Personal Accountability: 0.0027

Questioning Attitude: 0.0027

Effective Safety Communication: 0.1794

Leadership Safety Values and Actions: 0.2636

Decision Making: 0.0027

Respectful Work Environment: 0.0027

Continuous Learning: 0.2566

Problem Identification & Resolution: 0.2194

Environment for Raising Concerns: 0.0027

Work Processes: 0.0676

Likely Traits: ['continuous learning', 'leadership safety values and actions', 'problem identification and resolution']

Actual Traits: ['leadership safety values and actions', 'problem identification and resolution', 'work processes']

Accuracy score: 0.50

Precision score: 0.67

Recall: 0.67

F1-Score: 0.67



Summary of Model Performance

Model Evaluation on Gold Standard:

Average Accuracy on Test Data: 33.48 %

Average Precision on Test Data: 42.87 %

Average Recall on Test Data: 55.15 %

Average F1-Score on Test Data: **48.3 %**

Baseline performance (Random):

Average F1-Score: **12%**

Future Work:

- Refining the list of seed words.
- Changing aggregation method.
- Increase training data size.
- Improving pre-processing.
- Generalizing the model to work on other types of documents.
- Evaluating “negativeness” of text.

Appendix 1: Current Seed Words



personal_accountability = ['responsibility', 'accountability', 'help', 'support', 'trained', 'qualified', 'understand', 'complete', 'involvement']

questioning_attitude = ['complacency', 'complacent', 'challenge', 'error', 'hazard', 'caution', 'discrepancy', 'anomaly', 'assumption', 'question', 'uncertain', 'unknown', 'risk', 'trend', 'unexpected', 'unclear', 'degrading', 'aging']

safety_communication = ['communication', 'licensee', 'event', 'report', 'documentation', 'request', 'LER', 'information', 'safety', 'prompt', 'share', 'respond', 'listen', 'concern', 'expectation', 'clear']

leadership_values = ['leadership', 'management', 'leader', 'owner', 'ownership', 'program', 'guidance', 'policy', 'resource', 'staffing', 'oversight', 'reinforce', 'priority', 'plan', 'delegate', 'align', 'define', 'manage', 'resolve', 'address', 'translate', 'funding', 'implementation', 'violation']

decision_making = ['thorough', 'conservative', 'systematic', 'consistent', 'process', 'choice', 'consequence', 'authority', 'future', 'timely', 'executive', 'senior']

respectful_environment = ['trust', 'respect', 'opinion', 'dignity', 'fair', 'disagree', 'receptive', 'valuable', 'tolerate', 'value', 'insight', 'perspective', 'collaboration', 'conflict', 'listening']

continuous_learning = ['learn', 'training', 'assessment', 'improve', 'performance', 'scrutiny', 'monitor', 'adopt', 'idea', 'benchmarking', 'knowledge', 'competent', 'skills', 'develop', 'acquire']

problem_identification = ['identify', 'corrective', 'action', 'issue', 'yellow', 'red', 'prevent', 'foreign', 'poor', 'inadequate', 'degraded', 'evaluation', 'problem', 'cause', 'root', 'investigation', 'investigate', 'recommendation', 'resolution', 'mitigate']

environment_raising_concerns = ['environment', 'fear', 'harassment', 'discrimination', 'promote', 'severity', 'failure', 'submit', 'report', 'expired', 'raise']

work_processes = ['engineering', 'control', 'activity', 'contingency', 'production', 'schedule', 'work', 'margin', 'operate', 'maintain', 'maintenance', 'procedure', 'package', 'accurate', 'current', 'backlog', 'instruction', 'operation', 'design', 'requirement', 'standard']