Dieter W. Jahns Student Practitioner Award Application

Title

The Skip-Order-Action Framework: An Approach to Documenting and Analyzing Deviations in Petrochemical Facility Procedures

Author

Atif Mohammed Ashraf

Advisors

Dr. S. Camille Peres, Dr. Farzan Sasangohar

University Affiliation

Texas A&M University, Department of Industrial and Systems Engineering

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Framework development: 2021	Statistical analysis (GLMM): 2024

Introduction

Procedures serve as critical safety barriers in high-risk industries, yet their effectiveness depends on how they're actually used by workers [1], [2]. In petrochemical facilities, procedure-related issues contribute to approximately 70% of process safety incidents [3], with procedural deviations being identified as significant contributors to major accidents including the Texas City refinery explosion and the Macondo well blowout [4], [5]. Despite this critical safety role, studies suggest that 30-45% of procedural steps are routinely adapted or modified during normal operations [6], [7]. This persistent gap between Work-As-Imagined (WAI) and Work-As-Done (WAD) represents a significant challenge for safety management [8], [9]. Traditional approaches often view these adaptations as simple non-compliance requiring stricter enforcement, overlooking the complex reality of operational work [10], [11]. This project addresses this challenge by developing a systematic method to identify which procedural adaptations need correction and which might actually represent valuable expertise that should be incorporated into procedure design [12], [13].

Study Objective

This project aimed to develop a systematic framework for analyzing the differences between Work-As-Imagined (WAI) and Work-As-Done (WAD) in petrochemical facilities, with specific focus on worker interactions with operating procedures. The objectives were to: (1) Create a framework to objectively assess actual worker behavior compared to prescribed procedures and (2) Identify patterns of procedural variations that could inform both procedure design and safety management practices.

Explanation and Demonstration of Core Competencies

1. *Analysis Core Competency*

This project demonstrates the Analysis core competency through:

1. **User Research and Assessment**: The project employed ecological and contextual analysis techniques to observe workers in their natural environment, documenting real-world interactions with procedures while performing safety-critical tasks.
2. **Organizational Factors**: The work identified and employed relevant organizational factors by:
   - Comparing two different sites within the same company (one using paper procedures, one using digital)
   - Documenting how the organizational context of filling operations shapes procedure use
   - Analyzing how simultaneous management of multiple filling operations affects worker adherence to procedures
3. **Cognitive and Behavioral Characteristics**: The study identified behavioral characteristics through:
   - Development of the three-category variation taxonomy (Routine, Efficiency, Safety) that captures different patterns of procedural adaptation
   - Observation and documentation of worker behaviors and procedural choices in actual workplace settings
   - Analysis of how workers prioritize between different procedural requirements based on situational demands
   - Documentation of behavioral patterns when managing multiple simultaneous tasks
4. **Human-Technology Interface Evaluation**: The project applied evaluation methods by:
   - Directly comparing paper-based and digital procedure interfaces through quantitative analysis
   - Measuring objective performance metrics (skip, order, action)
   - Identifying statistically significant differences in performance based on how workers interacted with the procedure
   - Documenting how workers interact differently with paper versus digital procedures

2. *Design Core Competency*

While the primary focus was analysis, the project connects to Design through:

1. **Applied Ergonomic Principles**: The findings directly inform the design of more effective procedures that account for actual work practices.
2. **Task Design Recommendations**: The developed framework provides insights for designing tasks within human capabilities and limitations, considering workplace context to enable workers to accomplish goals safely, efficiently and effectively.

3. *Integration Core Competency*

The project demonstrates the Integration core competency through:

1. **Testing and Implementation**: The Skip-Order-Action (SOA) framework was tested in an actual petrochemical facility to validate its effectiveness in capturing procedural variations. The statistical validation through Generalized Linear Mixed Model (GLMM) analysis confirmed the framework's reliability and applicability in real-world settings.
2. **Performance Metrics Collection**: The project systematically collected and analyzed performance metrics (skip, order, and action attributes) to determine successful implementation of the framework, with results validated through both statistical analysis and Subject Matter Expert (SME) review.
3. **Validation Process**: The framework underwent rigorous validation through inter-rater reliability assessment, with three independent coders achieving 75% agreement and resolving discrepancies through consensus-building discussions. The validation process was strengthened through direct review sessions with SMEs from the

petrochemical facility, who confirmed the accuracy and relevance of the identified patterns from a practitioner perspective. This multi-faceted validation approach demonstrates the framework's potential for consistent application in various industrial contexts and ensures its practical utility for safety professionals.

4. **Implementation Pathway**: The research provides a methodological approach for analyzing procedural variations in industrial settings. While specific implementation guidelines weren't fully developed as part of this work, the framework offers a structured way to categorize and understand procedural adaptations. The SOA framework, along with the proposed three-category variation taxonomy (Routine, Efficiency, Safety), provides safety professionals with a vocabulary and analytical tool that could be applied to evaluate procedure use in their own facilities.

Methodology

This field study was conducted in a working petrochemical facility to capture real-world worker-procedure interactions in their natural context. The methodology was structured to ensure ecological validity while maintaining systematic rigor:

1. *Analysis of User Population and Situation:*
    - Target Population: Workers in a petrochemical facility responsible for dangerous filling operations
    - Contextual Constraints: High-risk environment with significant safety implications such as spills, exposure to chemicals, pressurized equipment etc.
    - Procedural Requirements: Following detailed step-by-step procedures to ensure safe operations
    - Industry Challenge: Persistent gap between prescribed and actual work practices despite safety criticality
2. *Naturalistic Data Collection:*
    - Real-World Setting: Data was collected during actual production operations
    - Authentic Tasks: Workers performed their regular duties without experimental manipulation
    - Unobtrusive Methods: Small cameras (Go-Pro style) attached to hard hats recorded the worker's perspective without interfering with their tasks
    - Contextual Factors: Captured real workplace constraints including time pressure, equipment limitations, and simultaneous operations
    - Task Breakdown: Each task was divided into three phases for analysis:
        1. Preparation (T1): Safety checks and equipment preparation
        2. Execution (T2): Chemical transfer operations
        3. Verification (T3): System securing and documentation
3. *Design Principles and Theoretical Foundation:*
    - Safety-II Paradigm: Focus on understanding successful adaptations rather than only deviations as failures
    - Resilience Engineering: Recognizing adaptations as potential sources of system resilience
    - Efficiency-Thoroughness Trade-Off (ETTO) Principle: Workers constantly balance efficiency against thoroughness
    - Grounded Theory Approach: Framework developed inductively from observational data
4. *Data Collection:*
    - Setting: Two sites within a major petrochemical facility in southern USA
    - Participants: 14 workers (13 males, 1 female) with similar experience levels
    - Medium Comparison: Site 1 (paper-based procedures) and Site 2 (digital procedures)
    - Observation Method: Head-mounted portable video recorders on workers' hard hats during routine tasks
    - Dataset: 1472 procedural steps analyzed across 40 procedures

5. *Skip-Order-Action (SOA) Framework Development:*

- Grounded Theory Process: Framework emerged from iterative analysis of observational data
- Three Key Attributes: Skip (completion), Order (sequence), and Action (execution)
- Coding Protocol: Systematic assessment of each procedural step against these attributes
- Validation: Inter-rater reliability assessment with 75% agreement threshold

6. *Analysis Process:*

- Multiple Coders: Three researchers independently applied the framework to enhance reliability
- Consensus Building: Regular discussions to resolve coding discrepancies
- SME Validation: Findings reviewed with Subject Matter Experts from the facility
- Statistical Analysis: Generalized Linear Mixed Models to identify significant patterns

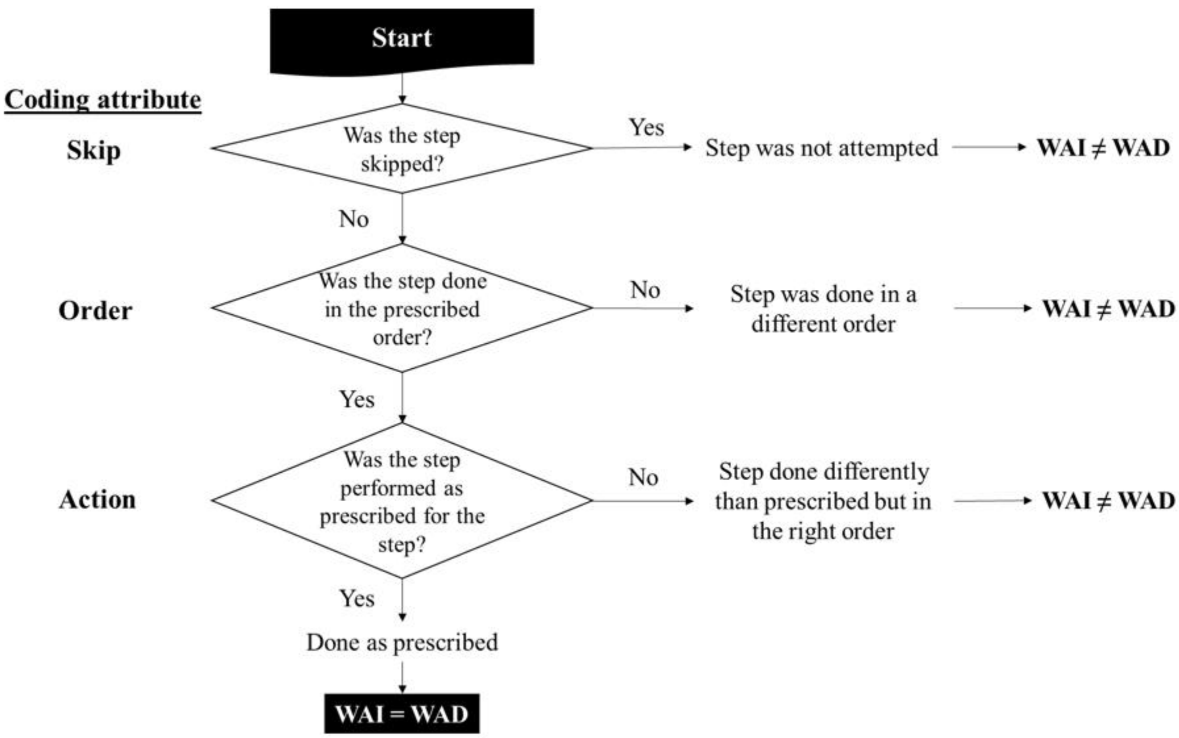

FIGURE 1: SOA Framework Logic Diagram

Results

Analysis of 1472 procedural steps revealed several key findings with direct practical implications:

1. *Overall Compliance Patterns:*

- Approximately 35% (average) of steps showed variations from prescribed procedures across both mediums
- While there wasn't a significant main effect of medium alone ($p = 0.060$), the data shows notable trends towards digital procedures in overall compliance rates
- The majority of variations (22%) were steps performed in a different order than prescribed
- Despite these variations, tasks were consistently completed successfully

FIGURE 2: Overall discrepancies between WAI and WAD

2. *Classification of Variations:*

Through collaboration with SMEs, we identified three distinct categories of procedural variations:

- **Routine Variations:** Steps skipped or modified according to established workplace norms; considered "the way things are done" without immediate safety implications
- **Efficiency Variations:** Steps performed out of sequence to optimize task completion, particularly when workers managed multiple simultaneous operations
- **Safety Variations:** Critical steps skipped or modified with direct implications for operational safety

TABLE 1: Classification of WAI-WAD variation patterns

Aspect	Routine	Efficiency	Safety
Nature of Variation	Steps skipped Steps partially completed Steps done differently	Steps completed as prescribed but in different order	Steps skipped Steps partially completed Steps done differently Steps done out of order
Safety Impact	No immediate threat to operational safety	No compromise to safety when properly managed	Direct implications for operational safety
Root Cause	Established workplace norms Considered "Way of doing things" Misperceptions of step importance Inaccurate mental models	Simultaneous operations Worker adaptations for efficiency	Oversight Non-compliance Lack of understanding of step criticality
Improvement Focus	Alignment of procedures with work practices Better communication of step importance Addressing normalized deviations	Support for beneficial adaptations Integration of efficiency considerations Development of flexible procedures	Reinforcement of compliance Identification of commonly skipped critical steps Enhanced safety controls

Aspect	Routine	Efficiency	Safety
Example	Worker does not use the sample catcher fitting but collected the sample directly from the outlet	Do multiple steps in advance on one railcar, while predominantly working on another railcar	Workers do not wear hearing protection while using the pneumatic wrench

3. *Task Phase Effects:*

Our analysis revealed significant operational patterns:

- Task Phase Variations: Execution phase showed 279% higher odds of skipped steps compared to pre-loading ($p < 0.001$), while Verification phase demonstrated 61% better order compliance ($p = 0.036$) but less precise execution than Preparation phase.
- Key Interactions: Digital procedures maintained consistent compliance across all phases, while paper procedures showed declining compliance, particularly in Verification phase ($p < .001$).

Discussion

The SOA framework represents a significant advancement in ergonomics practice by providing practitioners with a systematic approach to understanding and supporting the complex relationship between standard operating procedures and actual work behaviors:

1. *Practical Application Context:*

This field study directly addresses a critical challenge in high-risk industries – the persistent gap between prescribed and actual work practices. The framework provides practitioners with a structured method to:

- Document actual work practices objectively
- Identify patterns in procedural adaptations
- Distinguish between beneficial adaptations and potentially hazardous deviations

2. *Beyond Binary Compliance:*

Traditional approaches often view deviations as simple non-compliance. The SOA framework offers a more nuanced understanding that:

- Recognizes adaptations as potentially beneficial for system performance
- Provides a structured vocabulary for describing different types of adaptations
- Supports targeted interventions based on the nature and risk level of variations

3. *Task Phase-Specific Applications*

Our findings provide targeted guidance for each operational phase:

- Preparation (T1): Focus on step execution rather than sequence; address preparation-related skipping.
- Execution (T2): Implement safeguards for commonly skipped steps; design for simultaneous operations where step skipping is highest.
- Verification (T3): Allow sequence flexibility while ensuring completion; digital formats significantly outperform paper here.

4. *Validation and Implementation in Applied Settings:*

The framework's effectiveness was validated through:

- Consensus-building with multiple coders

- Subject Matter Expert review
- Statistical validation through GLMM analysis

Implementation value is demonstrated through:

- Immediate applicability for procedure designers
- Actionable insights for safety managers
- Structured approach for analyzing work-as-done in various contexts

5. *Limitations and Future Applications:*

- Field study constraints: Limited to one facility and specific task types
- Potential observer (Hawthorne) effects despite unobtrusive observation methods
- Future applications include extending the framework to different industries and task types

Impact

This project delivers several specific benefits with immediate practical applications:

1. *Enhanced Procedure Design:*

The findings directly inform the design of both paper and digital procedures by:

- Identifying where flexibility should be permitted vs. where strict compliance is essential
- Providing evidence for digital procedure advantages in certain contexts
- Supporting procedure format decisions based on task characteristics

Example: A facility could immediately apply the SOA framework to analyze their loading procedures, identifying which verification steps are routinely performed out of sequence but safely, and redesign their procedures to officially accommodate this workflow.

2. *Safety Management Applications:*

The framework enables safety professionals to:

- Identify patterns of procedural variations during normal operations
- Implement targeted interventions before incidents occur
- Move beyond punitive approaches to non-compliance
- Support a more nuanced safety culture

Example: Safety managers could use the framework to conduct a one-week assessment of critical loading operations, quickly identifying safety-critical steps that are frequently skipped before they contribute to an incident, potentially avoiding costly near-misses or accidents.

3. *Training Impact:*

The variation taxonomy provides trainers with:

- A structured approach for discussing procedural adaptations
- Targeted training focused on safety-critical aspects
- Methods for developing expertise in appropriate adaptation

Example: The framework provides an immediate return on investment by focusing training resources on the specific procedural steps that present the highest risk, rather than generic compliance training that may not address actual workplace challenges.

4. *Methodological Contribution:*

The SOA framework provides practitioners with:

- A structured, replicable method for analyzing worker-procedure interactions
- A common vocabulary for discussing procedural variations
- A pathway for continuous improvement of procedures based on actual use patterns

Conclusion

The SOA framework makes a significant contribution to ergonomics practice by providing empirical evidence for theoretical principles like the ETTO. By systematically documenting where, how, and why procedural adaptations occur through objective measurements rather than subjective judgments, this tool transforms our understanding of procedural variations from theoretical constructs to quantifiable phenomena. This objective framework reveals that workers' adaptations often represent sophisticated balancing acts between competing priorities rather than simple non-compliance. The findings challenge traditional compliance-centered approaches and represent an essential first step toward developing adaptive procedures that support rather than constrain performance. The SOA framework provides a tool for safety professionals to systematically analyze procedure use, identify improvement opportunities, and develop more effective safety systems that enhance both safety and performance while respecting the expertise workers bring to their daily tasks.

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