An Analysis of CSB Investigation Reports

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Outline

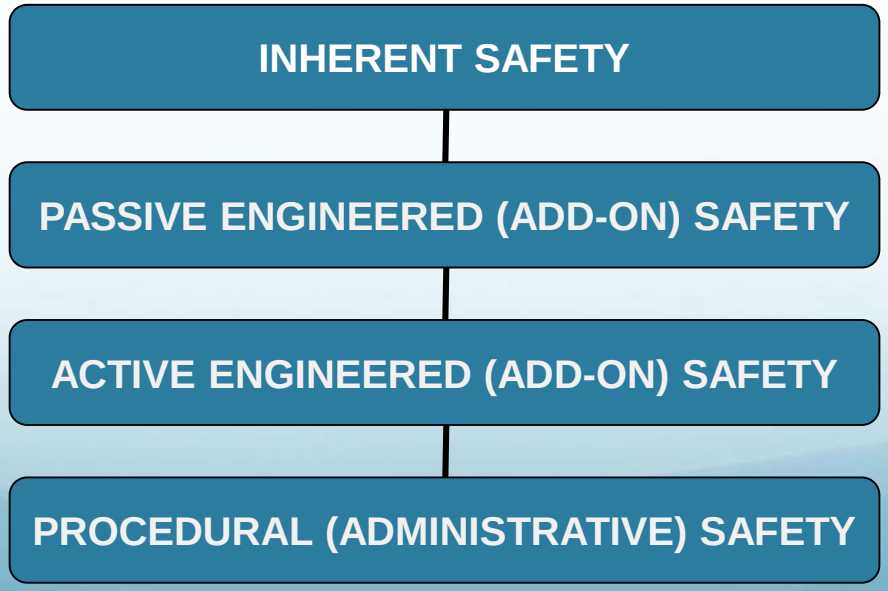
- Introduction
- Explicit Inherent Safety Considerations in CSB Reports
- Results of CSB Report Analysis
- Inherent Safety Learnings
- Concluding Remarks
- Acknowledgements

Introduction

- **Scope**
  - Analysis of CSB reports with respect to hierarchy of risk controls
- **Motivation**
  - Significant value of CSB reports with respect to lessons learned
- **Objective**
  - Highlight role of ISD within hierarchy of risk control measures and process safety management systems

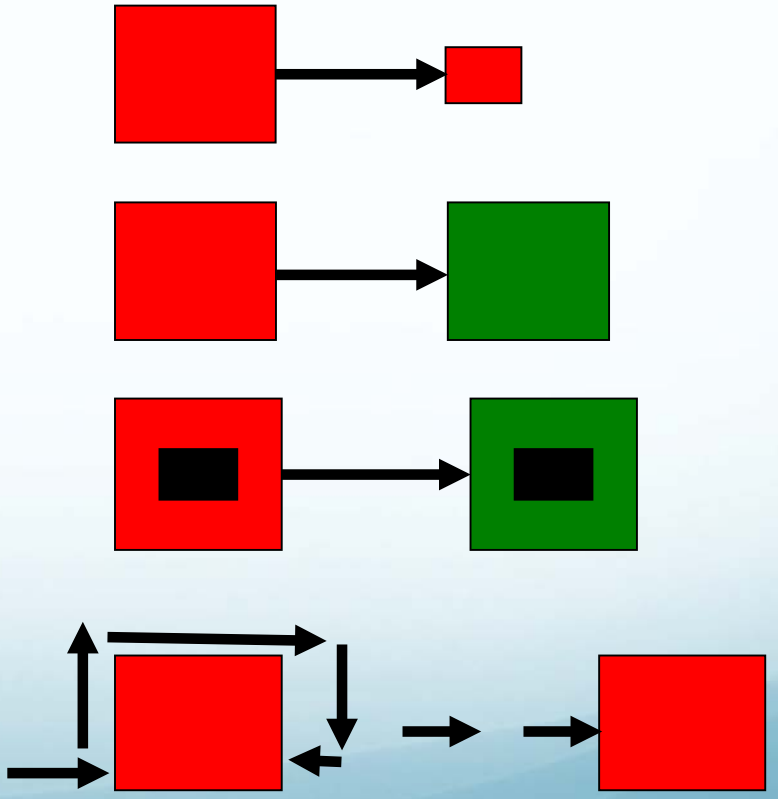
Analysis Framework

- **85** CSB reports – investigation reports, case studies, safety bulletins, urgent recommendations
  - Initial analysis: 60 reports (1998 – 2010)
  - Second analysis: 25 reports (2010 – 2016)
  - Combined analysis: 85 reports (1998 – 2016)
- By category in hierarchy of safety measures



Analysis Framework

- By risk component
  - Likelihood → Prevention
  - Severity → Mitigation
- By Process Safety Management (PSM) element
  - 12-element CSChE PSM system (PSM Guide, 4th ed.)
- By inherent safety (ISD) principle



Table

West Fertilizer Explosion, 2015

Quote	Type of safety measure	Rationale	P/M	PSM Element
CSB concluded that… the lack of an automatic sprinkler system plausibly contributed to the detonation.	Active	An automatic sprinkler system would act as an active add-on device.	M	PRM
The West Volunteer Fire Department did not conduct pre-incident planning.	Procedural		M	PRM
Ventilation at ground level was limited to only a few louvered vents.	Passive	Ventilation louvers are passive safety devices.	P	Capital Project Review and Design Procedures
[An example of simplification would be to] Limit the types of FGAN blends sold to minimize the need for staff to handle FGAN.	ISD - Simplification	This example is found in Table 6, which explicitly mentions ISD - simplification when addressing this example.	P	PRM

Explicit Inherent Safety Considerations in CSB Reports

- Earlier CSB reports generally have implicit examples of ISD and limited use of ISD terminology (or language)

- Trend in recent investigations to explicit use of ISD terminology
  - *inherently safer approaches (alternatives)*
  - *eliminating the hazard*
  - *hierarchy of controls*
  - *substitution*

Xcel Energy

- Cabin Creek, CO
- October 2007
- Penstock fire
- 5 deaths + …
- Recoating of enclosed penstock (tunnel)
- **Substitution**
  - Non-flammable solvent instead of highly flammable MEK

West Fertilizer

- West, TX
- April 2013
- Ammonium nitrate plant explosion
- 15 deaths

West Fertilizer

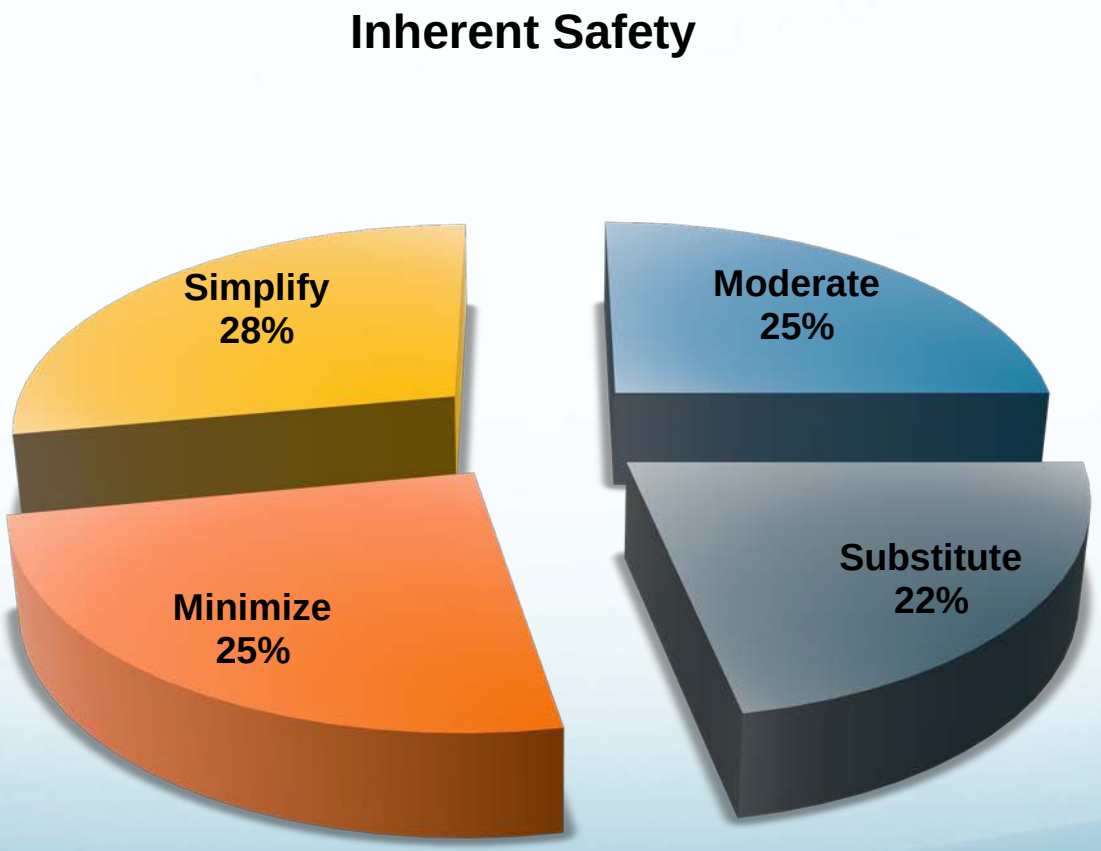
Table 6. Inherently Safer Approaches for handling FGAN

Inherently Safer Strategy	Description	Examples
Substitution	Replacing a hazardous material with a safer option	Use a fertilizer with less explosive potential than FGAN
Minimization	Reducing the quantity of a hazardous material used in a chemical process	Store FGAN in purpose-built buildings holding smaller quantities of materials, well separated from one another and from potential sources of contamination
Moderation	Using a hazardous material under the least hazardous conditions	Store FGAN in bins constructed of materials impervious to the effects of AN and in areas where electric service is not required
Limitation of effects (a form of moderation)	Change designs or reaction conditions rather than adding protective equipment	Construct FGAN storage bins to minimize the consequences of a possible explosion
Simplification	Eliminating process complexity to provide fewer opportunities for error and equipment failure	Limit the types of FGAN blends sold to minimize the need for staff to handle FGAN

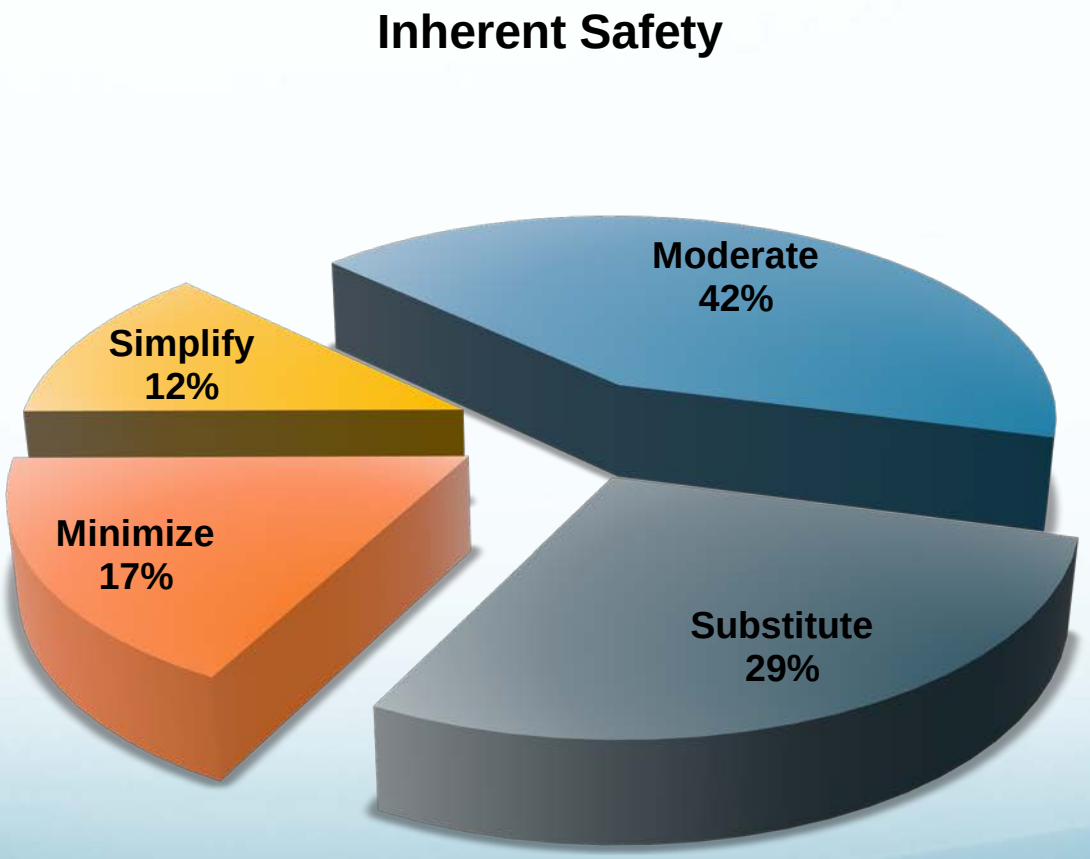
Results

- By initial, second, and combined analysis
  - Initial 60-report analysis
  - Second 25-report analysis
  - Combined 85-report analysis
- ISD analysis
- Hierarchy analysis
- Prevention & mitigation analysis

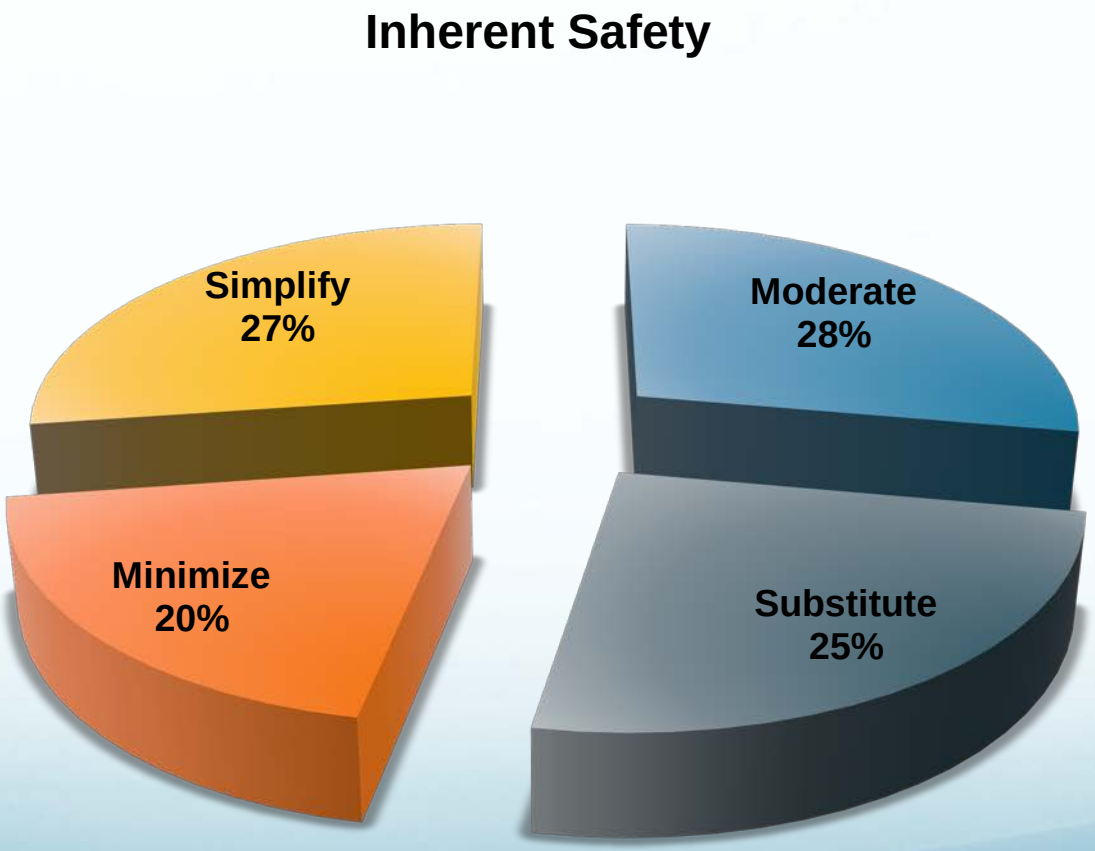
Initial Analysis
93 ISD Examples



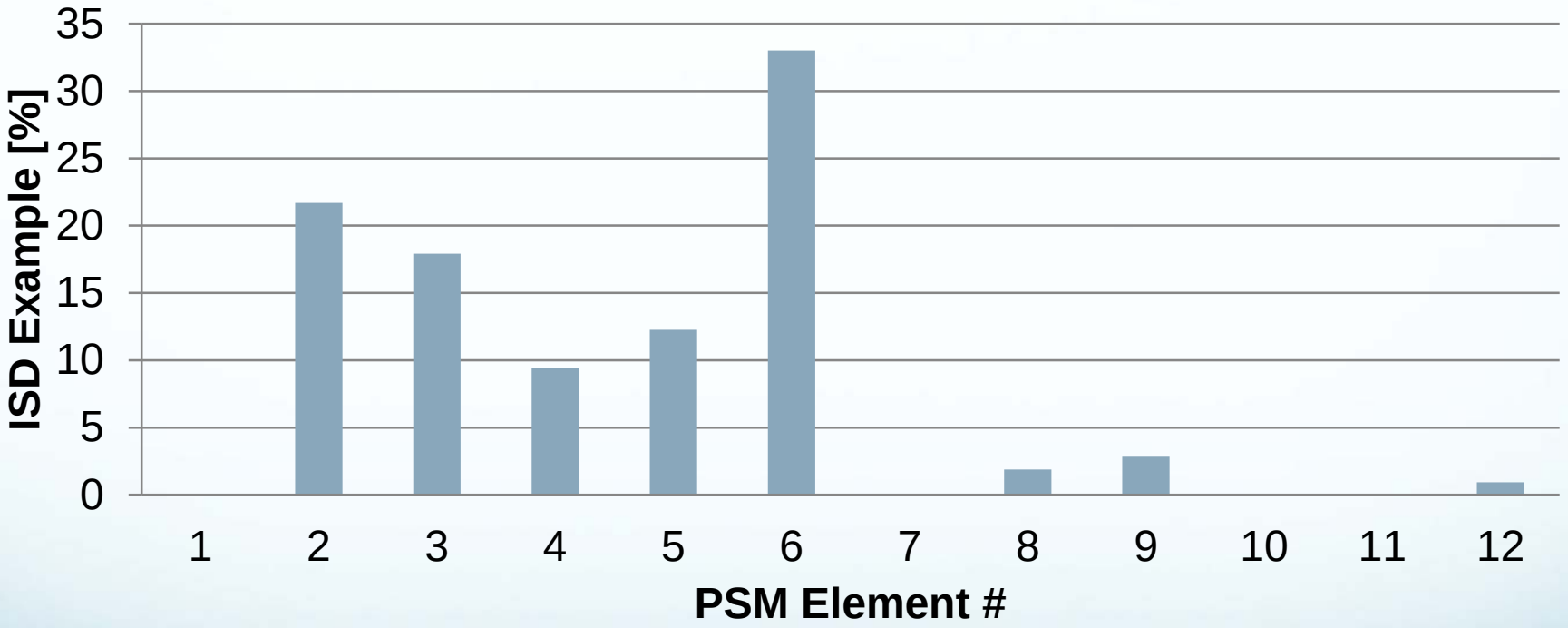
Second Analysis
82 ISD Examples



Overall Analysis
175 ISD Examples

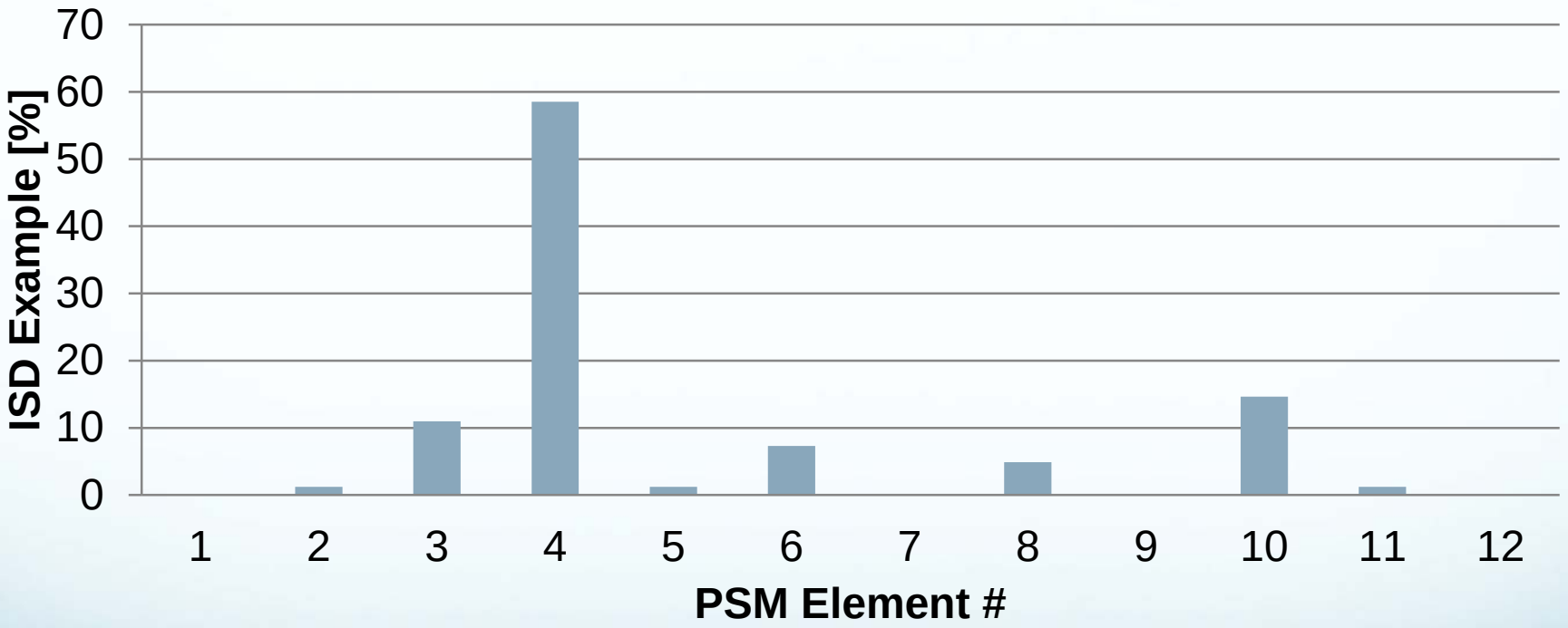


Initial Analysis
ISD Analysis by PSM Element



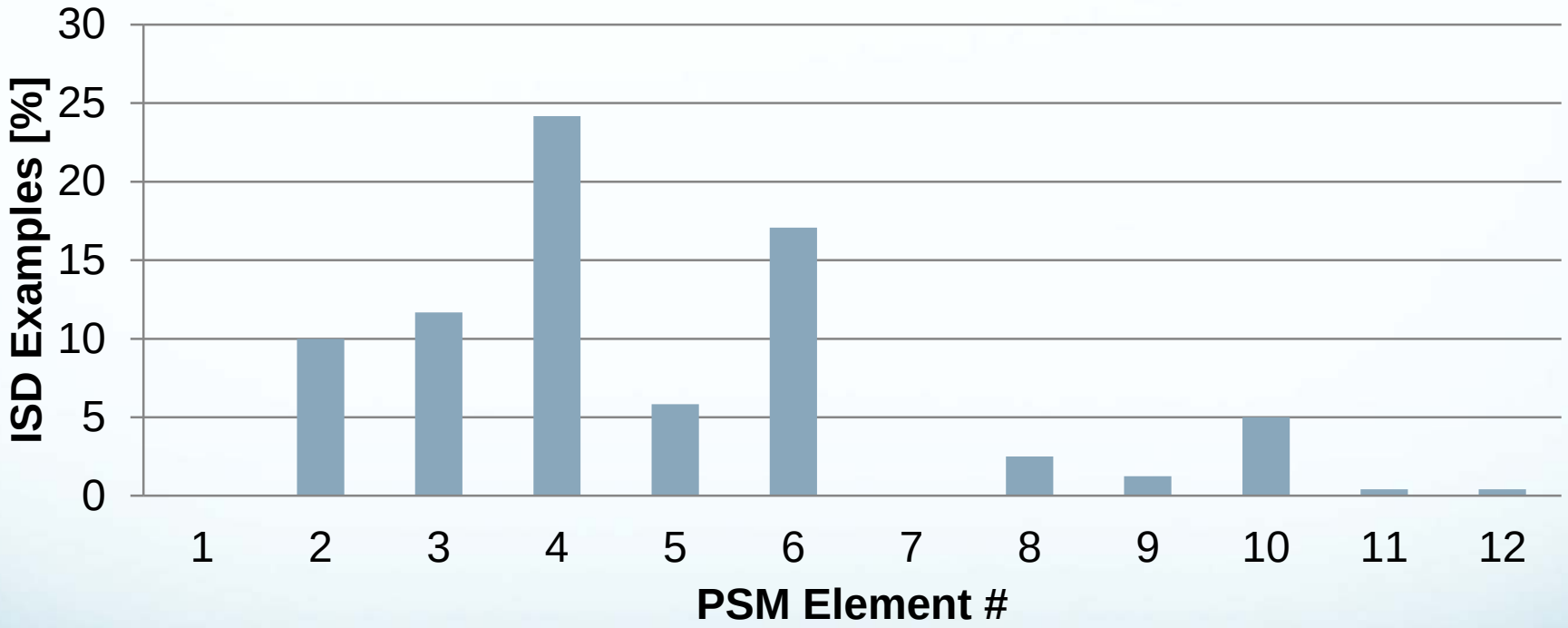
6 – Process and Equipment Integrity
2 – Process Knowledge & Documentation
3 – Capital Project Review and Design Procedures
5 – Management of Change

Second Analysis
ISD Analysis by PSM Element



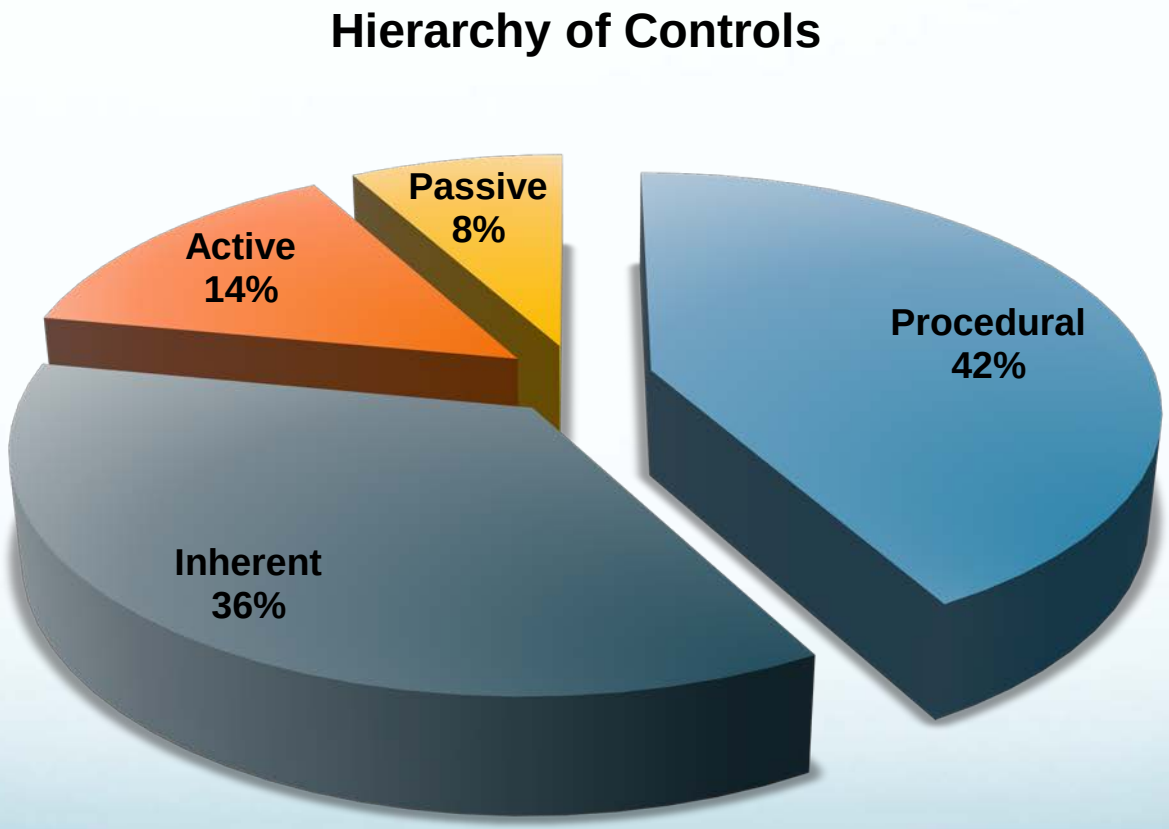
4 – Process Risk Management
10 – Company Standards, Codes, and Regulations
3 – Capital Project Review and Design Procedures
6 – Process and Equipment Integrity

Overall Analysis
ISD Analysis by PSM Element

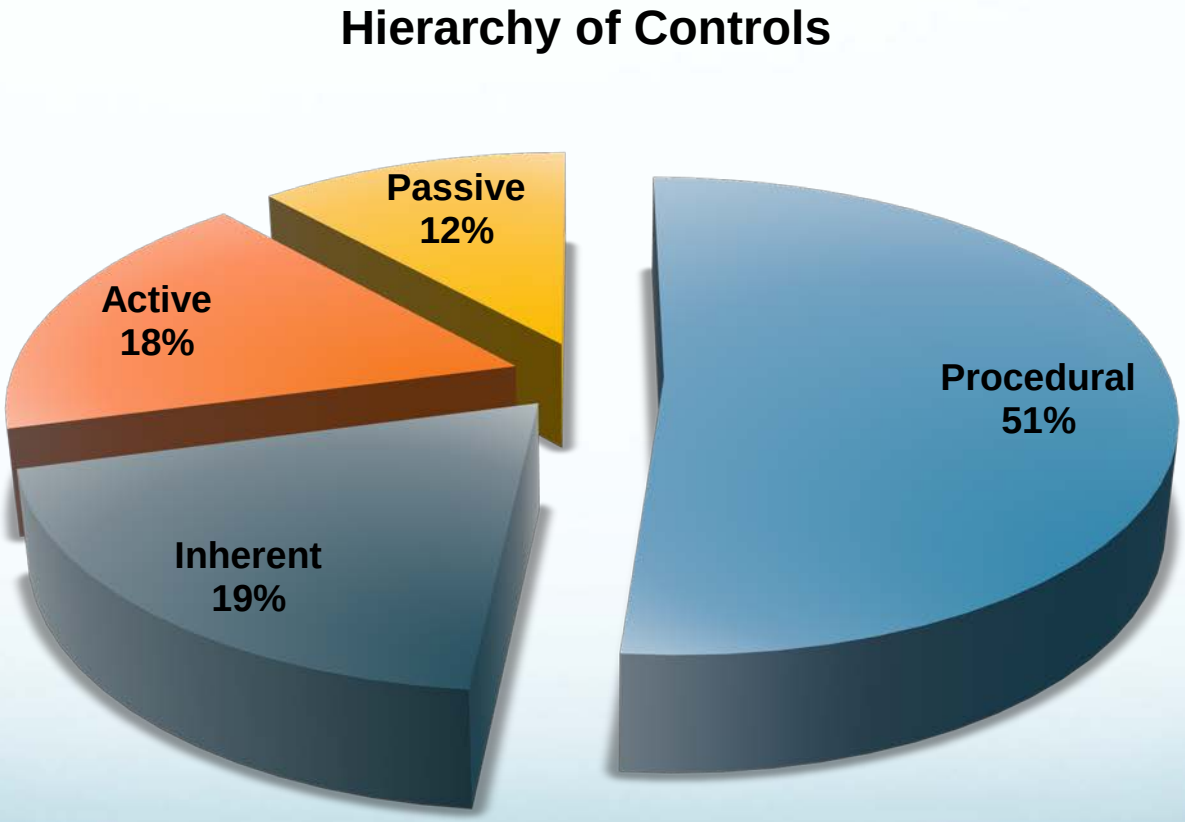


4 – Process Risk Management
6 – Process and Equipment Integrity
3 – Capital Project Review and Design Procedures
2 – Process Knowledge and Documentation

Initial Analysis
258 Hierarchy Examples
70% Prevention / 30% Mitigation



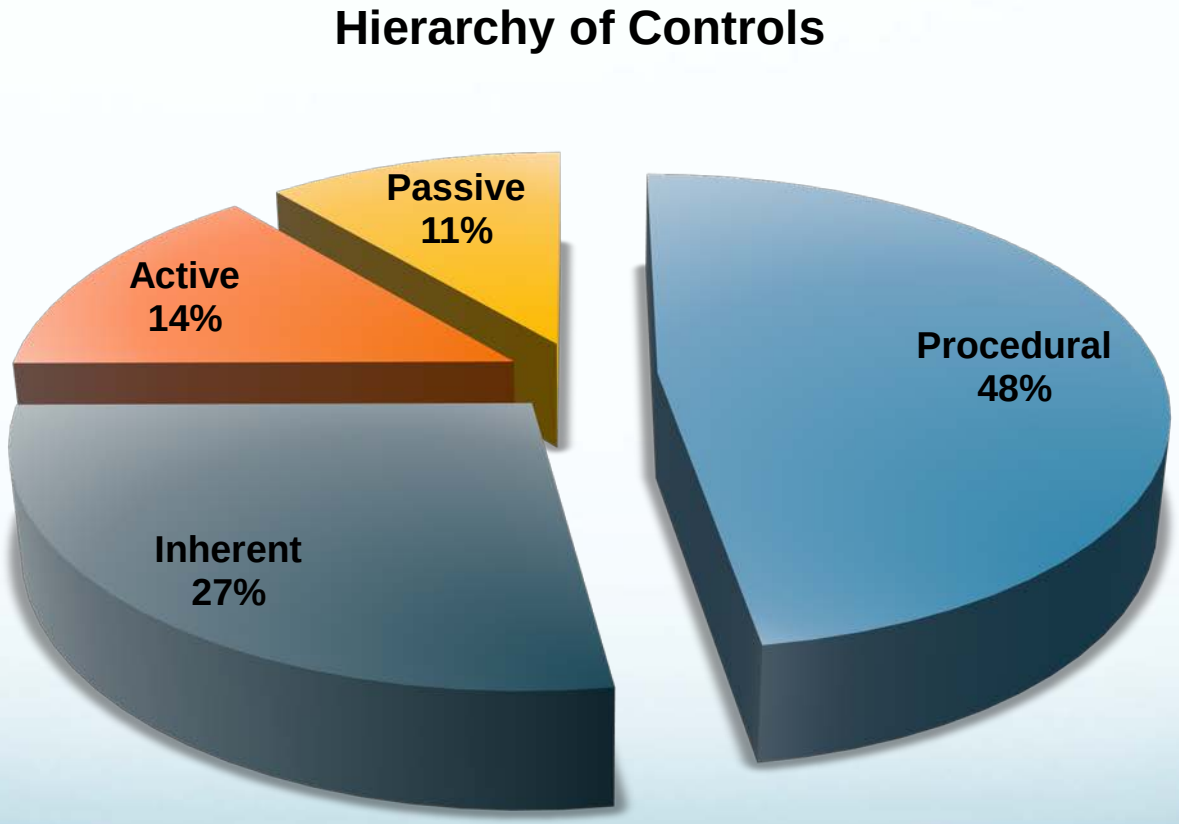
Second Analysis
421 Hierarchy Examples
76% Prevention / 24% Mitigation



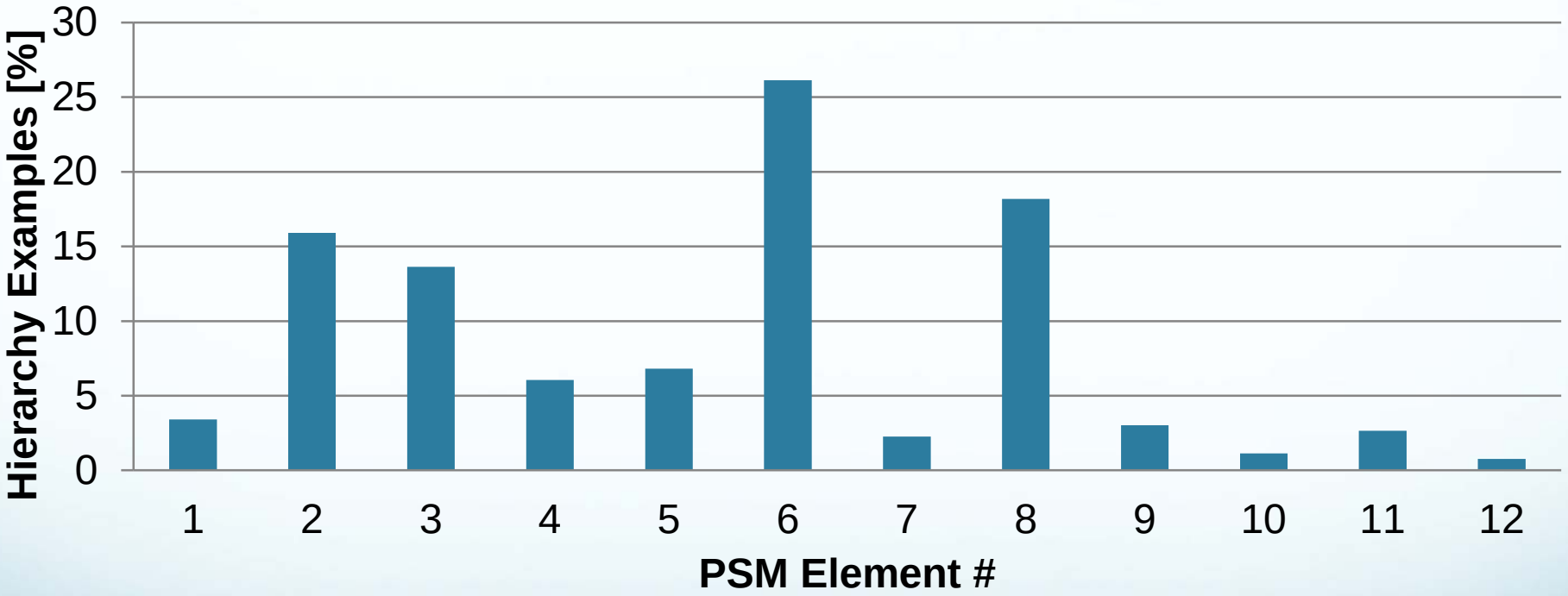
Overall Analysis

679 Hierarchy Examples

74% Prevention / 26% Mitigation

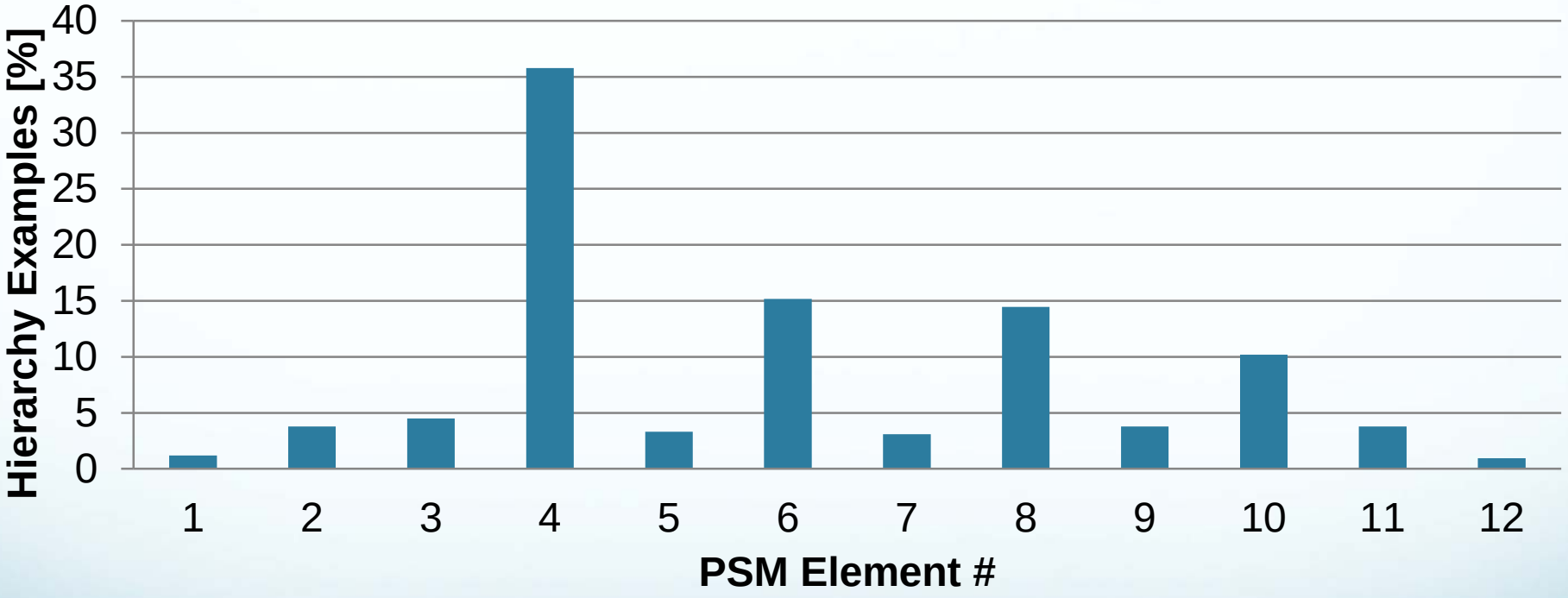


Initial Analysis
Hierarchy Analysis by PSM Element



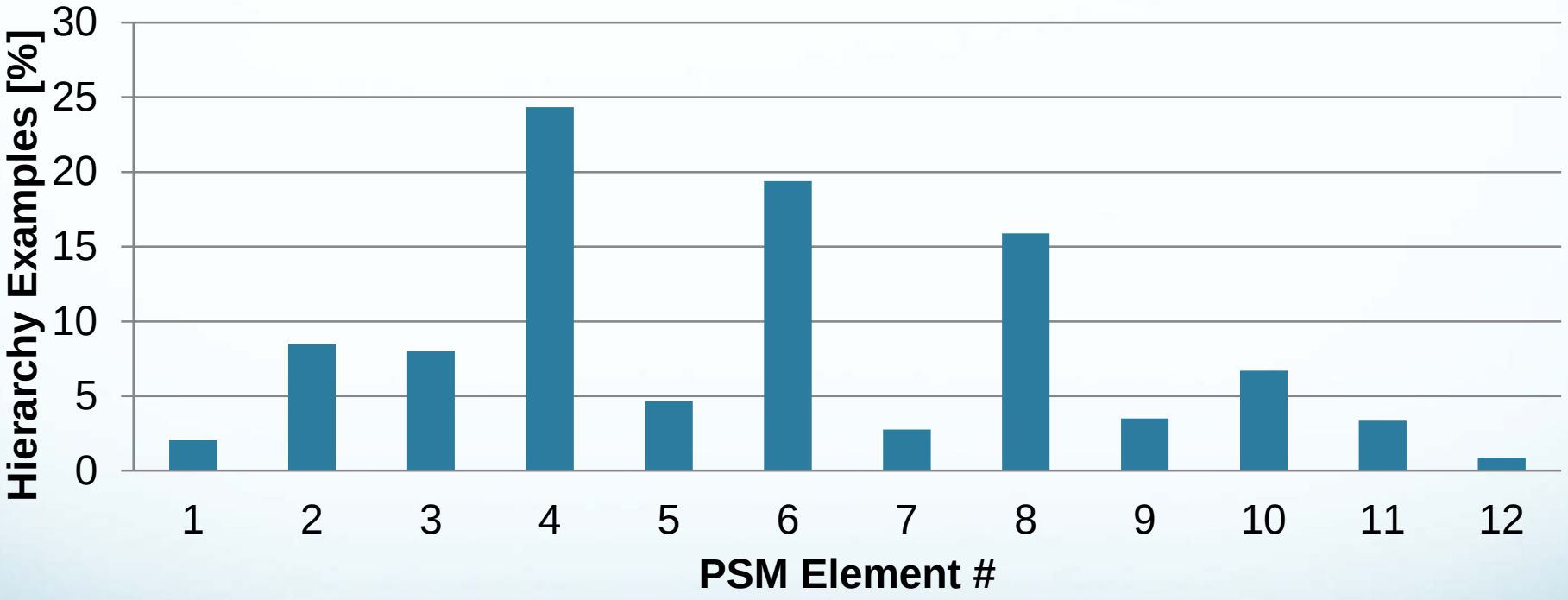
6 – Process and Equipment Integrity
8 – Training and Performance
2 – Process Knowledge and Documentation
3 – Capital Project Review & Design Procedures

Second Analysis
Hierarchy Analysis by PSM Element



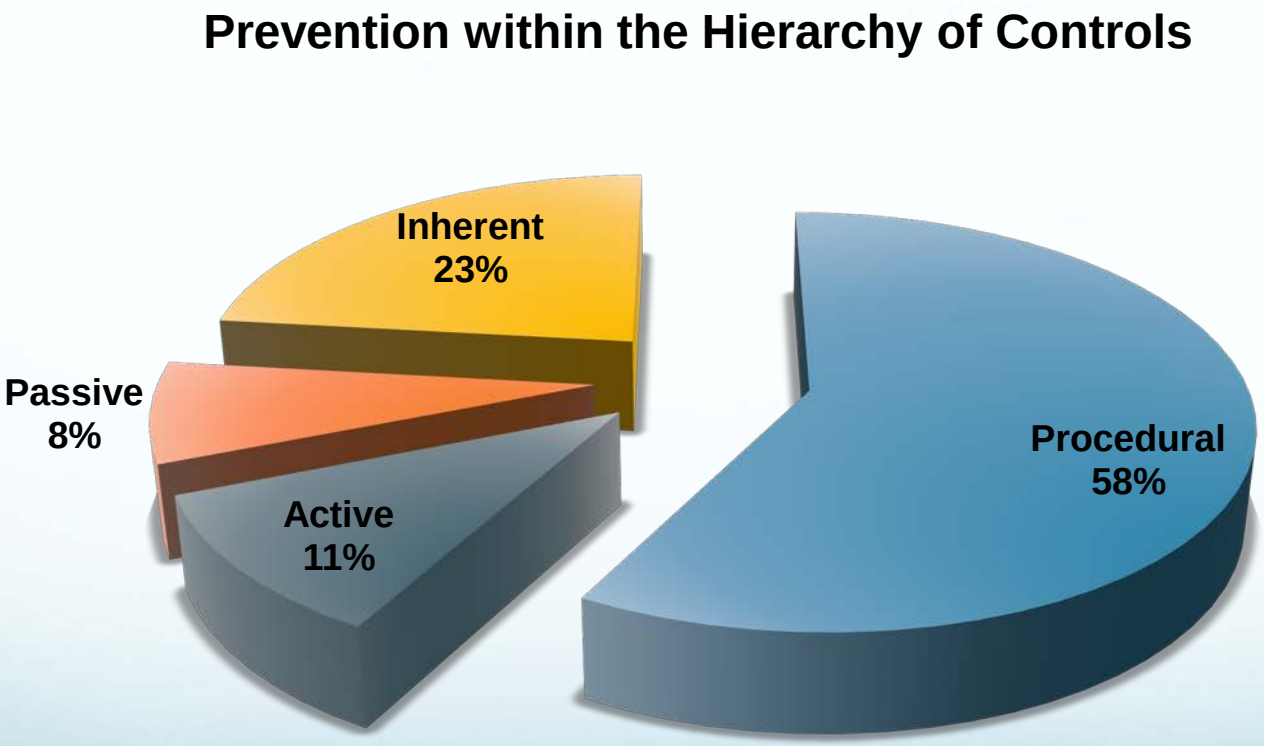
4 – Process Risk Management
6 – Process and Equipment Integrity
8 – Training and Performance
10 – Company Standards, Codes, and Regulations

Overall Analysis
Hierarchy Analysis by PSM Element

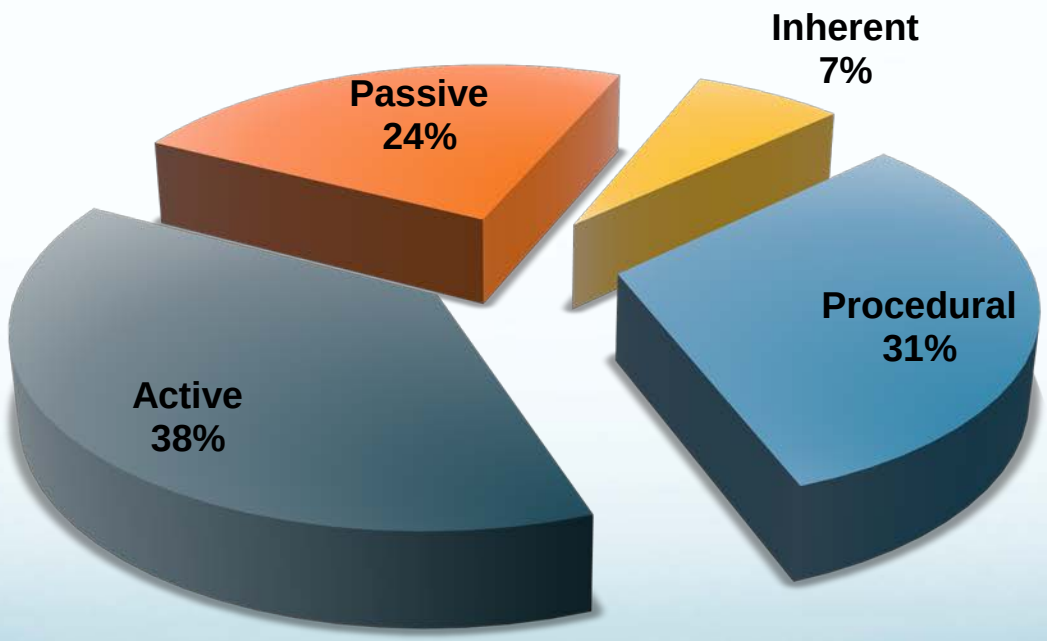


4 – Process Risk Management
6 – Process and Equipment Integrity
8 – Training and Performance
2 – Process Knowledge and Documentation

Second Analysis
Prevention



Second Analysis
Mitigation



Inherent Safety Learnings

Findings here are generally consistent with:

- Kidam et al. (2010): 13th Intl Symp. Loss Prevention
  - Failure Knowledge Database (Japan)
  - e.g. high percentage of procedural safety issues
- Yang et al. (2009): Hazards XXI
  - Analysis of case histories for common lessons learned
  - e.g. importance of all levels in the hierarchy of controls
- Fyffe et al. (2016): Analysis of key issues in CSB reports
  - Predominance of design & engineering issues
  - Predominance of process hazard analyses

Concluding Remarks

- Procedural safety is most popular
- Active safety common among mitigation efforts
- Prevention consistently more common than mitigation
- ISD has clear role to play in process incident prevention/mitigation
- All ISD principles are relevant to process safety assurance

Acknowledgements

- Financial support of the Natural Sciences and Engineering Research Council (NSERC) of Canada
  - Undergraduate Student Research Award
  - Discovery Grants