

Lean Construction Institute

Provider Number H561



Designing for Safety in Construction and throughout the Facility Lifecycle

20918P2SLDF.6 / 2018

John Gambatese

February 8, 2018 – 12:45 PM - 3:45 PM



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Questions related to specific materials, methods, and services will be addressed at the conclusion of this presentation.

Course Description

Prevention through Design (PtD) is a National Institute of Safety & Health initiative to improve safety throughout the lifecycle of products of all types. In the built environment domain, that means to design facilities so they can be safely constructed, safely maintained and operated, safely used for business, and safely altered and decommissioned. Challenges to realizing these goals include the construction industry habit of excluding downstream users of facility design from the design process. Further, even when builders are brought into the design phase of projects, they may not be made full members of the design team, but rather limited to providing feedback on cost or constructability. This presentation will explain what can and is being done to design the built environment for safe construction.

Learning Objectives

At the end of the this course, participants will be able to:

1. Learn what Prevention through Design is.
2. Learn why Prevention through Design is important and needed.
3. Learn how to do Prevention through Design in the design phase of construction projects.
4. Understand the challenges to successful implementation and how to overcome them.

Designing for Safety in Construction and throughout the Facility Lifecycle

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**Project Production Systems
Laboratory (P²SL)**

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February 8-9, 2018



Recent News

SmartMarket Report

SAFETY MANAGEMENT IN THE CONSTRUCTION INDUSTRY 2017 SMARTMARKET REPORT

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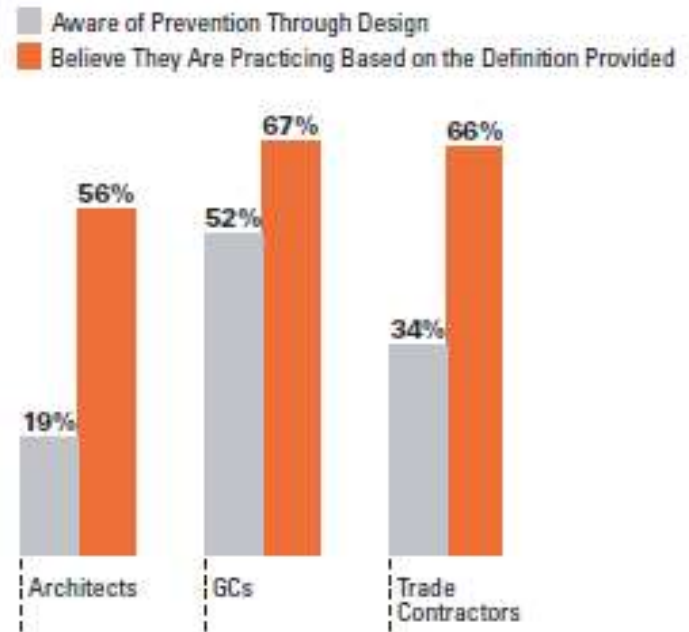
45 Influence Factors

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Awareness and Reported Practice of Prevention Through Design (According to Architects, GCs and Trade Contractors)

Dodge Data & Analytics, 2017



PtD: Moving Safety Upstream

“PtD encompasses all of the efforts to anticipate and design out hazards to workers in facilities, work methods and operations, processes, equipment, tools, products, new technologies, and the organization of work.”

(www.cdc.gov/niosh/topics/ptd/)



“Safety Constructability”

Prevention through Design (PtD) = SiD = DfS = EfS

Why implement PtD?



The Importance of Design

- “Things alter for the wrong spontaneously, if they be not altered for the better designedly.”

Francis Bacon (1561-1626), British author, statesman, philosopher, and scientist



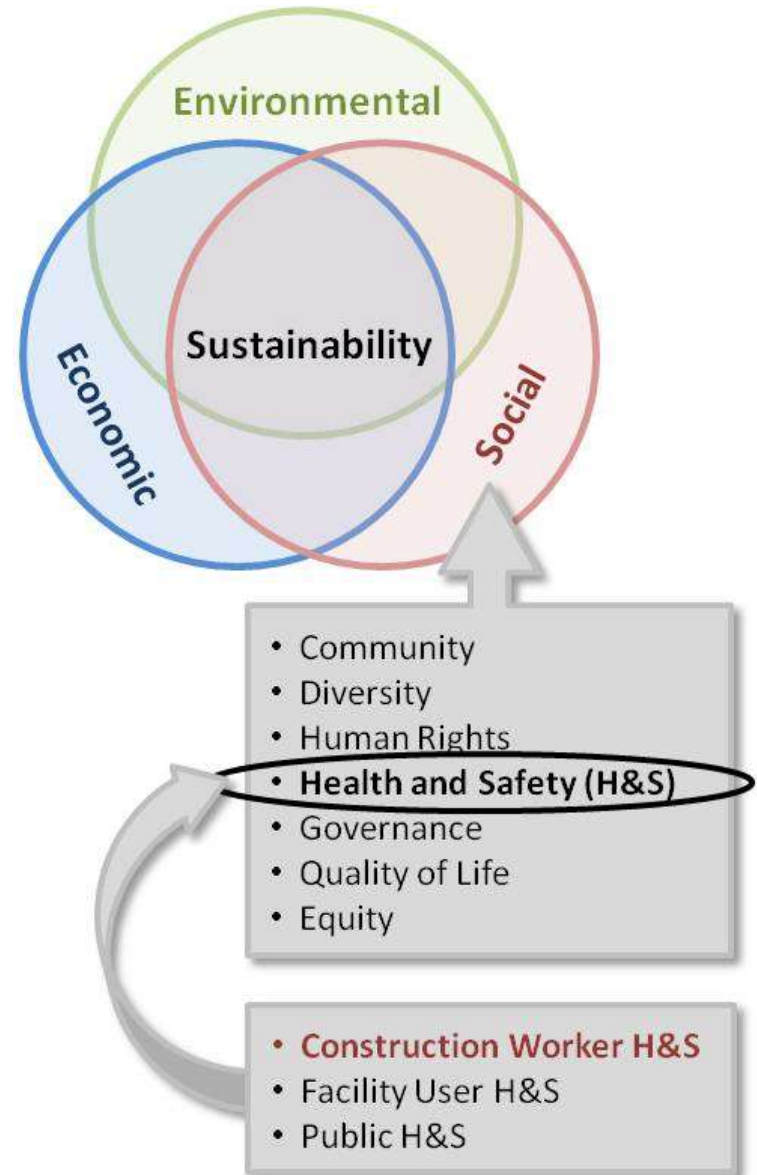
A Focus on Ethics

- National Society of Professional Engineers (NSPE) Code of Ethics:
 - “Engineers shall **hold paramount the safety, health, and welfare of the public.**”
- American Society of Civil Engineers (ASCE) Code of Ethics:
 - “Engineers shall **recognize that lives, safety, health and welfare of the general public are dependent upon engineering decisions.....**”



Sustainable Development

- USGBC – Prevention through Design LEED Pilot Credit, IPpc93 
- Safety Design Review
- Safety Constructability Review



Supporting Research

- **22%** of 226 injuries that occurred from 2000-2002 in Oregon, WA, and CA related to design¹
- **42%** of 224 fatalities in US between 1990-2003 related to design¹
- **60%** of fatal accidents resulted in part from decisions made before site work began²
- **63%** of all fatalities and injuries could be attributed to design decisions or lack of planning³



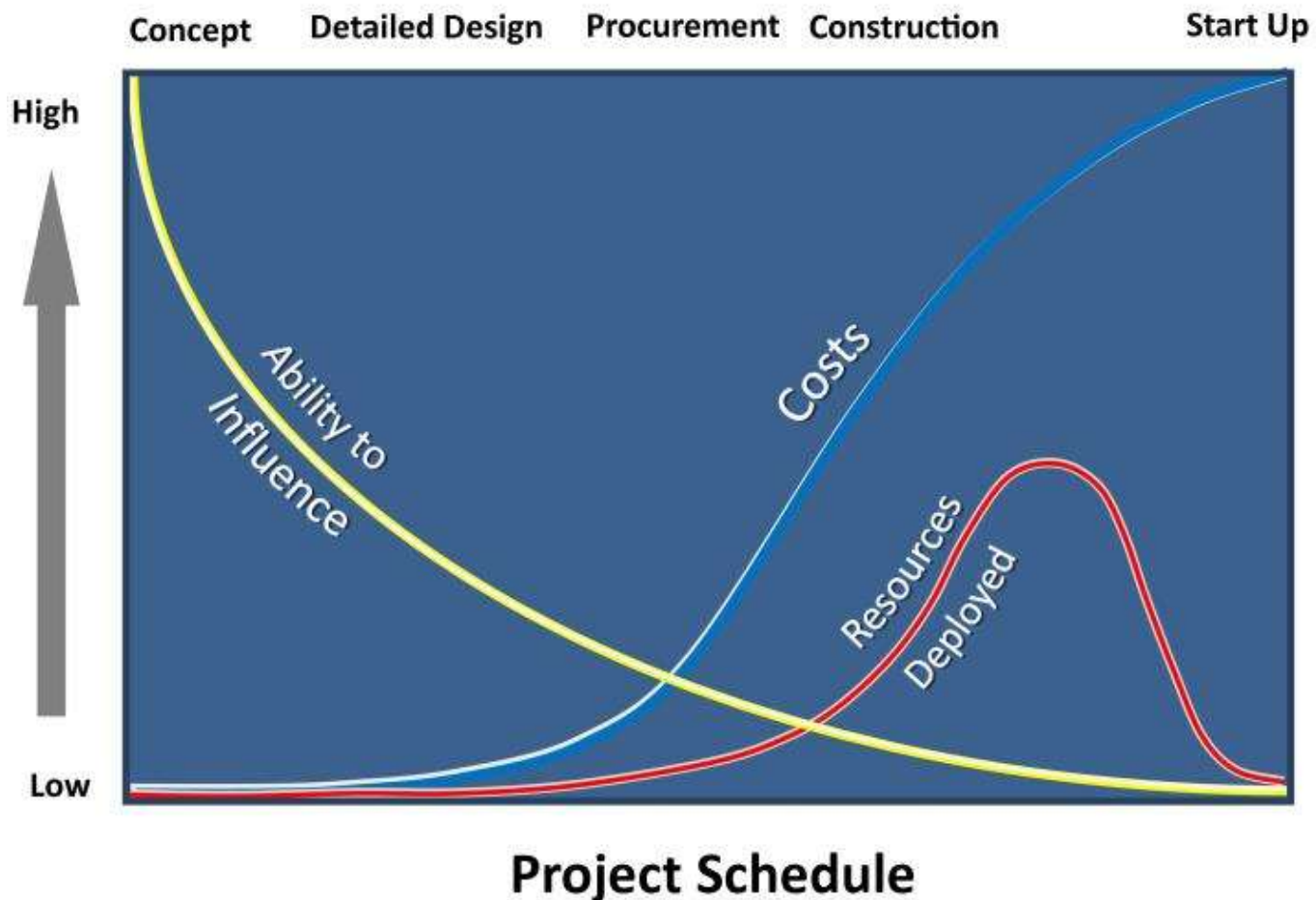
¹ Behm, M., "Linking Construction Fatalities to the Design for Constr. Safety Concept" (2005)

² European Foundation for the Improvement of Living and Working Conditions

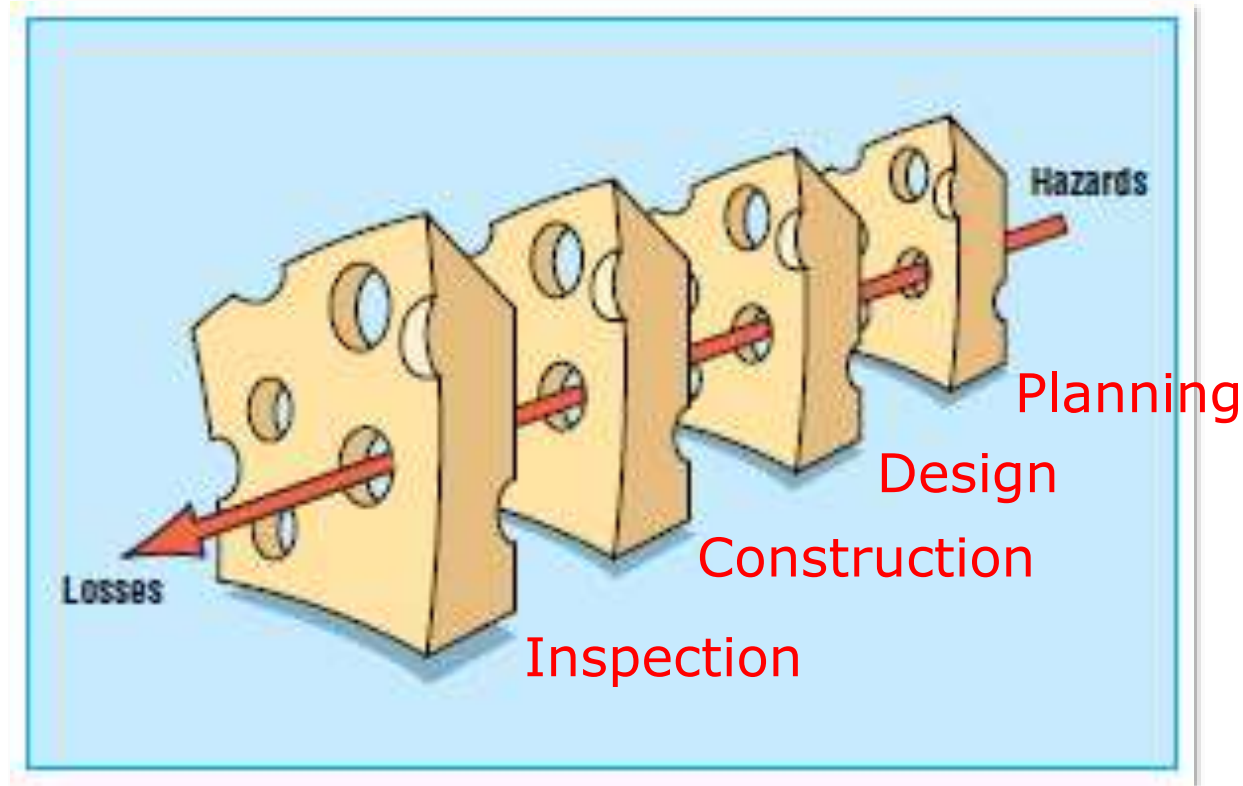
³ NSW WorkCover, *CHAIR Safety in Design Tool*, 2001

Project Impacts

- Ability to influence safety is greatest early in the project schedule during planning and design (Szymberski, 1997)



Models of Accident Causation

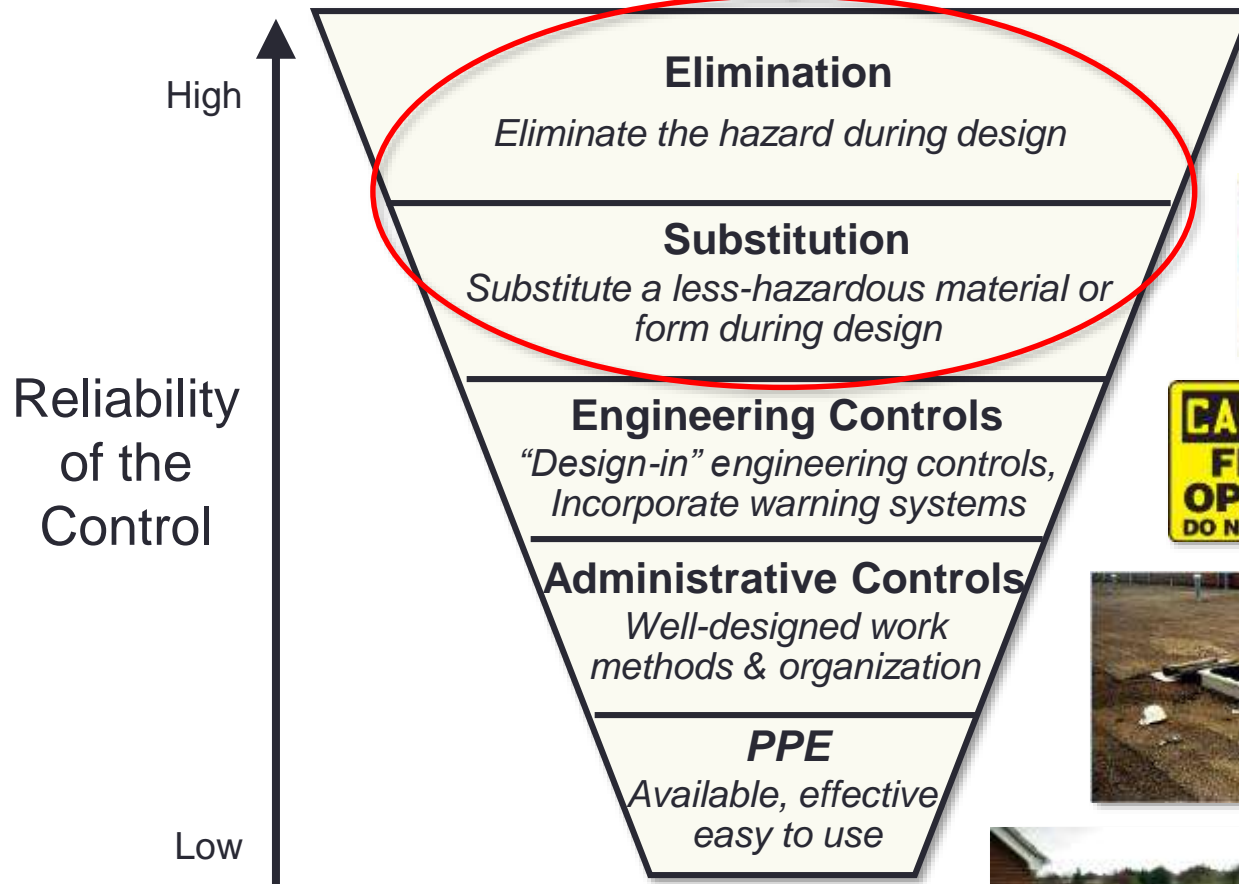


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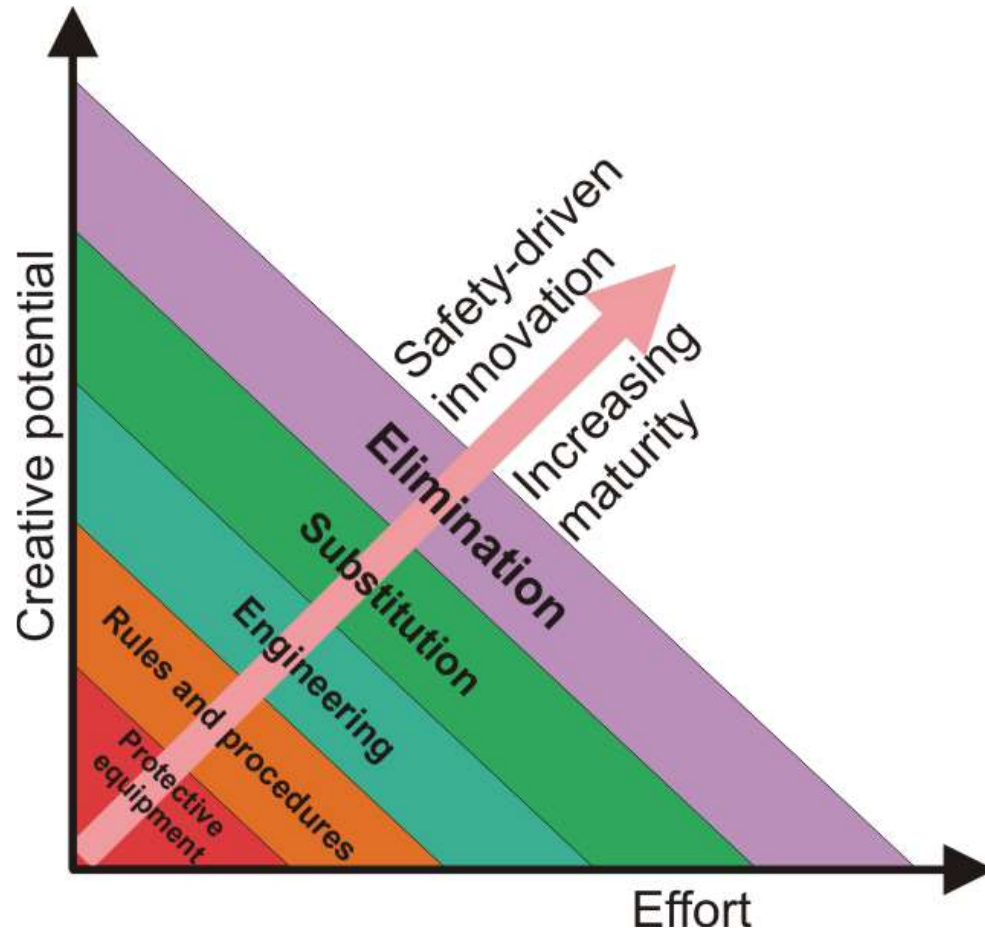
Reason, J., "Human Error: Models and Management." British Medical Journal, Vol. 320, 768-770, March 2000

Hierarchy of Controls

Prevention through Design (PtD)



A Driver of Innovation



Source: Culvenor, J. (2006). "Creating Transformational Change through Innovation in Risk Management Keynote Address: 'Creating transformational change through innovation in risk management.'" *Risk Management Research and Practice: An Educational Perspective*, Welsh Risk Pool and University of Wales, Bangor, Trearddur Bay Hotel and Conference Centre, Holyhead, Anglesey, UK, March 30-31, 2006.

Benefits of PtD Implementation

- Reduced site hazards
 - Fewer worker injuries and fatalities
- Increased productivity
- Increased quality
- Fewer delays due to accidents
- Designer-constructor collaboration
- Improved operations/maint. safety
- Reduced workers' comp. premiums
- Marketing, recognition



**SAFE
BY DESIGN**

AT SOUTHLAND, WE BELIEVE IN
PREVENTION THROUGH DESIGN.
BY INCORPORATING SPECIFIC SAFETY GUIDELINES
DURING THE DESIGN PHASE, WE HAVE PIONEERED
AN APPROACH TO SAFETY THAT BEGINS THE SECOND
OUR DESIGN ENGINEERS PUT PENCIL TO PAPER.

Focusing on safety, we take a holistic approach to your
building systems design to lessen the chance of accidents
during installation and increase ease of maintenance for
the life of your building.

As one of the nation's largest building systems experts,
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Expected Impacts

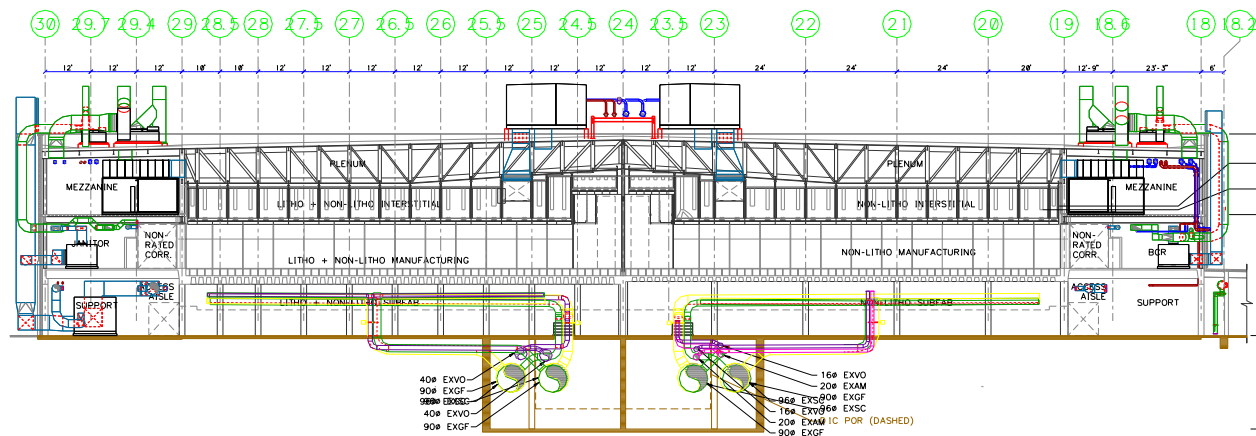
Survey of design and construction professionals in the UK:

- Change as a result of implementing PtD (% of respondents)

Item	Decrease	No Change	Increase
Design cost (n=35)	6%	46%	49%
Construction cost (n=38)	34%	24%	42%
Design duration (n=37)	8%	57%	35%
Construction duration (n=39)	38%	44%	18%
Construction quality (n=39)	8%	28%	64%
Construction worker productivity (n=30)	13%	33%	53%
Construction worker health & safety (n=45)	4%	9%	87%
End-user health and safety (n=42)	5%	10%	86%

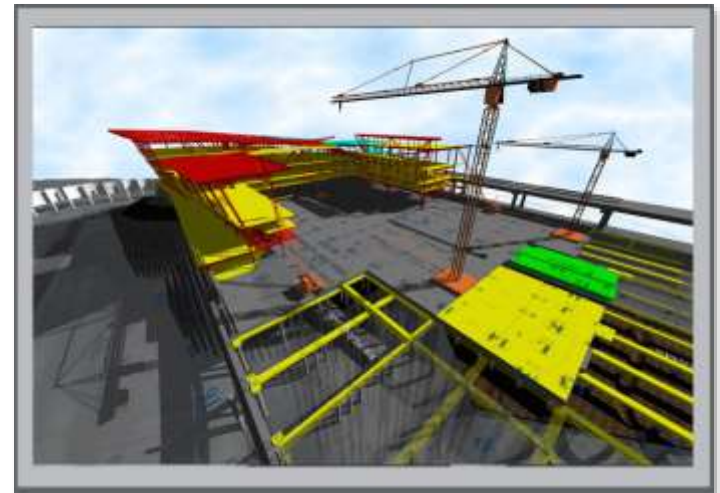
Inhibitors of PtD Implementation

- No or minimal designer education and training in safety
 - Site safety and designing for safety
- Difficult to assess risks during design
- Contractual separation of design and construction
- Cost/time required to implement PtD
- Fear of increased liability
- Competing priorities (e.g., safety vs. cost/schedule)



Enablers of PtD Implementation

- A committed owner/client
- Positive safety culture
- Design engineer experience and training
 - Construction, maintenance, and safety
- Integrated project delivery methods
- Design/construction visualization tools



PtD Initiatives

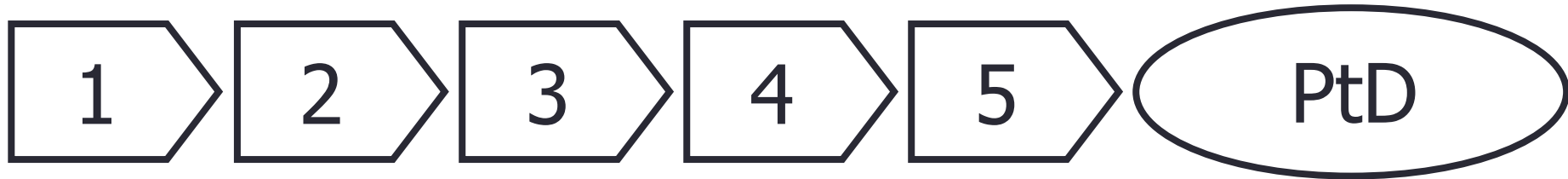
- NIOSH PtD National Initiative
- OSHA Construction Alliance Roundtable
- ANSI/ASSE PtD Standard Z590.3-2011
- U.K.: Construction (Design and Management) Regulations
- Spain: Royal Decree 1627/1997
- Singapore: Design for Safety Pledge, 2012
- Other EU countries, Australia, South Africa, and more



How can organizations implement and facilitate PtD?



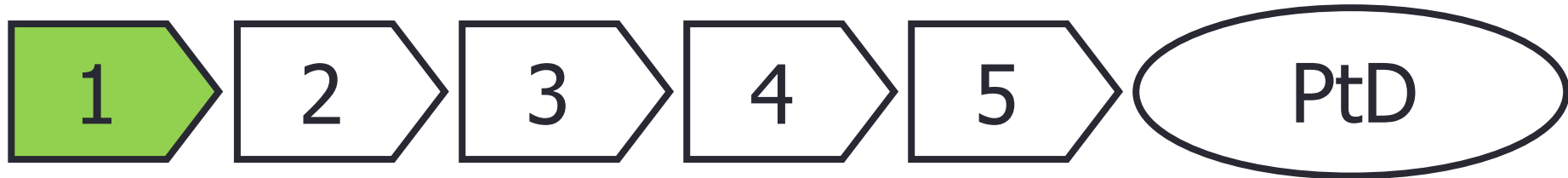
Steps to Implementing PtD in Practice



Source:

Gambatese, J.A., "Designing for Construction Safety and Health: From Research to Practice," keynote presentation. *Working Together: Planning, Designing, and Building a Healthy and Safe Construction Industry*, International Council for Research and Innovation in Building and Construction (CIB) W99 Conference, Melbourne, Australia, Oct. 21-23, 2009.

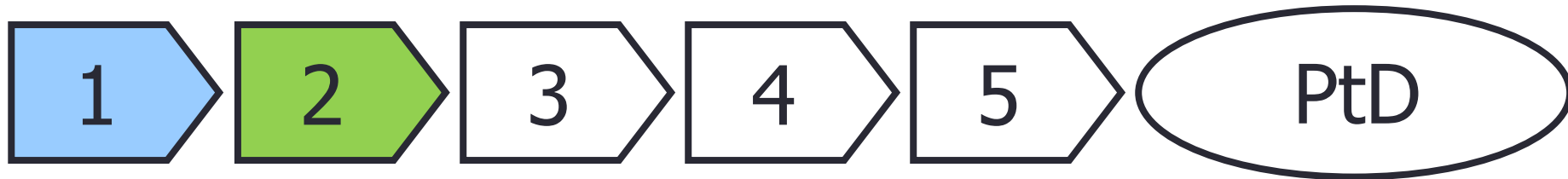
Steps to Implementing PtD in Practice



- **Education, training, and tools**

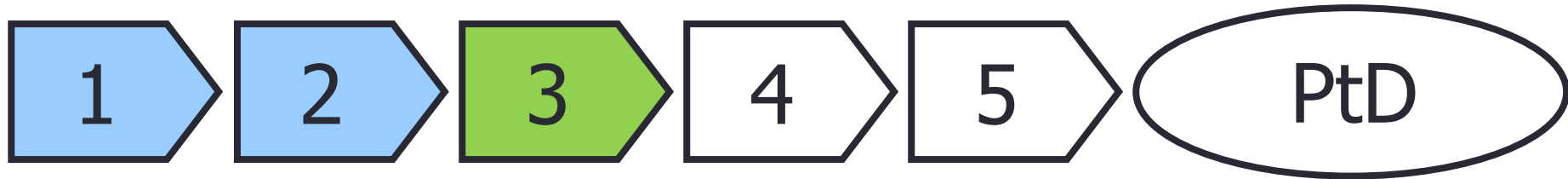
- Safety in architecture/engineering education
- Professional continuing education classes
- Safety in professional licensure requirements
- Visualization and work flow tools

Steps to Implementing PtD in Practice



- **Right place, right time, right resources**
 - Safety review in project development process
 - Integrated project delivery methods
 - Co-locating design and construction staff
 - Supported by owner/client (resources)

Steps to Implementing PtD in Practice



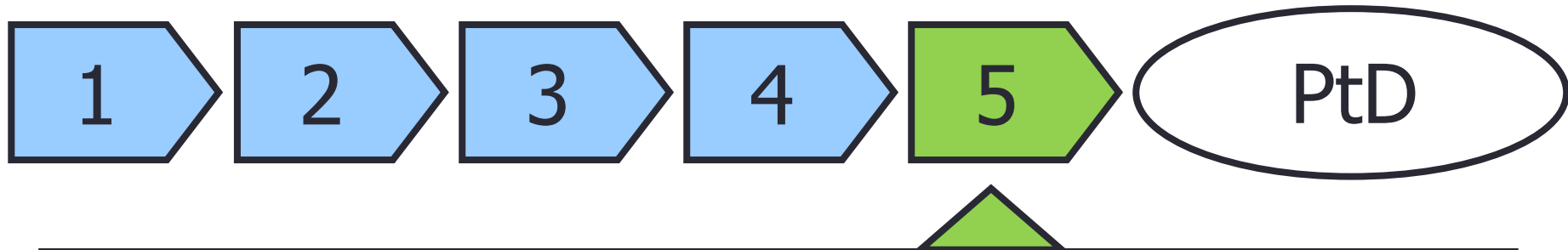
- **Safety is a design criterion**
 - Part of standard design practice
 - Incorporated into design codes
 - Contractually prescribed by owner/client
 - Required by legislation

Steps to Implementing PtD in Practice



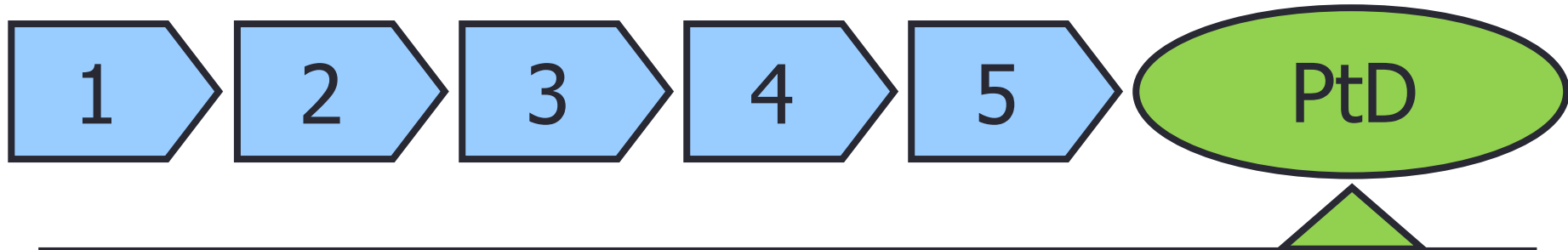
- **Safety is a high priority**
 - Authorization to modify the design for safety
 - Designing out the hazard is first choice
 - Safety and health given high priority relative to other project criteria

Steps to Implementing PtD in Practice



- **Designing for safety has value**
 - Lifecycle savings outweigh costs, and economically feasible for designers
 - Improvements in safety, quality, productivity
 - Morally/ethically responsible
 - Desired by owners/clients (priority)

Steps to Implementing PtD in Practice

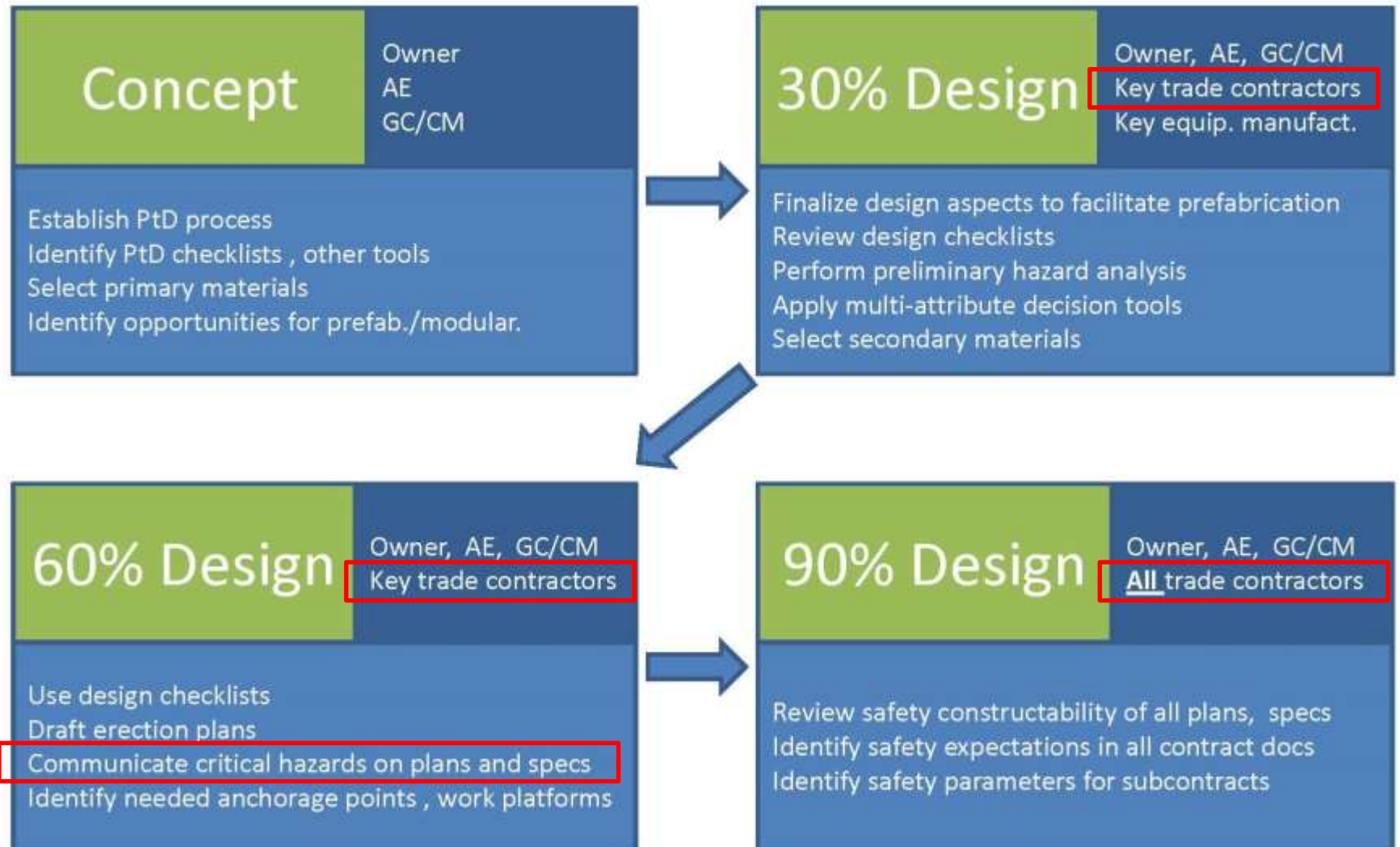


- **Designed for construction safety and health**
 - Construction site hazards eliminated/reduced
 - Improvements in safety, quality, productivity
 - Improvements in maintenance safety
 - Design and construction integration and collaboration

What PtD processes and tools have been developed?

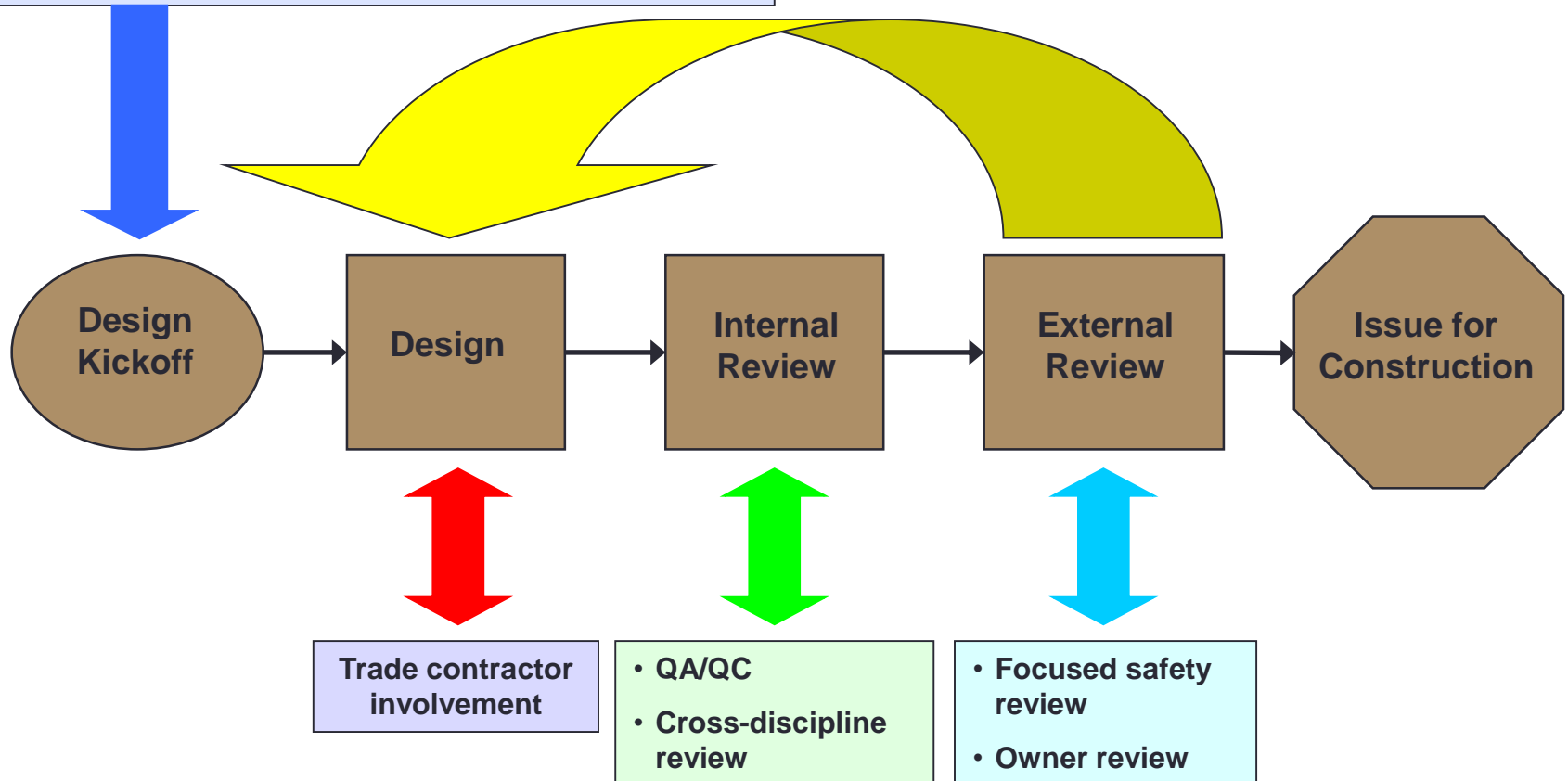


Planning and Design Process



Design Development

- Establish design for safety expectations
- Include construction and operation perspective
- Identify design for safety process and tools



Example PtD Program

- The Haskell Co.: “Safety Alert System” (SAS)
- Designer safety education, training, awareness
- Safety reviews during design
 - All disciplines
 - Identify hazards
 - Incorporate safety suggestions into design
- Safety symbols on design drawings
 - Alert constructors to safety hazards
 - Include reference to related OSHA standards



Example: BHP Billiton PtD Initiative

- PtD staff embedded in procurement and design
- Communication and training
- PtD in technical specifications

The collage illustrates the BHP Billiton PtD initiative through various materials:

- List of Courses:** A webpage titled "FORWARD SAFETY" showing a list of courses. The table below summarizes the data from the screenshot:

Course Title	Module	Duration	Start Date	End Date	Location
HSE in Design Module 1 (Version 1.0)	Introduction	1	01-01-2009	01-01-2009	01-01-2009
HSE in Design Module 2 (Version 1.0)	Introduction	1	01-01-2009	01-01-2009	01-01-2009
HSE in Design Module 3 (Version 1.0)	Introduction	1	01-01-2009	01-01-2009	01-01-2009
HSE in Design Module 4 (Version 1.0)	Introduction	1	01-01-2009	01-01-2009	01-01-2009
HSE in Design Module 5 (Version 1.0)	Introduction	1	01-01-2009	01-01-2009	01-01-2009
HSE in Design Module 6 (Version 1.0)	Introduction	1	01-01-2009	01-01-2009	01-01-2009
HSE in Design Module 7 (Version 1.0)	Introduction	1	01-01-2009	01-01-2009	01-01-2009
HSE in Design Module 8 (Version 1.0)	Introduction	1	01-01-2009	01-01-2009	01-01-2009
HSE in Design Module 9 (Version 1.0)	Introduction	1	01-01-2009	01-01-2009	01-01-2009
HSE in Design Module 10 (Version 1.0)	Introduction	1	01-01-2009	01-01-2009	01-01-2009

- Prevention through Design Module 1:** A browser window showing the training interface for "Prevention through Design Module 1 (Version 1.0)".
- Prevention through Design Poster:** A detailed poster titled "Prevention through Design" by BHP Billiton. It includes a definition of PtD, a flowchart of the PtD process, and various diagrams illustrating the application of PtD in different stages of design.
- POTASH CANADA'S PREVENTION THROUGH DESIGN LEARNING PROGRAMME:** A screenshot of the learning programme interface, showing "Module 1: Understanding HSE in Design" with buttons for "Course Introduction", "Module 1 Overview", and "Learning Objectives".
- Prevention Through Design Quick Reference Guide:** A physical copy of the guide, showing the BHP Billiton logo and the title "Prevention Through Design Quick Reference Guide".

Courtesy of BHP Billiton

PtD Tools: Design Risk Assessment

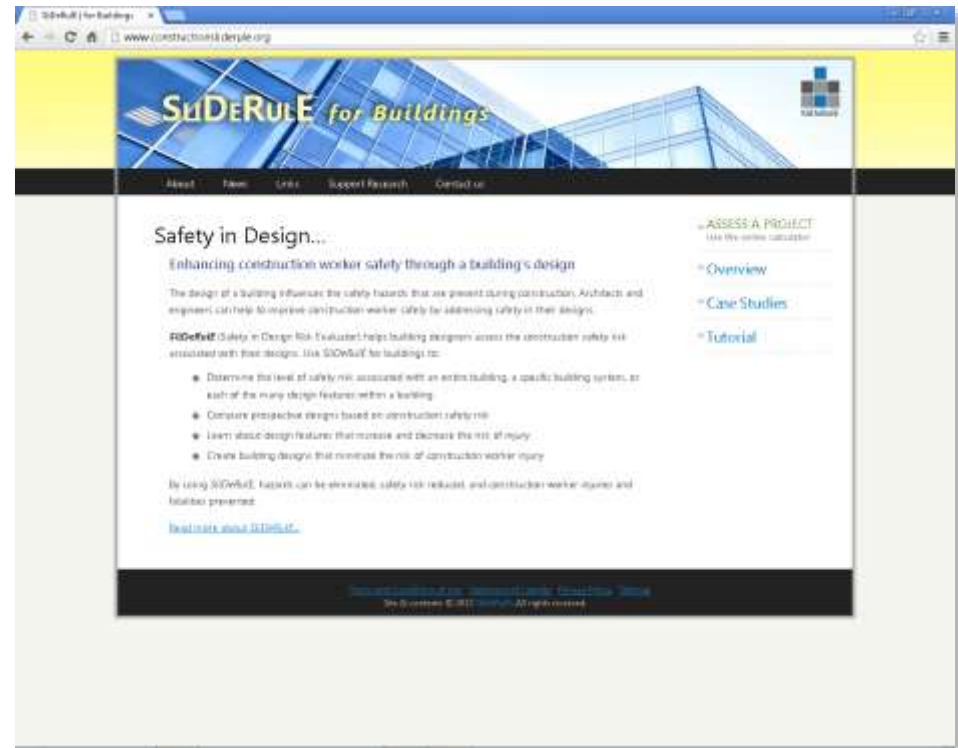
Which is safer to build? How much safer?



Steel-framed building



Concrete-framed building



www.constructionsliderule.org

What does a safe design look like in practice?



PtD Example: Steel Design

- Bechtel's steel design process
- PtD elements:
 - Temporary access platforms
 - Lifting lugs
 - Shop installed vertical brace ladders
 - Bolt-on column ladders and work platforms



Graphic courtesy of Bechtel Corp.

PtD Example: Steel Design



Temporary ladder,
platform, and safety line



Photos courtesy of Bechtel Corp.

PtD Example: Steel Design



Modular platforms



Photos courtesy of Bechtel Corp.

PtD Example: Steel Design



Brace lifting clips and rungs



Photos courtesy of Bechtel Corp.

PtD Example: Anchorage Points



Roof anchors

Panel and guardrail
anchor points



PtD Example: Roofs and Perimeters

Skylights



Upper story
windows

Parapet walls



PtD Example: Walking Surfaces

- Walkable ceiling space to allow worker access



PtD Example: Prefabrication



Steel
stairs

Concrete
wall
panels



Concrete
segmented
bridge

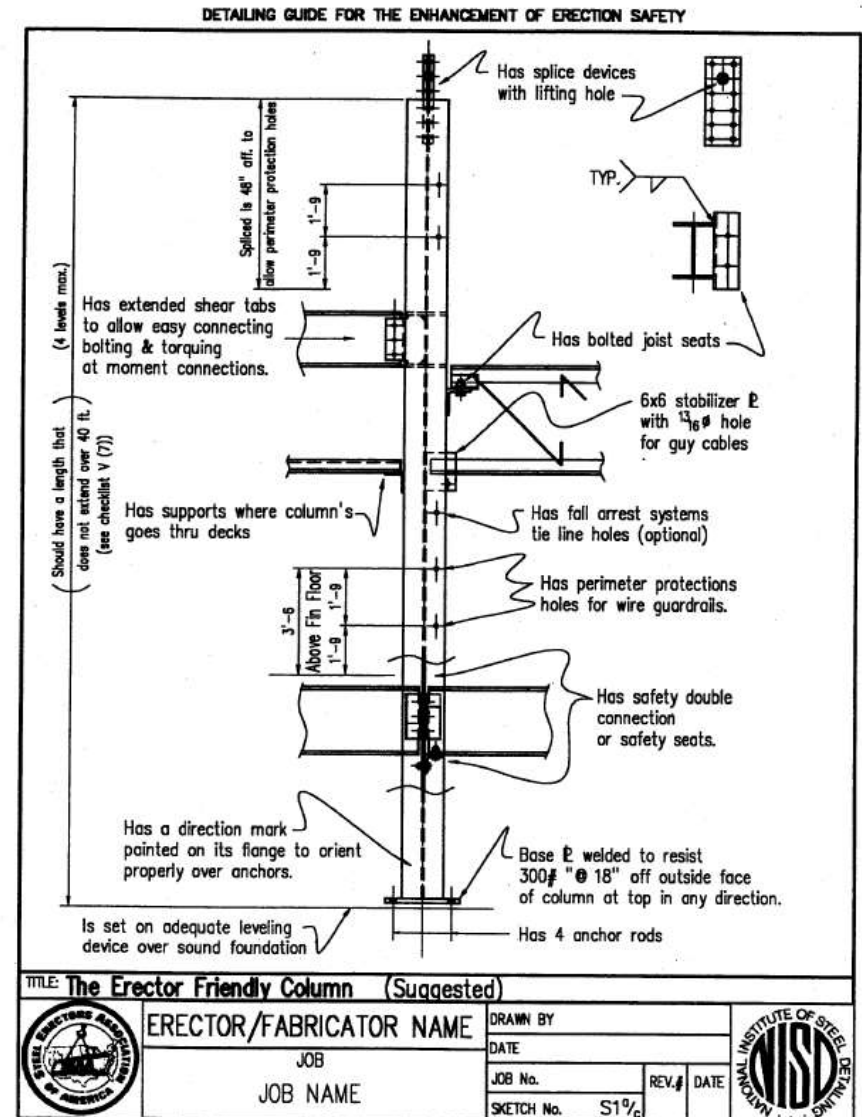
PtD Example: Modularization

- Modular service risers



PtD Example: The Erector Friendly Column

- National Institute of Steel Detailers (NISD) and Steel Erectors Association of America



PtD Example: The Erector Friendly Column

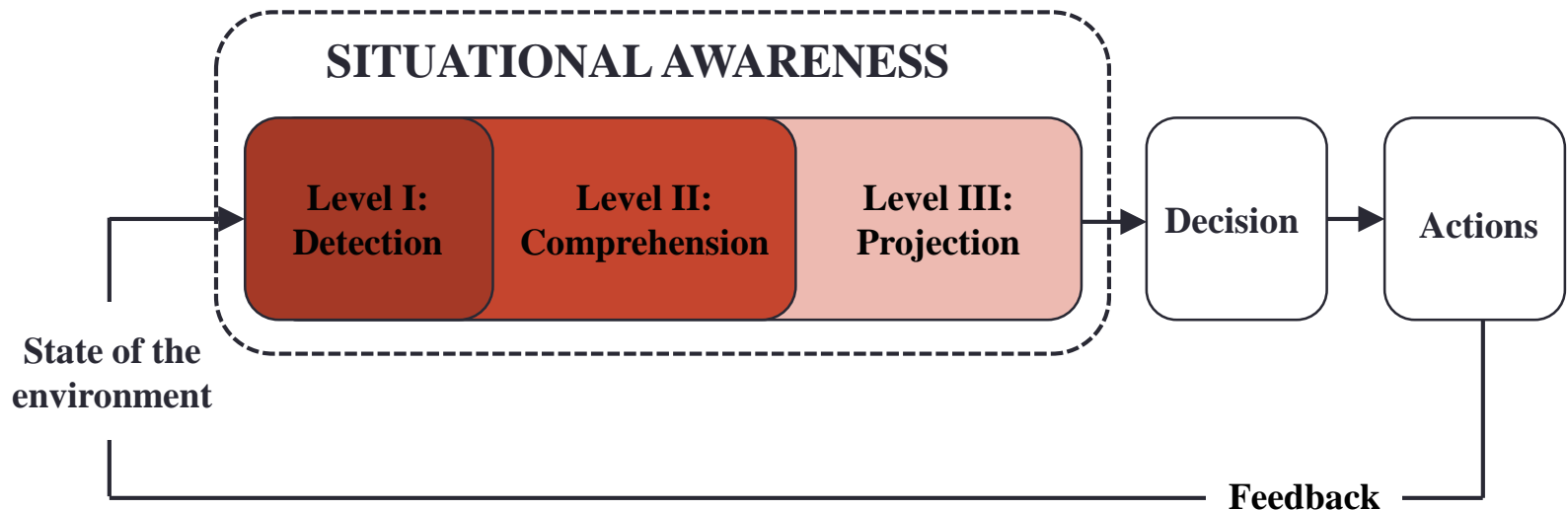
- Holes in columns at 21" and 42" for guardrail cables
- Column splices and connections at reasonable heights above floor
- Seats for beam connections



How to conduct a safety in design review?



Situational Awareness



Sources:

Artman, H. (2000). "Team Situation Assessment and Information Distribution." *Ergonomics*, 43(8), 1111-1128.

Hallowell, M. (2013). "Human Factors Engineering: Situational Awareness and Signal Detection Theory."

Situational Awareness[^] *for Safety in Design*

1. Hazard identification

- What work conditions does the design create?
- Which of the work conditions creates a safety hazard?

Guidewords

Degrees of Connectivity

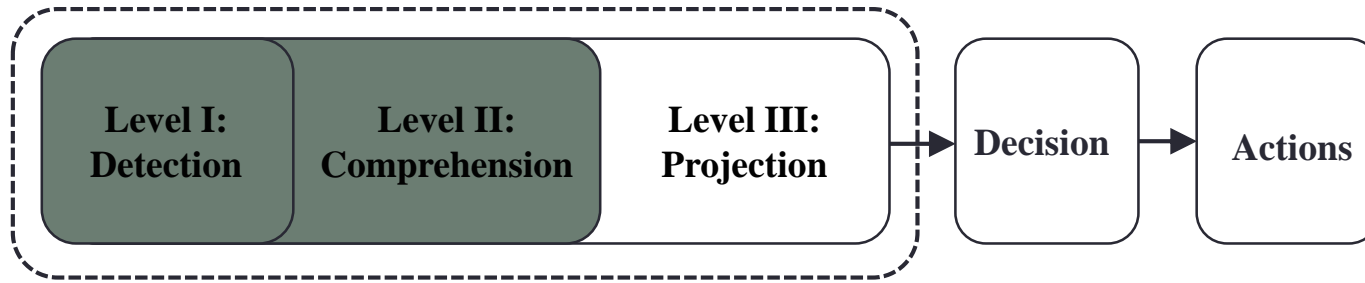
2. Risk assessment

- What is the level of safety and health risk associated with each hazard?

3. Alternative identification, valuation, and selection

- What can be done to the design to eliminate or reduce the hazards?
- How much risk is mitigated? How reliable is the alternative?
- Which alternative should be selected?

Hierarchy of Controls



1. Hazard identification

- What work conditions does the design create?

Guidewords

Design Review Guidewords

- **Dimensions**
 - Size, weight, height, depth, shape, clearance
- **Actions/Interactions**
 - Access, support, sequence, placement, connection
- **Position**
 - Orientation, location
- **Surroundings/Exposures**
 - Perimeters, openings, surfaces (coatings), obstructions
- **Design-Human Interface**
 - Poka-yoke (mistake-proofing), buffers
- **System Performance**
 - Reliability, redundancy, resiliency

Dimensions: Size and Weight



Dimensions: Shape



Source: “Detailing Guide for the Enhancement of Erection Safety,” National Institute for Steel Detailing and the Steel Erectors Association of America.

DETAILING GUIDE FOR THE ENHANCEMENT OF ERECTION SAFETY

Problem: Dangerous corners can snag clothes or puncture skin in field or shop.

Solutions: Could be to clip gussets corner **Or:** Hide the gusset corner within the bracing depth

TITLE: Puncture / Snagging Hazards

	ERECTOR/FABRICATOR NAME		DRAWN BY	
	JOB		DATE	
	JOB NAME		JOB No.	REV.#
			SKETCH No.	DATE

S4 %_b

Dimensions: Clearance



Photos courtesy of URS/Washington Division

Actions: Access



Actions: Access



Actions: Access

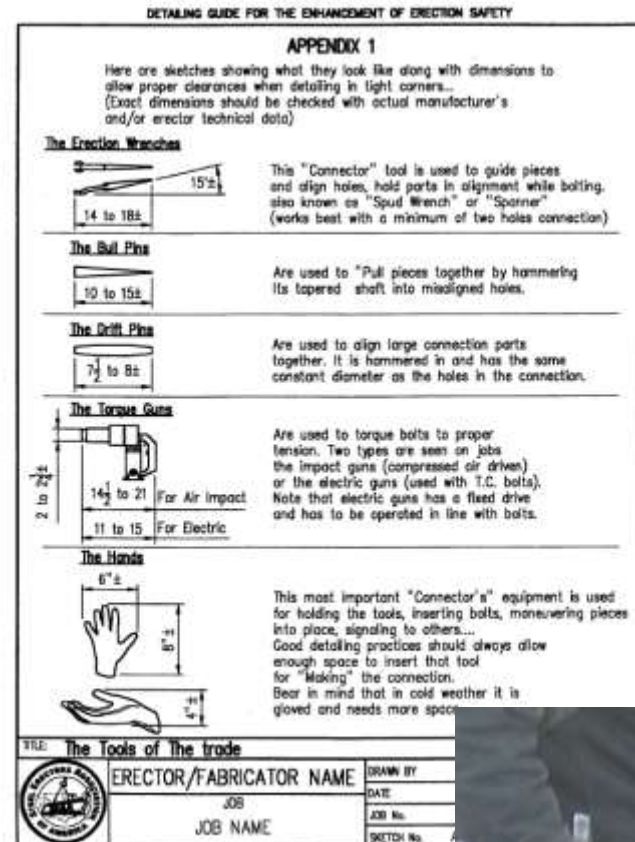
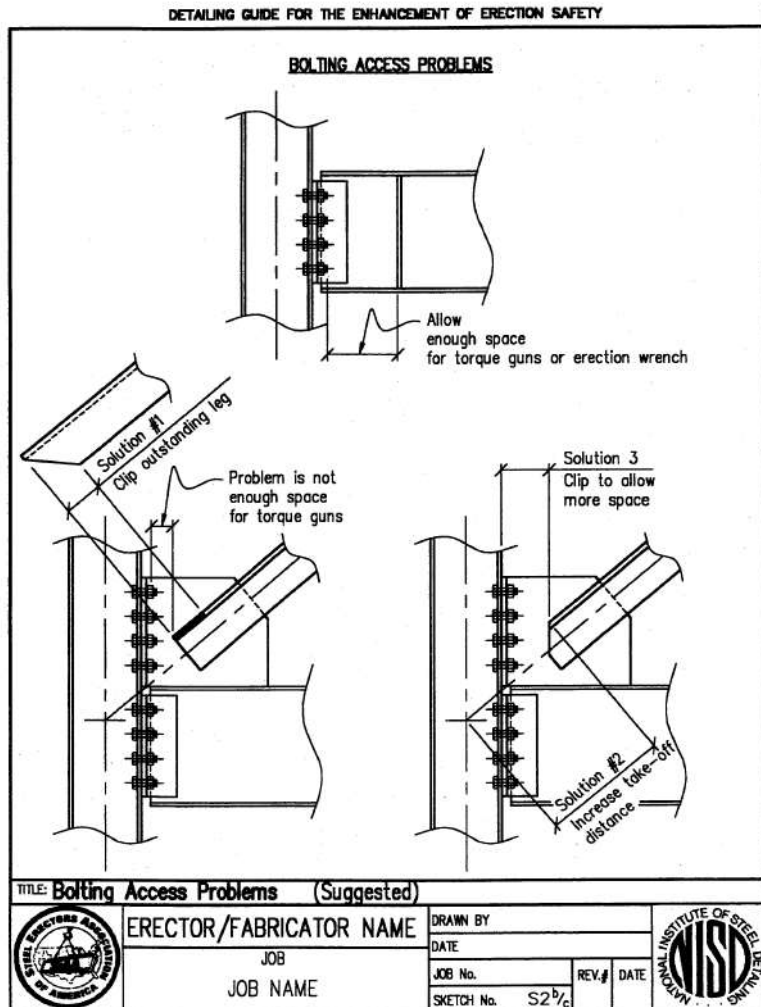


Photo: AISC educator ppt

Actions: Support



DETAILING GUIDE FOR THE ENHANCEMENT OF ERECTION SAFETY

SELF-SUPPORT CONNECTIONS
(Bear On Instead Of Hang From)

AVOID (Hang)

DO (Bear on) (Opt #1)

Choker

Allows quicker release and safer erection (N/S flange not shown for clarity)

DO (Bear on) (Opt #2)

TITLE: Self Support Connections (Suggested)

	ERECTOR/FABRICATOR NAME	DRAWN BY	
	JOB	DATE	
	JOB NAME	JOB No.	REV.#
	SKETCH No.	S5%	DATE

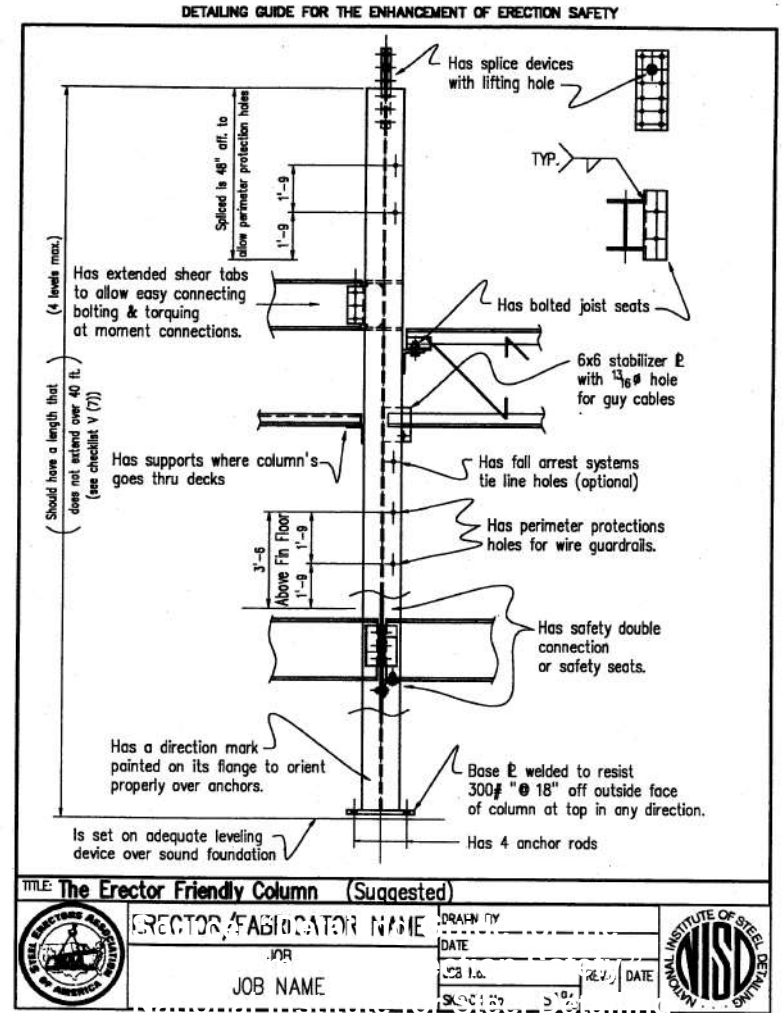
Actions: Connection

- The Erector Friendly Column

- Holes at 21" and 42" above floor levels for guardrail cables, and at higher locations for fall protection tie-offs
- Column splices and connections at reasonable heights above floor
- Seats for beam connections



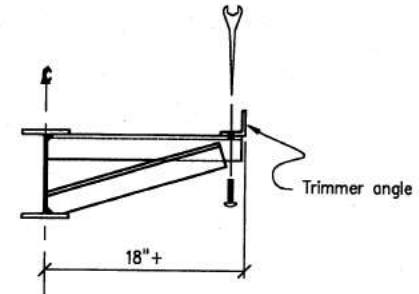
Photo: AISC educator ppt



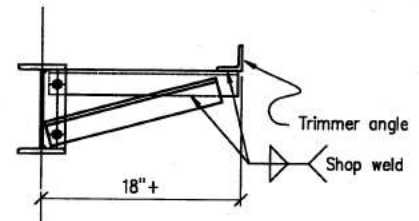
Position: Orientation



DETAILING GUIDE FOR THE ENHANCEMENT OF ERECTION SAFETY



Problem: Bolting or welding at this location forces connector or welder to hang his body weight out of position.



Solution: Could be to shop weld trimmer angle with bracket angles and field bolt to a tab plate or stiffener where the connector does not have to "Hang Out" to make connection.

TITLE: Out Of Position Bolting / Welding



ERECTOR/FABRICATOR NAME

JOB

JOB NAME

DRAWN BY

DATE

JOB No.

SKETCH No. SB

REV.#

DATE



Position: Location



Position: Ergonomics



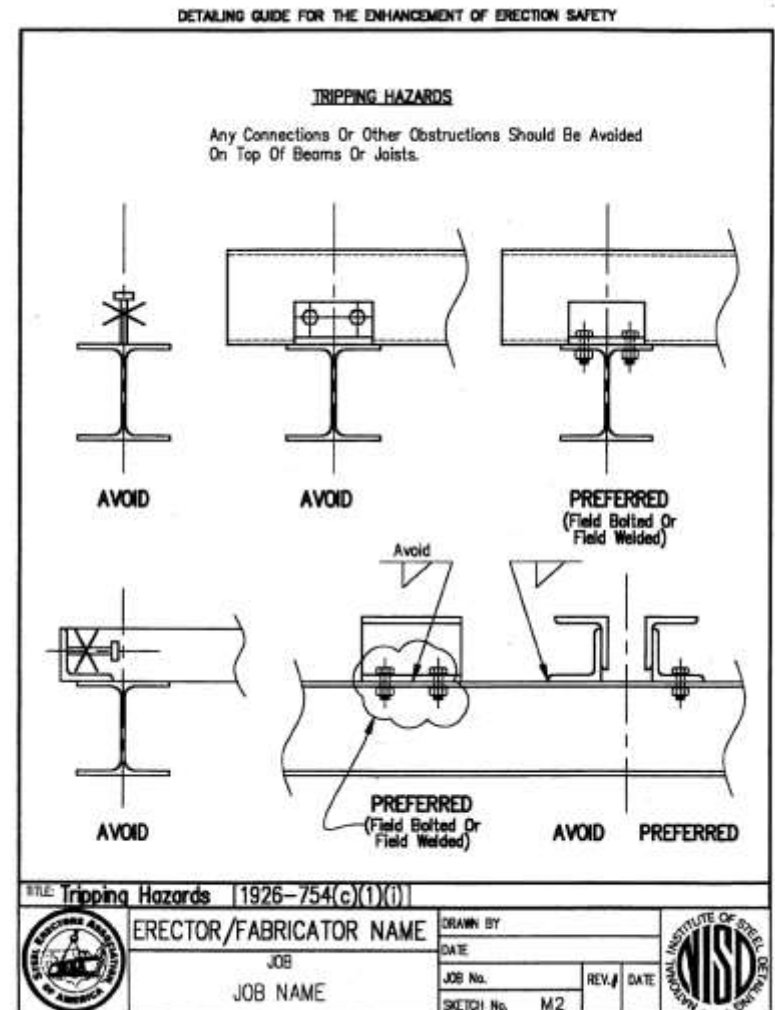
Surroundings: Perimeters



Surroundings: Openings



Surroundings: Surfaces/Obstructions



Exposures: Coatings

- Non-isocyanate
- Low volatile organic compounds (VOC)



Design-Human Interface: Poka-yoke



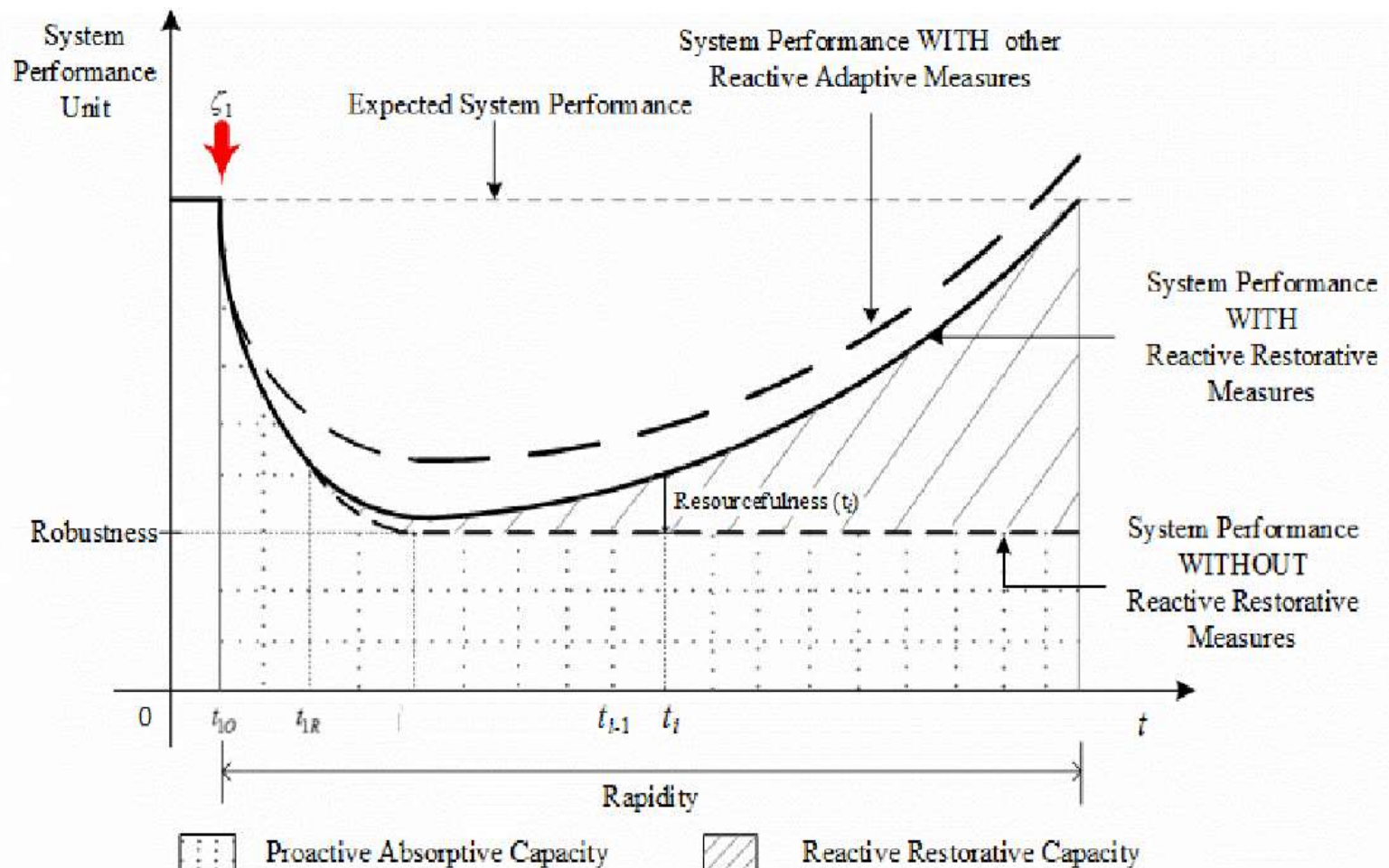
Design-Human Interface: Buffers

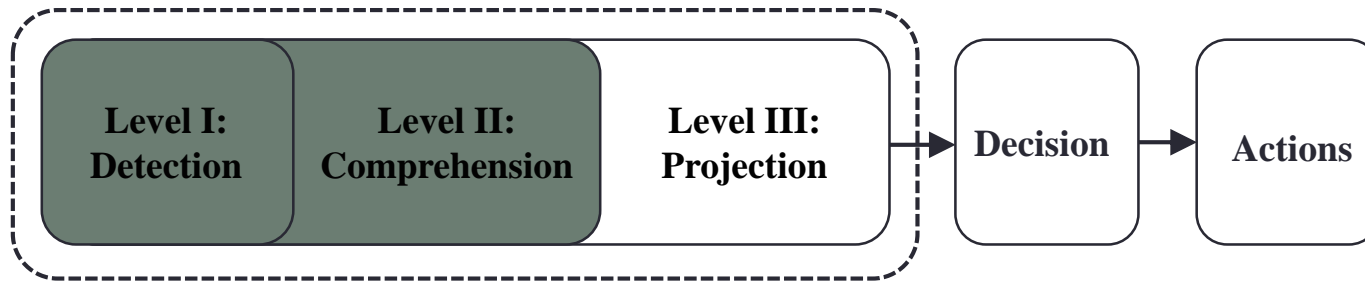


System Performance: Reliability



System Performance: Resiliency



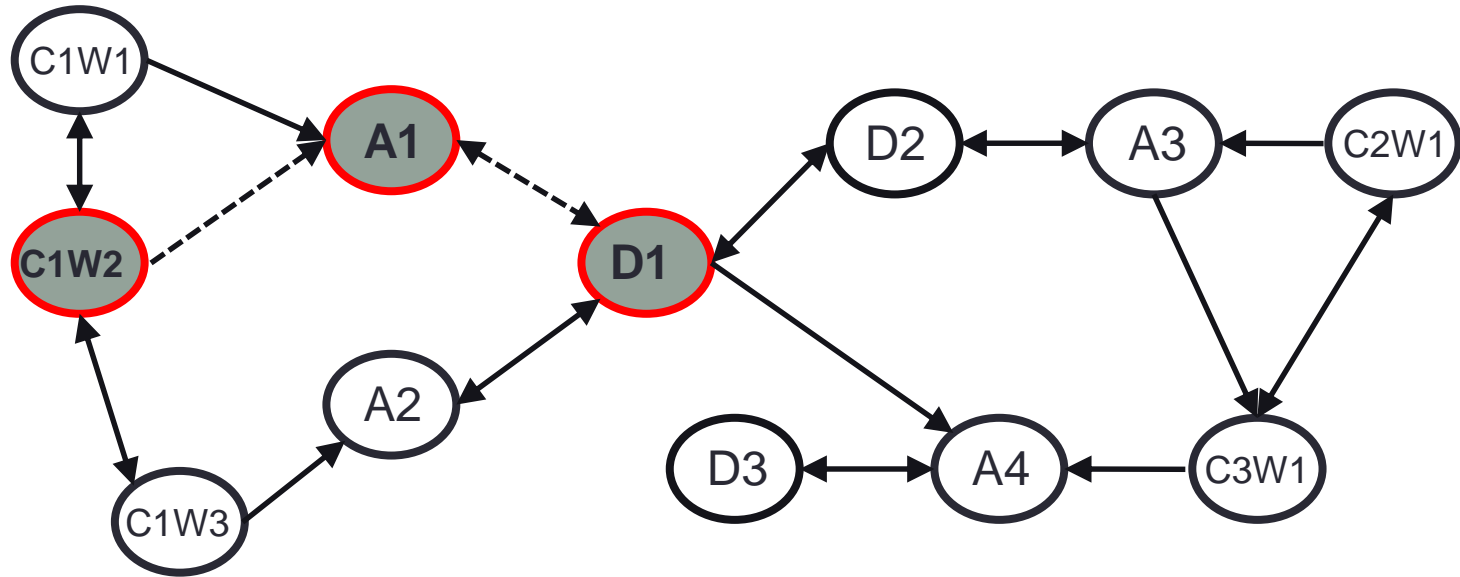


1. Hazard identification

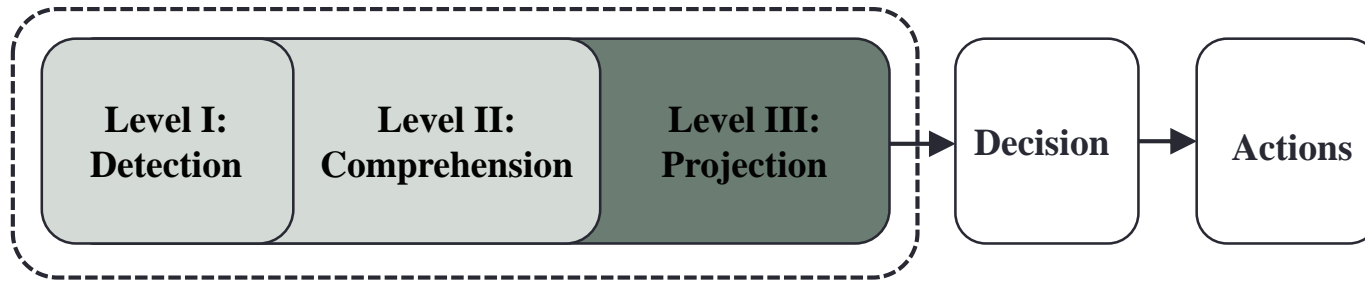
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Degrees of Connectivity

Degrees of Connectivity



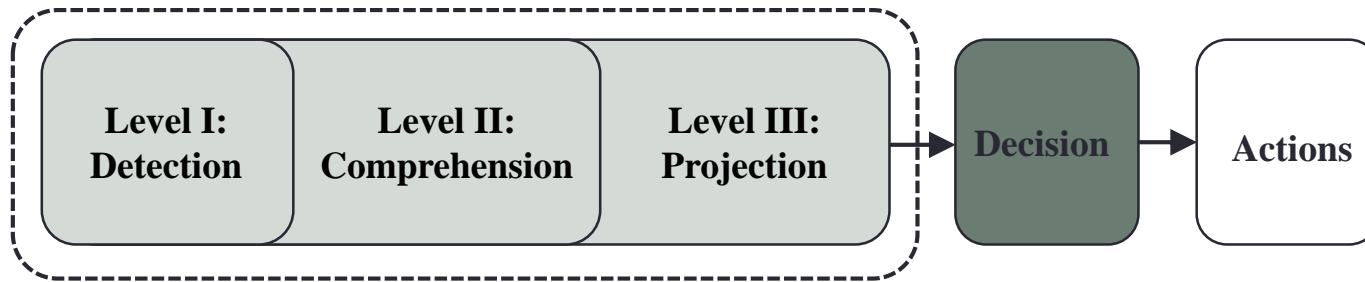
D = Design element A = Activity C = Crew W = Worker



2. Risk Assessment

- What is the level of safety and health risk associated with each hazard?

$$Risk = Frequency * Severity * Exposure$$



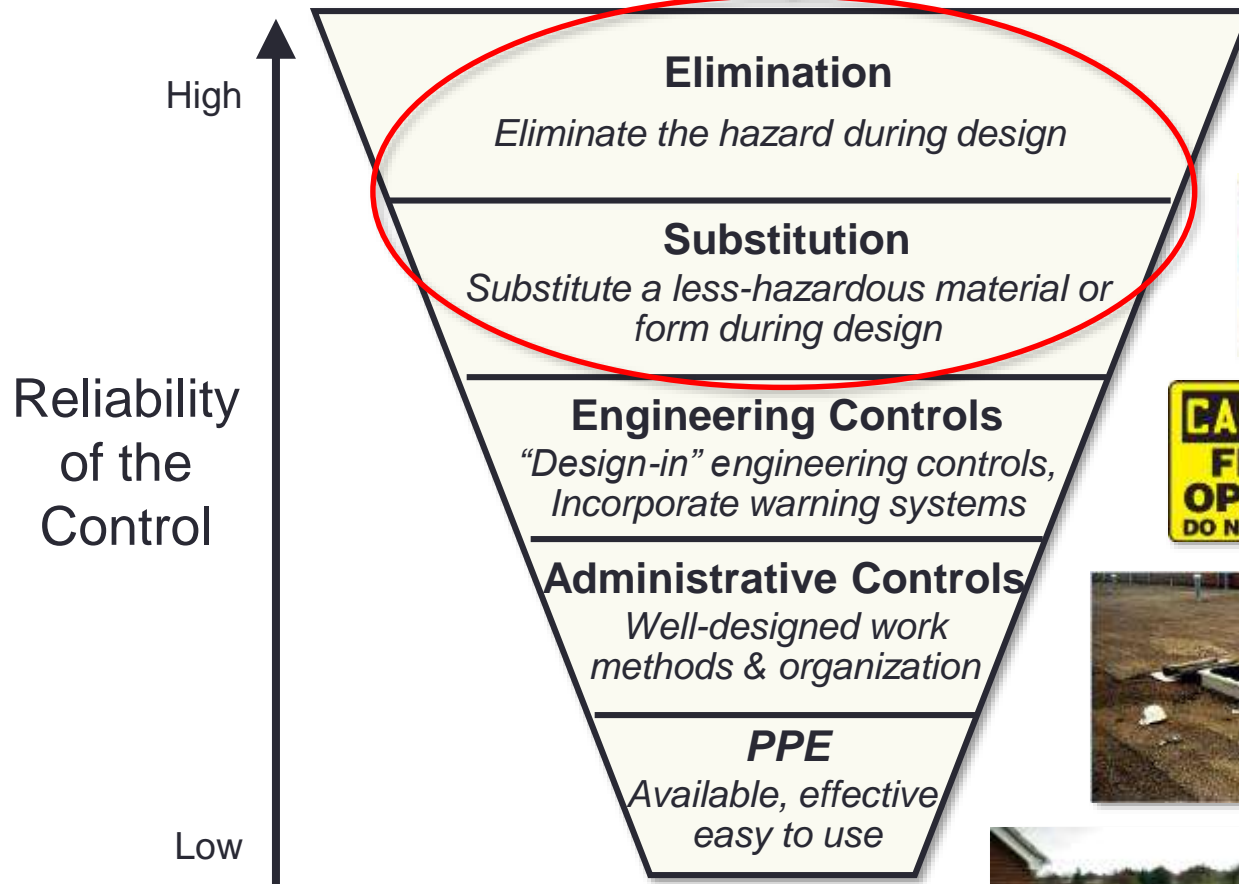
3. Alternative identification, valuation, and selection

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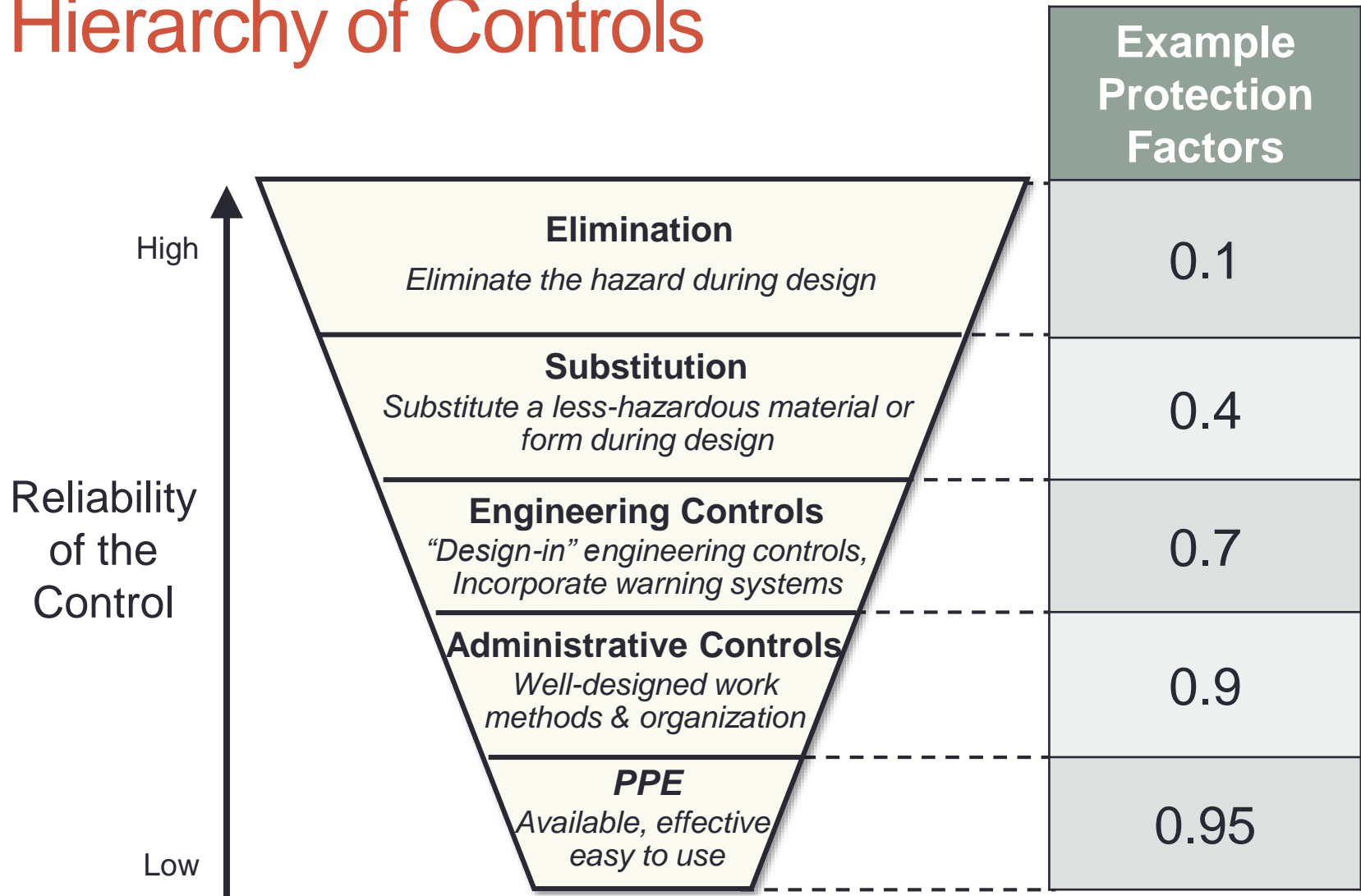
Hierarchy of Controls

Hierarchy of Controls

Prevention through Design (PtD)

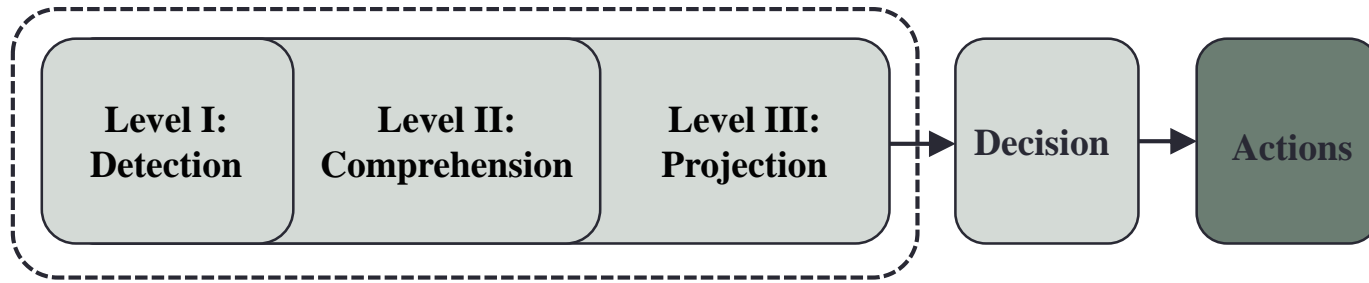


Hierarchy of Controls



Protection factors source:

Popov, G., Lyon, B.K., and Hollcroft B. (2016). "Risk Assessment: A Practical Guide to Assessing Operational Risks." John Wiley & Sons, Hoboken, NJ, pg. 83.



4. Select an alternative

5. Implement the selected alternative

Designing for Safety in Construction and throughout the Facility Lifecycle

- Questions? Comments?
- For more information...
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This concludes The American Institute of Architects
Continuing Education Systems Course

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