PtD Research: Why Implement Prevention through Design?

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Prevention through Design Workshop
March 11 of 2020, Tempe, AZ

NIOSH Award #1 R13OH011707-01-00

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Outline

- The Importance of Design
- Research: Connecting Design to Safety
- Research: Identification of Practice Impediments
- Research: Development of Supporting Tools and Resources

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The Importance of Design

- Design is a powerful ability.



The Importance of Design

- Good design demands attention.

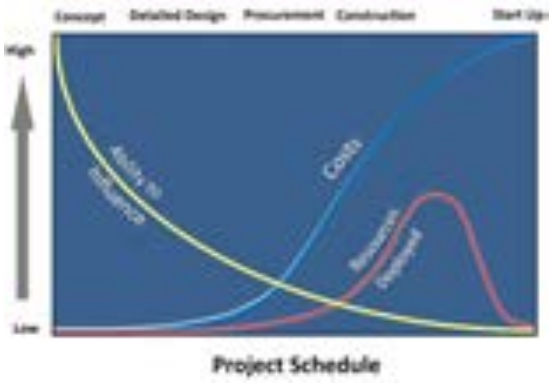
"Things alter for the wrong spontaneously, if they be not altered for the better designedly."

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



The Importance of Design

The ability to influence safety is greatest early in the project schedule during planning and design. (Szymberski, 1997)



Szymberski, R. (1997). "Construction project safety planning." *TAPPI Journal*, 80(11): 69-74.

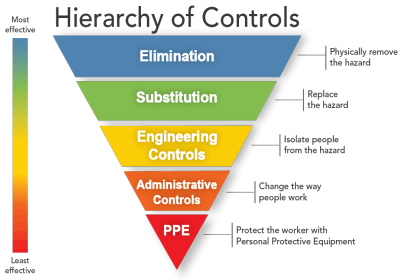
The Importance of Design to Safety

An academic argument for PtD:

1. We create designs.
2. Designs impact safety.
3. Therefore, we impact safety through designs.

Makes sense, but…… Is there objective data that confirms the impact?

Yes, but……
Are there impediments in design practice and/or culture that prevent PtD implementation?



Research Focus

- What are we designing and whose safety are we considering.

Design of what?	Safety of who?		
	Constructor	End User / Operator	Maintainer
Permanent facility		✓	
Permanent equipment		✓	
Temporary construction structures	✓	*N/A*	*N/A*
Construction equipment	✓	*N/A*	*N/A*
Construction process	✓	*N/A*	*N/A*
Other…			

The focus of greatest interest, concern, and research in construction

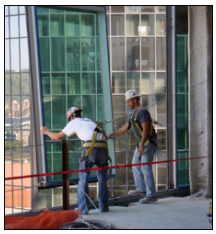
Impact of Design on Safety

22% of 226 injuries that occurred from 2000-2002 in Oregon, WA, and CA related to design[1]

42% of 224 fatalities in US between 1990-2003 related to design[1]

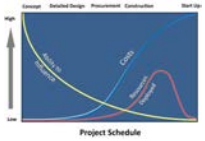
Changes in the design of the permanent structure could have reduced the likelihood of 47% of construction site incidents[2]

60% of fatal accidents resulted in part from decisions made before site work began[3]



[1] Behm, M., "Linking Construction Fatalities to the Design for Constr. Safety Concept" (2005)
[2] Gibb et al. (2004). "The Role of Design in Accident Causality."
[3] Lorent, P. (1987). European Foundation for the Improvement of Living and Working Conditions

Impact of Design on Safety



- Is the time-safety curve correct?
- Evaluation using Sustainable Construction Safety and Health (SCSH) rating system
  - Comparison of SCSH credits earned and TRIR
- Analysis: [Poisson, a.k.a., log-linear, regression]
  - Influence of safety input (explanatory variable) on the incident rate (response variable) after accounting for project phase in which the safety input is implemented

Karakhan, A., Rajendran, S., and Gambatese, J. (2018). "Validation of Time-Safety Influence Curve Using Empirical Safety and Injury Data." In *Proceedings of the Construction Research Congress 2018*, ASCE, New Orleans, LA, April 2-4, 2018.

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Impact of Design on Safety

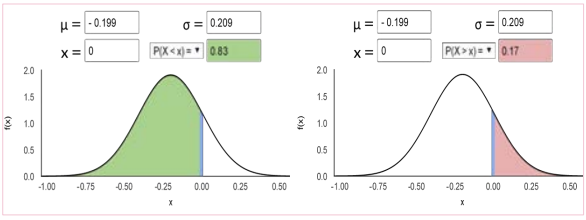
Phases when safety input is provided:
- Design (DE)
- Procurement (PRO)
- Construction (CON)

SCSH and TRIR data from 64 project built from 2006-2016

Offset-Poisson Regression Output

Variable	β	SE	z-stat.	p-value	95% CI	Significance	
						Statistical	Practical
Constant	4.473	1.022	4.62	0.000	2.72 to 6.73	✓	—
DE	− 0.125	0.020	− 6.16	0.000	-0.16 to -0.09	✓	✓
PRO	− 0.199	0.209	− 0.95	0.342	-0.61 to 0.21	—	✓
CON	− 0.054	0.020	− 2.63	0.008	-0.09 to -0.01	✓	✓
PRO:CON	0.004	0.004	1.03	0.302	-0.01 to 0.01	—	—

83% LIKELIHOOD TO REDUCE INCIDENT RATES



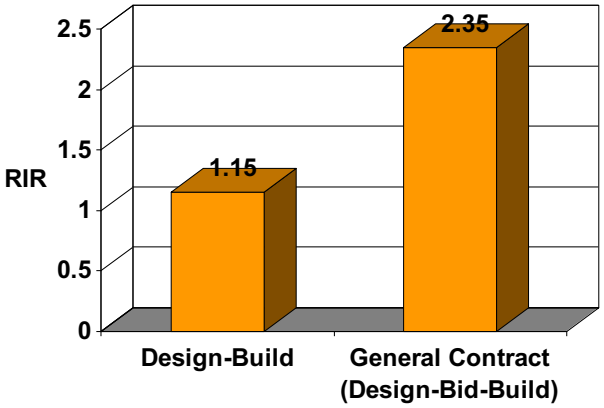
17% LIKELIHOOD TO INCREASE INCIDENT RATES

Karakhan, A., Rajendran, S., and Gambatese, J. (2018). "Validation of Time-Safety Influence Curve Using Empirical Safety and Injury Data." In *Proceedings of the Construction Research Congress 2018*, ASCE, New Orleans, LA, April 2-4, 2018.

Impact of Design on Safety

Recordable Injury Rate (RIR)

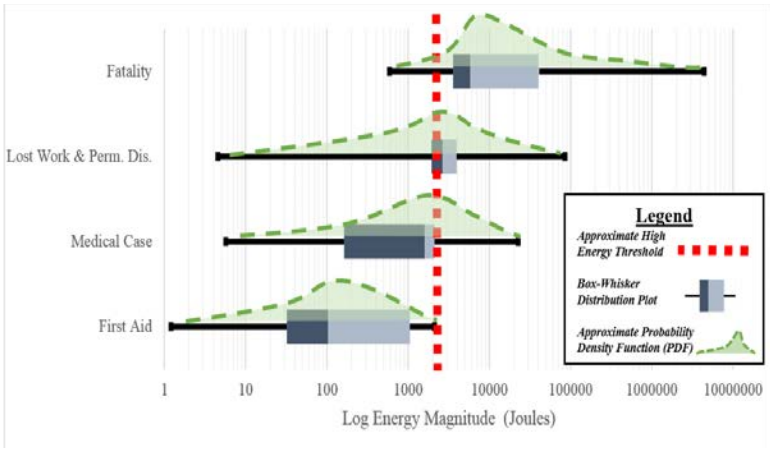
- Number of OSHA recordable injuries per 200,000 worker hours



Hinze, J. (2003). "The Owner's Role in Construction Safety." CII RS-190-1, March 2003.

Impact of Design on Safety

- Physical energy and injury severity



Graphic source: CII, RT-321, Precursor Analysis.

Impact of Design on Safety

Design elements that prohibit workers from using conventional tools can lead to:

- Risk-taking
- Risk discounting

Shimmin, S., Corbett, J., and McHugh, D. (1980). "Human Behavior: Some Aspects of Risk-taking in the Construction Industry." Inst. of Civil Eng. (ICE), London, 13-22.

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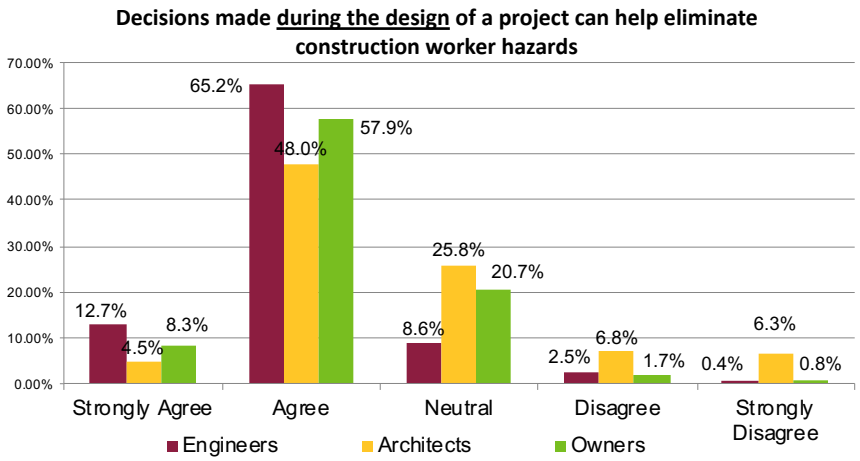
Impact of Design on Safety

Perspectives of the impact of design decisions on safety by:

- Engineers (n = 244)
- Architects (n = 221)
- Owners (n = 121)



Tymvios, N. and Gambatese, J.A. (2016). "Perceptions about design for construction worker safety: Viewpoints from contractors, designers, and university facility owners." *Journal of Construction Engineering and Management*, ASCE, 142(2).

Benefits

- Reduced site hazards
- Increased productivity
- Increased quality
- Fewer delays due to accidents
- Designer-constructor collaboration
- Improved operations and maintenance safety
- Reduced workers' compensation premiums
- Marketing, recognition

Expected Impacts

Survey of design and construction professionals in the UK:

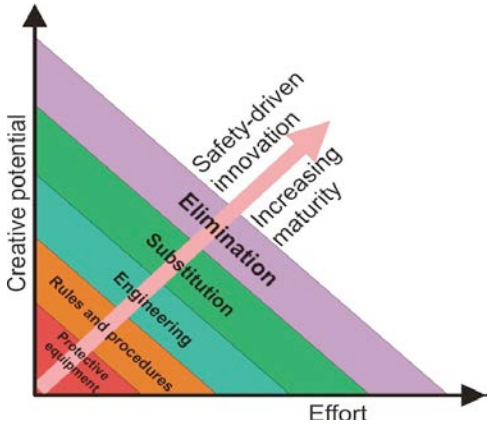
- Change as a result of implementing PtD (% of respondents)

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%

Source: Final Report, NIOSH PtD in the UK study, May 2013.

Expected Impacts

- Innovation



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.

Interest in PtD

- Owner attitudes toward PtD

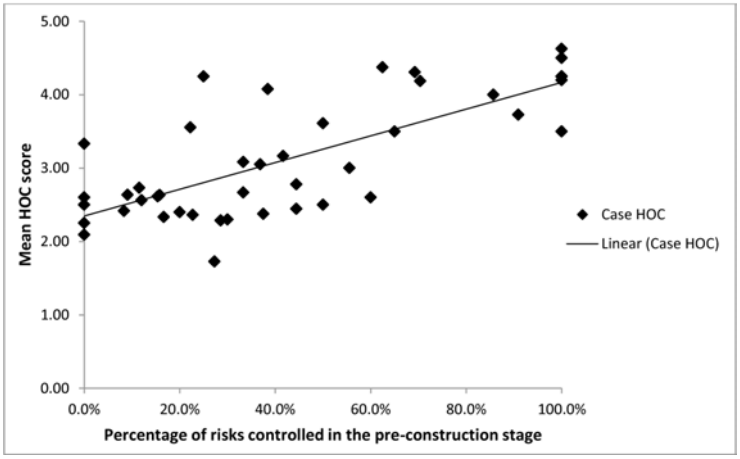
	Industry Surveys (n = 103)	Case Study Surveys (n = 79)	All Surveys (n = 182)
The potential benefits of PtD do not seem compelling to me.	5%	4%	4%
The benefits of PtD sound promising but there are too many barriers to try implementing it.	11%	3%	7%
The benefits of PtD sound like a good idea. I would consider trying it.	68%	46%	58%
PtD sounds like a winner. I have already or will likely try to implement it.	17%	48%	30%

Toole, T.M., Gambatese, J.A., and Abowitz, D.A. (2016). "Owners' Role in Facilitating Prevention through Design." *Journal of Professional Issues in Engineering Education and Practice*, ASCE, 143(1), 04016012.

Ability to Address Safety during Design

HOC = Hierarchy of Control

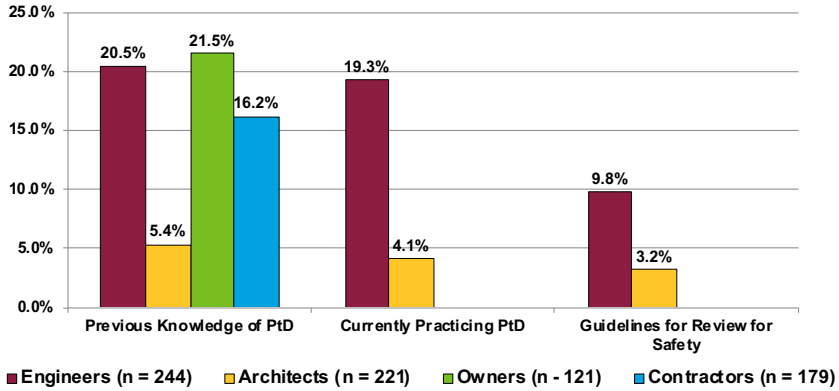
5 = Elimination
4 = Substitution
3 = Engineering
2 = Administrative
1 = PPE



Lingard et al. (2014). "Safety in Design." Centre for Construction Work Health and Safety, RMIT University and Australian Constructors Association.
Lingard et al. (2015). "The relationship between pre-construction decision-making and the effectiveness of risk control: Testing the time-safety influence curve."

Ability to Address Safety during Design

- Industry survey: PtD knowledge in the US construction industry



Tymvios, N. and Gambatese, J.A. (2016). "Perceptions about design for construction worker safety: Viewpoints from contractors, designers, and university facility owners." *Journal of Construction Engineering and Management*, ASCE, 142(2).

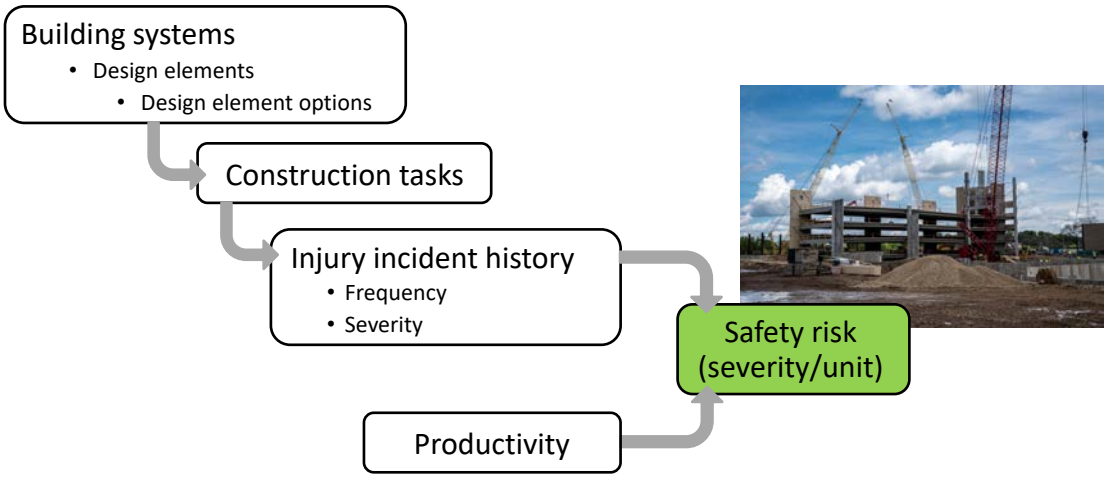
Addressing Safety in the Design

- Which building is safer to build? How much safer?

Concrete-framed building

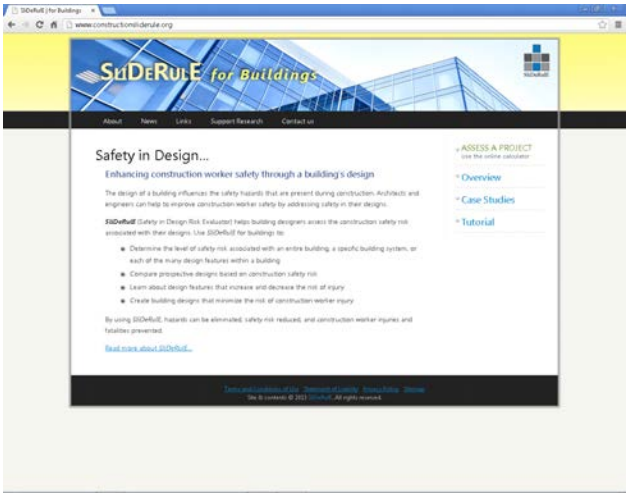
Steel-framed building

Addressing Safety in the Design



Addressing Safety in the Design

www.constructionsliderule.org



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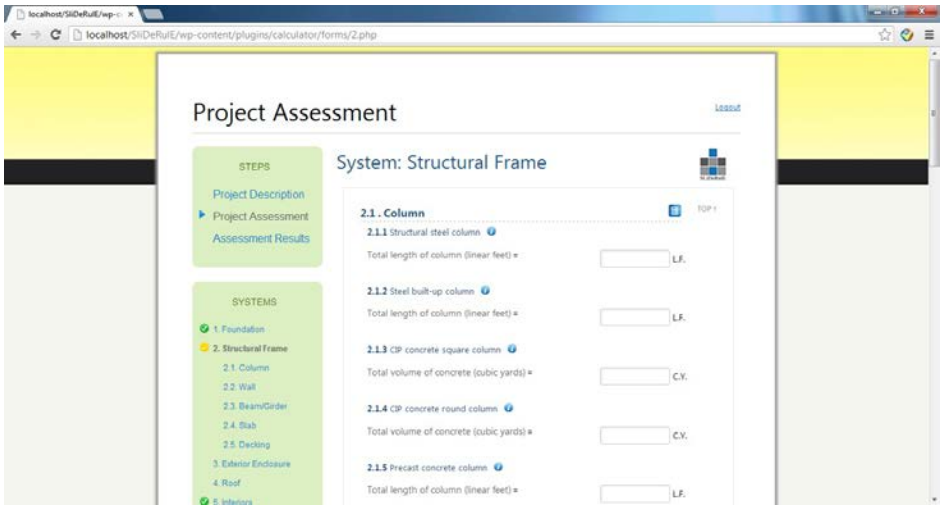

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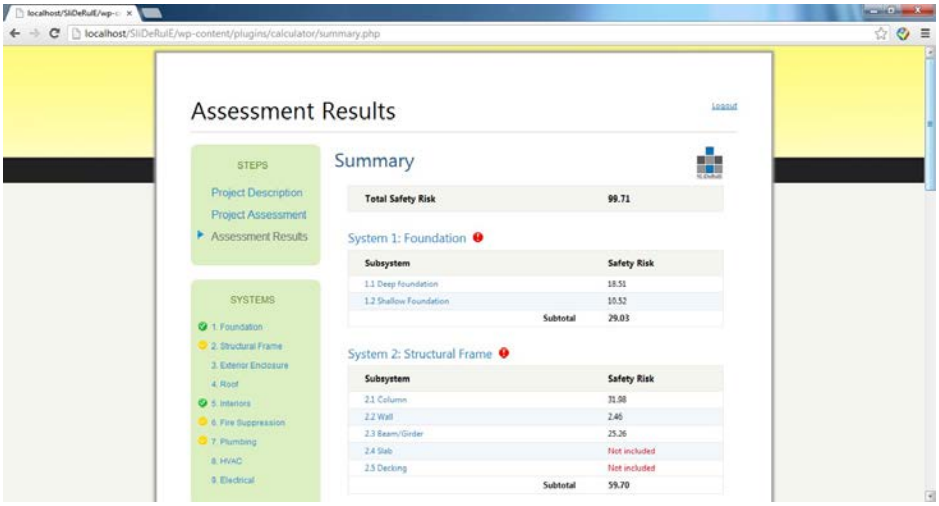
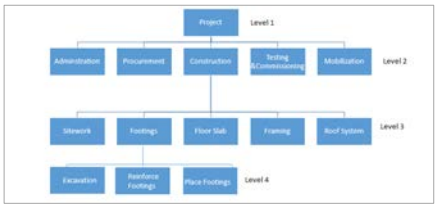
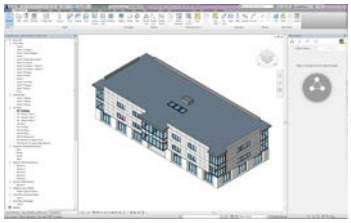


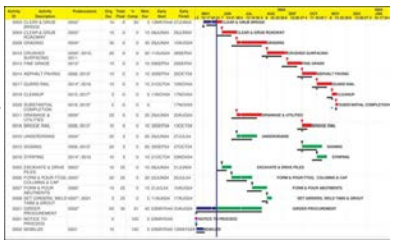
Addressing Safety in the Design

Link risk-loaded BIM model to:

- Work breakdown structure
- Project schedule (Synchro PRO)



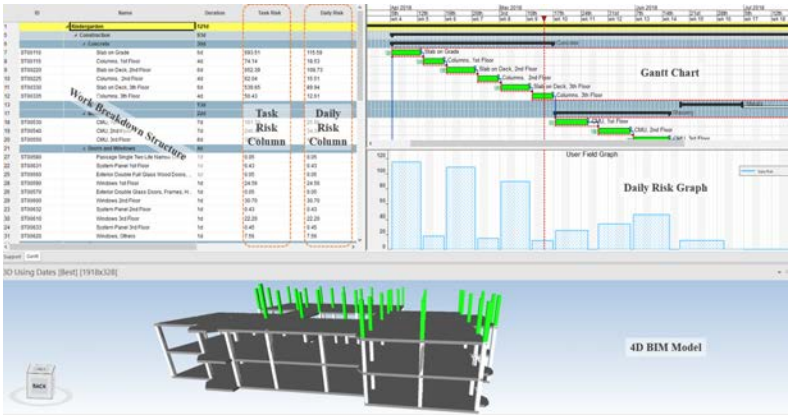




Jin, Z., Gambatese, J., Liu, D., and Dharmapalan, V. (2019). "Using 4D BIM to Assess Construction Risks during the Design Phase." *Engineering, Construction and Architectural Management*, Emerald Insight, http://doi.org/10.1108/ECAM-09-2018-0379.

Addressing Safety in the Design

- Results: Risk visualization



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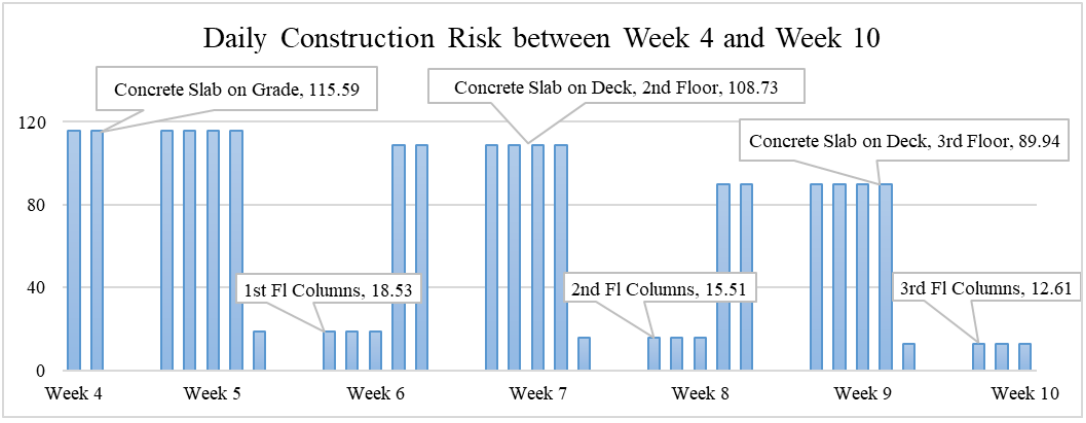
Addressing Safety in the Design

- Results: Daily risk schedule



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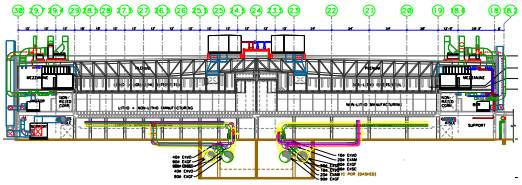
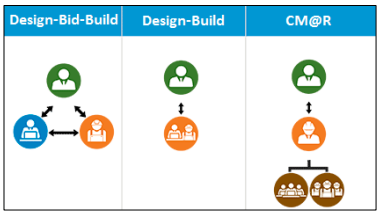
Impediments to PtD

- No or minimal designer education and training in:
  - Site safety
  - Designing for safety
- Difficult to assess risks during design
- Contractual separation of design and construction
- Cost and time required to design for safety
- Fear of increased liability
- Competing priorities:
  - Safety vs. cost/schedule/aesthetics





(Source: http://www.btea.com/2016/11/28/comparing-project-delivery-methods/)

Impediments to PtD

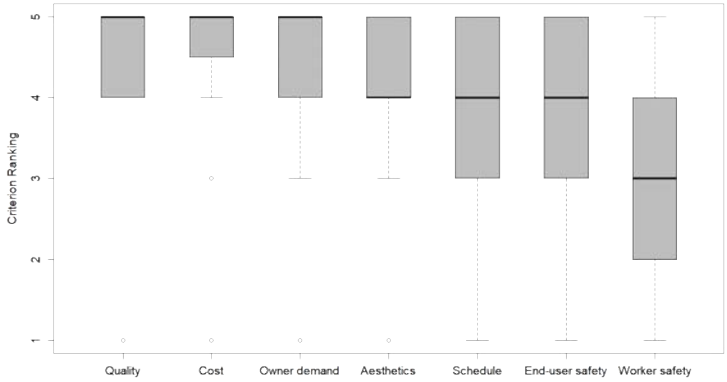
- How frequently do you consider each of the following criteria during facility design?

	Always (5)	Often (4)	Sometimes (3)	Rarely (2)	Never (1)
Quality of design	✓				
Cost of construction		✓			
Owner demand	✓				
Building aesthetics		✓			
Construction schedule				✓	
End-user safety	✓				
Worker safety				✓	

Karakhan, A., Gambatese, J., AlOmari, K., and Liu, D. (2018). "Consideration of Worker Safety in the Design Process: A Statistical-based Approach Using Analysis of Variance (ANOVA)." In *Proceedings of the Construction Research Congress 2018*, ASCE, New Orleans, LA, April 2-4, 2018.

Impediments to PtD

- Does worker safety receive a level of priority that is equal to other design criteria?



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Source of Variation	Degree of Freedom Numerator	Denominator	F-Statistic	*p*-value
Among design criteria	6	228.64	25.15	2.2e-16
Worker safety vs others	1	85.97	100.07	4.5e-16

Impediments to PtD

Ranking: 1 = Greatest inhibitor of PtD; 8 = Least inhibitor of PtD

Challenges to Adoption of PtD	Rank	Relative Index (RI)
1. No immediate financial incentive for Architects/Engineers	1	0.89
2. Lack of regulatory requirement of Architects/Engineers	2	0.83
3. Lack of recognizable duty of Architects/Engineers	3	0.74
4. Reluctance to change the standard contracts to enable the adoption of PtD	4	0.71
5. Lack of knowledge and training about PtD among Architects/Engineers	5	0.68
6. Resistance from Architects/Engineers to adopt PtD	6	0.67
7. Resistance from Owners to adopt PtD	6	0.67
8. Lack of knowledge and training about PtD among Owners	8	0.64

Ghosh, S., Langar, S., and Bhattacharjee, S. (2015). "A Cross Sectional Study of the Perceptions of Large Contractors towards Prevention through Design." *51st ASC Annual International Conference Proceedings*, Associated Schools of Construction, College Station, TX, April 22-25, 2015.

PtD Diffusion

- Next step…putting PtD into practice

	Knowledge	Desire (motivation)	Ability	Execution
Components	• PtD concept • Hierarchy of controls • Expected impacts	• Contract • Business case – ROI • Recognition • Regulation • Duty • Morals/Ethics • Innovation	• Resources and tools • Safety hazard recognition • Identification of safe designs • Timing • Foreseeability	• Priority • Standard practice • Authority • Innovation

Gambatese, J.A. (2013). "Final Report – Activity 2: Assess the Effects of PtD Regulations on Construction Companies in the UK." National Institute for Occupational Safety and Health (NIOSH), Education and Information Division, May 2013.

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CDC Workplace Safety and Health NIOSH

ASU Ira A. Fulton Schools of Engineering Arizona State University

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Thank you!

https://ptd.engineering.asu.edu/

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CDC Workplace Safety and Health NIOSH

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