Exploring the Relationship between Project Integration and Safety Performance

Presented by:

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Safety, Risk Management, And Decision-making Research Group

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Project Motivation

- **<u>Safety Performance:</u>**
  - ✓ Implementing various injury prevention strategies;
    - o Job hazard analysis;
    - o Incentive programs;
    - o Testing drug abuse;
    - o …
  - ✓ Workers demographic background;
  - ✓ Providing Training;
  - ✓ …

Project Motivation

- Small number of studies have **EMPIRICALLY** investigated the impact of following variables:
  - ✓ Project delivery method;
  - ✓ Team selection;
  - ✓ Contract terms;
  - ✓ Time of involvement of different parties;
  - ✓ Using co-location;
  - ✓ Using partnering;
  - ✓ …

Background

University of Colorado Boulder

PENNSTATE

CHARLES PANKOW FOUNDATION
Building Innovation through Research

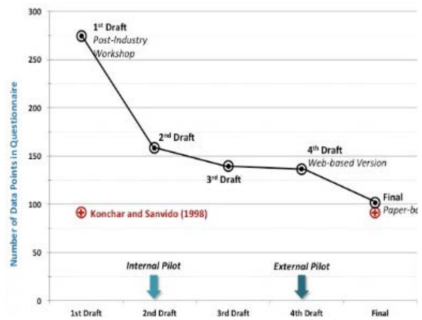
Construction Industry Institute®

2012-2014

Objective: Provide objective data and ***empirical evidence*** to support how the performance is impacted by owner's role, system integration, team behaviors, and various project delivery methods."

Background

- Develop survey questionnaire
  - **Literature review**
  - **Industry advisory board**



Research Methods

Project Organization

Delivery method

✓*(Design-Bid-Build, CM at Risk, Design-Build, IPD)*

Contract terms

✓*(Lump Sum, Cost Plus, GMP)*

Team selection

✓*(Low Bid, Prequalified Bid, Negotiated)*

Project Execution

Project Success

Budget & schedule performance

✓*(Unit cost, Cost growth, Schedule growth, Delivery speed)*

Safety performance

✓*(Number of Incidents, Number of LWT, Worker Hours)*

Facility quality

✓*(System, Aesthetics, Functionality)*

Rank	*Processes*	*Technologies*	*Behaviors*
1	Prequalification of team	BIM uses	Open book accounting
2	BIM execution planning	File sharing systems	Shared risk and reward
3	Partnering/team building	Modularized designs	Joint project management
4	Co-location of team	Communication latency	Communication formality
5	Lean decision-making tools	File to fabrication	Level of trust
6	Risk management	BIM ownership	Clarity of leadership
7	Process facilitator	Facility management	Contingency management
8	Offsite prefabrication	Last Planner	Goal commitment
9	Decision-making procedure	Electronic design reviews	Prior team relationship
10	Design responsibility	Visual management	Multi-trade prefabrication

Research Methods *(Safety Metrics)*

- Recordable Incident Rate (RIR):

$$\text{RIR} = \frac{\text{Number of Recordable Cases}}{\text{Number of Employee Labor Hours Worked}} \times 200{,}000$$

- Lost Time Case Rate (LTC):

$$\text{LTC} = \frac{\text{Number of Lost Time Cases}}{\text{Number of Employee Labor Hours Worked}} \times 200{,}000$$

- Days Away/Restricted or Job Transfer (DART):

$$\text{DART} = \frac{\text{Total Number of DART Incidents}}{\text{Number of Employee Labor Hours Worked}} \times 200{,}000$$

- Severity Rate (SR):

$$\text{SR} = \frac{\text{Total Number Lost Workdays}}{\text{Total Number of Recordable Incidents}}$$

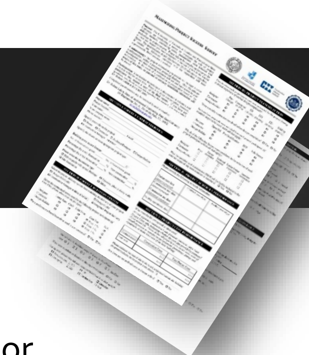
Research Methods *(Safety Metrics)*

Number of worker-hours was missing for most of the projects.

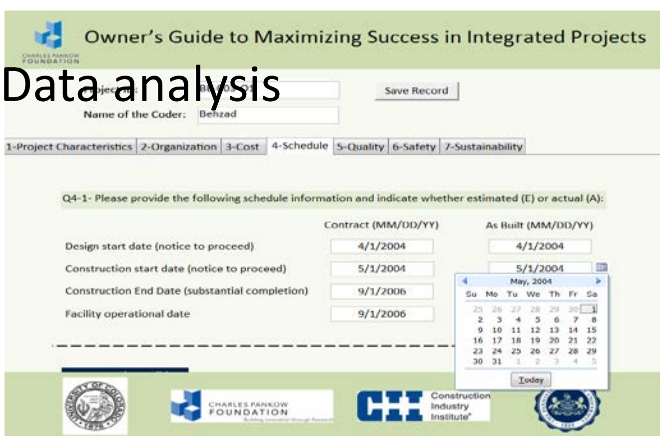
1. $$\text{Safety Performance} = \frac{\text{Number of Recordable Incidents}}{\text{Area (ft}^2\text{)}} \times 100{,}000$$

2. $$\text{Safety Performance} = \frac{\text{Number of Lost Time Incidents}}{\text{Area (ft}^2\text{)}} \times 100{,}000$$

Research Methods

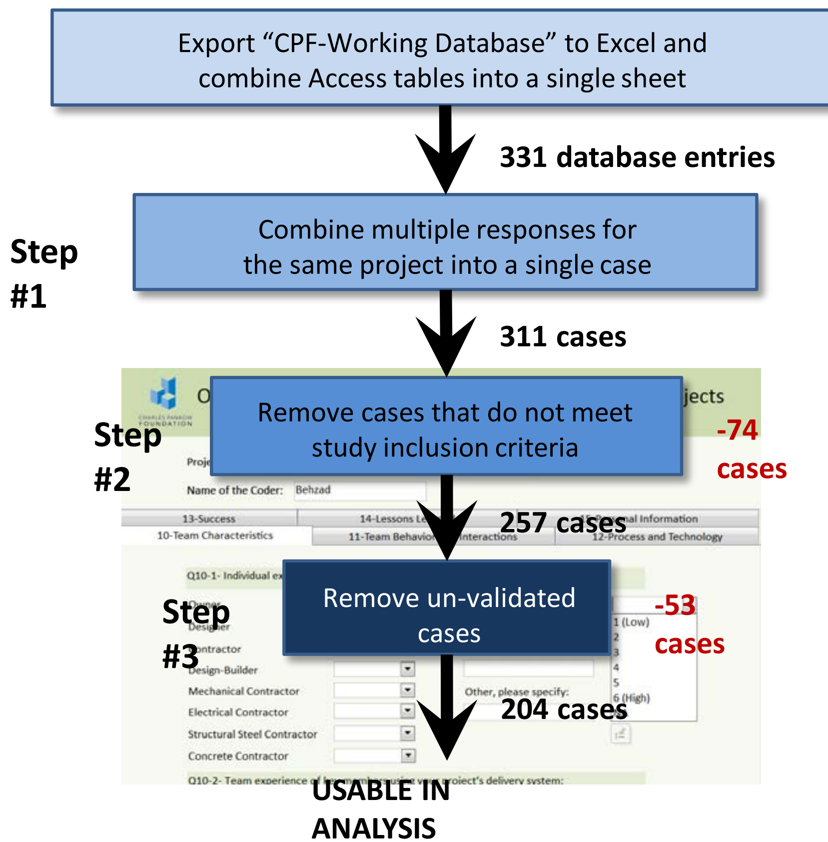


- Develop Survey questionnaire
- Pilot test (internal / external)
- Collect data
- Verify survey response data
- Data analysis

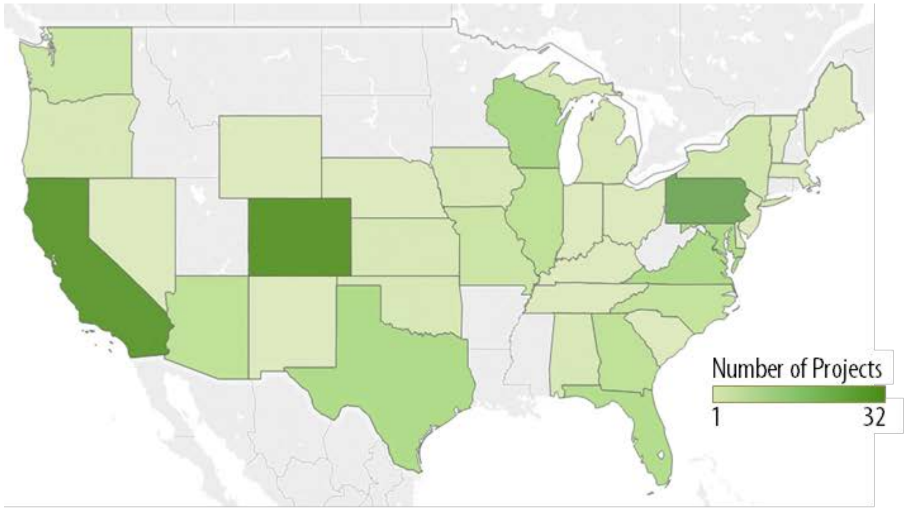


Validation

- ❖ Call back contractor
- ❖ Call back owner
- ❖ Developing FAQ sheet
- ❖ Developing call-back guideline



Project Data Characteristics



124 Had Safety Data!

204 Projects

Public:	127 (62%)
Private:	77 (38%)

Completed between: 2008 - 2013

Facility Types

Educational	56 (27%)
Office	41 (20%)
Health Care	32 (16%)
Lodging	27 (13%)
Commercial	20 (10%)
Sports & Recreation	11 (5%)
Manufacturing	11 (5%)
Correctional	4 (2%)
Transportation	2 (1%)

Facility Sizes

(8%)	16	> 550,000 ft^2
(2%)	4	450,001 - 550,000 ft^2
(3%)	6	350,001 - 450,000 ft^2
(10%)	21	250,001 - 350,000 ft^2
(20%)	40	150,001 - 250,000 ft^2
(30%)	61	50,001 - 150,000 ft^2
(27%)	56	0 - 50,000 ft^2

Research Methods *(Analysis)*

Categorical

Ordinal

Naturally ordered as increasing or decreasing

Examples:
- 6pt rating scales
- Level of LEED certification
- Phase of involvement

Nominal

Non-ordered

Examples:
- Delivery method
- Contract terms
- Owner type

Continuous

Ordered with meaningful intervals

Examples:
- Cost growth
- Schedule growth
- Delivery speed

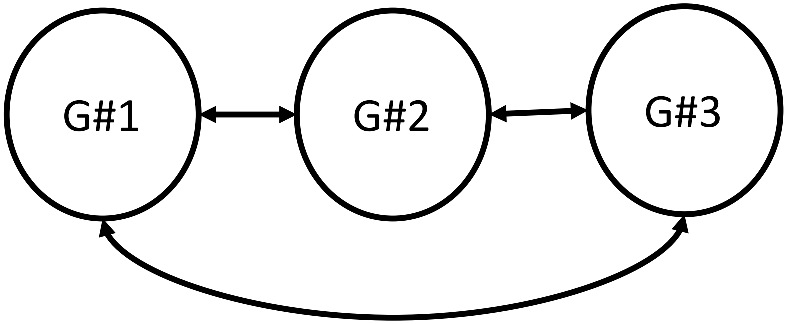
Research Methods *(Analysis)*

Correlation

Tests for directional relationship between 2 variables
May be positive or negative

Group Comparison

Tests for equal means, median, population distribution



The Kruskal-Wallis test was used because:

- *The response variables was significantly non-normal; and*
- *The group sizes within could be relatively small for some categories.*

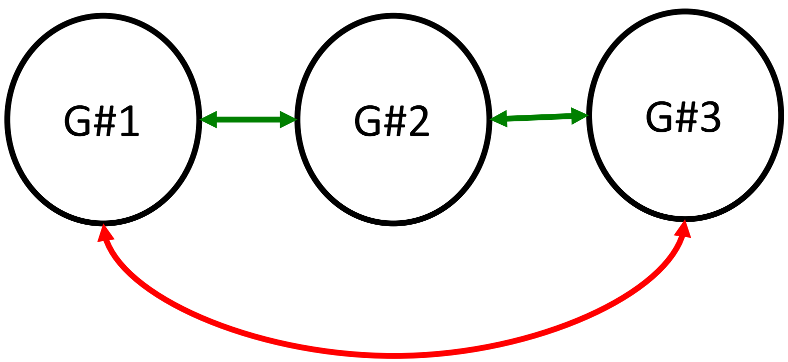
- ✓ *Since there are lots of "ties" in the data (observations with the same number of incidents) and in some cases quite a few groups, a chi-square approximation was used to calculate the p-value.*
- ✓ *All analyses were done using R.*

Research Methods *(Analysis)*

Post Hoc Analysis

*Post-hoc analyses were also conducted on significant groupings using pairwise **Wilcox-Mann-Whitney** tests with a **Bonferroni adjustment**.*

Since there were multiple comparisons in this data set, the Bonferroni adjustment kept the Type 1 error probability controlled.



Results and Discussion (Recordable Accident/SQF)

Variable	Mean	SD	n
Recordable Incidents	1.230	1.776	124
Lost work Time	0.289	0.750	122

Variable	0	>0
Recordable Incidents	48%	52%
Lost work Time	75%	25%

Results and Discussion (Recordable Accident/SQF)

Variable		Mean	SD	n
Delivery Method	CM at risk	1.320	1.466	43
	Design-bid-build	0.507	1.254	25
	Design-build	1.433	2.112	54
	IPD	2.821	1.606	2

Variable		Mean	SD	n
Using BIM	Yes	1.516	1.874	90
	No	0.472	1.209	34
Using Prefabrication	Low	1.037	1.747	62
	High	1.441	1.817	59
Using Lean Scheduling Tools	Yes	2.078	2.100	20
	No	1.137	1.669	104

Results and Discussion (Recordable Accident/SQF)

Variable		Mean	SD	n
Time of Builder Involvement	Pre-design	1.022	1.741	45
	Conceptual	1.927	2.186	27
	Schematic	1.388	1.452	14
	Development	2.513	2.087	5
	Documents	0.880	1.176	10
	Bidding	0.594	1.329	23
Time of Mechanical, Electrical, and Plumbing (MEP) Contractor Involvement	Pre-design	0.738	0.942	12
	Conceptual	2.007	2.339	11
	Schematic	1.859	1.827	15
	Development	1.732	2.109	12
	Documents	1.220	1.259	18
	Bidding	0.944	1.778	48
Time of Structural Contractor Involvement	Pre-design	0.496	0.653	12
	Conceptual	1.093	1.757	11
	Schematic	1.596	1.598	9
	Development	1.943	1.919	14
	Documents	1.547	1.603	16
	Bidding	1.158	1.937	54

Results and Discussion (Recordable Accident/SQF)

Variable		Mean	SD	n
Project Complexity	1~4 (Likert)	1.058	1.996	41
	5 (Likert)	1.068	1.387	41
	6 (Likert)	2.241	1.929	23
Using Partnering	Yes	1.244	1.732	32
	No	1.224	1.800	92
Builder Participated in Co-Location	Yes	1.588	1.771	19
	No	1.083	1.766	61
MEP Contractor Participated in Co-Location	Yes	1.920	1.842	9
	No	1.064	1.728	71
Structural Contractor Participated in Co-Location	Yes	1.916	1.875	6
	No	1.081	1.727	74
Builder Participated in Goal Setting	Yes	1.447	1.895	92
	No	0.629	1.243	28

Results and Discussion

Correlation Between Safety Performance Metrics & other Performance Measures

Variables	Recordable Incidents/SQF		Lost Time Incidents/SQF	
	Correlation	P-Value	Correlation	P-Value
Project Cost Growth (%)	-0.055	0.557	-0.143	0.127
Project Schedule Growth (%)	-0.044	0.627	-0.044	0.631
Construction Cost Growth (%)	0.180	0.064	0.013	0.894
Construction Schedule Growth (%)	-0.004	0.973	0.238	0.010
Unit Cost (log)	0.314	0.001	0.289	0.001
Project Delivery Speed (sf/month of project duration; log)	0.298	0.008	0.171	0.059
Construction Delivery Speed (sf/month of construction duration; log)	0.259	0.004	0.216	0.017

Results and Discussion

Correlation Between Safety Performance Metrics & other Performance Measures

Variables	Recordable Incidents/SQF		Lost Time Incidents/SQF	
	Correlation	P-Value	Correlation	P-Value
Project Cost Growth (%)	-0.055	0.557	-0.143	0.127
Project Schedule Growth (%)	-0.044	0.627	-0.044	0.631
Construction Cost Growth (%)	0.180	0.064	0.013	0.894
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Results and Discussion

Group Comparison Between Independent Variables Using Kruskal-wallis Test

	Recordable Incidents/SQF		Lost Time Incidents/SQF		
Grouping Variable	Test stat (chi-square)	p-value	Test stat (chi-square)	p-value	DF
Project Complexity	15.56	0.001	-	-	3
Delivery Methods	9.75	0.021	-	-	3
Time of Builder Involvement	12.95	0.024	11.73	0.039	5
MEP Contractor Participated in Co-Location	6.84	0.009	-	-	1
Struct. Contractor Participated in Co-Location	5.49	0.019	-	-	1
Using BIM in a Project	13.58	0.000	3.87	0.049	1
Using Lean Scheduling Tools in Project	5.12	0.024	-	-	1
Using Prefabrication	-	-	15.13	0.010	5
Electronic File & Information Sharing	-	-	11.57	0.041	5

Results and Discussion *(post hoc)*

- Very complex projects (Likert value=6) have lower safety performance than projects with medium (Likert value=5, p-value=0.005) and low complexity (Likert value=1~4, p-value=0.037).
- Projects delivered by design-bid-build (DBB) method had a better safety performance than projects delivered by construction manager-at-risk (p-value=0.032).
- Projects that did not use BIM had better safety performance.
- projects that used lean scheduling tools had more accident per square foot of a building (2.078) than projects that did not use any lean tools (1.137).

✓ SQF?	✓ Claims?
✓ Public vs Private?	✓ Selection criteria?
✓ Type of project?	✓ ……

\+ Follow up phone interviews.

Conclusions

- This study assessed the factors contributing to safety performance by looking at project integration measures.
- The results of this study provide preliminary evidence that early decisions of owners and contractors can impact the safety performance of projects.

Limitations

- ✓ Recordable incidents and lost work time incidents are lagging indicators to measure safety performance; leading indicators should also be considered.
- ✓ Safety performance is heavily impacted by foremen and supervisors attitude towards safety; considering only organizational variables does not help us to predict how workers behave on the site.

Future Works

Safety Performance

__Database__

- ✓ Lagging indicators
- ✓ Leading indicators

Building Projects

- Delivery Method
- Contract Terms
- Team Selection
- Processes
- Technology
- Behavior

Thank you for your time.