CONSTRUCTION INDUSTRY VALIDATION OF SCHEDULE PERFORMANCE MEASURE

Grant Number #07-16
Final Presentation

presented to the Charles Pankow Foundation
and its funding partner Construction Industry Institute

by

Gunnar Lucko, Ph.D., Principal Investigator
Catholic University of America
October 2019

CHARLES PANKOW FOUNDATION
Building Innovation through Research

Research Team

The Research Team

- Gunnar Lucko, PhD,
Ordinary Professor,
The Catholic University of America
- Rick Thompson, PhD,
Research Consultant and Subject Matter Expert
- Kelly Wallace,
Industry Champion,
Bozzuto

Industry Advisory Panel

- Pedro Astudillo-Leos, PE,
District of Columbia
- Shabtai Isaac, PhD
Ben-Gurion University, Beer-Sheva, Israel
- Christopher E. Reseigh, PE (retired)
Parsons Brinckerhoff Construction Services
- James E. Rowings, PhD
Kiewit Corporation
- Mark A. Rolfs
Forrester Construction
- Hisham M. M. Said, PhD
Santa Clara University
- John H. McTyre
HKA

CHARLES PANKOW
FOUNDATION
Building Innovation through Research

Origins of the Problem

- National Research Council – Two Overriding Defined Needs

"Construction firms ***do not have*** a single source of metrics for comparing the efficiency of their projects and processes, or for assessing their competitive position…and ***there is no single, official index or measure for the productivity of the construction industry***."

"U.S. construction industry ***does not have*** an industry-wide research agenda that identifies or prioritizes research areas with the most potential ***for improving its productivity, its competitiveness, or its efficiency***."

- National Research Council – The Ultimate Desire

"Project-level measures are needed to contribute to the understanding of ***how an individual project compares with other, similar projects***." Source: National Research Council "NRC" Report, 2009, "Advancing the Competitiveness and Efficiency of the U.S. Construction Industry"

CHARLES PANKOW FOUNDATION
Building Innovation through Research

Fundamental Purpose

"To establish a 'living' schedule performance measure that will be comparable across all project types, complexities, and company sizes for the construction industry."

- Expectations / Limitations

– Measure / Index has to be rooted in existing proven methods
(Capital Asset Pricing Model - CAPM: $E(R_i) = r_f + \boldsymbol{\beta}_i\,[E(R_m) - r_f]$)

– Measure / Index has to be easily determined and rooted in precedent (EMR: Standard Safety Measure)

– Measure / Index has to be recognized and universal (ASTM)

Fundamental Purpose

Individual Stocks have a Beta (β)

- Amazon = 1.63
- Apple = 1.10
- Microsoft = 0.96
- Harris Corp = –0.21
- Newmont Gold = –0.11

So, too, can Subcontractors and the Construction Industry.

CHARLES PANKOW FOUNDATION
Building Innovation through Research

Scope of Research: Concept & Responsibility

Research

National Science Foundation

– Funded the Research on Theory

Testing & Validation

The Charles Pankow Foundation &

Construction Industry Institute

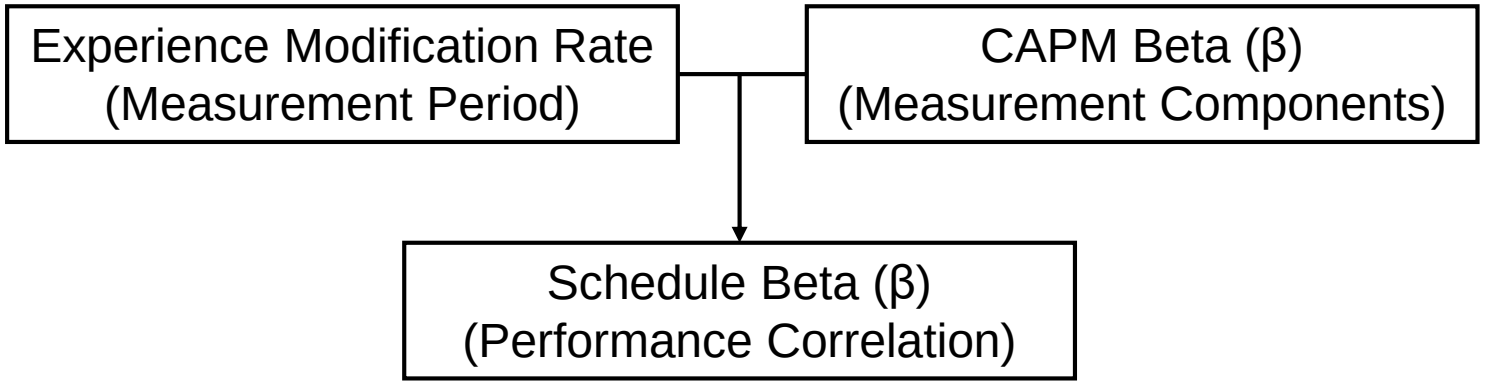
– Funded the Development & Validation of the Process

CHARLES PANKOW FOUNDATION

Building Innovation through Research

Scope of Research: Concept & Responsibility

The Concept:



The Process:

"As-Built" – "As-Planned"
+ ΔChange Orders – ΔSuspensions
= Performance

CHARLES PANKOW FOUNDATION
Building Innovation through Research

Origin of Beta: Capital Markets

Beta β (CAPM)

Helps investors understand whether a stock moves in the same direction as the rest of the market, and how volatile or risky it is compared to the market.

Origin of Beta: Capital Markets

Beta β (CAPM)

Helps investors understand whether a stock moves in the same direction as the rest of the market, and how volatile or risky it is compared to the market.

Schedule Beta β (CONSTR)

Helps understand individual subcontractor's deviation, risk, and / or performance as correlated to the collection of projects completed over a defined period of time.

What Is Beta (β) and What Does It Mean for Us?

- Beta measures the risk of volatility of a stock compared to the overall stock market

Return of an Individual Asset

Return of the Overall Market

$$\beta = \frac{Covariance\,(R_i, R_m)}{Variance\,(R_m)}$$

becomes

Subcontractor Duration Deltas

Project Duration Delta

$$\beta = \frac{Covariance\,(d_i, d_m)}{Variance\,(d_m)}$$

i.e., the collection of completed projects

Stock market ←→ Construction Industry

Individual Stock ←→ Individual Subcontractor

i.e., as defined by CPM activities

Trading Day's Results ←→ Trading Day Results

i.e., delta as-built to as-planned durations

CHARLES PANKOW FOUNDATION

Building Innovation through Research

Case Study Data

- Industry Champion provided a portfolio of projects as a data source
  - Twenty-two (22) Mixed Use Residential / Commercial projects were identified
  - Selection criteria established with Industry Advisory Board:

Location *Same region for commonality of subcontractors*	***Size*** *Mix of S/M/L*	***Complexity*** *Determined by schedule activities / dependencies*	***Duration*** *A diverse range short / medium / long*	***Timing*** *Completed (requirement for "as-built" durations)*
	Performance Difference (ahead / behind) expected	**Permission** Written data sharing agreement required	**Staffing** Project Manager / Project Executive needs to be available	

CHARLES PANKOW FOUNDATION
Building Innovation through Research

Case Study Data

- Industry Champion provided a portfolio of projects as a data source
  - Initially one large Mixed Use project with multiple phases near Catholic University
  - Ultimately twenty-two (22) Mixed Use projects for consideration (not all complete)

Eight (8) projects ultimately Selected

CHARLES PANKOW FOUNDATION
Building Innovation through Research

Case Study Data

8	1,037	39	691 days	$51 MM
• Commercial Projects	• Average # Activities	• Average # Subs	• Average Actual Duration	• Average Value

CHARLES PANKOW FOUNDATION
Building Innovation through Research

Case Study Data

- Required data from each project

Activity Data

- Activity ID
- Subcontractor Name
- Subcontractor Discipline
- Activity Description
- Subcontractor As-Planned Duration
- Subcontractor As-Built Duration
- Subcontractor Duration Delta (Calculated)

Project Data

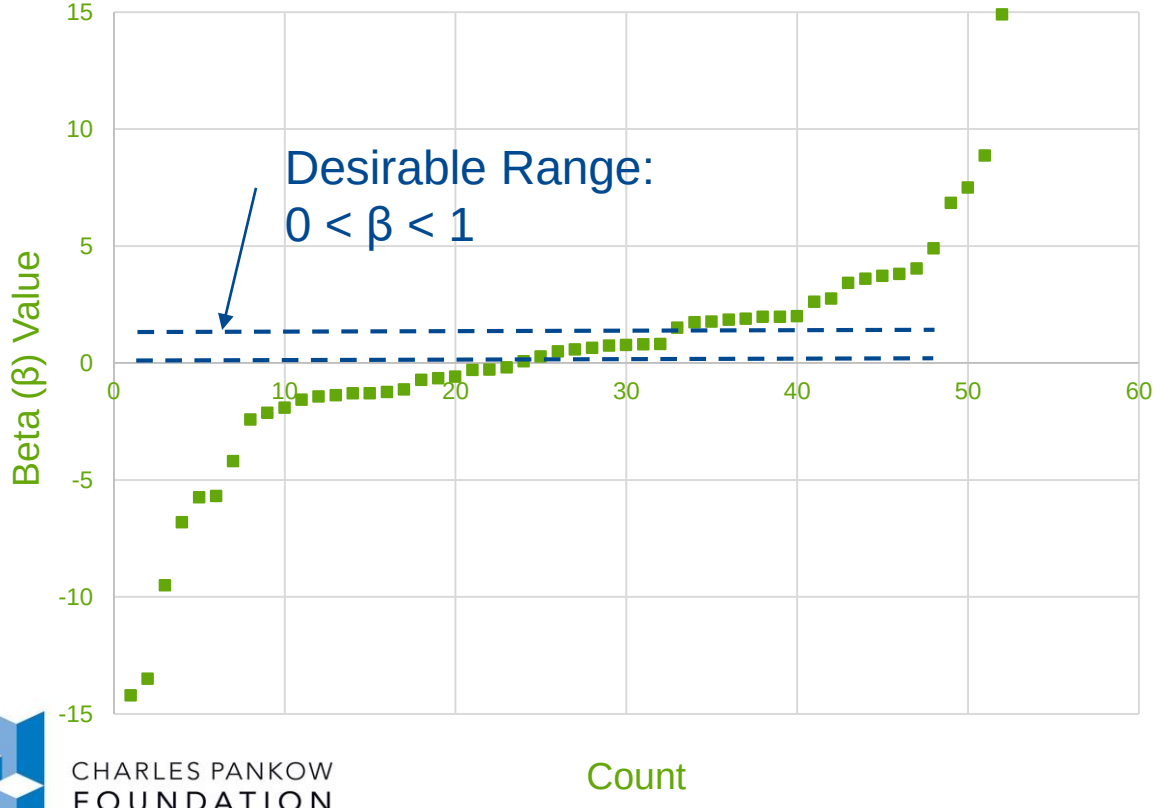
- Project As-Planned Duration
- Project As-Built Duration
- Project Duration Delta (Calculated)

Case Study Beta (β) Calculation (Sample)

Activity ID	Name	Blind Designation	Task	Duration					
				Activity			Project		
				As-Planned	As-Built	Delta	As-Planned	As-Built	Delta
U04090	*Redacted*	MSM29	Electrical	20	10	–10	911	911	0
SO1308	*Redacted*	MSM29	Electrical	5	5	0	779	740	–39
SO1312	*Redacted*	MSM29	Electrical	1	2	1	779	740	–39
SO1314	*Redacted*	MSM29	Electrical	5	5	0	779	740	–39
SO1316	*Redacted*	MSM29	Electrical	60	60	0	779	740	–39
SO1318	*Redacted*	MSM29	Electrical	4	15	11	779	740	–39
				Variance		44.27	Covariance		–67.17
				Activity Count		6	Beta		–1.52
				Project Count		2			

CHARLES PANKOW FOUNDATION
Building Innovation through Research

Case Study Beta (β) Calculation Results

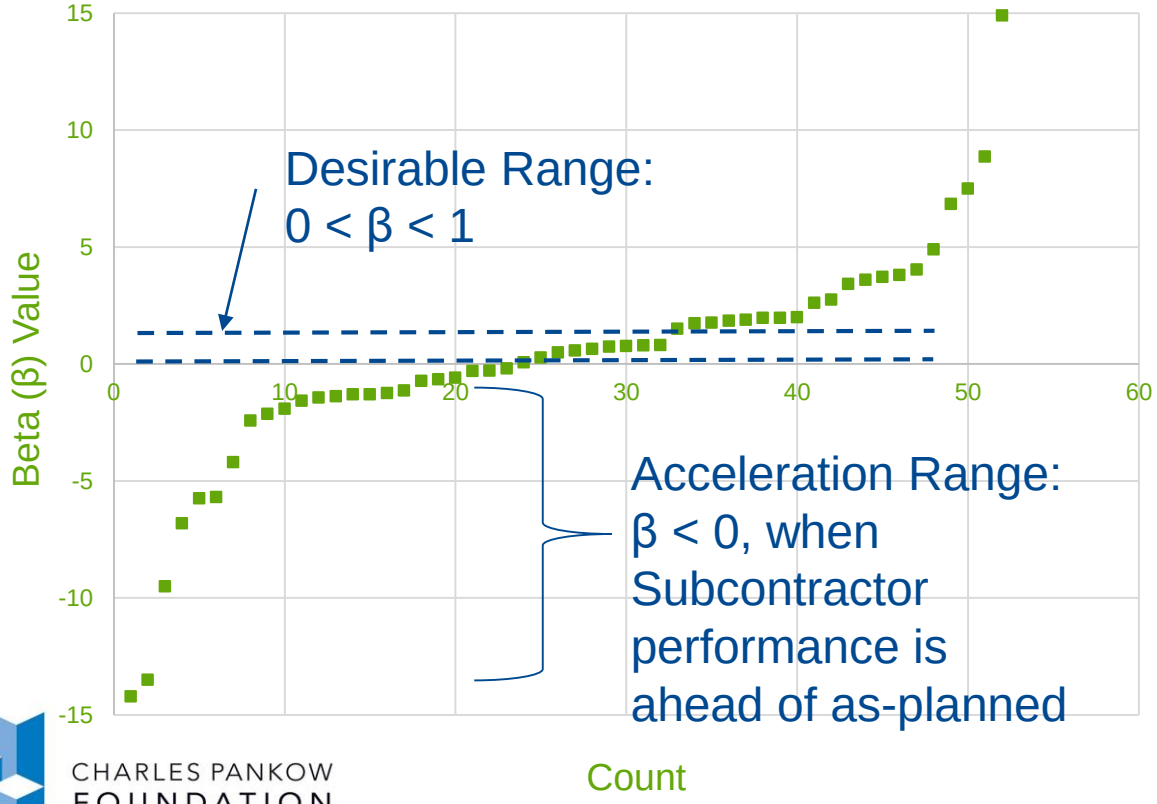


β > 0

Subcontractor performance tends to move the same as the projects on which they work

CHARLES PANKOW FOUNDATION
Building Innovation through Research

Case Study Beta (β) Calculation Results

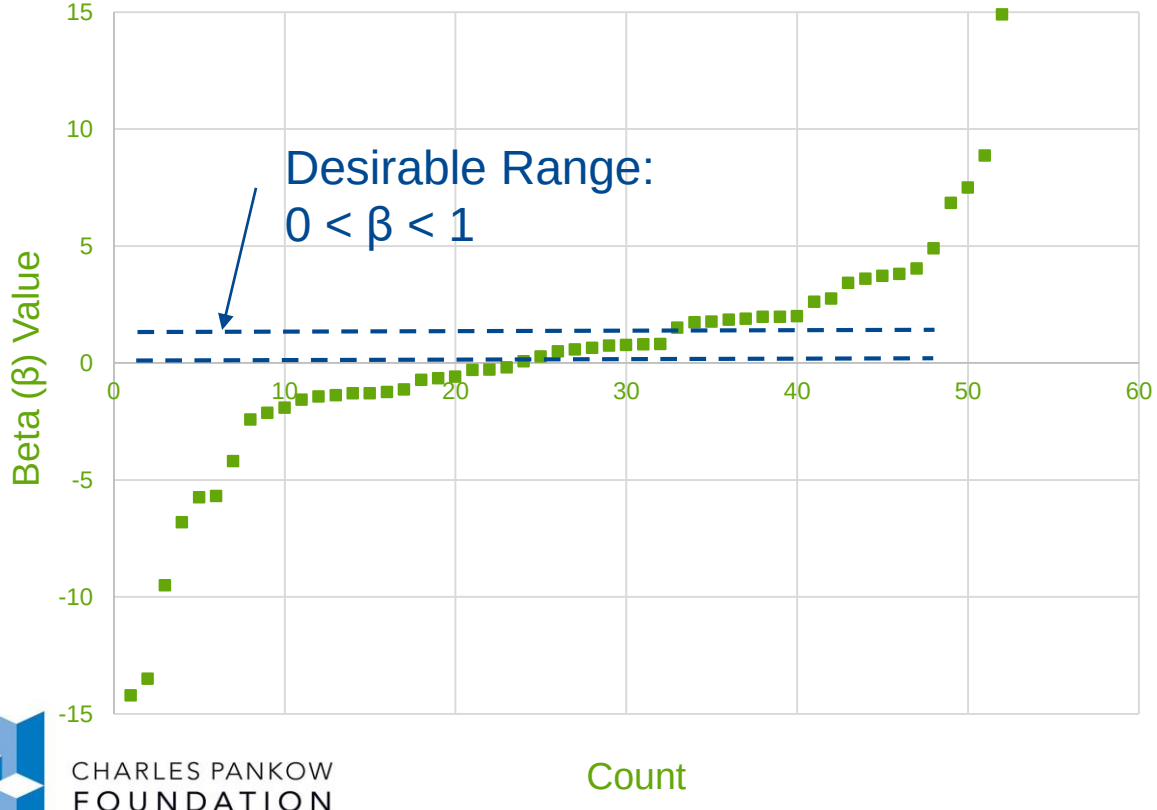


β < 0

Subcontractor performance tends to move in <u>opposite direction</u> as their projects and, while it may occur in small datasets, ***it is considered unrealistic over longer timeframes***

CHARLES PANKOW FOUNDATION
Building Innovation through Research

Case Study Beta (β) Calculation Results



0 < β < 1

or

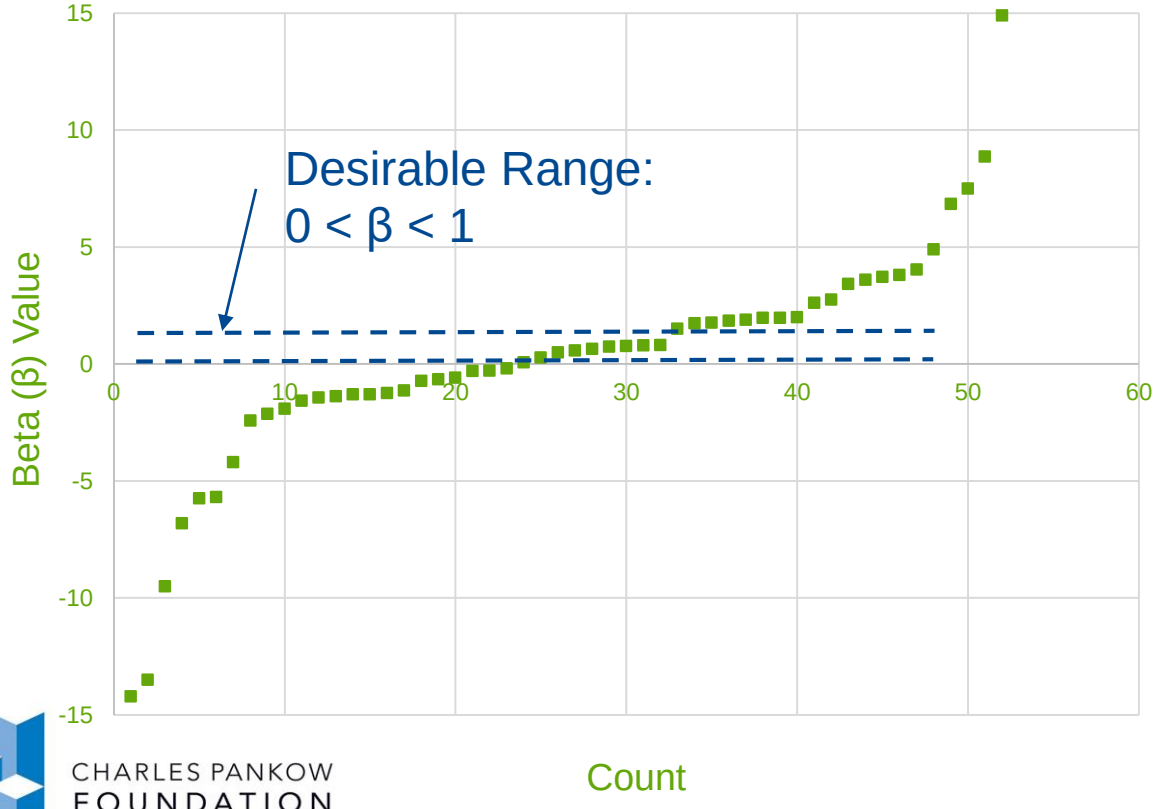
–1 < β < 0

Subcontractor has less deviations than the project and is less risky

CHARLES PANKOW FOUNDATION

Building Innovation through Research

Case Study Beta (β) Calculation Results

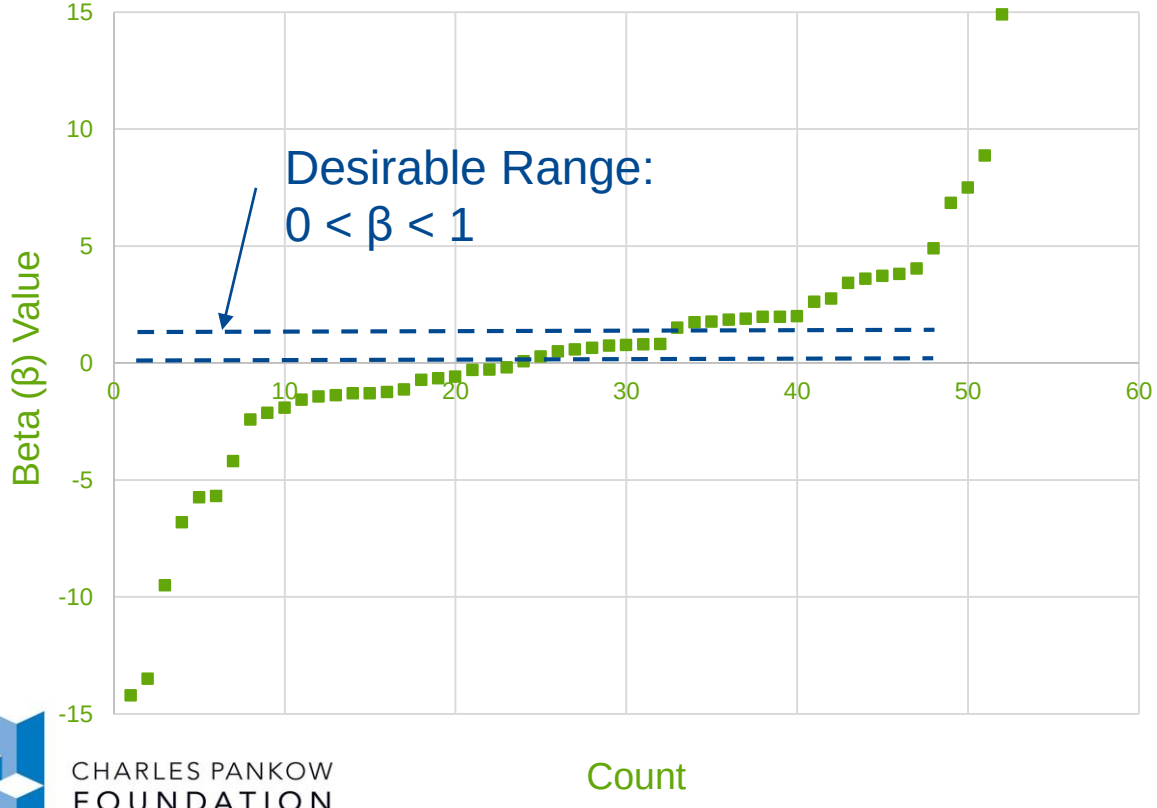


β > 1
or
β < –1

Subcontractor incurs stronger deviations than the project itself and <u>is risky</u>

CHARLES PANKOW FOUNDATION
Building Innovation through Research

Case Study Beta (β) Calculation Results

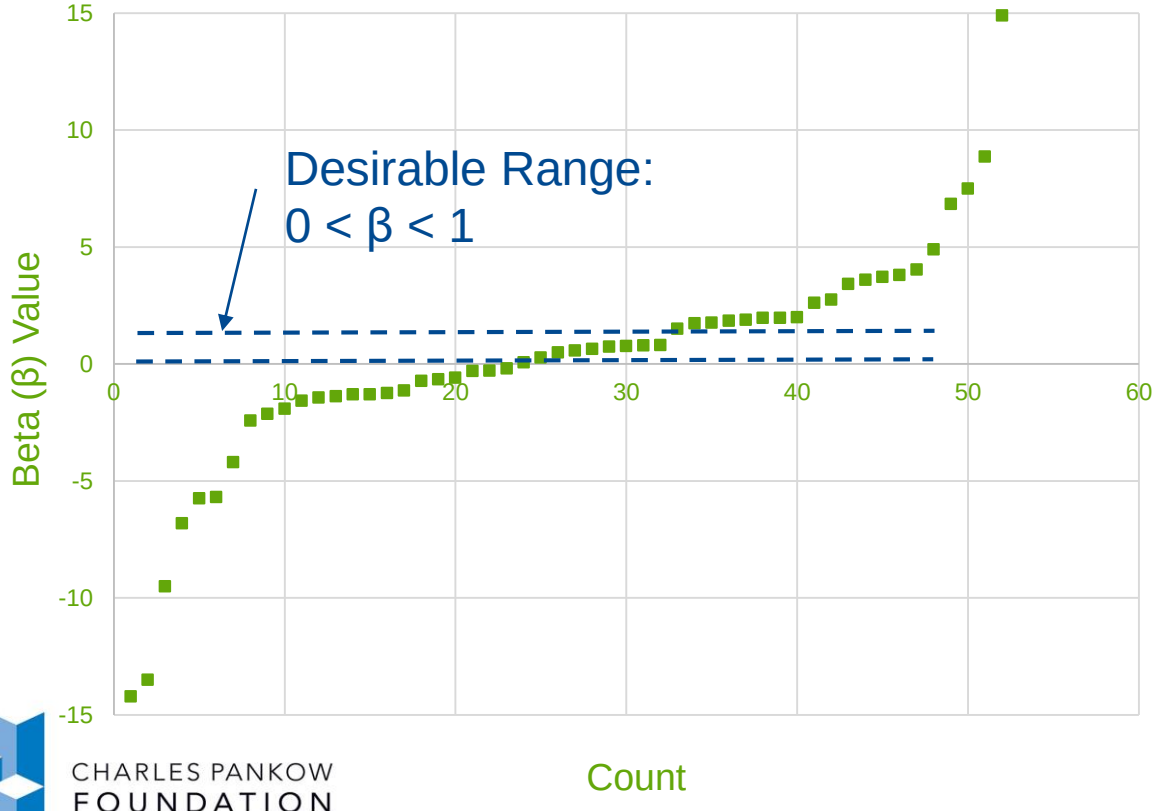


β = 1

Subcontractor performance has no distinction between it and the overall project performance

CHARLES PANKOW FOUNDATION
Building Innovation through Research

Case Study Beta (β) Calculation Results



β = 0

Activities move independently from their projects, which is unlikely, or planned and actual values are identical

CHARLES PANKOW FOUNDATION
Building Innovation through Research

Conclusion

Schedule Beta (β) can be used to benchmark subcontractor performance and aid in the selection of which ones to use, given the specific project parameters, goals, and needs.

Conclusion

AND,

As developed, Schedule Beta may not be limited to the Construction Industry. . . All that is needed is a group of schedule participants and a correlating group of projects.

Next Steps

- ASTM Standard
  (American Society for Testing and Materials)
  - Draft Standard accepted for consideration by E06.81 Subcommittee on Building Economics
  - External Review Committee / Advisor engaged

It will become an industry standard if adopted by ASTM

ASTM INTERNATIONAL

THE CATHOLIC UNIVERSITY OF AMERICA
DEPARTMENT OF CIVIL AND ENVIRONMENTAL ENGINEERING
CONSTRUCTION ENGINEERING AND MANAGEMENT PROGRAM

CONSTRUCTION INDUSTRY VALIDATION
OF SCHEDULE PERFORMANCE MEASURE

Grant Number #07-16
Final Report
presented to the

Charles Pankow Foundation
and its Funding Partner
Construction Industry Institute

by

Gunnar Lucko, Ph.D.
Principal Investigator
Professor

Washington, DC 20064
June 1, 2019

CHARLES PANKOW FOUNDATION
Construction Industry Institute

CHARLES PANKOW FOUNDATION
Building Innovation through Research

Additional Topics / Questions

- Inclusion of Separate Positive and Negative Schedule Beta Values
  - **Question Answered: Does a single Schedule Beta value accurately depict duration deltas?**
    Separate Positive / Negative Betas may lead to more detailed values – depicts magnitude of proclivity to perform ahead of as-planned versus proclivity to perform behind as-planned, ***not a blended*** value

- Case Study across a Single Discipline or Trade
  - **Question Answered: What are the Schedule Beta values expected?**
    Do they differ by trade, position in project (early, late, long, short, etc.)

Questions