Effect of Design Cost on Highway Construction Project Performance

Presenter:
Pramen P. Shrestha, Ph.D., P.E.

Co-author:
David R. Shields, Ph.D., P.E.

February 11, 2009

Presentation Outline

- Introduction
- Literature Review
- Research Methodology
- Construction Phase Project Performance
- Project Selection for Analysis
- Findings
- Conclusions & Future Research

Introduction

- Design Bid Build Project Delivery Method
  - Procure design, and construct separately
  - Designers perform design
  - Sometimes perform design in-house
  - Construction contract based on a completed set of design plans.

Introduction

- Design cost is the cost paid to engineers during design phase
- Construction cost is the contract award cost during construction phase
- Some research studies correlation between design cost and construction cost performance.

Literature Review

- Methods of Design cost payment (ASCE Manual #45)
  - Per diem
  - Cost plus a fixed fee
  - Fixed lump-sum payment
  - Salary cost times a multiplier plus direct non-salary expense
  - Retainer
  - Percentage of construction cost

Literature Review

- PSMJ survey on 2008 shows that
  - Fixed lump-sum form of payment is most widely used (51%)
- Research on professional fees (Carr & Beyor 2005)
  - Fees not adjusted over the time
  - Decline in professional fees when adjusted with inflation

Literature Review

- Research on design quality
  - Quantitative research to find correlation between design fees and design quality (Bushait et al. 1998)
  - 58 building projects data (Average cost = $2 million)
  - Design quality measured by Total Cost of Design Deficiency (TCDD)
    - TCDD = Cost of change order + Indirect cost resulting from delayed in project completion
  - Findings
    - Average design fees = 2.5 %
    - Inverse correlation: TCDD increases as design fees decreases

Literature Review

- Research on design phase cost performance (Kuprenas 2003)
  - Quantitative research to find correlation between design cost performance and project management practices
  - 270 design projects data from Department of Public Works, City of Los Angeles ($.5 M to $25 M)
  - Design Cost Performance Index (DCPI)

    = Actual Cost of Design Work Performed (ACWP) / Budgeted Cost of Design Work Performed (BCWP)
  - Average design cost of streets (Templates) = 25 % (projects over $5M)
  - Findings
    - Significantly correlated with frequency of meetings and reporting of design progress

Literature Review

- Research on relation between design fees & construction cost performance (Gransberg et al. 2003)
  - Quantitative research to find correlation between design cost and construction cost performance in road and bridge projects
  - 13 road projects ($4.9 M) & 18 bridge projects ($1.5 M)
  - Cost Growth from the Initial Estimate (CGIE)

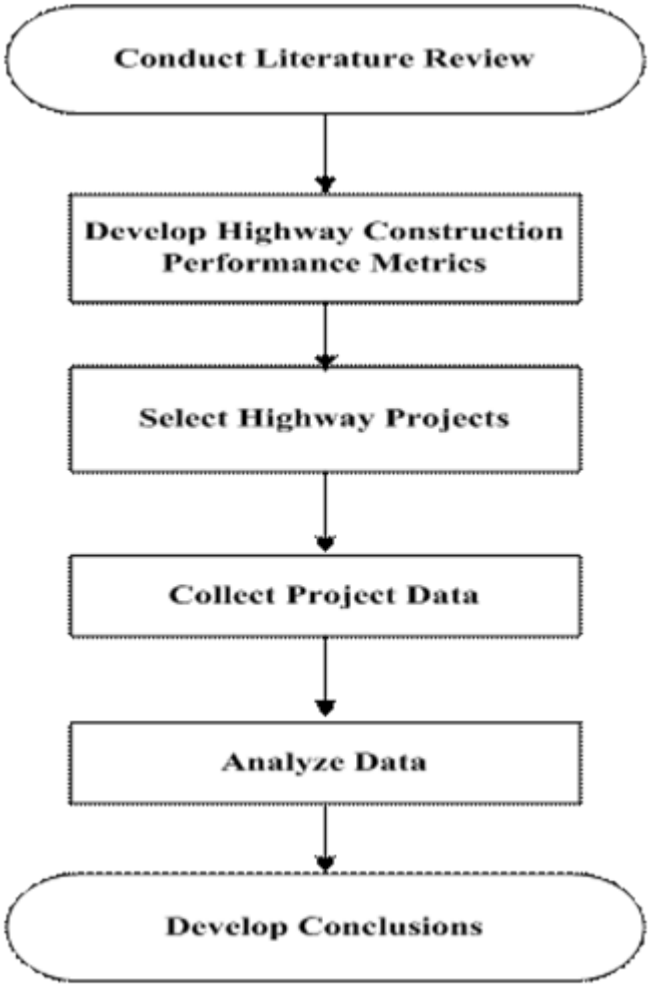
$$CGIE = \frac{\text{Final Construction Cost - Intital Estimated Cost}}{\text{Intital Estimated Cost}} \times 100\%$$

  - Findings
    - Average design cost of roads = 5.2 % (projects over $5M)
    - Inversely correlated: CGIE increases as design fees decreases, the correlation is stronger in bridge projects than road projects

Gaps in Research

- No comprehensive study done to correlate design cost and construction cost and schedule performance of large (cost > $30M) highway projects
- No absolute performance metrics (e.g. construction cost and delivery speed per-lane-mile) developed to compare the highway projects

Research Methodology



Design Cost Definition

- Cost expended for designing a highway project
- The cost includes only cost paid to designers
- Design cost is expressed in percentage of total design and construction cost

$$\text{Design Cost} = \frac{\text{Total Design Cost}}{\text{Total Design and Construction Cost}} \times 100\%$$

Construction Performance Metrics

- Construction Cost Growth (CCG):

$$CCG = \frac{\text{Actual Construction Cost - Estimated Construction Cost}}{\text{Estimated Construction Cost}} \times 100\%$$

- Construction Cost-per-Lane Mile (CCPLM):

$$CCPLM = \frac{\text{Actual Construction Cost}}{\text{Total Lane Miles}}$$

Construction Performance Metrics

- Construction Schedule Growth (CSG):

$$CSG = \frac{\text{Actual Construction Duration - Estimated Construction Duration}}{\text{Estimated Construction Duration}} \times 100\%$$

- Construction Delivery-per-Lane Mile (CDSLM):

$$CDSLM = \frac{\text{Actual Construction Duration}}{\text{Total Lane Miles}}$$

Selected Highway Projects

S.N.	Name of Projects	Construction Cost	Total Length (Lane Miles)	Type of Construction	Year of Completion
1	Dallas High Five Project	$282,200,000	64	Reconstruction/ Expansion	2006
	SH45 & Loop 1, Austin				
2	Section 1 & 2	$107,961,000	39	New Construction	2007
3	Section 3	$80,997,000	30	New Construction	2006
4	Section 4	$103,018,000	44	New Construction	2007
5	Section 5	$37,610,000	28	New Construction	2006
6	Section 6	$34,058,000	28	New Construction	2006
7	Section 7	$63,228,000	25	New Construction	2006
8	Section 8	$134,923,000	27	New Construction	2007
	Katy Freeway, Houston				
9	Section 1 &2	$276,550,000	31	Reconstruction	2007
10	Section 8 & 9	$220,430,000	120	Reconstruction	2006
11	Section 10	$89,750,000	47	Reconstruction	2006
	Total Cost	**$1,430,725,000**			

Average Construction Cost = $135 M

Findings: Design Cost Statistics

Types of Statistics	Design Cost (%)
Mean	11.7
Median	10.2
Maximum	30.2
Minimum	3.5
Standard Deviation	8.7
No. of Samples	11

Average Design Cost = 11.7%

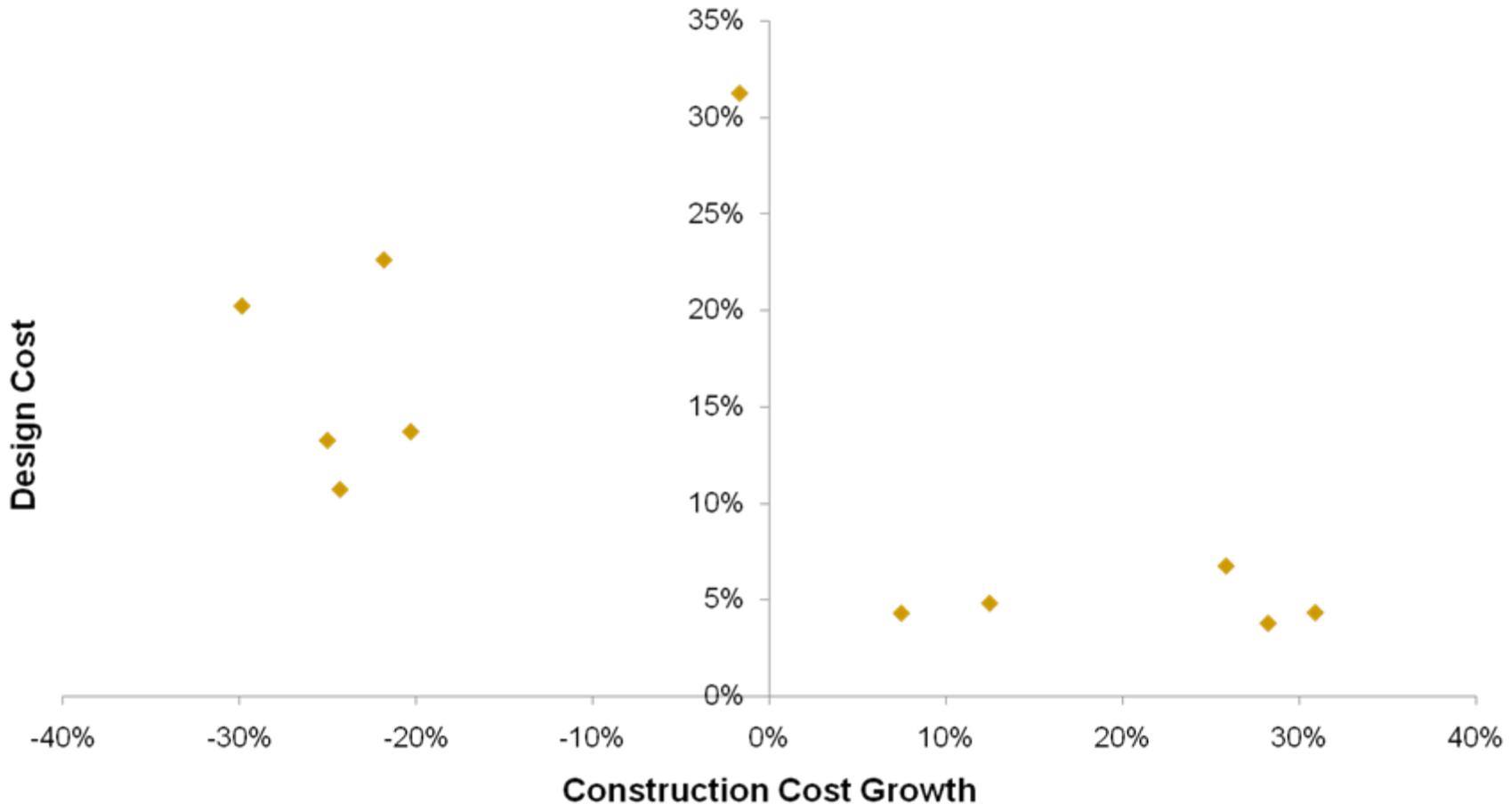
Findings:
Construction Performance Statistics

Types of Statistics	Cost Growth (%)	Cost per Lane Mile ($M)	Schedule Growth (%)	Delivery Speed per Lane Mile (Days)
Mean	-1.65	3.48	2.61	28.6
Median	-1.70	2.92	0	28.2
Maximum	30.91	8.90	35.05	44.5
Minimum	-29.90	1.32	-9.07	7.7
Standard Deviation	23.68	2.20	12.06	10.3
No. of Samples	11	11	11	11

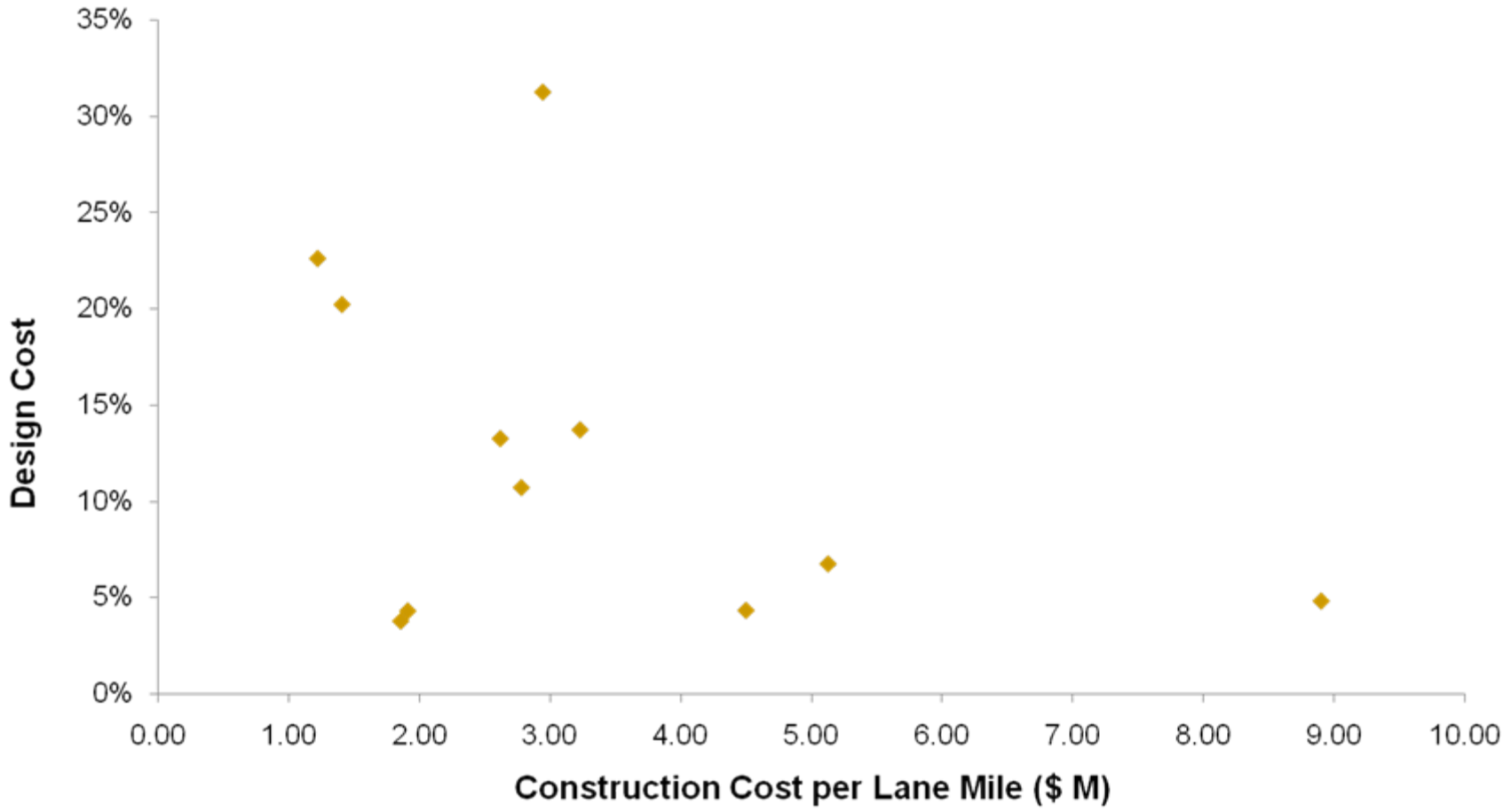
Average Cost Growth = -1.65%
Average Construction Cost-per-Lane Mile = $3.48 M

Average Schedule Growth = 2.61%
Average Construction Delivery Speed-per-Lane Mile = 29 Days

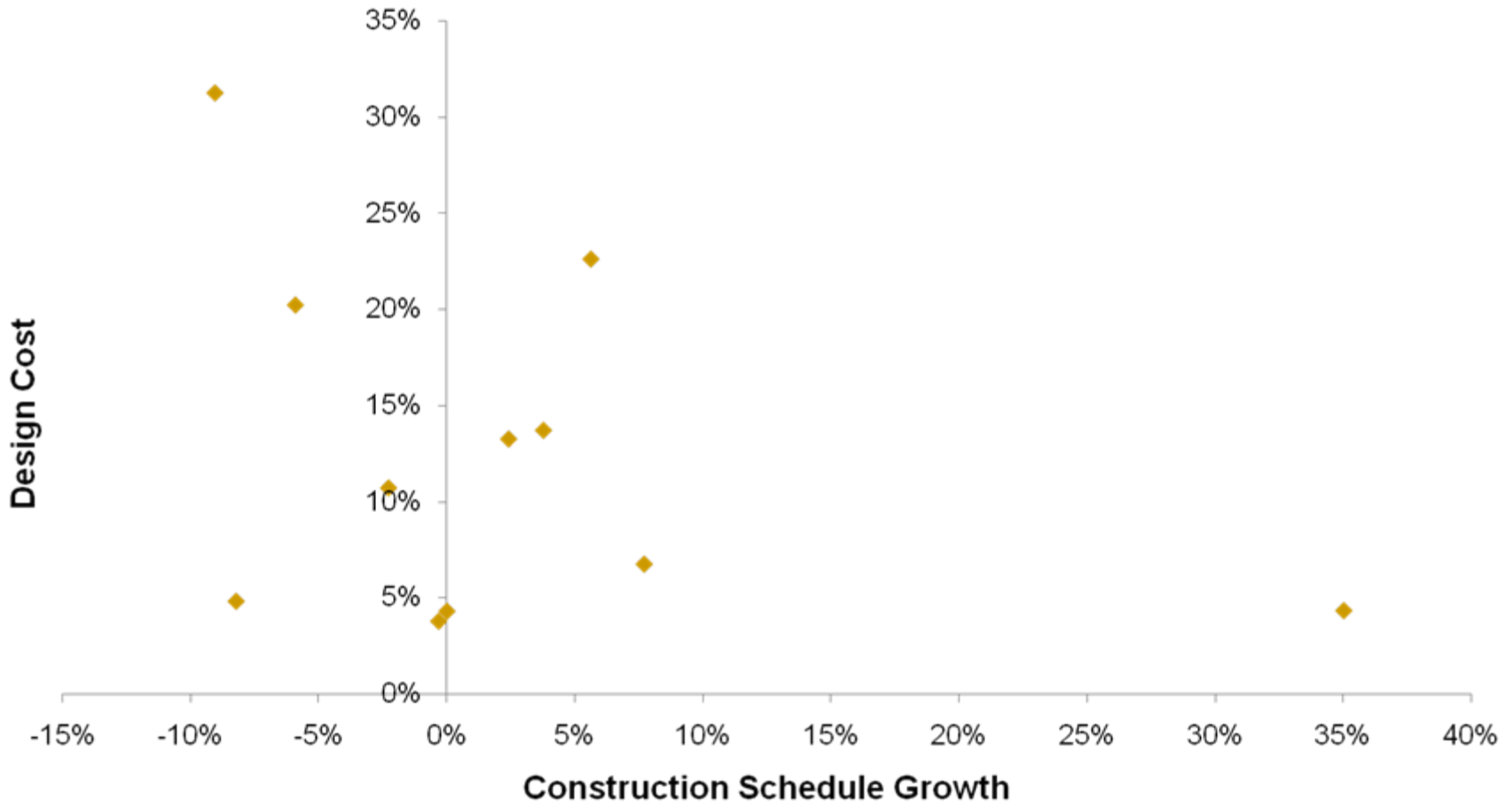
Findings: Correlation Analysis



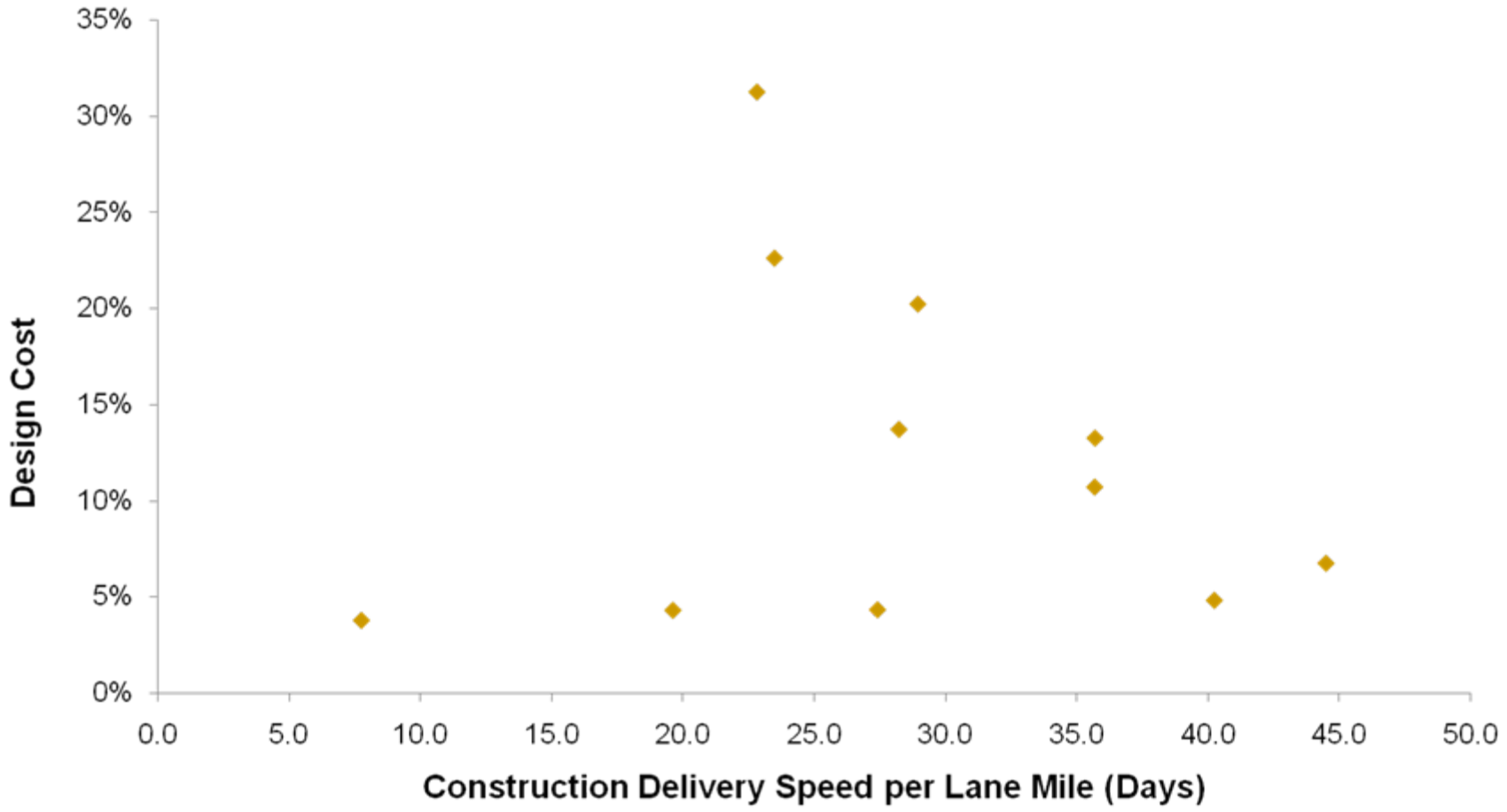
Findings: Correlation Analysis



Findings: Correlation Analysis



Findings: Correlation Analysis



Conclusions

- The trend shows
  - Construction cost growth decreases as the design cost increases
  - Construction cost-per-lane mile and delivery speed-per-lane mile decreases as design cost increases
- Due to limited sample size, the findings cannot be generalized
- Authors are collecting more data to validate these findings

Thank You

Questions ?