

CI & CRC Joint Conference 2024

Des Moines, IA | March 20-23

Division of Cost Deviations in Integrated Project Delivery Systems Using Cooperative Game Theory

Yomna Emad, Mohamed S. Eid, Hesham A. Bassioni



Arab Academy
For Science, Technology and Maritime Transport



IOWA STATE
UNIVERSITY



IOWA STATE
UNIVERSITY

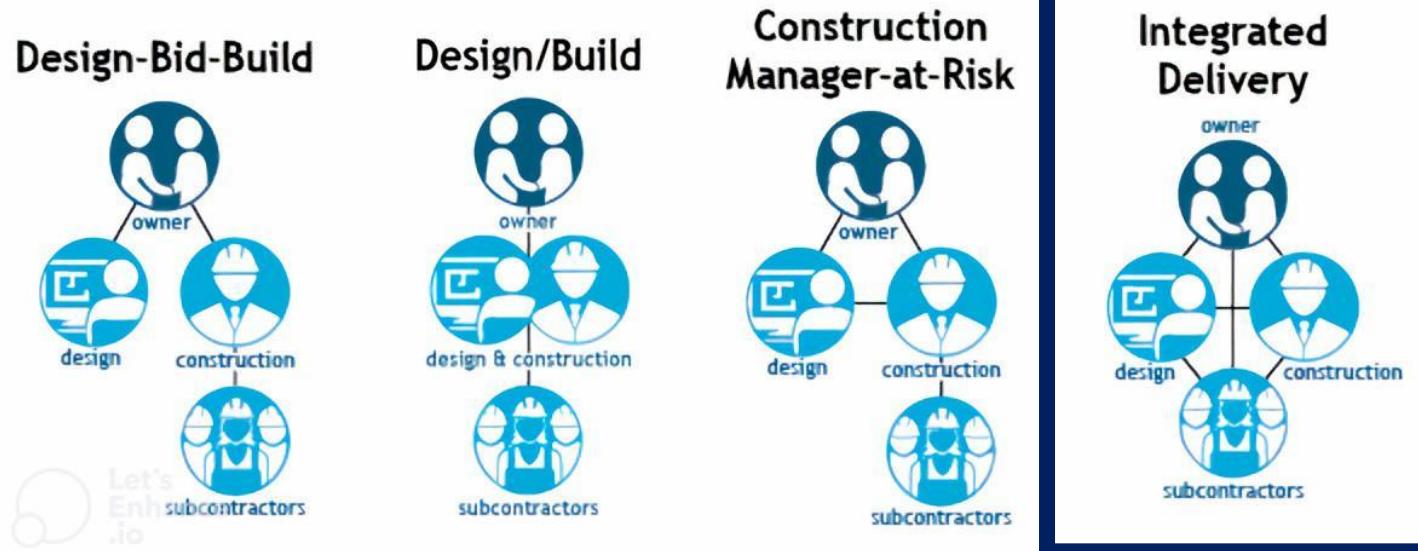
CI & CRC Joint Conference 2024

Des Moines, Iowa | March 20-23, 2024



Project Delivery Systems

A Project Delivery System (PDS) “is the comprehensive process by which a physical entity is designed and constructed (Gajurel 2014) .



(Webadmin.rexcs, 2021)

Gajurel, A. 2014. Performance-Based Contracts for Road Projects: Comparative Analysis of Different Types. New Delhi: Springer India.

INTRODUCTION

Research Gap Goal & Objectives Methodology Model Development Case Study Results & Discussion Future Recommendations



IOWA STATE
UNIVERSITY

CI & CRC Joint Conference 2024

Des Moines, Iowa | March 20-23, 2024



What is IPD?



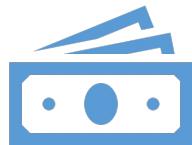
Early involvement
of all project
participants



One contract agreement
between the primary
project participants



Information sharing and
transparent
communications



Shared risks
and incentives



IOWA STATE
UNIVERSITY

CI & CRC Joint Conference 2024

Des Moines, Iowa | March 20-23, 2024



Background

Ahmed et al. 2021 & Eissa et al. 2024

- Main contractual issues facing IPD projects under AIA-C191 and ConsensusDocs 300: identification, management and allocation of cost deviations, etc.

Guo et al. 2022

- Distribution mechanism for risk and reward sharing is essential for IPD survival.



designed by freepik

Ahmed, M. O., M. Abdul Nabi, I. H. El-adaway, D. Caranci, J. Eberle, Z. Hawkins, and R. Sparrow. 2021. "Contractual Guidelines for Promoting Integrated Project Delivery." *J. Constr. Eng. Manag.*, 147 (11): 05021008. [https://doi.org/10.1061/\(ASCE\)CO.1943-7862.0002173](https://doi.org/10.1061/(ASCE)CO.1943-7862.0002173).

Eissa, R., M. Abdul Nabi, and I. H. El-adaway. 2024. "Risk-Reward Share Allocation under Different Integrated Project Delivery Relational Structures: A Monte-Carlo Simulation and Cooperative Game Theoretic Solutions Approach." *J. Constr. Eng. Manag.*, 150 (4): 04024013. <https://doi.org/10.1061/JCEMD4.COENG-13181>.

Guo, S., J. Wang, and H. Xiong. 2022. "The influence of effort level on profit distribution strategies in IPD projects." *Eng. Constr. Archit. Manag.* <https://doi.org/10.1108/ECAM-02-2022-0107>.

INTRODUCTION

Research Gap Goal & Objectives Methodology Model Development Case Study Results & Discussion Future Recommendations



IOWA STATE
UNIVERSITY

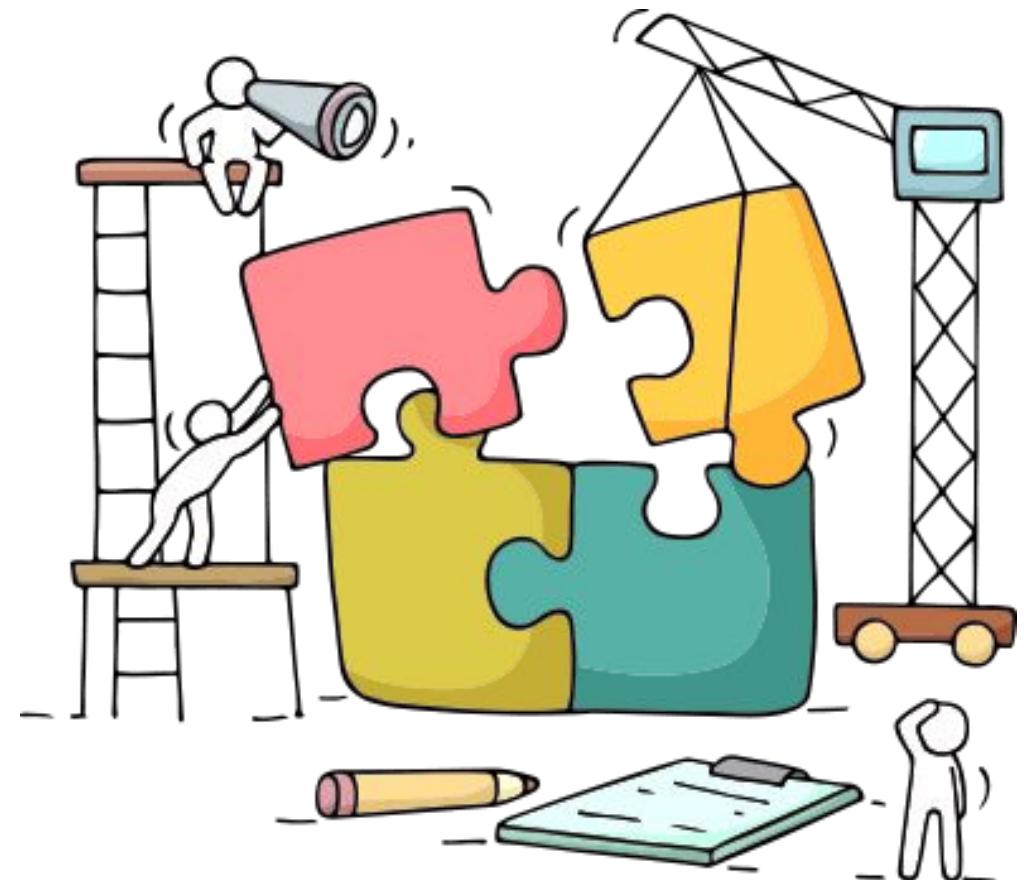
CI & CRC Joint Conference 2024

Des Moines, Iowa | March 20-23, 2024



Research Gap

The lack of a model that **fairly distributes / divides** cost savings and/or overruns,
(Cost Deviations).





IOWA STATE
UNIVERSITY

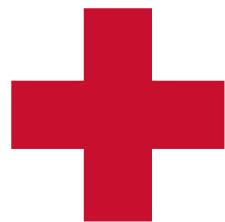
CI & CRC Joint Conference 2024

Des Moines, Iowa | March 20-23, 2024



Goal & Objectives

Quantifying
the IPD
objectives
based on
monetary
values



Determining
cost deviation
per project
participant



Fairly distribute
cost deviations
in IPD projects
between the
stakeholders



IOWA STATE
UNIVERSITY

CI & CRC Joint Conference 2024

Des Moines, Iowa | March 20-23, 2024



Methodology





IOWA STATE
UNIVERSITY

CI & CRC Joint Conference 2024

Des Moines, Iowa | March 20-23, 2024



Model Development

STEP 1

$$CV_i^t = EV_i^t - AC_i^t$$

$$TCV^t = \sum_{i=2 \text{ to } n} CV_i^t$$

AC: Actual Cost
CV: Cost Variance
EV: Earned Value
i: Player
n: No. of players

v: Worth
S: No. of Players in a coalition
\$: Shared Value
t: milestone
TB: Target Band

TC: Target Cost
TCV: Total Cost Variance
TTB: Total Target Band
φ: Shapely Value



Created by Flat Icons



IOWA STATE
UNIVERSITY

CI & CRC Joint Conference 2024

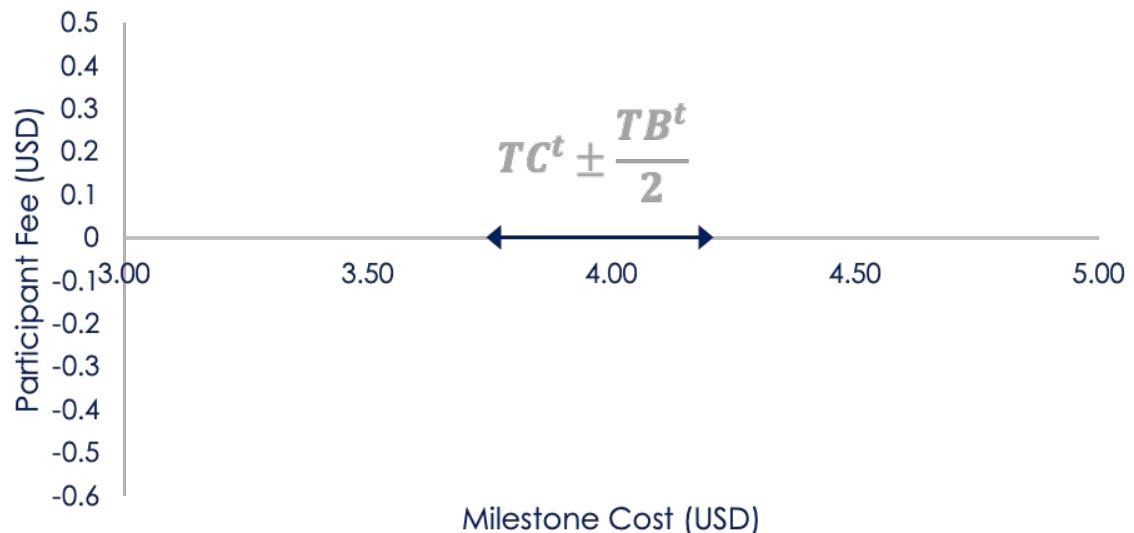
Des Moines, Iowa | March 20-23, 2024



Model Development

STEP 2

$$TB^t = \frac{\sum_{i=2 \text{ to } n} EV_i^t}{TC} \times TTB$$



AC: Actual Cost
CV: Cost Variance
EV: Earned Value
i: Player
n: No. of players

v: Worth
S: No. of Players in a coalition
SV: Shared Value
t: milestone
TB: Target Band

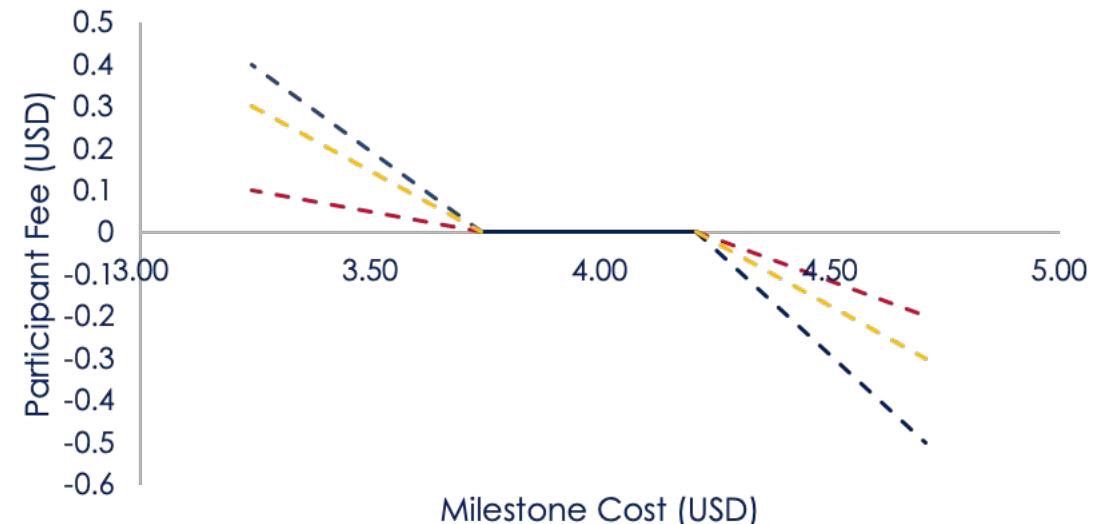
TC: Target Cost
TCV: Total Cost Variance
TTB: Total Target Band
φ: Shapely Value



Model Development

STEP 3

$$SV^t = \begin{cases} 0, & \text{if } -\frac{TB^t}{2} \leq TCV^t \leq \frac{TB^t}{2} \\ TCV^t - \frac{TB^t}{2}, & \text{if } TCV^t > \frac{TB^t}{2} \\ \left| -\frac{TB^t}{2} \right| - |TCV^t|, & \text{if } TCV^t < -\frac{TB^t}{2} \end{cases}$$



AC: Actual Cost
CV: Cost Variance
EV: Earned Value
i: Player
n: No. of players

v: Worth
S: No. of Players in a coalition
SV: Shared Value
t: milestone
TB: Target Band

TC: Target Cost
TCV: Total Cost Variance
TTB: Total Target Band
 φ : Shapely Value



IOWA STATE
UNIVERSITY

CI & CRC Joint Conference 2024

Des Moines, Iowa | March 20-23, 2024



Arab Academy

For Science, Technology and Maritime Transport

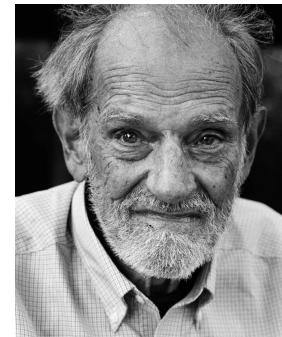
Model Development

STEP 4

$$\varphi_i^t = \sum_{S \subseteq n_{i \in S}} \frac{(|S| - 1)! * (|n| - |S|)!}{|n|!} * [v(S) - v(S - \{i\})]$$

Weighted Average

Player i marginal contribution



Lloyd Stowell Shapley
1923-2016

AC: Actual Cost
CV: Cost Variance
EV: Earned Value
i: Player
n: No. of players

v: Worth
S: No. of Players in a coalition
SV: Shared Value
t: milestone
TB: Target Band

TC: Target Cost
TCV: Total Cost Variance
TTB: Total Target Band
 φ : Shapely Value



IOWA STATE
UNIVERSITY

CI & CRC Joint Conference 2024

Des Moines, Iowa | March 20-23, 2024



Staub-French, S., P. Zadeh, D. Bhone, C. Webber, K. Jaeger, K. Consulting, M. Allison, M. Williams, P. Taylor, J. Ford, L. Consulting, D. Loewen, A. Mechanical, P. Sprokay, Erik A. Poirier, and Ahmad Arar. 2022. INVESTIGATING FACTORS LEADING TO IPD PROJECT SUCCESS IN CANADA. 143. UNIVERSITY OF BRITISH COLUMBIA; ECOLE DE TECHNOLOGIE SUPERIEURE; INTEGRATED PROJECT DELIVERY ALLIANCE.

Case Study

Barrie-Simcoe Emergency Services Campus (BSESC)

- **Budget:** \$85,799,954
- **Duration:** 38 months
- **Delivery System:** IPD
- **Core Group Members:** Owner, Architect, & Contractor
- **Project Location:** Ontario, Canada





IOWA STATE
UNIVERSITY

CI & CRC Joint Conference 2024

Des Moines, Iowa | March 20-23, 2024



Case Study

Barrie-Simcoe Emergency Services Campus (BSESC)

Assumptions

- Total Target Band (*TTB*): \$8,579,995
- Target Cost (*TC*): \$72,929,962
- Actual Cost (*AC*): \$76,000,313
- Project Milestones (*T*): 6

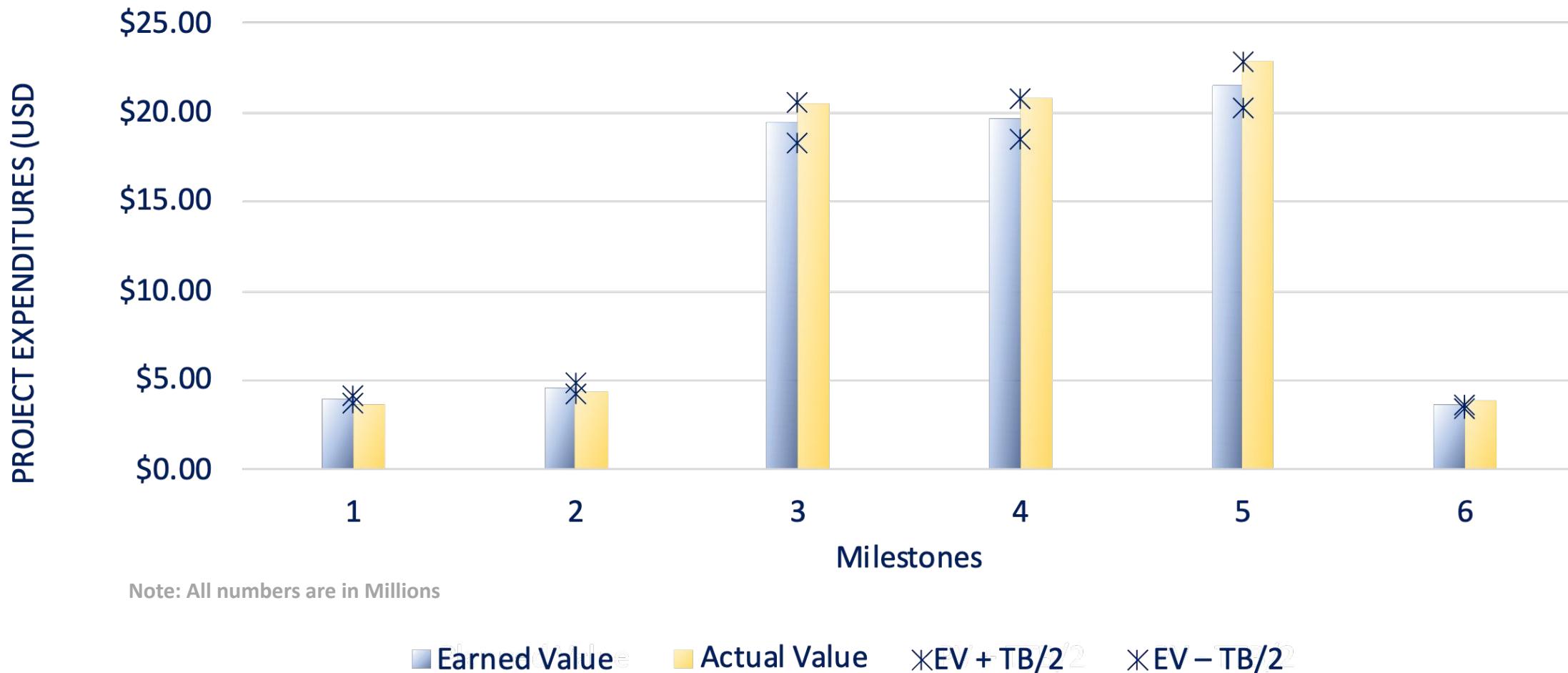




IOWA STATE
UNIVERSITY

CI & CRC Joint Conference 2024

Des Moines, Iowa | March 20-23, 2024





IOWA STATE
UNIVERSITY

CI & CRC Joint Conference 2024

Des Moines, Iowa | March 20-23, 2024



Case Study

Value Description						
	Months 1-6	Months 7-12	Months 13-18	Months 19-24	Months 25-30	Months 31-38
	\$0.0944	\$0.263	\$0.0197	\$0.0197	\$0.0197	\$0.007
	\$0.0164	-\$0.028	-\$1.065	-\$1.129	-\$1.293	-\$0.228
TCV	\$0.345	\$0.235	\$1.046	-\$1.109	-\$1.273	-\$0.221
TB_t	\$0.468	\$0.539	\$2.293	\$2.317	\$2.538	\$0.426
SV_t	\$0.111	\$0.000	\$0.000	\$0.000	-\$0.004	-\$0.008

Note: All numbers are in Millions



IOWA STATE
UNIVERSITY

CI & CRC Joint Conference 2024

Des Moines, Iowa | March 20-23, 2024



Arab Academy

For Science, Technology and Maritime Transport

Case Study

Participant		Months	Months	Months
		1-6 ($t=1$)	25-30 ($t=5$)	31-38 ($t=6$)
Owner		\$0.0527	-\$0.0054	-\$0.0053
Architect		\$0.0527	\$0.0066	\$0.0022
Contractor		\$0.0055	-\$0.0054	-\$0.0053

Note: All numbers are in Millions



IOWA STATE
UNIVERSITY

CI & CRC Joint Conference 2024

Des Moines, Iowa | March 20-23, 2024



Results & Discussion

Owner's shapely value



Image by Vectorarte on Freepik

Contribution to a specific time window



Image by pch.vector on Freepik

Positive/negative contribution

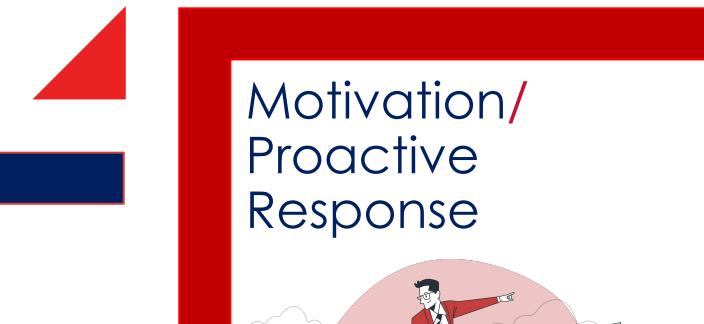


Image by vectorjuice on Freepik

Motivation/
Proactive Response



Money illustrations by Storyset





IOWA STATE
UNIVERSITY

CI & CRC Joint Conference 2024

Des Moines, Iowa | March 20-23, 2024



Arab Academy

For Science, Technology and Maritime Transport

Future Recommendations



Effect of **time**



Validation of results by a larger number of **case studies**



Quantify an **Architect's efforts**



Introducing the framework to **work professionals** in the industry



IOWA STATE
UNIVERSITY



Arab Academy
For Science, Technology and Maritime Transport

Thank You!

