NYU TANDON SCHOOL OF ENGINEERING

C2SMART
CONNECTED CITIES WITH SMART TRANSPORTATION

NYC DDC TOWN +GOWN

Culture+Data for Better Capital Project Delivery.2

December 14, 2022

Workforce Planning

Building Effective Project Delivery Teams

AGC NEW YORK STATE

NYU Tandon School of Engineering
Department of Civil and Urban Engineering

Francis X. DarConte, PhD, RA
Research Professor

Associated General Contractors of New York State

Joseph P. Hogan CDT
Vice President, Building Services

Today's Discussion

- An Industry in Crisis – Delivering New York State Mission Critical Projects
- Workforce Planning Research
  NYU - C2SMART and NYSDOT - CPRM
- Next Steps – An Industry Response – Creating a Collaborative Environment – Building Effective Project Delivery Teams
- AGC NYS Engagement in NYU Research - Metrics that Matter – Stakeholder Perspectives

An Industry in Crisis

Consider the Following…….

You are Tasked with Delivering A Mission Critical, Cannot Fail *(MCCF)* Project

"a high-risk, complex project where the failure to meet the owner's objectives and goals would cause a major disruption for its intended use or a disastrous failure in business operations."

Bud Griffis

Leadership, Ethics and Project Execution – An Evidence-Based Project Success Model. Routledge, 2022

An Industry in Crisis

Consider the Following…….

- **Projects continue to become more complex and costly**. With ever increasing emphasis on desired performance outcomes, maximizing the end-user experience, and integrating costlier, complex technical systems, **a premium is placed on a best value outcome for the design and construction of the asset.**

- Failure to achieve these outcomes can cause serious value destruction both during construction and most importantly over the life of the asset.

Responding to a Clash of Market Conditions.....

- A tremendous market on the horizon for **New York State** headlined by such signature projects as Buffalo Bills Stadium, I-81, Micron, Kensington Expressway and Genesee Stamp to name just a few.
- Beyond that will be myriad supportive projects both to support the needed manufacturing operations and the infrastructure – horizontal and vertical (including work on the grid)– necessary for the needs of the ongoing operations of the facilities.
- NYS Environmental Bond Act

Responding to a Clash of Market Conditions.....

- As the AEC industry prepares for this market, we face severe headwinds. Workforce shortages at all levels from design consultants, craft labor to supervisory personnel are a general issue the industry faces.
- The public owner is consistently challenged to plan, design, and construct projects with limited resources at its disposal.

Project Delivery Teams are Required to do More with Less!

Responding to a Clash of Market Conditions.....

Effective Project Delivery is about the

- **Management Systems** the delivery team can deploy.
- the **Operational Environment** that has been created to support their delivery functions.
- **Resources** a delivery team has available to perform their roles.

Workforce Planning is about

- Understanding the **Availability and Capability** of the Delivery Team Workforce.
- **Onboarding and Building Effective Project Delivery Teams**

Responding to a Clash of Market Conditions……

Can we Meet the Moment?

NYSDOT Capital Project Resource Model

A Case Study – Phase 1

Kaan Ozbay PhD
Director, C2SMART University Transportation Center
New York University

Frank DarConte PhD, RA
Principal Investigator, C2SMART University Transportation Center
New York University

Tu Lan, PhD Candidate
Data Scientist

Dilruba Ozmen-Ertekin PhD
Data Scientist

Liu Yang
Computer Programmer

NYSDOT Capital Project Resource Model

A Case Study

- The **NYSDOT CPRM** examination explored the type of design and construction-oriented personnel required by project type, position title, function code, and number of transaction hours (FTE) including the timing of the task linked to development phase of the project.

- The analysis has yielded an **empirically defined snapshot** of the project development team leading to the development of staffing templates linked to specific project Scopes of Work (SOW) that can be used to model resources required for future capital program delivery.

CPRM PROGRAM RECAP

NYSDOT uses its Capital Program Plan to allocate resources to the many capital improvement projects being planned throughout the State.

The *objective* of this study is to develop a model (algorithm) that links the resource requirements for Capital Program delivery functions with the NYSDOT Capital Program.

The goal is to estimate NYSDOT resource needs over five years to build their capital program.

The *long-term goal* for the department is to have a comprehensive model that would allow this resource link at a level as granular as individual projects.

This project is intended to support NYSDOT with their *workforce planning*, identify staffing gaps, missing resources, shortfalls and provide a roadmap for aligning project needs with resources required to deliver a highly successful project.

C2SMART – Underpinnings of the Investigation

Simplistically the Chief Engineer asks…

- ***How many staff hours do I need in year X in Region Y to deliver the capital program?***

Basic Concept

- Determine how NYSDOT really spends its time to deliver projects across the 11 regional offices
- Not previously explored at NYSDOT – Not clear that this has been done at any DOT (or at least not documented) across the country

Research Tasks

1. **What are Other Agencies Doing?** ***(Best Practices/Literature Review)***

2. **Database Discussions** ***(Data Requirements and Availability)***
   - FTE Model Data Sources and Verification
     - Proof of Concept - 719 Project Database
     - Supplemental 35,660 Project Database
   - FTE Model Data Validation and Reliability
   - FTE Model Data Variation

3. ***What Data do we Need to Include so the Algorithm Functions Optimally?***
   - Portfolio of Variables
   - Independent and Dependent Variables
   - Generic Staffing Templates

4. ***Capturing Insights and Relationships – Data Mining Efforts and Outcomes***
   - Metrics that Matter
   - Capture the Range of Complexities encountered within a given project type.

NYSDOT DATABASE RECAP

- FTE 719 Datasets – Proof of Concept Analysis
  - 28 Original Project Type
  - MTD Hours/Costs for Design/Construction by project

- CPRM 16,211 Accounting – Employee Transactions - Datasets by Regions
  - PS: Position Title Oriented:

    Position Title, Hours, Amount, Function Code
  - NPS-Capital: Transaction Oriented:

    Amount, Function Code, Fund Categories

- PSS DW 35,660 Datasets
  - Transportation Parameters
  - Work Type Parameters

NYSDOT PSS DATABASE RECAP – 11 REGIONS

6.4 M

Transactions

- **14 Columns**
- **11 regions**
- **16,211 PINs**

- Hudson Valley: Region 8
- New York City: Region 11
- Upstate: Region 1~7, 9
- Long Island: Region 10

31

Years

From the Oldest Transaction to the Newest
6/20/1990
||
3/4/2021

28 Project Types:

- Hudson Valley : 19 project types
- New York City: 14 project types
- Upstate: 28 project types
- Long Island 9 project types

8

Key Data Points

- **Transaction Date**
- **Letting Date**
- **Detailed Design Authorization Date**

- PINS - Regions
- FTE Hours
- Position Titles - CST
- Function Codes
- Project Types
- Project Development Stages
- Construction Cost

MECHANICS OF THE MODEL

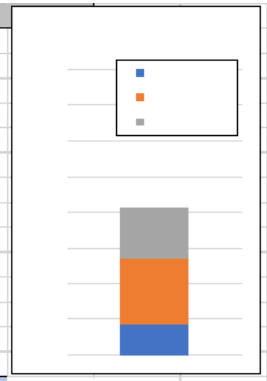
Sample Table – CPRM Bio Sheet Summary

Project Type	Bridge Replacement (<$5M)

STATEWIDE DATA SUMMARY	
# Projects	29
Avg. Const. Cost	3.4
Median Const. Cost	3.5
St. Dev. Const. Cost	1.5

Hours per 1$M of Construction ($2021)

	Avg	Median	St. Dev	Q1	Q3	Min	Max
Preliminary Design	857	857	286	557	1114	129	1886
Final Design	1857	1857	619	1207	2414	378	4114
Construction	1429	1429	476	929	1857	214	3143
Total	4143	4143	1381	2693	5386	721	9143



FTE Hours, Avg. % of Total by Phase

	Prelimin	Final De	Construction
Technicians	10%	5%	20%
CS1/AE/TA	40%	25%	40%
PE1	20%	25%	10%
PE2	5%	10%	5%
Mngmt	5%	5%	5%
Environmental	10%	10%	5%
OROW	0%	10%	0%
Tech. Specialists	5%	5%	10%
Other	5%	5%	5%

REGIONAL COST AND FTE DELIVERY VARIATION

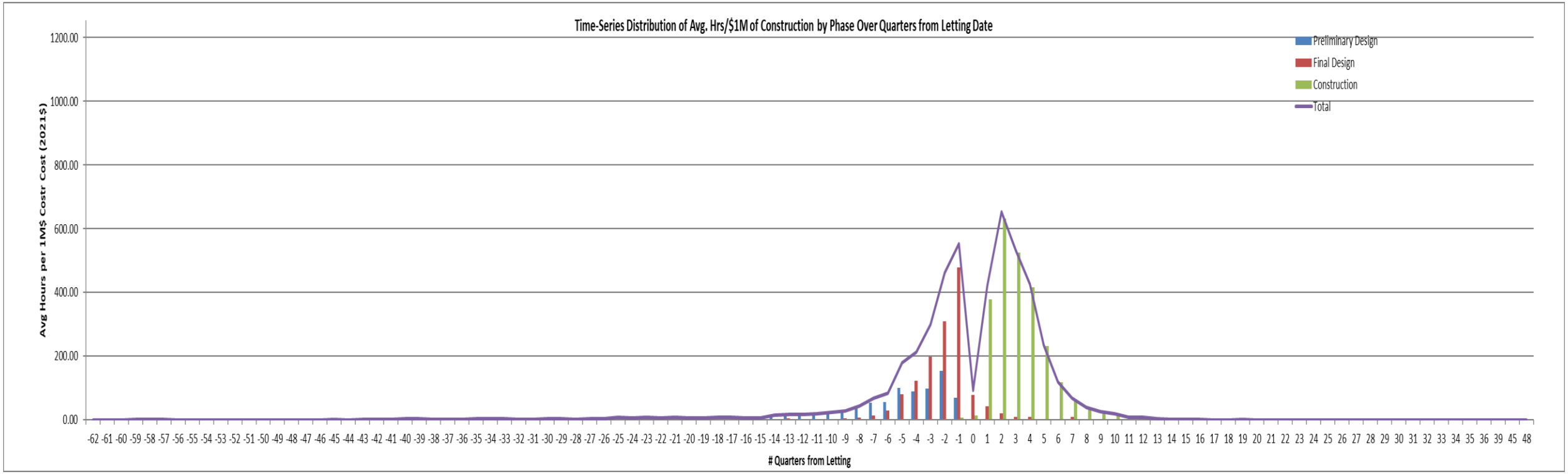
	# Proje	(Reg Co	(Reg FTE):(SW FTE)
R1	50	1.01	1.01
R2	25	0.85	0.85
R3	40	1.02	1.02
R4	35	1.00	1.00
R5	50	1.02	1.02
R6	25	0.90	0.90
R7	25	0.92	0.92
R8	60	1.15	1.15
R9	60	1.02	1.02
R10	10	1.20	1.20
R11	0	NA	NA

FTE Hours by Function (Top 90% hrs detailed)	
Function 1	
Function 2	
etc	
etc	
etc	

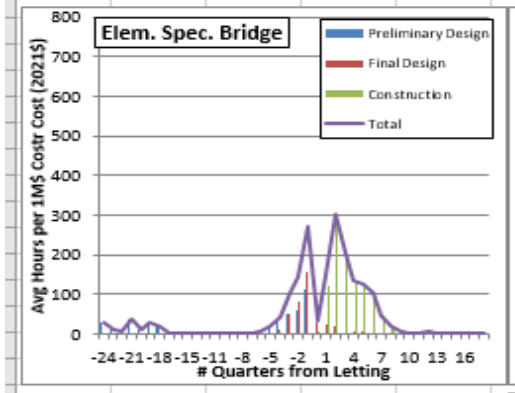
	Hours per 1$M of Construction ($2021)				% Total Hours Per Phase			
Quarters fr	Preliminary De	Final Design	Construction	Total	Preliminar	Final Desig	Constructi	Total
-16	9	0	0	9	1.0%	0.0%	0.0%	0.2%
-15	17	0	0	17	2.0%	0.0%	0.0%	0.4%
-14	26	0	0	26	2.9%	0.0%	0.0%	0.6%
-13	34	0	0	34	3.9%	0.0%	0.0%	0.8%
-12	43	0	0	43	4.9%	0.0%	0.0%	1.0%
-11	51	0	0	51	5.9%	0.0%	0.0%	1.2%
-10	69	0	0	69	7.8%	0.0%	0.0%	1.6%
-9	86	0	0	86	9.8%	0.0%	0.0%	2.1%
-8	94	0	0	94	10.8%	0.0%	0.0%	2.3%
-7	103	37	0	140	11.8%	2.0%	0.0%	3.4%
-6	137	149	0	286	15.7%	8.0%	0.0%	6.9%
-5	86	186	0	271	9.8%	10.0%	0.0%	6.5%
-4	69	279	0	347	7.8%	15.0%	0.0%	8.3%
-3	34	316	0	350	3.9%	17.0%	0.0%	8.4%
-2	17	427	0	444	2.0%	23.0%	0.0%	10.7%
-1		464	0	464	0.0%	25.0%	0.0%	11.2%
0	0	0	29	29	0.0%	0.0%	2.0%	0.7%
1	0	0	143	143	0.0%	0.0%	10.0%	3.4%
2	0	0	286	286	0.0%	0.0%	20.0%	6.9%
3	0	0	286	286	0.0%	0.0%	20.0%	6.9%
4	0	0	143	143	0.0%	0.0%	10.0%	3.4%
5	0	0	143	143	0.0%	0.0%	10.0%	3.4%

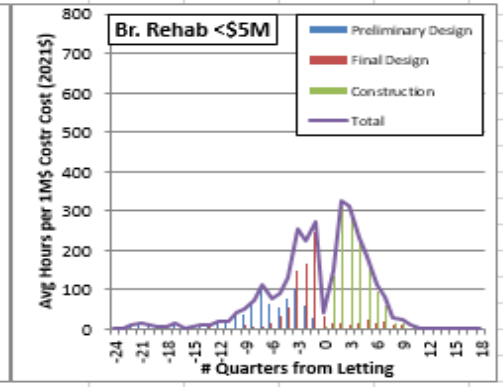
MECHANICS OF THE MODEL

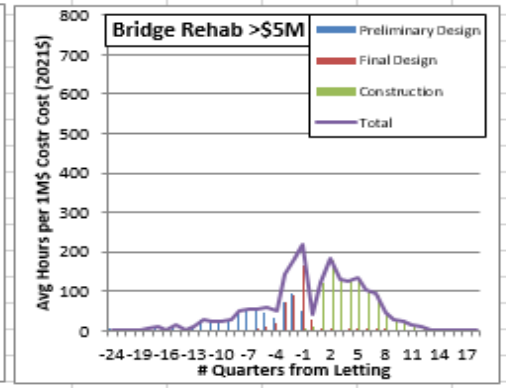
Sample Time – Series Distribution by Project Development Phase

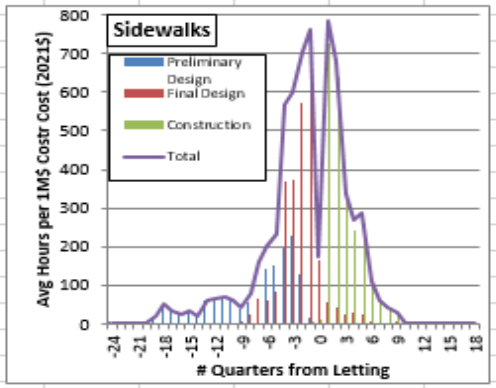


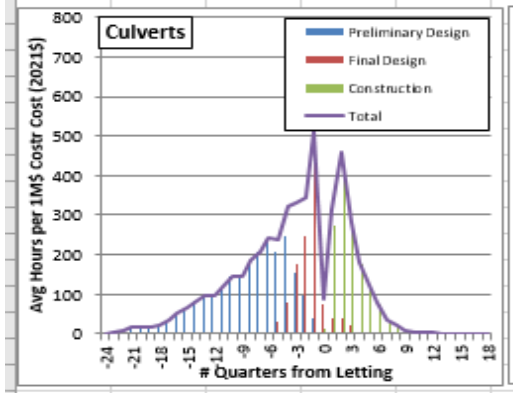
CPRM - FTE Hours / $1M Construction Preliminary Results-Upstate

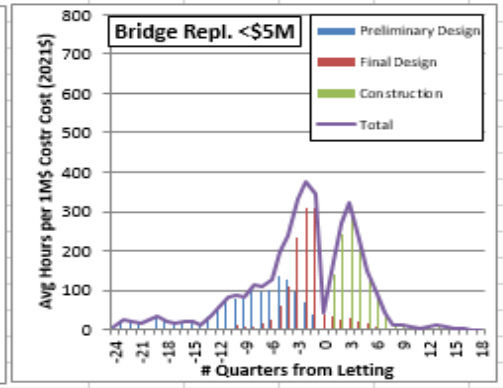


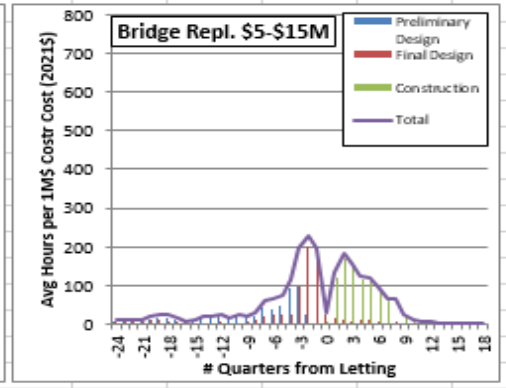


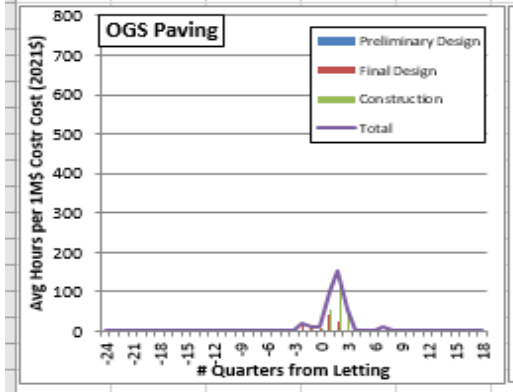


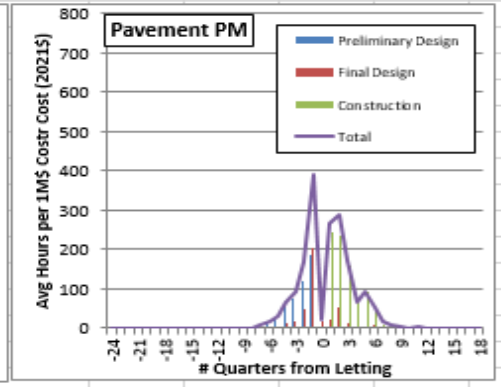


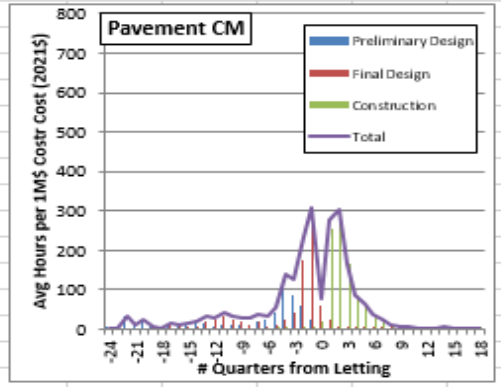












NYU

C2SMART

NYSDOT 5-Year Capital Plan
Regional Resource Projections

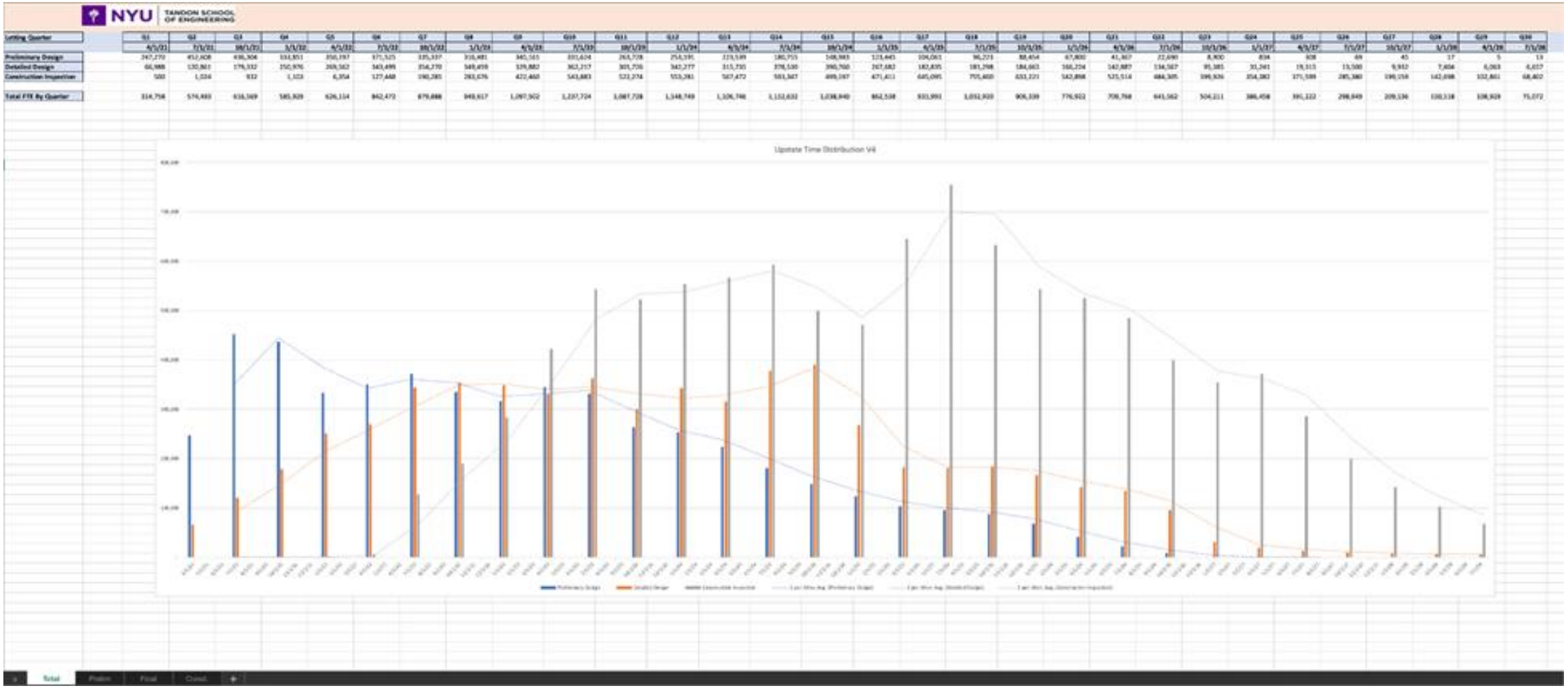
- The Regional Resource Projection is the summation of quarterly FTE hours of all projects in that super region. Grouping of Regions into 4 Super Regions.

- The FTE hours needed for each 5YCP project, and its time distribution are calculated/projected for the three project development work phases: **preliminary design, final detailed design and construction inspection.**

- The general information profile introduced the Region, PIN, Project Title, Project Type, Complexity, Letting Source Organization, Area Type, Current Stage, Current Status, Consultant Involvement, Federal Environmental Classification, and State Environmental Classification

- FTE resources mapped into a unified timeframe from 04/01/2021 to 07/01/2028.

NYSDOT 5-Year Capital Plan
Regional Resource Projections



Long Term Project Goals

Doing more with less

- Evaluate efficiencies of project teams and relationship to project types and scopes of work
- Cross-regional team formation – 11 NYSDOT Regions
- Staffing Gaps – 5 Year Capital Plan – identify NYSDOT resource needs
- Matching resource requirements with delivery workloads
- Define Project Complexity
- RAID Model - Building High Performance Teams – Team Alignment Assessments

Technologies and Techniques to enhance our analysis

- Dashboard design - efficient user interface
- **AI – Machine learning - optimization**

Flow Diagram – CPRM Tool Development

Step 1 – Historical Analysis

FTE Staff Resource Utilization by Project Type & Region

NYSDOT 719 Project Database
Mega-Project Database

Step 2 – Historical Analysis

FTE Staff Resource Utilization by Project Scope Description & Region

NYSDOT – Additional 10-Year 35,000 Project Database

Step 3 – Staffing Templates

- Project Identification (PIN)
- Project Scope Description /Region
NYSDOT Employee FTEs - (.100,.200,.300 PIN categories)
Convert/apply project external consulting costs
- Synthesis/sort civil service titles w/CST Function Codes
- Synthesis/Sort FTE Transaction Hours w/Transaction Dates

Development of Interactive Dashboard – Applying Project Attributes

Project Attributes

Step 4 – Independent Variables

(1) Project Scope Des. – OPPM List
(2) Complexity Level
(3) Environmental Category
(4) Area Type
(5) Contract Mechanism (PDM)
(6) Project Description
(7) Region
(8)) Project Construction Cost

Apply Attribute Weights

Projecting FTE Requirements

Step 5 – Define Dependent Variables

(1) Total Development Cost - FTEs
(2) Subtotal Design Cost - FTEs
(3) Subtotal Construction Cost - FTEs
(4) FTE Transactions - Timing
(5) Organization Codes
(6) Function Codes
(7) Civil Service Types
(8) Staff Resource Categories

Applying Expert Systems
Optimization of Staffing Structures
Development of Staffing Templates

5- Year Capital Plan Project List

Capital Project Development Define Resource Requirements and Gap Analysis

What Data do we Need to Include so the Algorithm Functions Optimally?

Dependent and Independent Variables

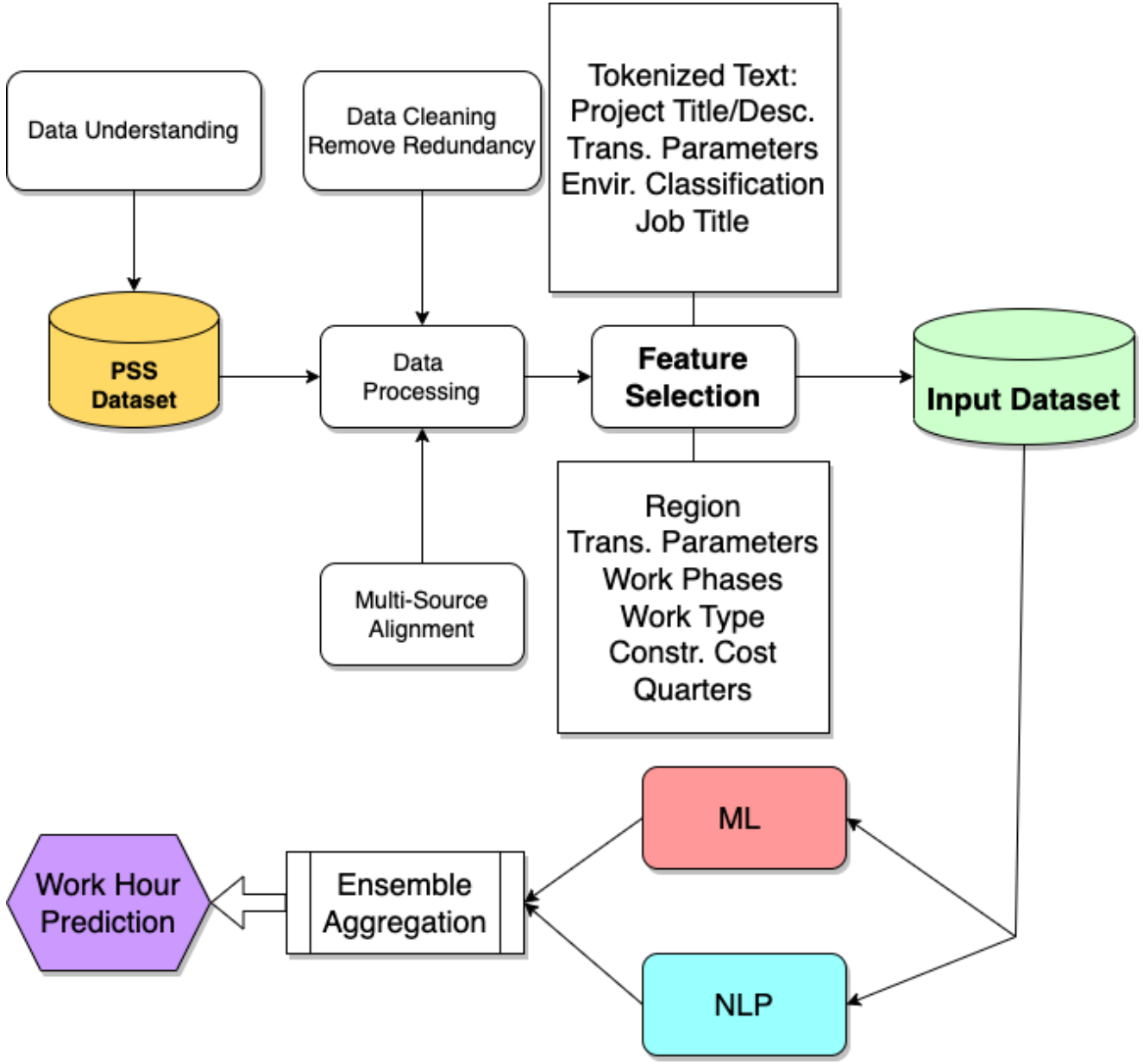
Dependent Variables **Model Outputs** **Project Specific Outputs**	Independent Variables **Model Inputs** **Project Specific Characteristics**
FTEs	Project Type Project Complexity Project Scale – Construction Cost Range Projected Schedule Duration Project Phase Project Delivery Method Project Uniqueness Contract Mechanism Regional Area External Influences Regional Productivity Factor Regulatory Involvement

Introducing AI Machine Learning into Workforce Prediction

- **Enhanced More Computational Power to Improve Prediction Accuracy**
  - Now: One Model per Project Type per Super-region
  - Then: One Model per Position Title/Function per Quarter per Work Phase per Project Type per Region and more!
- **Future Adaptivity**
  - The main advantage over statistical and mathematical DM algorithms is additivity of Machine Learning algorithms to a changing environment
  - Inputs of new projects and transactions to the ML model do NOT require reconstruction
- **Human Labor Economic**
  - Once a well-built ML model is ready, it is more economic in human labor to maintain and improve the running model than statistical algorithms
  - We do not to repeat the same work every 5 years!
- **Utilize Unused Attributes**
  - Computational Linguistic Technology enable us to comprehensively consider characteristics of a capital project including its "Project Title" and "Project Description" to improve labeling and prediction accuracy

THUS: ML algorithms are suitable for modelling complex CP data which can hardly be programmed and up to a certain point mimic the human learning process.

ML Workflow


Data Understanding
Data Cleaning
Remove Redundancy
Tokenized Text:
Project Title/Desc.
Trans. Parameters
Envir. Classification
Job Title
PSS
Dataset
Data
Processing
Feature
Selection
Input Dataset
Region
Trans. Parameters
Work Phases
Work Type
Constr. Cost
Quarters
Multi-Source
Alignment
ML
Work Hour
Prediction
Ensemble
Aggregation
NLP

Next Steps
AEC Industry Engagement

AEC Industry Engagement – New York State

Building Effective Project Delivery Teams

- Broad Discussions about Solving Industry Issues
- Creating a Collaborative Environment – Owners/Designers/Constructors
- Private and Public Owners
- AGC NYS and NYS EDC
- AGC NYS and NYU Tandon Research

Delivering a Mission Critical Cannot Fail Project

- To meet the project's desired performance outcomes, an owner must assemble a capable team and employ a project delivery method (PDM) that best supports the vision for project execution.

- It is especially important for designers and constructors, whose primary interdependent function is the sharing of expertise and knowledge, to take the steps necessary to successfully on-board and integrate their workforce.

Delivering a Mission Critical Cannot Fail Project

- An appropriate set of project execution strategies, if understood and adopted by the project delivery team, can result in (or lead to) significant improvements in project performance outcomes. **Starts with the Stakeholders walking in each others' shoes.**

- The competitive advantage and effectiveness of projects/ construction organizations can be improved with the help of understanding and managing cross-cultural differences between stakeholder organizations.

- **Team effectiveness** can be enhanced by eliminating AEC organizational cultural barriers in the construction project.

Change the Culture from

protecting individual self-interests

to looking out for each other

Project First Thinking

Rapid Alignment Initiated Delivery™

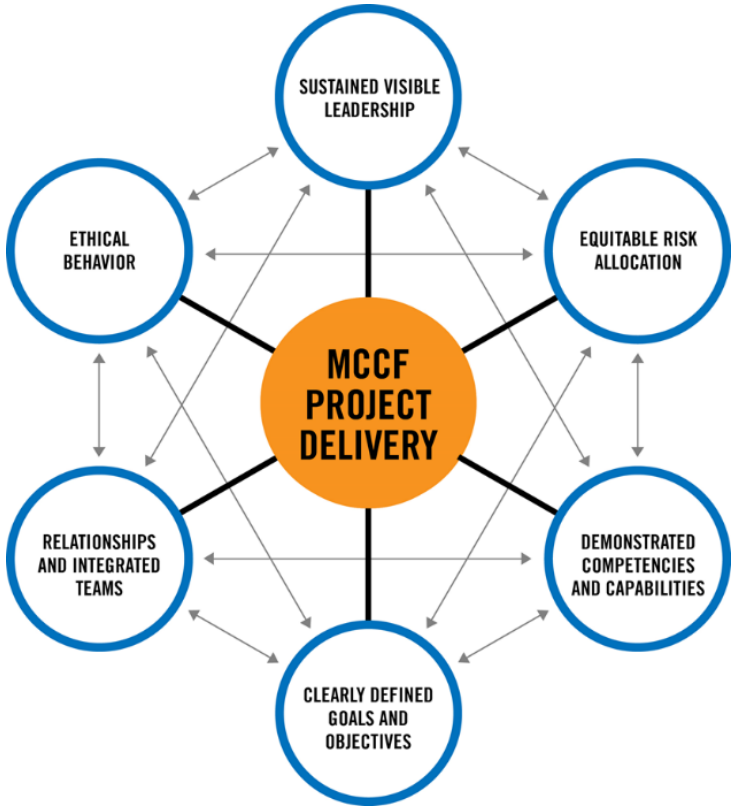
The *Rapid Alignment Initiated Delivery ™* Diagnostic Tool was developed by Dr. Bud Griffis, Dr. Andrew Bates, and Dr. Frank DarConte to provide a method of benchmarking the alignment level and potential effectiveness within a team by working through several constructs - Stakeholder Alignment Proposition Elements or SAPEs found to be critical to project delivery performance outcomes.

Rapid Alignment Initiated Delivery™

ETHICAL BEHAVIOR
Characterized by honesty, accountability, and transparency that supports the conditions to build trust amongst the project stakeholders. A top-down attribute, leadership exhibiting ethical behavior will foster a culture of cooperation.

EQUITABLE RISK ALLOCATION
Reasoned risk allocation, prompt payment and change management practices all supported by fairness and equity in relationships.

CLEARLY DEFINED OBJECTIVES AND GOALS
Goal setting involves the team's conscious process of establishing high levels of performance and a shared vision for achievability to obtain desired performance outcomes.



SUSTAINED VISIBLE LEADERSHIP
The visible leader sets a clear vision for the project, creates a tone for engagement fostering a building of trust in relationships. Sustained visible leadership requires ethical leaders.

RELATIONSHIPS AND INTEGRATED TEAMS
Primary stakeholders working together in the best interest of the project **(Project First Thinking).**

The arrangement requires a willingness to share knowledge that supports an interdependent, team-based approach to the work.

DEMONSTRATED COMPETENCIES AND CAPABILITIES
Demonstrated competencies and capabilities lead to excellence in project team performance.

CE-GY 8393 Leadership, Ethics, and Project Execution

Graduate CM - Summer Capstone Research

- To meet the project's desired performance outcomes, an owner must assemble a capable team and employ a project delivery method (PDM) that best supports the vision for project execution.

- It is especially important for designers and constructors, whose primary interdependent function is the sharing of expertise and knowledge, to take the steps necessary to successfully on-board and integrate their workforce.

- **Leaders must take the time to invest in developing a high-performance team as early as possible in the project delivery life cycle.** Hence, the selection of the PDM and alignment with a team's operational culture can have a significant impact on project success.

The Study Vision

Beginning with the end in mind – how might we best inform and support the AEC industry in New York State?

- Presenting the **Constructor's** perspective, the Summer Capstone study is conducted as an initial step to uncover insights and strategies that define the most effective path to delivering capital projects - achievability – *one that benefits each of the primary stakeholders and yields the best of possible outcomes – A Best Value Outcome.*

- Future assessments (Spring 2023) will target the **design consultants** and **project owner** perspectives.

Project Delivery Insights – AGC NYS Member Findings

- Preferred Project Owner: Private Sector by 8:1 Margin.
- Private Sector Work: Large Percentage of Repeat Clientele Work.
- 100% Agree or Strongly Agree that the use of Performance Measurement Mechanisms is an effective tool to bring about accountability of team members
- CM/GC or CMR preferred methods of project delivery.
- CMR is the PDM most likely to maintain budgets, schedules, and quality control.
- DBB most likely to result in contract disputes. CMR and IPD the least likely.
- Contract documents are vehicles that tend to benefit the design consultant and are problematic for the constructor.

Project Delivery Insights – AGC NYS Member Findings

- Contractors overwhelmingly believe design consultants spend to much time on design aesthetics and not enough time on construction details.
- Strong Ethical Behavior exhibited by Team Members correlated with Highly Successful Projects.
- Most Project Owners and Design Consultants are not accountable and do not accept responsibility for their mistakes. Believe the opposite about themselves.
- Most Design Consultants will not acknowledge responsibility for project changes connected to errors and omissions in the contract documents.
- Completeness and coordination of construction documents generally considered to be poor.
- Project delivery stakeholders tend to place individual interest ahead of project interest.

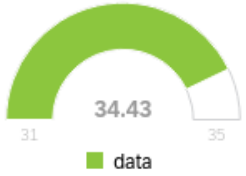
Project Delivery Insights – AGC NYS Member Findings

- Contractors view the issue of Designer Consultants and Project Owner determining fair value of change orders as problematic.
- Profitability of the contractor and trade contractors is critically important.
- Building of Trust among the team members is the most critical factor for achieving project success.
- Contractors apply a greater focus and effort on projects they view as having "No Option for Failure."
- Project teams with strong interpersonal relationships tend to treat each other more fairly than teams that do not exhibit them.
- **To become an effective team, each of the primary stakeholders must align their personal and professional goals with the goals (Project First Thinking).**

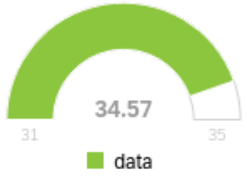
RAID Model Stakeholder Alignment Proposition Elements (SAPEs)

Rate the importance of each RAID model construct regarding its contribution to project success?

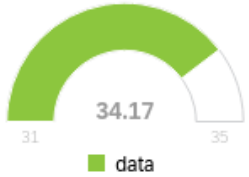
Ethical Behavior



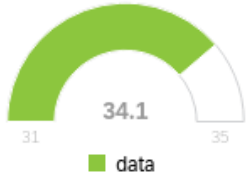
Clearly Defined Objectives and Goals



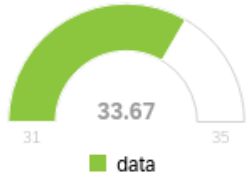
Demonstrated Competencies and Capabilities



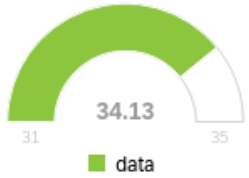
Relationships and Integrated Teams

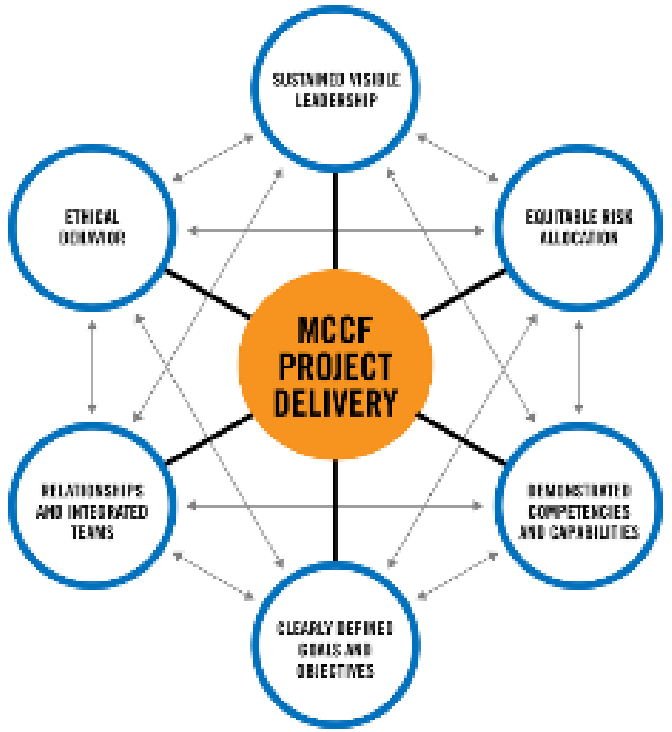


Equitable risk Allocation



Sustained Visible Leadership





Thank You