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TRANSPORTATION RESEARCH BOARD

TRB Webinar: Building Information Modeling for Infrastructure

November 1, 2021

2:00- 4:00 PM Eastern

@NASEMTRB
#TRBwebinar

PDH Certification Information:

- 2 Professional Development Hours (PDH) – see follow-up email for instructions
- You must attend the entire webinar to be eligible to receive PDH credits
- Questions? Contact Beth Ewoldsen at Bewoldsen@nas.edu

#TRBwebinar

The Transportation Research Board has met the standards and requirements of the Registered Continuing Education Providers Program. Credit earned on completion of this program will be reported to RCEP. A certificate of completion will be issued to participants that have registered and attended the entire session. As such, it does not include content that may be deemed or construed to be an approval or endorsement by RCEP.

RCEP

REGISTERED CONTINUING EDUCATION PROGRAM

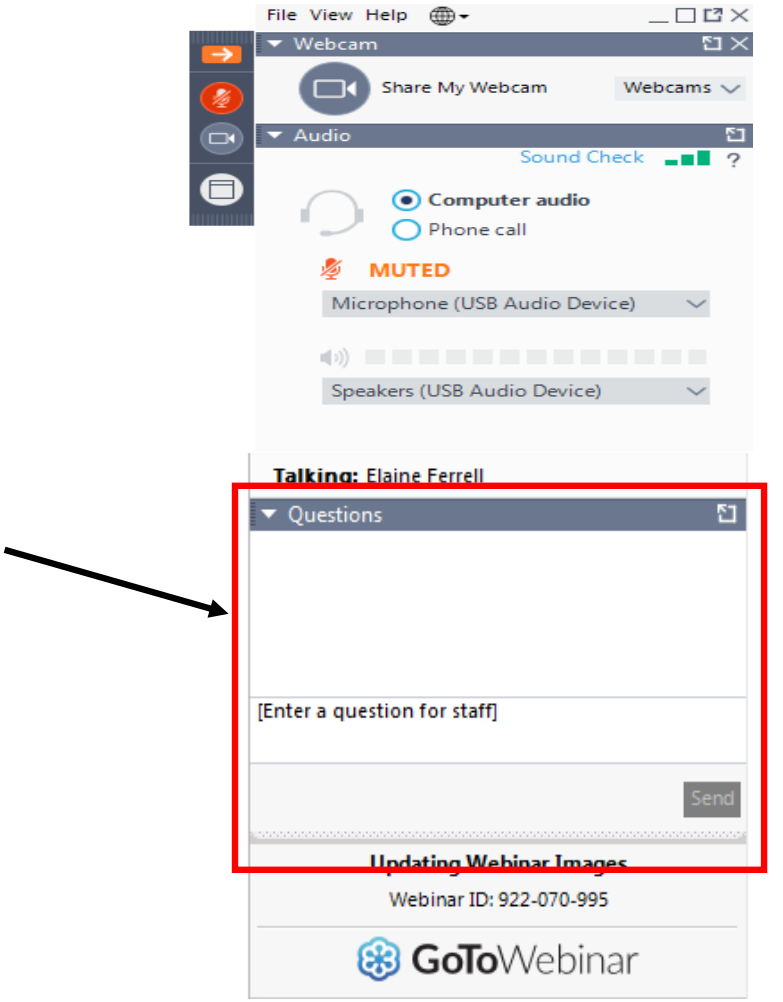
Learning Objectives

- Identify strategic steps to implement or advance BIM within their organizations
- Discuss benefits and costs of deploying BIM for infrastructure at the enterprise level
- Identify metrics to calculate ROI

#TRBwebinar

Questions and Answers

- Please type your questions into your webinar control panel
- We will read your questions out loud, and answer as many as time allows



#TRBwebinar

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Lifecycle BIM for Infrastructure

Research Findings & ROI Webinar

November 1, 2021

Agenda

- Research Overview
- What is BIM?
- BIM Use Cases
- Costs and Benefits of BIM
- BIM Execution Planning
- Research Findings
- ROI Tool Tutorial
- Q&A Session

Research Overview

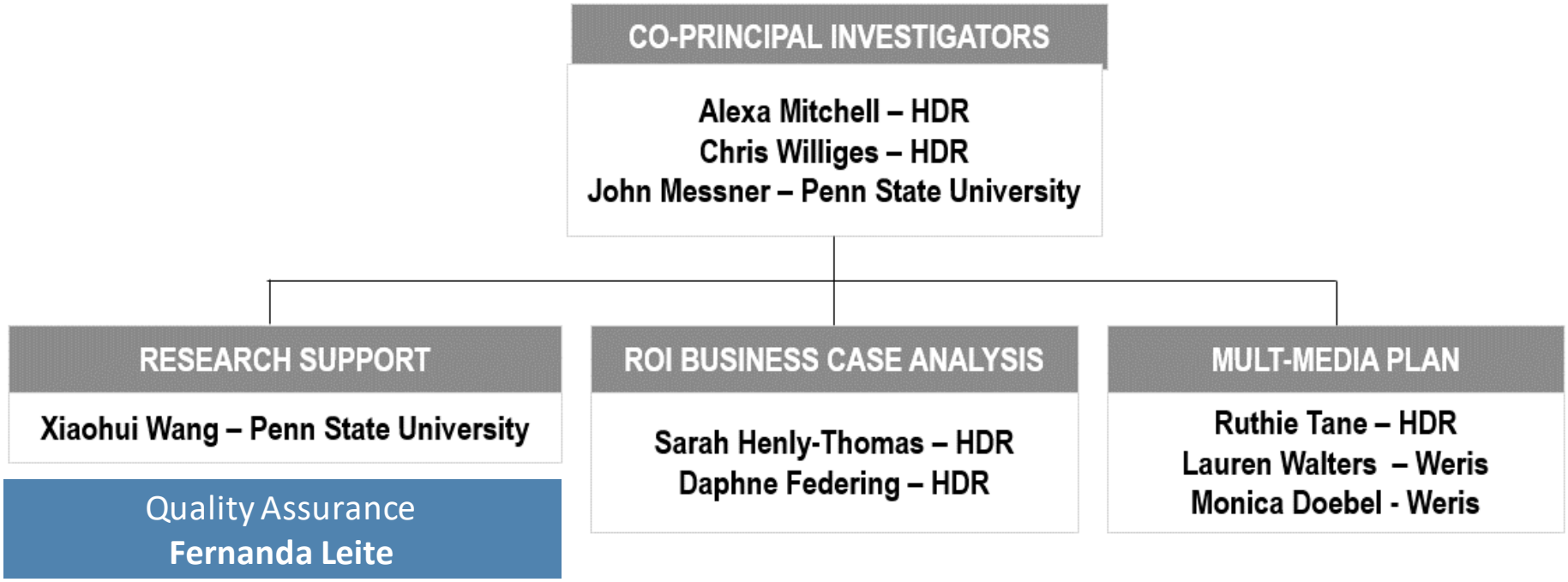
Research Overview

Objective: To evaluate and communicate the business case for BIM deployment in the US

Desired Outcomes: Development of resources to support BIM adoption by highway agencies

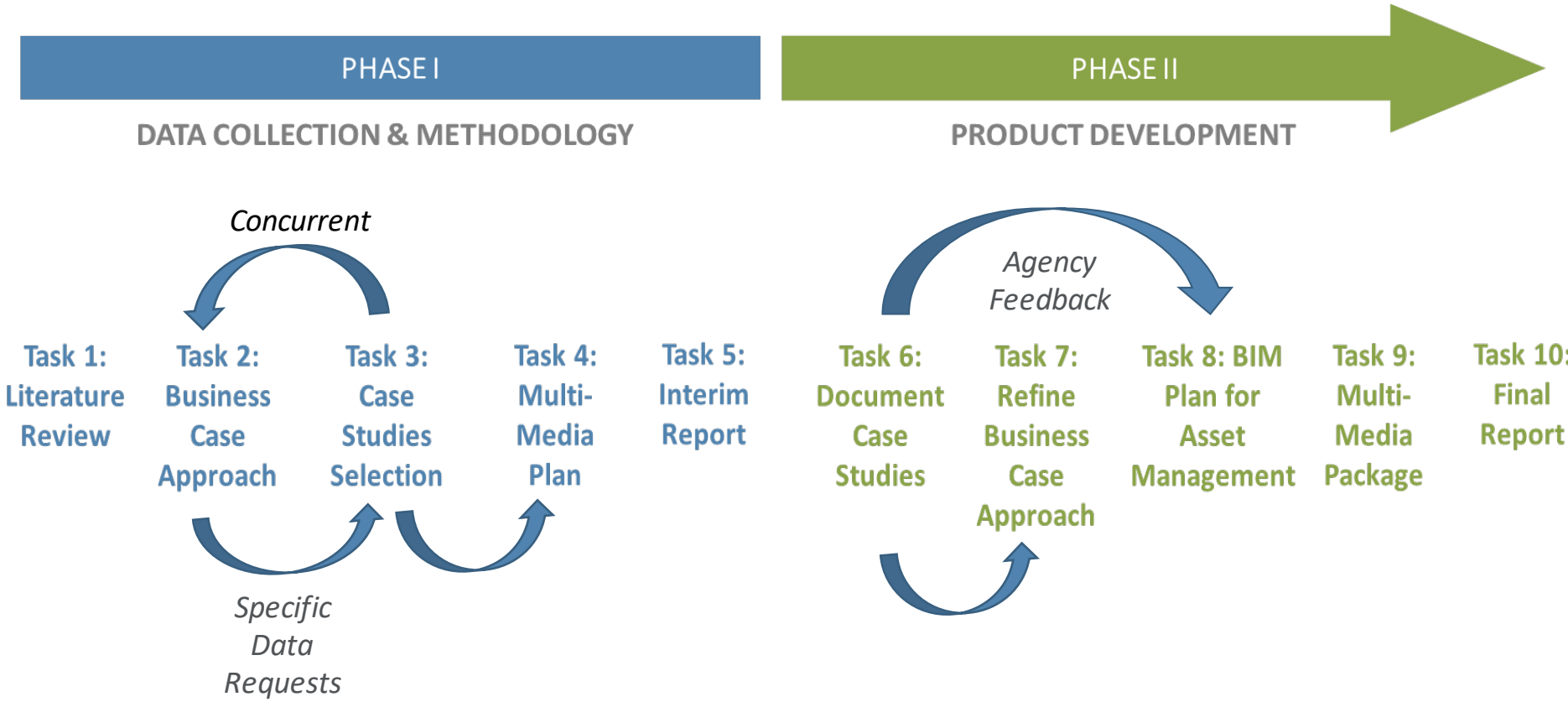
Funded By: FHWA Office of Research, Development, & Technology (in cooperation with NCHRP)

Research Team



TFRS-02 Panel Members: Lance Parve – WSP (Chair); Morgan Kessler – FHWA (Sponsor); Becky Hjelm – UDOT; Bill Pratt – CTDOT; John Wilkerson – MDOT; Jon Starr – NDOT; Mike Kennerly – Iowa DOT; Mohamed Mahogub – NJIT; Steve Tritsch - IASU

Project Approach



Business Case Framework

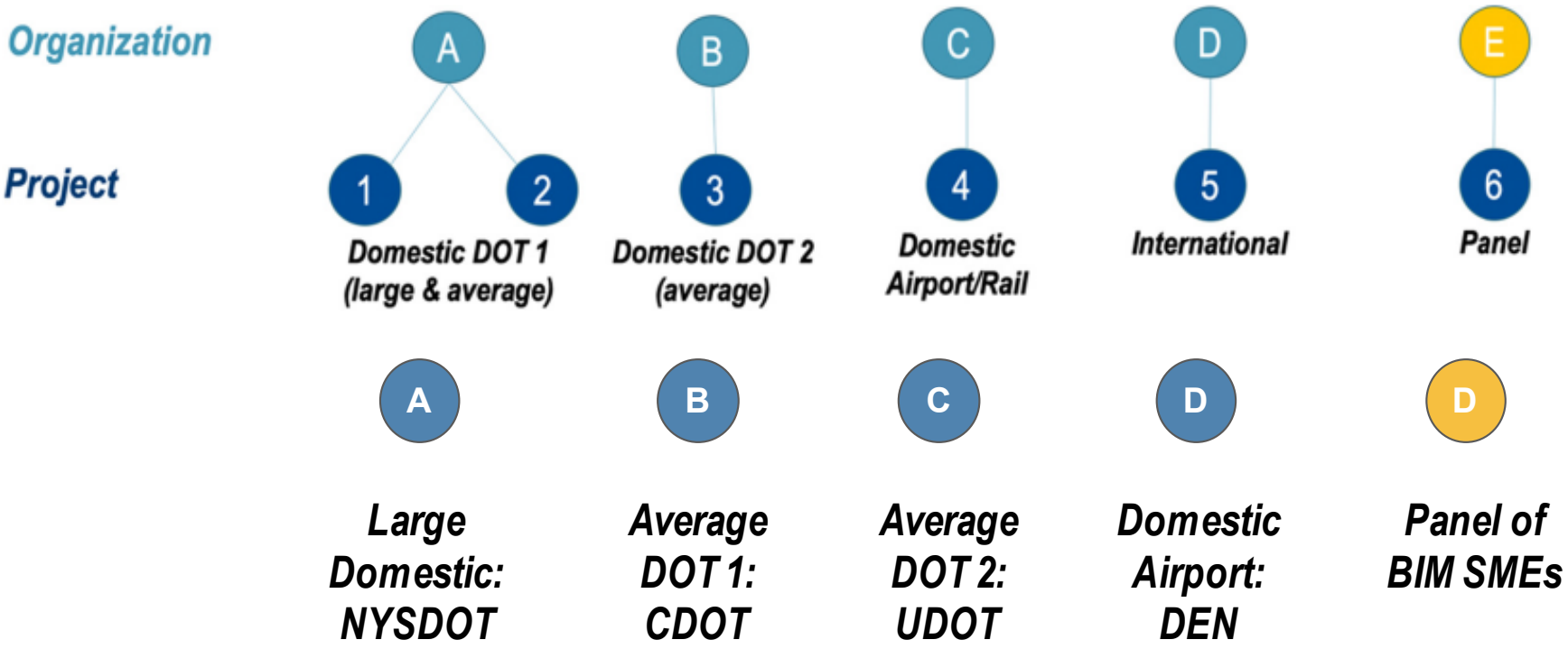
Final Report – Chapter 4

- Benefit-cost analysis (BCA) based ROI tool
- Benefits mapped to use cases
- Program level analysis
- BIM capability levels
- Defining BIM
- Base Case vs Investment Case Distinctions

Case Studies and BIM Expert Validation

Final Report – Chapter 3

Case Studies Approach



Case Studies and BIM Expert Validation

Final Report – Chapter 3

5-Step Process for Incorporating Expert Opinion

Step 1	Task 1: Literature Review	Develop ROI framework and identify major benefits and costs from Literature Review
Step 2	Task 2: Business Approach Structure & Logic Diagrams	Map out calculations to identify variables needed for monetizing benefits and costs
Step 3	Task 3&6: Case Studies	Gather data needed to calculate benefits and costs through case studies
Step 4	Task 6: Expert Panel	**Use expert panel to develop consensus on a range of values for all variables, and gather data not identified through case studies**
Step 5	Task 7: Create Tool to Calculate ROI	Apply data gathered to structure & logic models to calculate overall return on investment

BIM for Asset Management Plan

Final Report – Chapter 5

4-Part Process for Creating an Implementation Plan

- Part 1: BIM for Asset Data Management Strategic Plan
- Part 2: Information Exchange Requirements for BIM Asset Data
- Part 3: BIM in the Delivery Phase
- Part 4: BIM for Operation Phase

BIM for Asset Management Plan

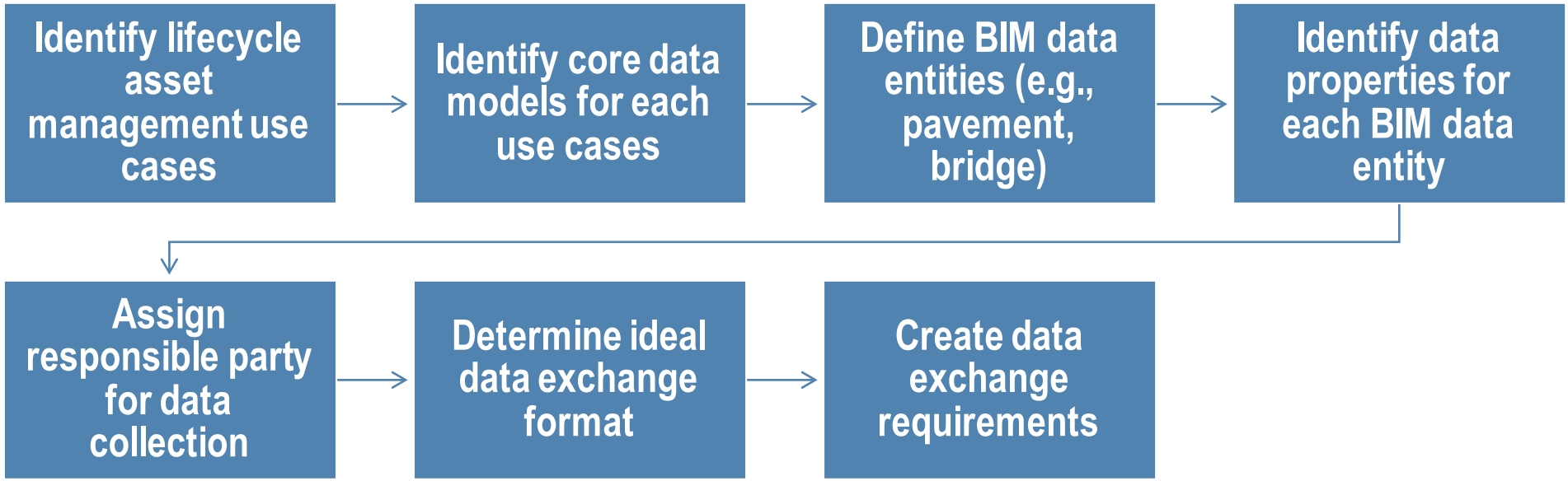
Final Report – Chapter 5

Part 1: BIM for Asset Data Management Strategic Plan

BIM for Asset Management Plan

Final Report – Chapter 5

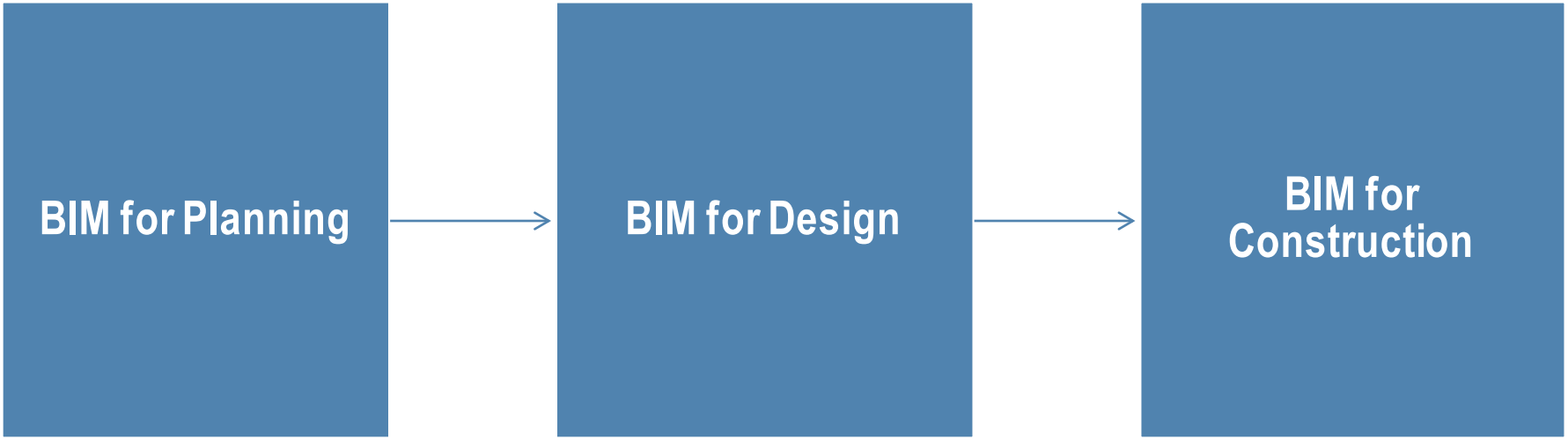
Part 2: Information Exchange Requirements for BIM Asset Data



BIM for Asset Management Plan

Final Report – Chapter 5

Part 3: BIM in the Delivery Phase



BIM for Asset Management Plan

Final Report – Chapter 5

Part 4: BIM for Operations Phase

What is BIM?

Defining and Understanding BIM

What Is BIM?

Set of Tools

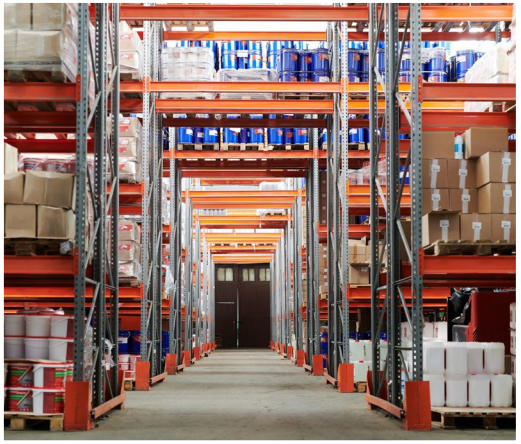
Lifecycle Management

Digital Processes that Touch Planning, Design, Construction, and O&M

Collaborative

Using BIM for Data Management

Asset Management



- Improved inventory management and inventory record models
- Centralized databases

Infrastructure Project Delivery

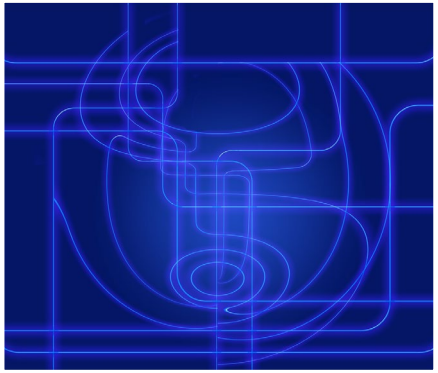
- Capture existing conditions, review and compare with design models, and analyze engineering performance

Maintenance Schedules and Work Orders

- Use road or bridge models to schedule maintenance activities
- Information about design can be accessed in the field

Using BIM for Infrastructure Design

Improve Design Processes



- Find most effective engineering method
- Leverage design element library
- More detailed reviews
- Integration and acceleration of processes
- Enhanced information sharing and data retrieval

Clearly Identify Cases

- Infrastructure cases must be identified and planned
- Used for different project phases

Case Examples

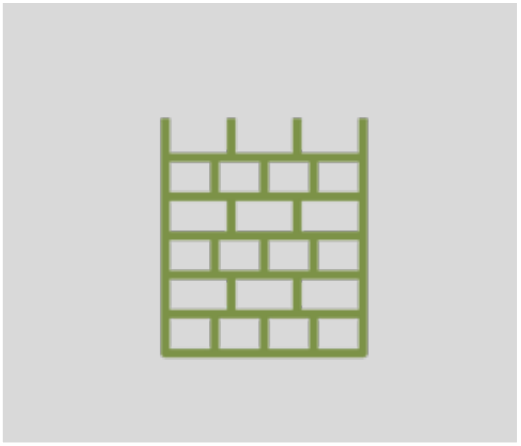
- 4D model shows construction phases and space requirements
- Mapping a project lifecycle with BIM to perform cost estimates

Using BIM for Construction Management

Project Delivery

- Reduction in schedule delays
- Increased productivity

Materials & Drawings



- Increased prefabrication of construction materials
- Production of in-house shop and field drawings

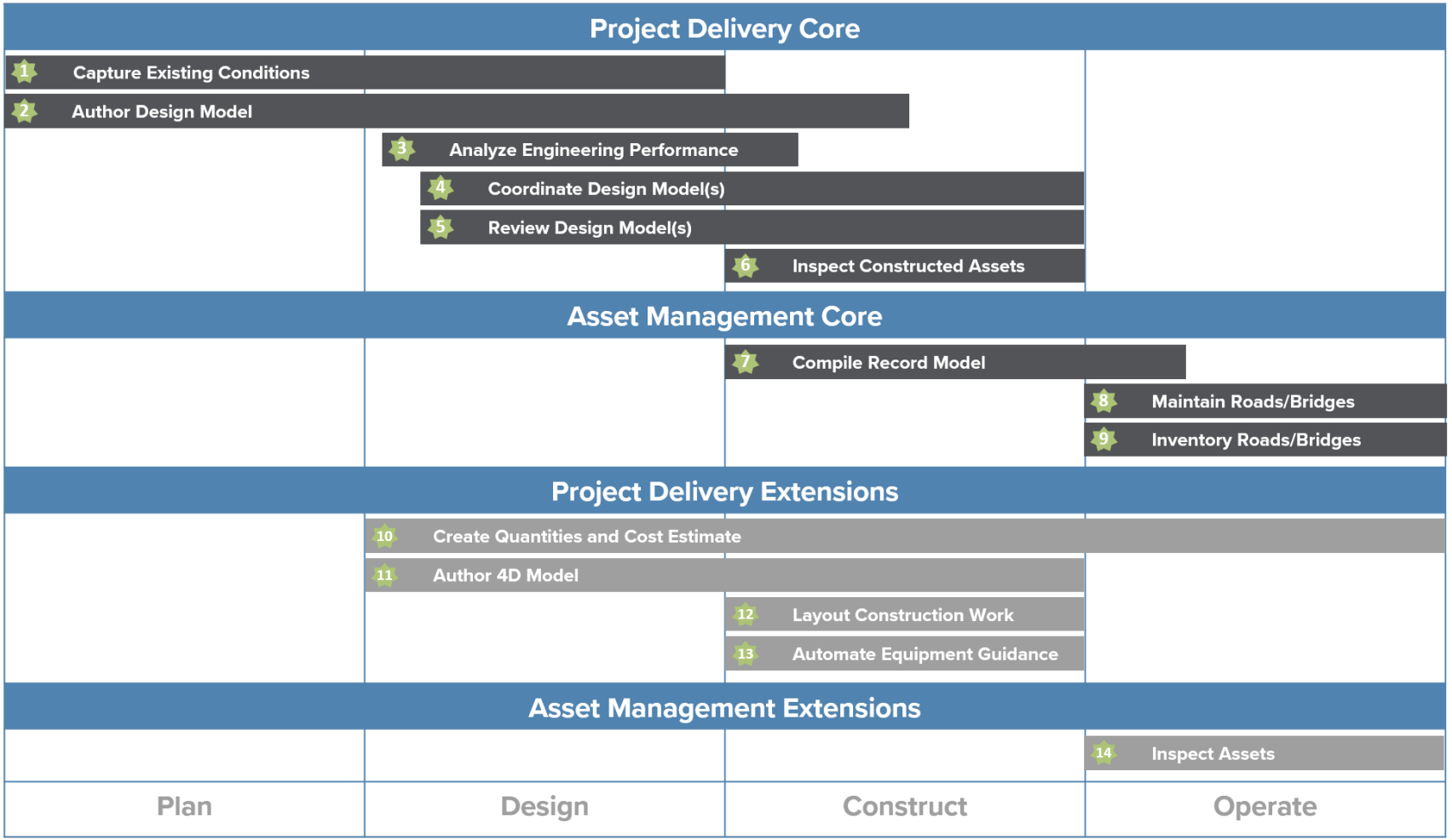
Assembly Processes

- Automated assembly processes

BIM Use Cases

How BIM Is Being Used by States and Industry

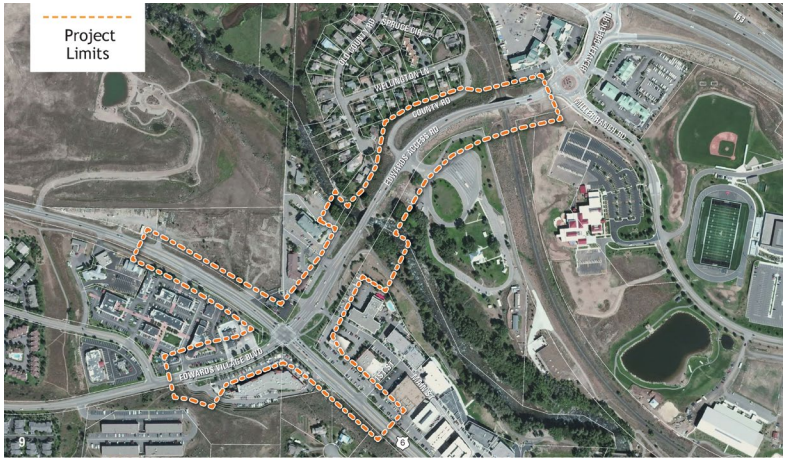
Determining the Right Use Case for BIM



Determining the Right Tools for BIM

CDOT: I70G Edwards Spur Road

- This project improved the intersection of I70G and U.S. Highway 6 by creating a 2-lane roundabout and adding pedestrian bridges and other features.
- CDOT utilized BIM as a **risk mitigation strategy**, creating **3D models** to analyze and improve the engineering design.

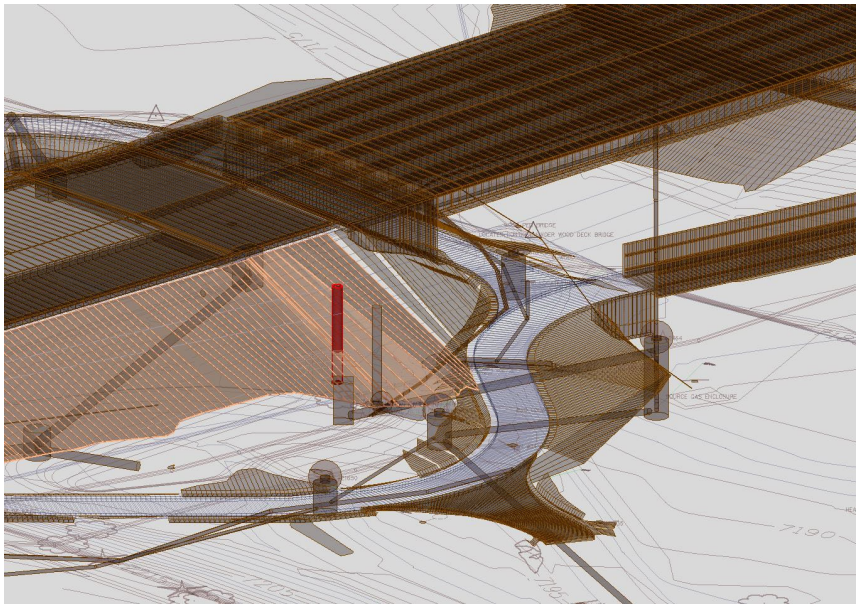


Source: Colorado DOT

Cost	$21 million
Completion date	October 2020
Time savings from improved design efficiency	40-80 hours
Cost savings from avoided change orders	$1.5 million

Determining the Right Tools for BIM: CDOT

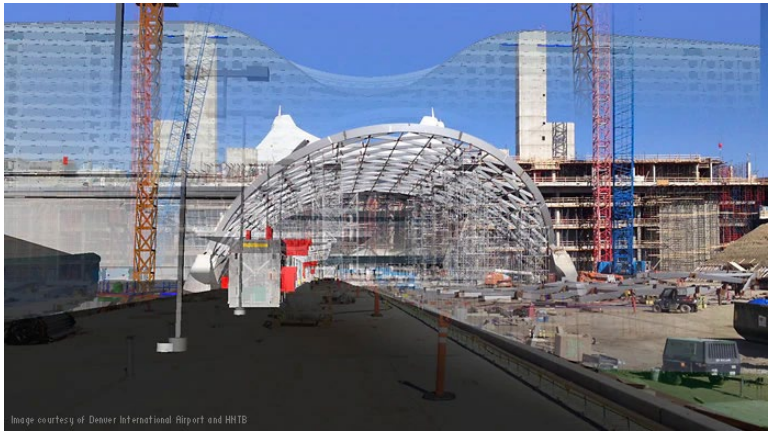
- **Purpose:** To create corridors, surfaces, and solids of infrastructure objects to perform clash detection and prepare traditional 2D plan sets.
- **Tools:**
  - Aerial lidar and ground survey to create existing condition model
  - 3D design software
  - Subsurface utility and drainage analysis library for future use



Source: HDR, Inc. ©

Denver International Airport

- This project included Denver International Airport's (DEN) construction of a commuter rail transit center and a 519-room hotel.
- DEN used BIM for **3D modeling** during the design phase, **4D modeling** during the construction phase, and as a **data source** for facility management.



Source: Autodesk (courtesy of Denver International Airport and HNTB)

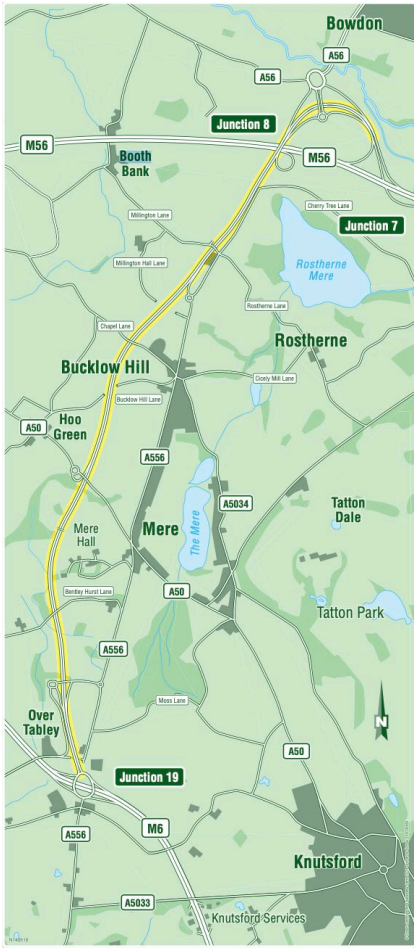
Cost	$720 million
Time savings in document review	20% reduction in approval time
Cost savings from focusing on preventive maintenance rather than corrective	5x reduction in cost

Determining the Right Tools for BIM: DEN

Source: Autodesk (courtesy of Denver International Airport and Gensler)

- **Purpose:** Develop 3D models to support design of the commuter rail transit center and hotel.
- **Tools:**
  - Revit software
  - 3D computer-aided design tools
  - Cloud-based BIM management solutions

Highways England



- This project included Highways England's construction of a 7-kilometer highway in Cheshire in Northwest England to expand capacity in a congested corridor.
- Highways England utilized BIM for **automated machine guidance and 3D modeling**.

Cost	£200 million
Cost savings in reduced redundancy	£1 million
Cost savings from optimization of construction material	£300,000

Determining the Right Tools for BIM: Highways England

- **Purpose:** Automated machine guidance and modeling to support construction of highway.

- **Tools:**
  - BIM software such as Revit
  - Data Design Systems (DDS) viewer
  - Navisworks software

NYSDOT Kew Gardens

- This project included the New York State Department of Transportation's (NYSDOT) implementation of operational improvements for the Kew Gardens Interchange.
- NYSDOT utilized BIM for **3D, 4D, and 5D modeling**.

Source: Courtesy of NYSDOT, Halmar International, and HDR, Inc.

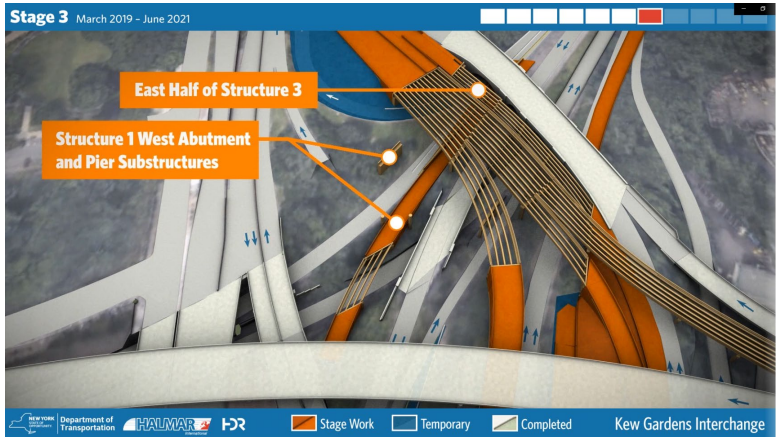
Cost	$728 million
Time savings from reusing previous BIM content	80-120 hours
Time savings on compiling and checking earthwork quantities	11 days

Determining the Right Tools for BIM: NYSDOT

Purpose: Use digital models to support the implementation of operational improvements for the Kew Gardens Interchange.

Tools:

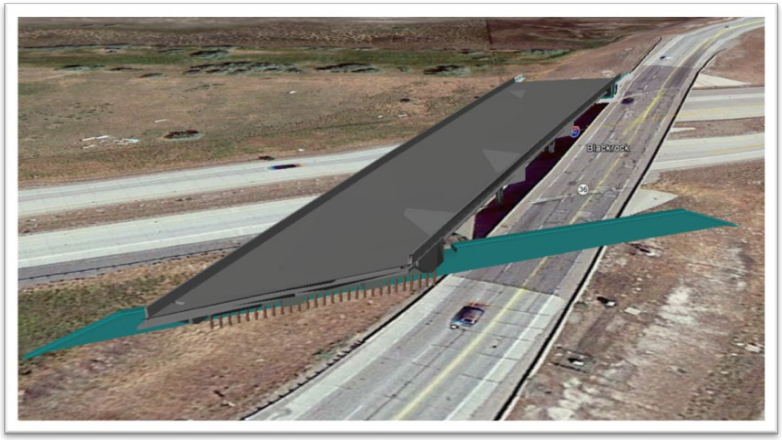
- Roadway design – Inroads SS2 (using NYSDOT standard template library)
- 3D CADD software – Microstation to develop 3D solids for structures
- 4D and 5D modeling and simulation software



Source: Courtesy of NYSDOT, Halmar International, and HDR, Inc.

UDOT Digital Delivery

- These projects include the Utah Department of Transportation's (UDOT) work using modeling as a legal document, including its work on I-80, SR-68, and SR-209.
- UDOT utilizes BIM across a variety of projects to **capture existing conditions, estimate material quantities, and create 3D models**.



Source: HDR

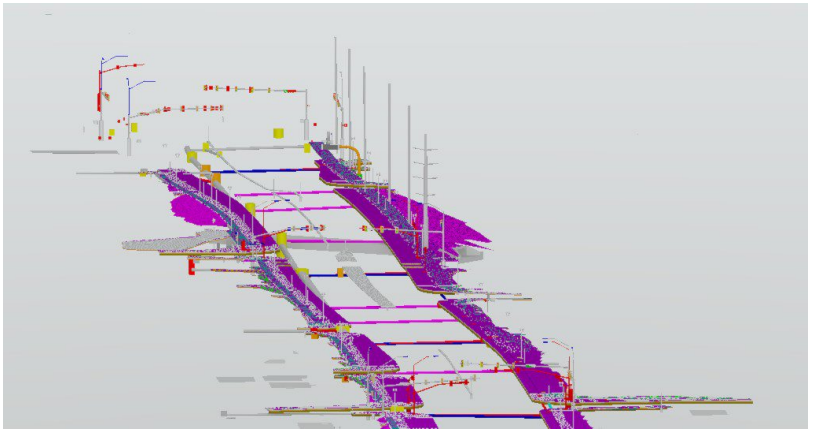
Number of projects	14
Typical cost	$5 million- $50 million
Cost savings	Reduction in change orders and more efficient construction inspections

Determining the Right Tools for BIM - UDOT

Purpose: Capture existing conditions, estimate material quantities, and create 3D models.

Tools:

- Lidar for light detection and ranging
- 3D modeling software (InRoads SS4)
- Global Positioning Systems (GPS) and Geographic Information Systems (GIS)
- Drones for inspections
- UPlan web mapping application



Source: Courtesy of UDOT

Best Practices & Lessons Learned

- **Training is key!**
  - CDOT recommends training programs that cover uses of technology, BIM processes and methods, use of modeling standards.

- **Standards must be established and continuously reviewed.**
  - NYSDOT found that standardization of BIM tools saves time and prevents manual adjustments later.

- **Collaboration leads to success.**
  - Highways England recommends that designers and contractors work together to achieve mutual project goals.

Best Practices & Lessons Learned Continued

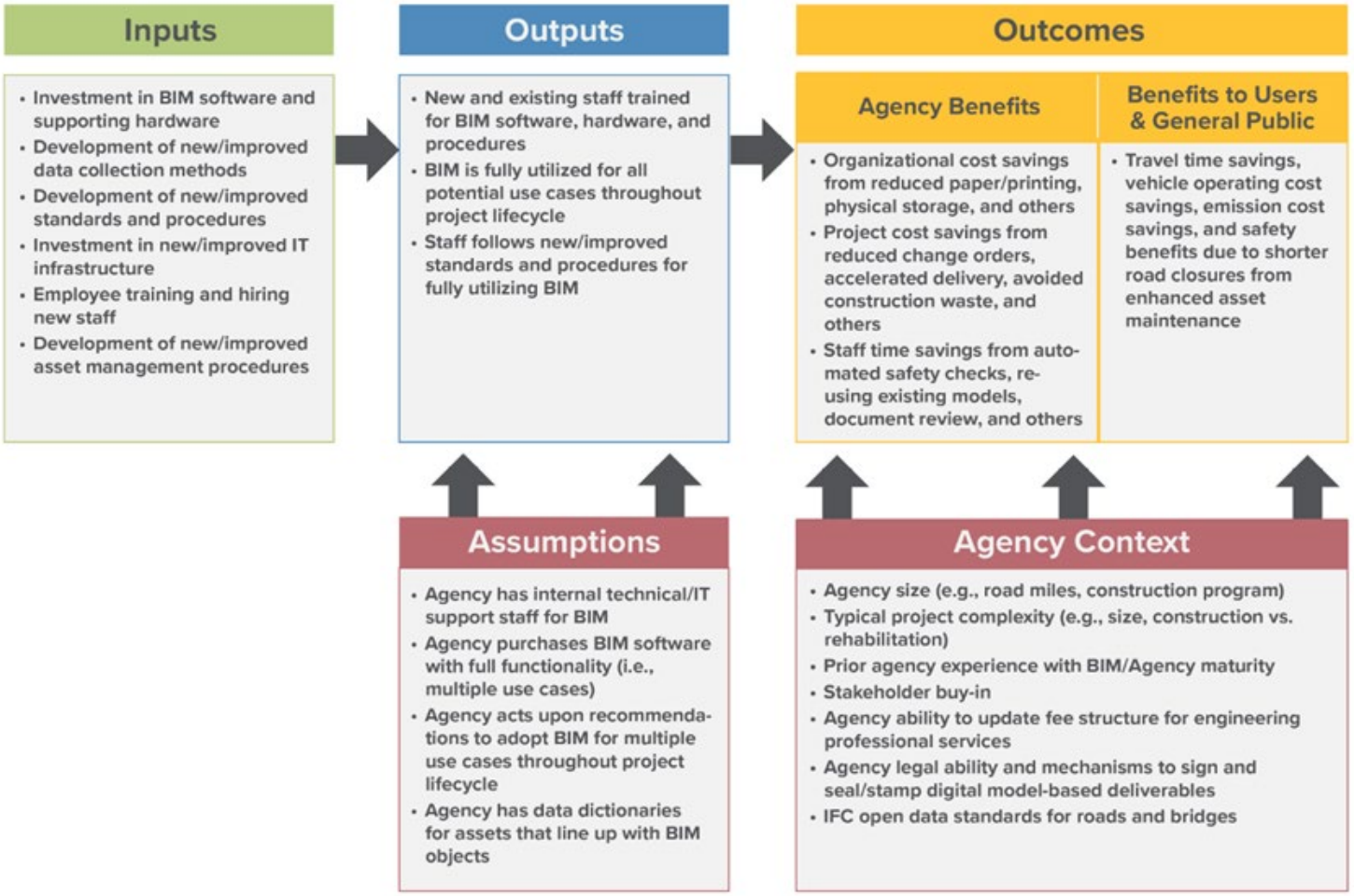
- **Leverage Machine Learning & 3D Models**
  - UDOT found that machine learning helped improve and automate existing processes (ex: automated model generation via Scan-to-BIM).
  - NYSDOT recommends developing 3D models for non-roadway features ahead of releasing construction plans.

- **Dedicated Leads & Stakeholder Input**
  - Having a dedicated lead can help ensure processes are followed, stakeholders are on board, and the right use cases/tools are identified.

Costs and Benefits of BIM

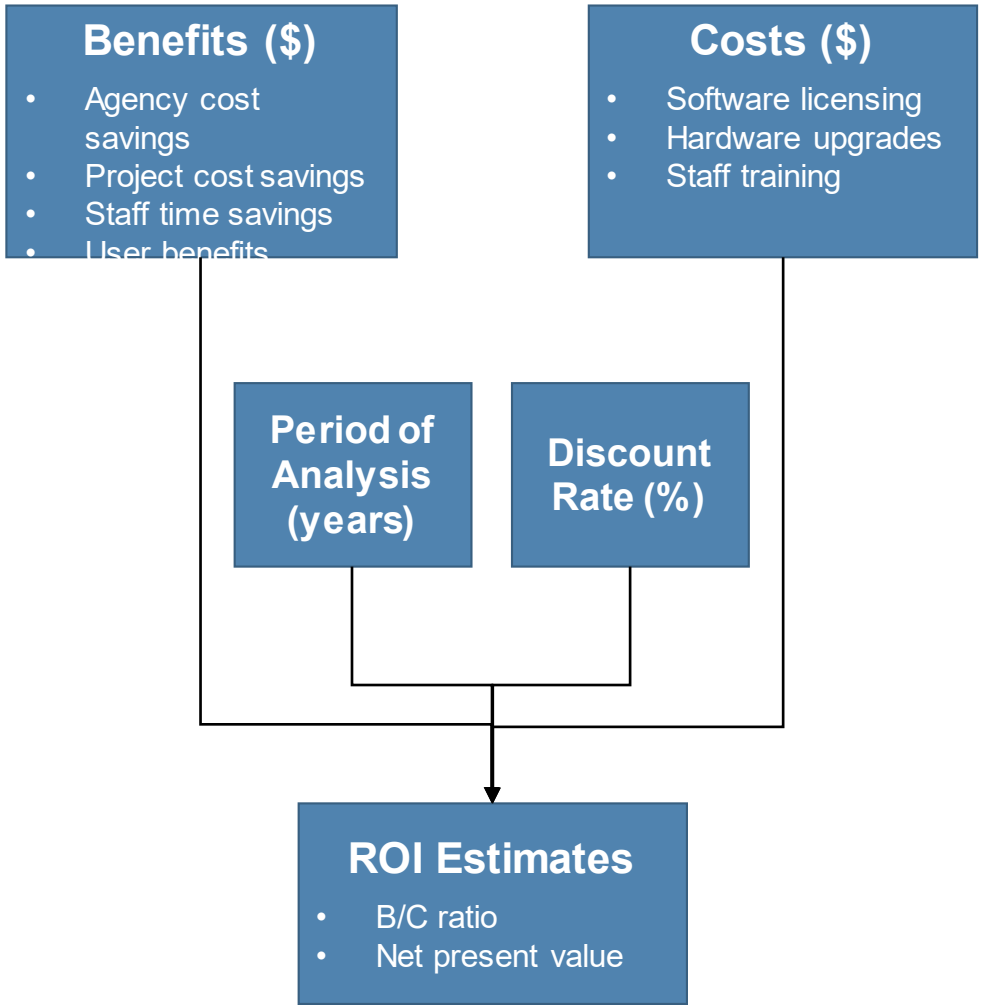
How Investing in BIM Creates Long-Term Benefits

Input-Output Approach for Identifying Outcomes from Adopting BIM



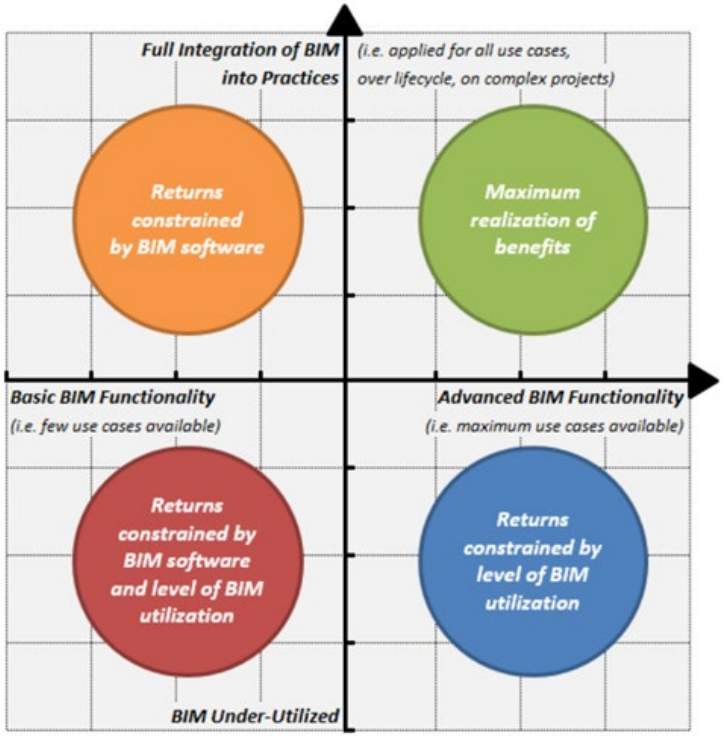
ROI Defined

- ROI analysis determined by benefit-cost analysis (BCA)
- Base Case:
  - State of the world where investment in BIM is not made (i.e., business as usual)
- Investment Case:
  - State of the world where investment is made



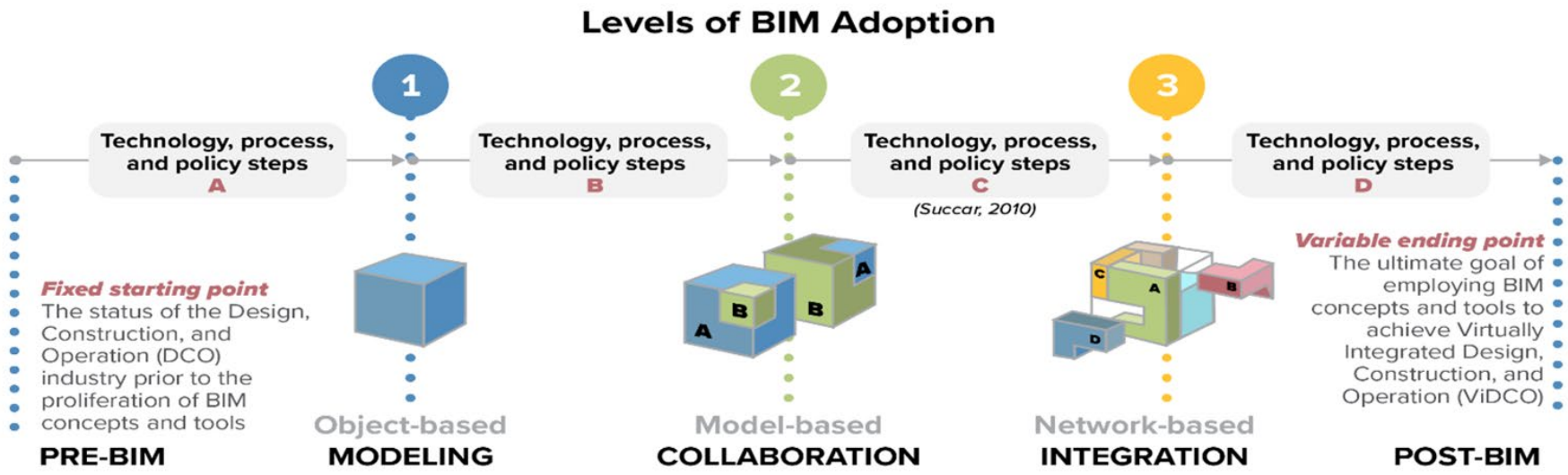
ROI Approach

- Mapped benefits to one or more use cases to create a link
  - Purchasing functionality that supports more use cases provides more opportunities for benefits
- Program-level ROI
  - Costs not fully recovered by one project
  - Some benefits accrue to the agency, not a specific project
  - Benefits build up over time
  - Program of “typical” projects



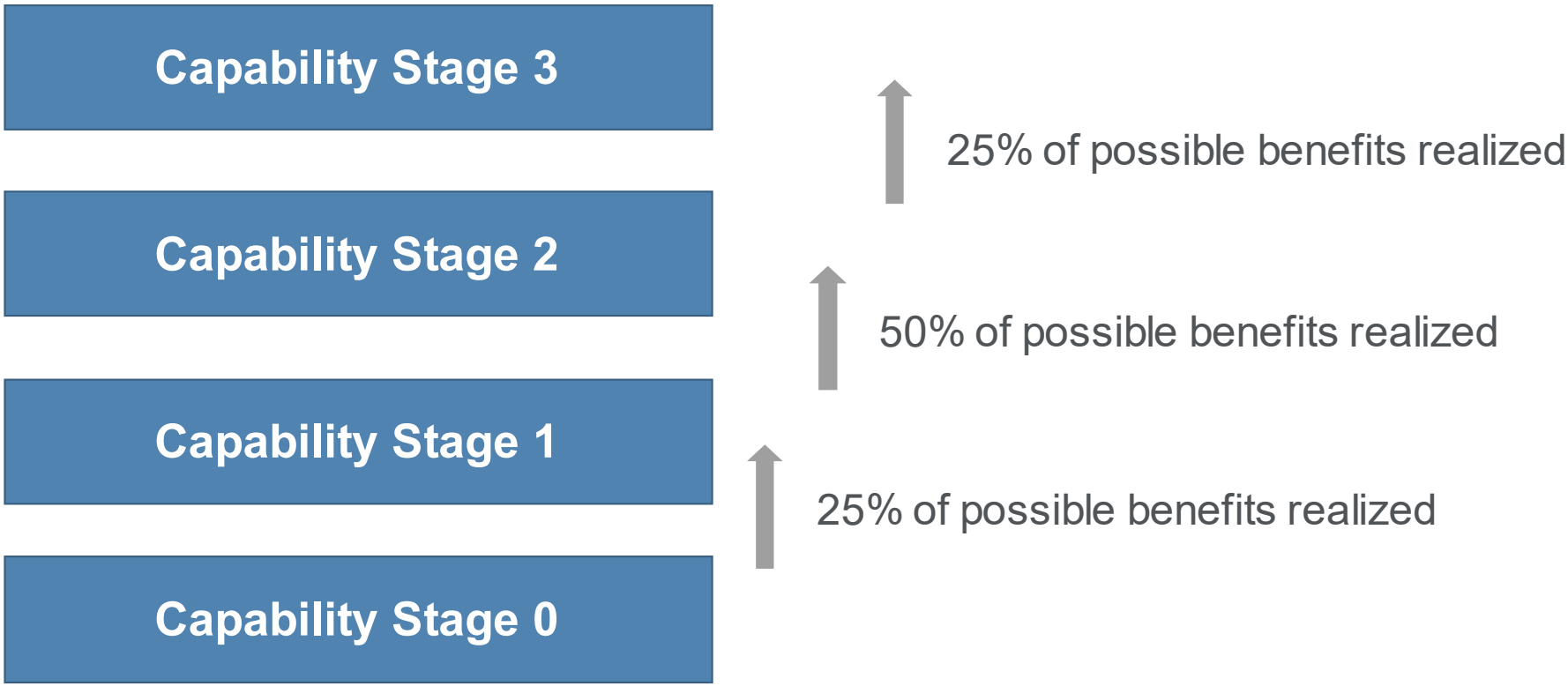
Agency Maturity

Increasing BIM Maturity



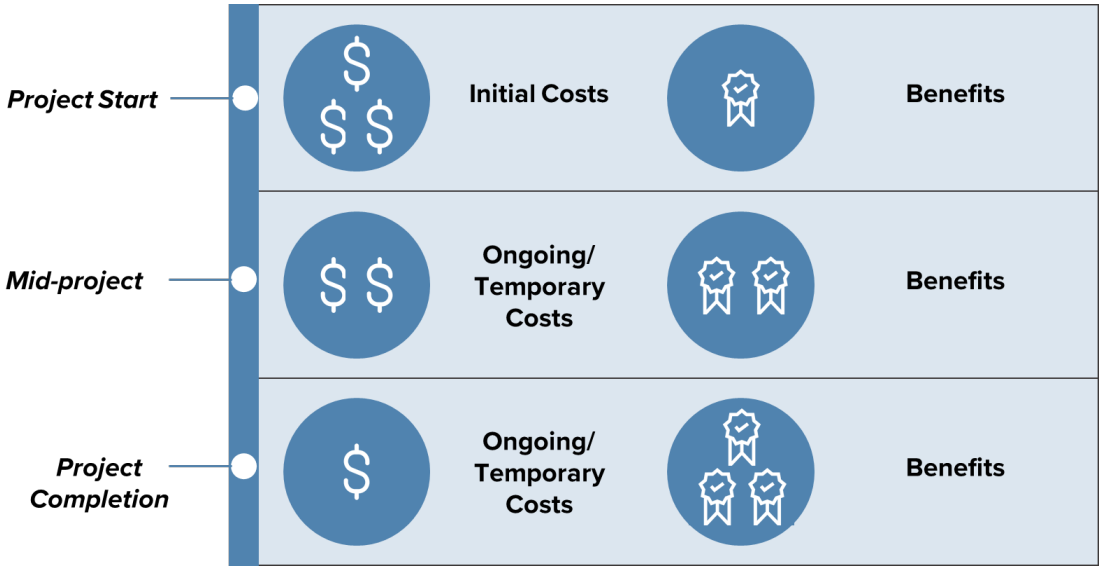
Adapted from original source: Source: Succar, et. al., 2013

BIM Capability Stages

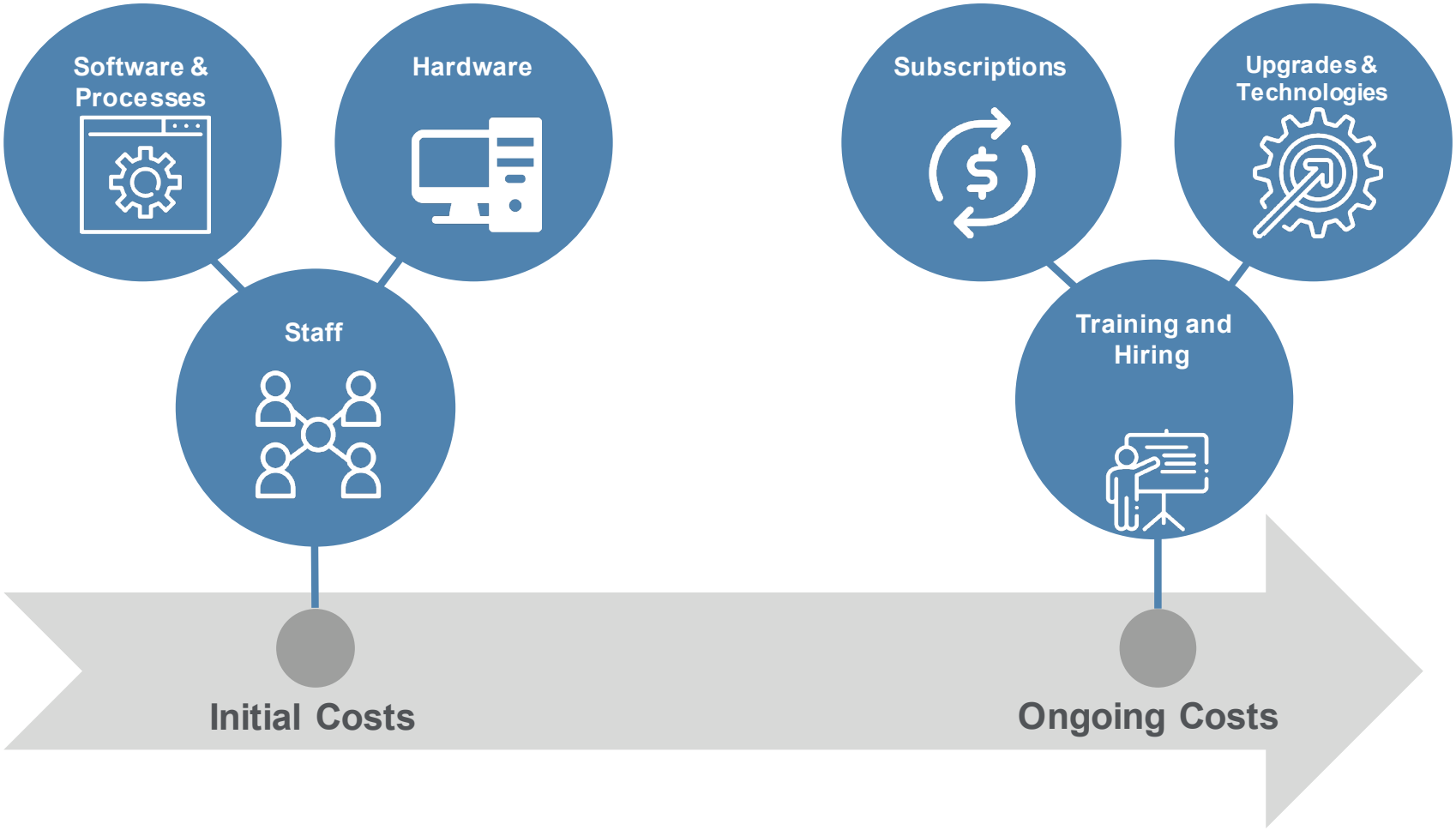


BIM Investments

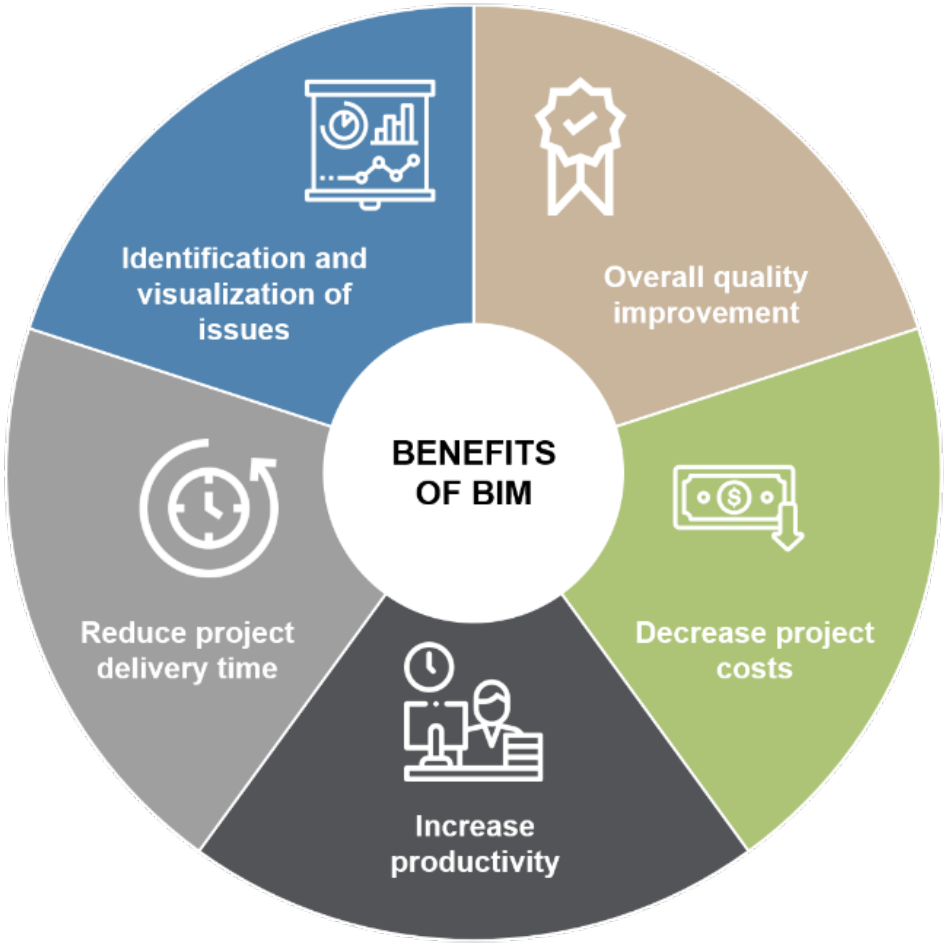
- Implementing BIM can require significant upfront investments, including:
  - Transforming legacy processes and practices.
  - Employee training initiatives.
  - Software and hardware.



Framework: Costs of Implementing BIM



BIM Outcomes

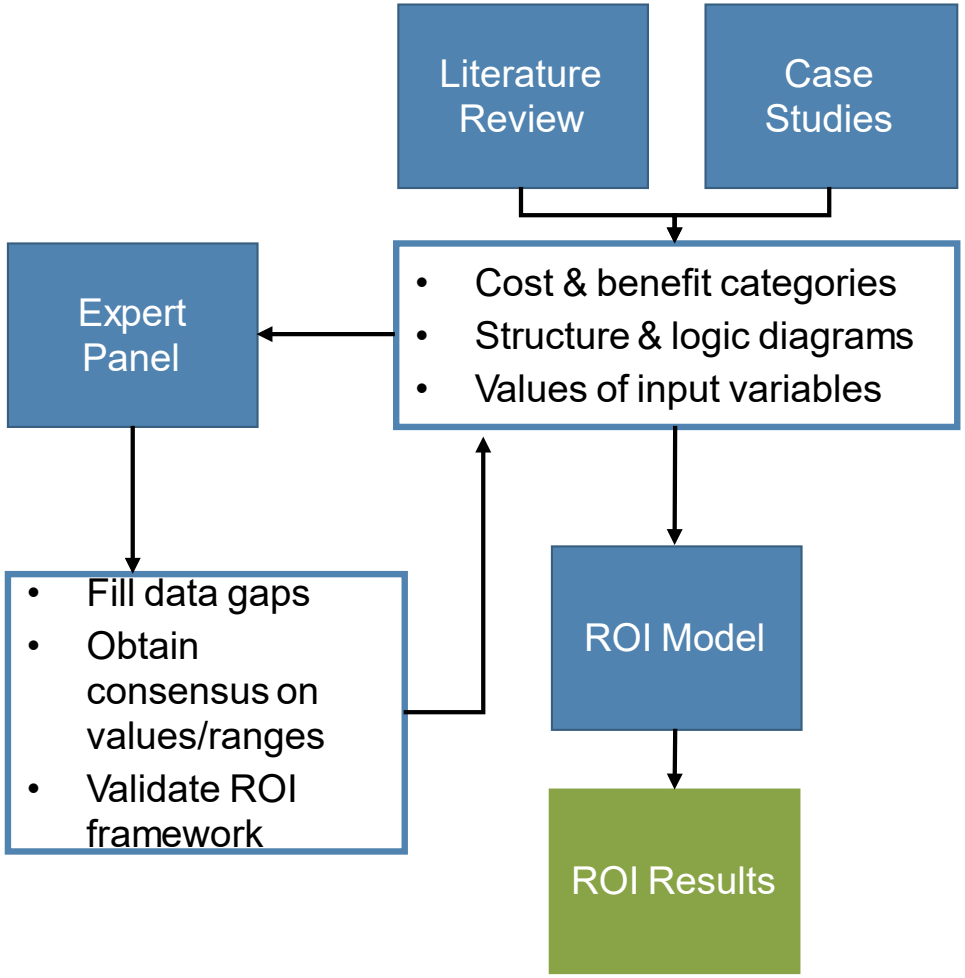


Framework: Quantifiable Benefits of Implementing BIM

 In-house agency cost savings	 Project cost savings
 Staff time savings	 User benefits

Data Collection on Costs and Quantifiable Benefits

- Identified major costs and benefits of BIM from literature review
- S&L diagrams to identify variables needed
- Gathered data through:
  - Literature review
  - Case studies
  - Expert panel



Agency-Specific Benefits

	CDOT	DIA	Highways England	NYSDOT	UDOT
Improved Design Efficiency	✓			✓	
Avoided Change Orders	✓	✓		✓	✓
Improved Schedule Management	✓				
Construction Material Optimization	✓				
Improved Worker Safety		✓	✓		✓
Reduced Need for Non-Scheduled Maintenance		✓			
Reduced Physical Storage Needs		✓			
Improved Quantity Estimation			✓		
Pre-Construction Utility Visualization			✓		
Accelerated Delivery			✓		
Increased Accuracy in Material Quantities				✓	
Identification of Alternate Construction Options				✓	
Centralization of Information					✓
High-Quality Design and Visualization					✓

BIM Execution Planning

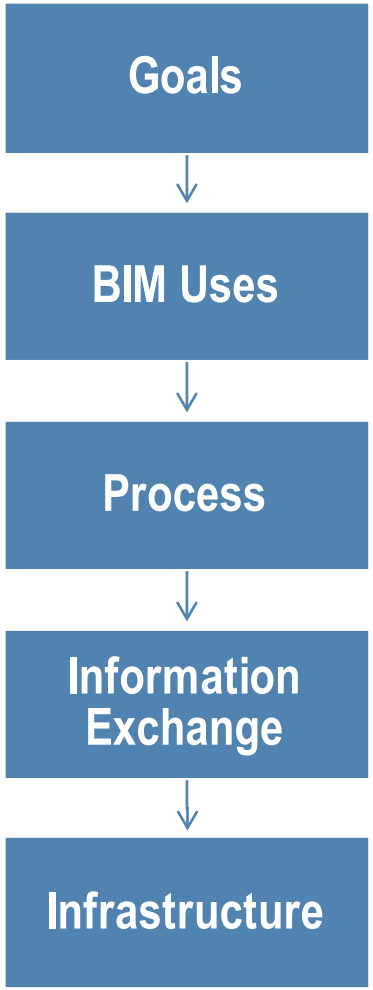
Planning for Successful Implementation

BIM Execution Planning (BEP)

- BIM Project Execution Plan
  - The BIM Execution Plan is a plan developed by the project team that defines how BIM will be implemented throughout the project lifecycle.
- BIM Project Execution Planning Procedure
  - A process for planning the execution of BIM on a project. It has five primary steps:
    1) Define Goals for BIM adoption
    2) Identify BIM Uses
    3) Design BIM Project Execution Process
    4) Develop Information Exchanges
    5) Define supporting infrastructure for BIM implementation

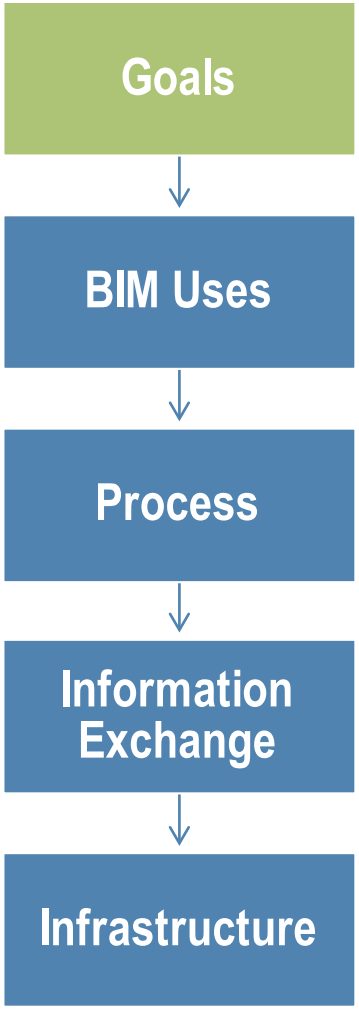
Source: The BIM Project Execution Planning Guide, Version 3, The Pennsylvania State University

BIM Execution Planning (BEP) Workflow



Source: BIM Project Execution Planning Guide available at bim.psu.edu

Determining BIM Goals



Priority (1-3) 1= Most Important	Project Goal	Potential BIM Uses
1	Ensure a high quality of design and design documentation	Design Authoring, Design Reviews, 3D Coordination
1	Coordinate the sequence of construction activities	4D Modeling
2	Increase the productivity of field installation	Design Reviews, 3D Coordination
2	Accurately track the progress of construction	4D Modeling
2	Develop an accurate record of the accepted construction model for use in future projects	Record Model (or Digital As-Built), 3D Coordination
1	Assess engineering design functionality	Engineering Analysis
3	Accurately review the cost impact of changes in a timely manner	Design Authoring, Cost Estimation

Source: BIM Project Execution Planning Guide available at bim.psu.edu

Identify BIM Uses

Goals

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BIM Uses

↓

Process

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Information Exchange

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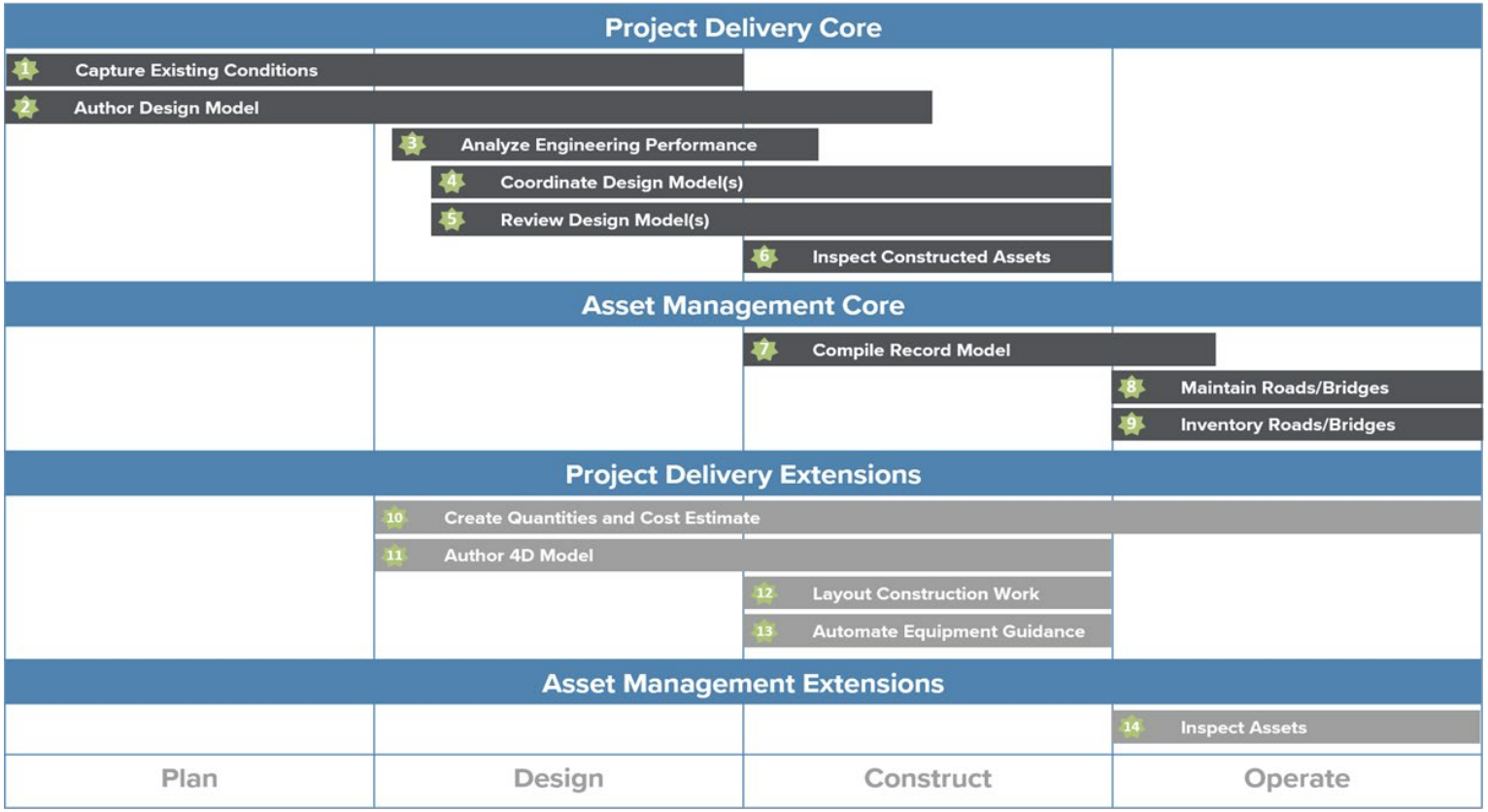
Infrastructure



Source: BIM Project Execution Planning Guide available at bim.psu.edu

Design BIM Process

- Goals
- BIM Uses
- Process
- Information Exchange
- Infrastructure

Example of a Modeling Authoring Process Map

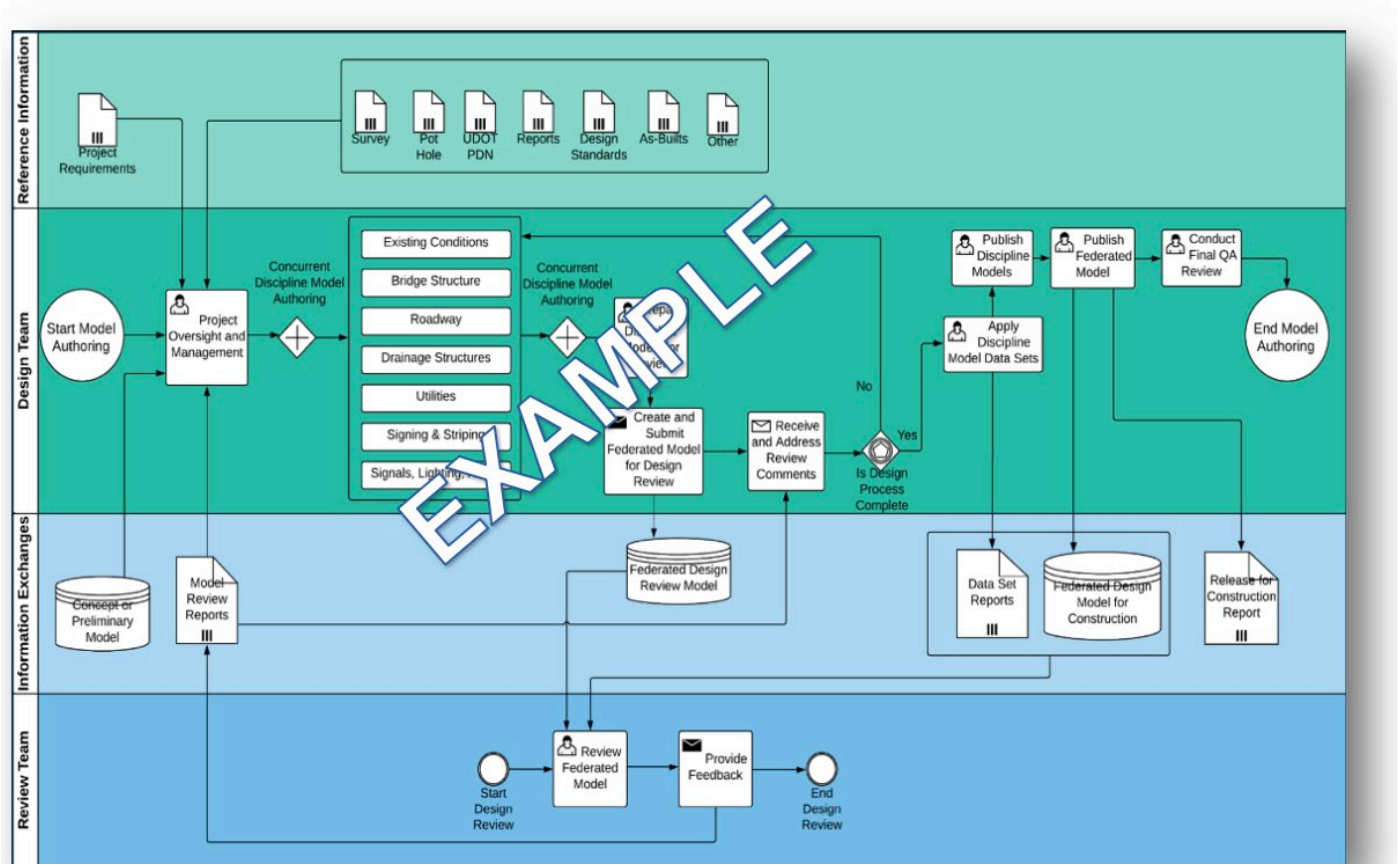


Image Source: UDOT Model Development Standards available at https://digitaldelivery.udot.utah.gov/pages/standards

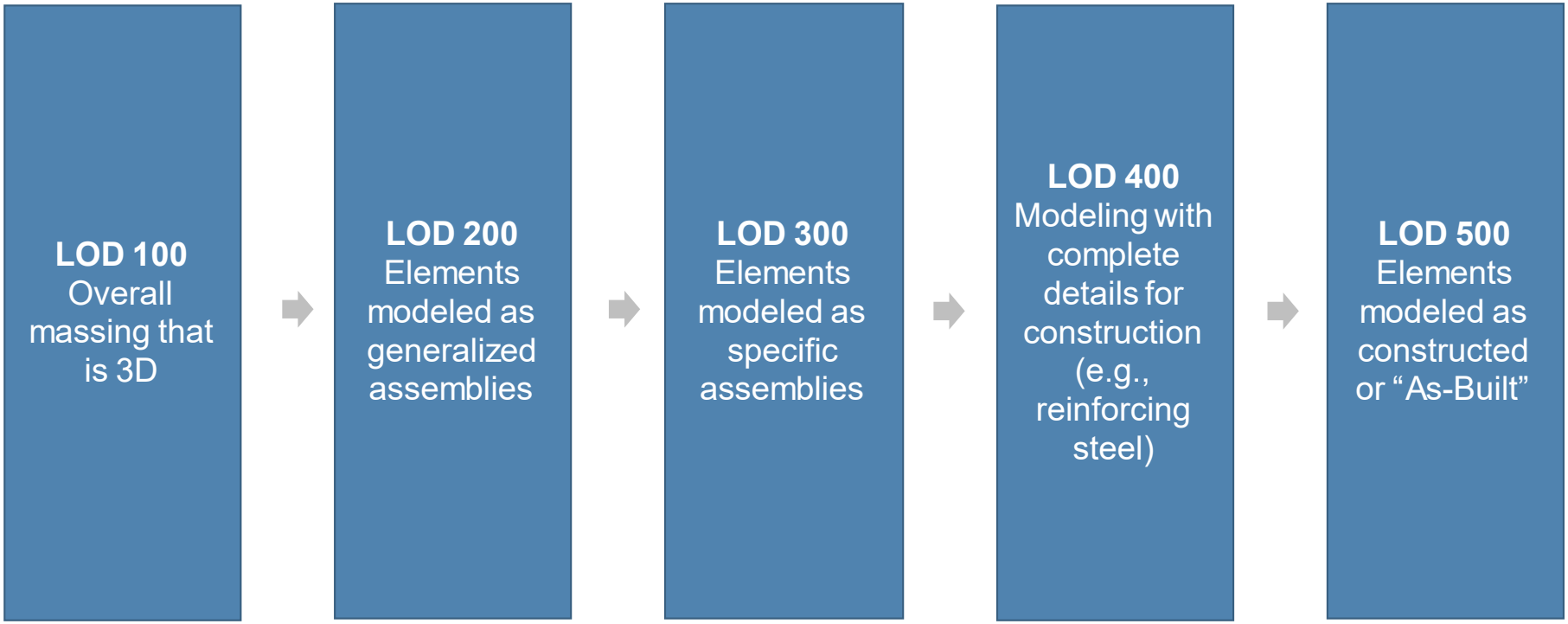
Develop Information Exchanges

- Goals
- BIM Uses
- Process
- Information Exchange
- Infrastructure

Model Element Group	Model Element Name	Included in Project?	Engineer of Record	LOD Standard	LOD Deviation	Applicable Specification	2D/3D	Required Data Attributes				
Group 01	Alignments and Right-of-Way Geometry											
Group 02	Horizontal - Proposed			400		N/A	2D	Alignment, stationing	Geometric information (e.g. curve data, spirals, SE)	N/A	N/A	N/A
Group 02	Horizontal and Vertical - Proposed			400		N/A	3D	Alignment, stationing	Geometric information (e.g. curve data, spirals, SE, grade, K-value, SSD)	N/A	N/A	N/A
Group 02	Right-of-Way Geometry (ROW, Property and Easements Lines)			200		N/A	2D	Alignment, station and offset information	Geometric informaton (e.g. direction/bearing)	Dimensions (e.g. area, length)	N/A	N/A
Group 01	Roadway											
Group 02	Embankment, Borrow, and Backfill					02056	3D	Pay item, number, units and quantity information	Alignment, station and offset information	Note (optional)	N/A	N/A
Group 03	*Borrow/Embankment*			*300*		*N/A*	*3D*	*See Embankment, Borrow and Backfill*				
Group 03	*Granular Borrow*			*400*		*N/A*	*3D*	*See Embankment, Borrow and Backfill*				
Group 03	*Embankment for Bridge*			*300*		*N/A*	*3D*	*See Embankment, Borrow and Backfill*				
Group 02	Roadway Excavation			300		02316	3D	Pay item, number, units and quantity information	Alignment, station and offset information	Note (optional)	N/A	N/A
Group 02	Ditch Excavation			300		02318	3D	Pay item, number, units and quantity information	Alignment, station and offset information	Note (optional)	N/A	N/A
Group 02	Untreated Base Course (UTBC)			400		02721	3D	Pay item, number, units and quantity information	Alignment, station and offset information	Note (optional)	N/A	N/A
Group 02	Hot Mix Asphalt (HMA)			400		02741	3D	Pay item, number, units and quantity information	Alignment, station and offset information	Note (optional)	N/A	N/A
Group 02	Hot Mix Asphalt - Bike and Pedestrian Paths			400		02743	3D	Pay item, number, units and quantity information	Alignment, station and offset information	Note (optional)	N/A	N/A
Group 02	Stone Matrix Asphalt			400		02744	3D	Pay item, number, units and quantity information	Alignment, station and offset information	Note (optional)	N/A	N/A
Group 02	Portland Cement Concrete Pavement			300		02752	3D	Pay item, number, units and quantity information	Alignment, station and offset information	Note (optional)	N/A	N/A
Group 02	Geotextiles			200		02741	2D	Pay item, number, units and quantity information	Alignment, station and offset information	Note (optional)	N/A	N/A
Group 02	Micro-Surfacing			200		02743	2D	Pay item, number, units and quantity information	Alignment, station and offset information	Note (optional)	N/A	N/A
Group 02	Longitudinal Rumble Strip			200		02744	2D	Pay item, number, units and quantity information	Alignment, station and offset information	Note (optional)	N/A	N/A
Group 02	Chip Seal Coat			200		02752	2D	Pay item, number, units and quantity information	Alignment, station and offset information	Note (optional)	N/A	N/A
Group 02	Bonded Wearing Course (BWC)			200		02075	2D	Pay item, number, units and quantity information	Alignment, station and offset information	Note (optional)	N/A	N/A
Group 02	Rotomilling			200		02735	2D	Pay item, number, units and quantity information	Alignment, station and offset information	Note (optional)	N/A	N/A

Source: UDOT Model Development Standards available at https://digitaldelivery.udot.utah.gov/pages/standards

BIM Level of Development (LOD)



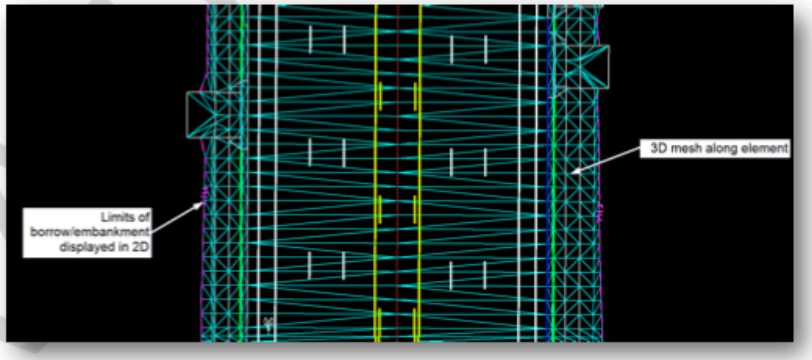
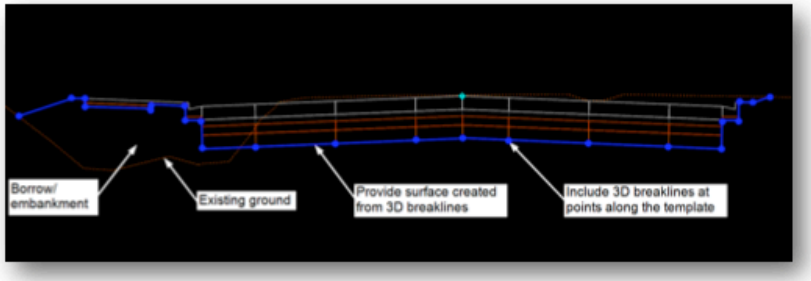
Source: Extracted from NYSDOT BIM LOD KGI Contract Requirements

Example LOD

2.3.1.1 Borrow and Embankment

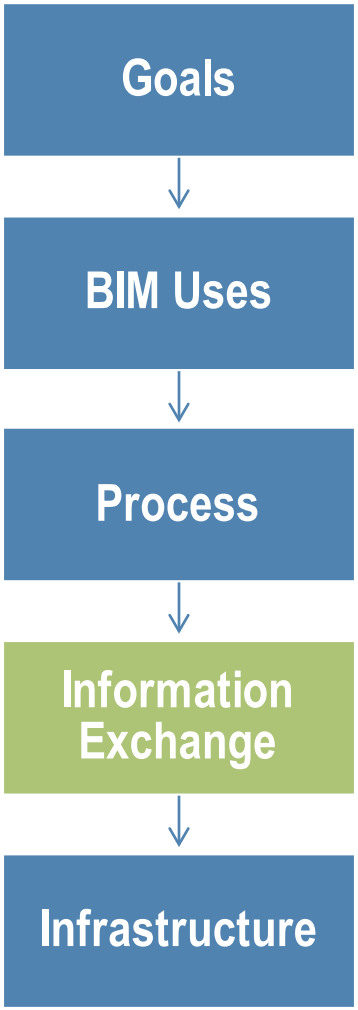
Table 2-4 – Modeling Criteria for Borrow and Embankment

Modeling Criteria	Graphical Representation

• Standard LOD 300 Criteria
  ○ Include LOD 200 criteria of the design element to show the 2D polygon in the plan view to delineate the area that represents the design element. Extend the 2D shape to the limits of borrow or embankment.
  ○ Attach attributes to the 2D polygon in the plan view.
  ○ Design borrow as a 3D mesh.
  ○ Represent points delineating the 3D mesh as 3D break lines along the grading surface.
  ○ Design 3D break lines to delineate boundaries for generating the surface used for measuring volumes between the existing and proposed conditions.
  ○ Do not model the topsoil component.
  ○ Do not provide assumed shrink and swell factors.
	
	 

Source: UDOT Model Development Standards available at https://digitaldelivery.udot.utah.gov/pages/standards

Develop Supporting Technology Infrastructure



Examples of Technology Infrastructure

- Software
  - Support each use case
- Hardware
  - Computers that can accommodate the software requirements
- Telecommunication/IT requirements
  - Internet speed
  - Connection to fiber lines
  - Cloud usage

BIM Roles & Responsibilities

Lead Information Manager/
Digital Delivery Lead

Engineer/Designer

Model Manager

Model User(s)

Key Takeaways

Research Findings

Research Questions

1. Can benefits of BIM be quantified?
2. Are the benefits of BIM substantial enough to justify the investment?
3. What is the cost of inaction?
4. How do you maximize the benefits of BIM?

Research Questions Answered

Can benefits be quantified?

Yes – we identified 20 quantifiable benefits.

Research Questions Answered

Are the benefits of BIM substantial enough to justify the investment?

Yes – using the ROI tool – there are positive returns.

Research Questions Answered

What is the cost of inaction?

There is a significant long-term cost of not investing in BIM.

Research Questions Answered

How do you maximize the benefits of BIM?

- **Optimize Use Cases**
- **Higher BIM Maturity Levels**
- **Open BIM Standards**

Research Conclusions

Final Report – Chapter 6

- BIM provides significant opportunities to use digital data for lifecycle asset management
- International and domestic standards initiatives can provide structured guidance
- Research products can assist in developing a customizable ROI framework
- A high-level strategic plan can accelerate the advancement BIM adoption
- Communication and training are key components for successful implementation

Suggestions for Future Research

Final Report – Chapter 6

- Support for data schema standards to facilitate interoperability
- Structured guidance for defining approaches to standardization of processes to ensure consistency
- Benchmarking data to support individual business cases
- Solutions for legal and contractual challenges
- Channels to support education and training of all affected parties

Research Products

Excel-Based
ROI Toolkit

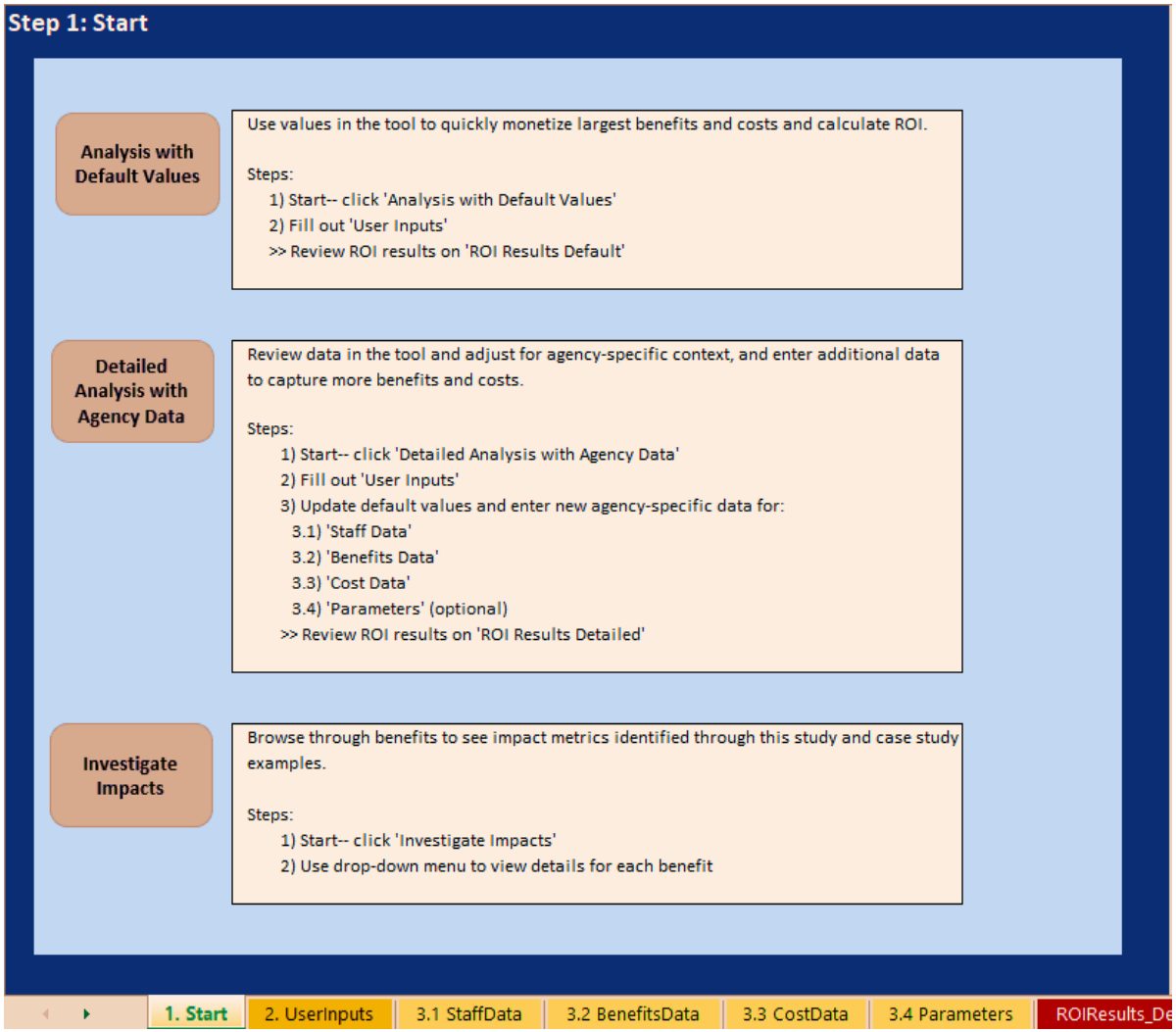
Multi-Media
Package

Final Report

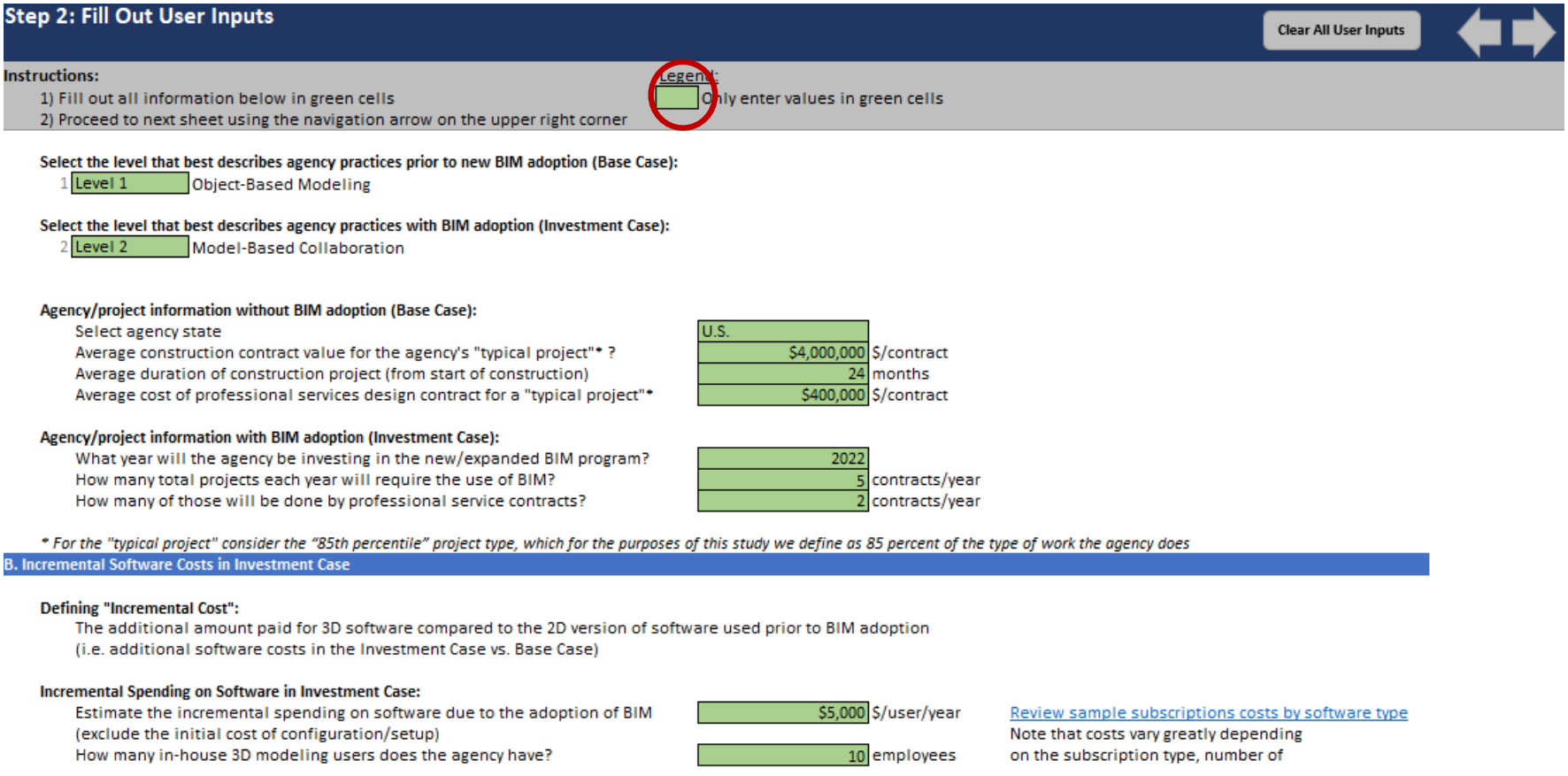
ROI Tool Tutorial

ROI Tool Tutorial- Additional Slides

Using the ROI Tool



Using the ROI Tool



Step 2: Fill Out User Inputs

Clear All User Inputs

Instructions:
1) Fill out all information below in green cells
2) Proceed to next sheet using the navigation arrow on the upper right corner

Legend:
Only enter values in green cells

Select the level that best describes agency practices prior to new BIM adoption (Base Case):
1 Level 1 Object-Based Modeling

Select the level that best describes agency practices with BIM adoption (Investment Case):
2 Level 2 Model-Based Collaboration

Agency/project information without BIM adoption (Base Case):

Select agency state	U.S.	
Average construction contract value for the agency's "typical project"* ?	$4,000,000	$/contract
Average duration of construction project (from start of construction)	24	months
Average cost of professional services design contract for a "typical project"*	$400,000	$/contract

Agency/project information with BIM adoption (Investment Case):

What year will the agency be investing in the new/expanded BIM program?	2022	
How many total projects each year will require the use of BIM?	5	contracts/year
How many of those will be done by professional service contracts?	2	contracts/year

** For the "typical project" consider the "85th percentile" project type, which for the purposes of this study we define as 85 percent of the type of work the agency does*

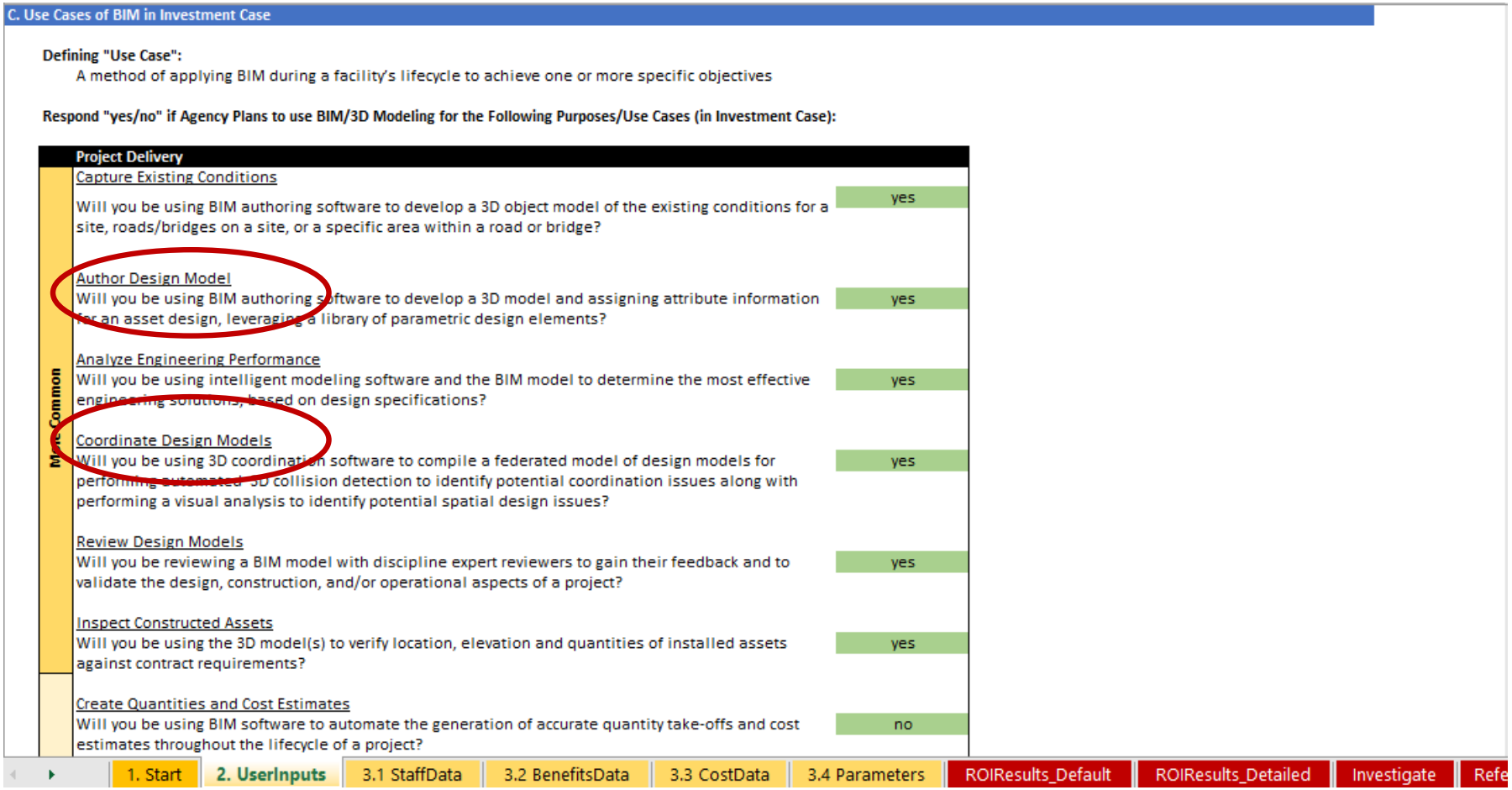
B. Incremental Software Costs in Investment Case

Defining "Incremental Cost":
The additional amount paid for 3D software compared to the 2D version of software used prior to BIM adoption
(i.e. additional software costs in the Investment Case vs. Base Case)

Incremental Spending on Software in Investment Case:

Estimate the incremental spending on software due to the adoption of BIM (exclude the initial cost of configuration/setup)	$5,000	$/user/year	Review sample subscriptions costs by software type
How many in-house 3D modeling users does the agency have?	10	employees	Note that costs vary greatly depending on the subscription type, number of

Using the ROI Tool



C. Use Cases of BIM in Investment Case

Defining "Use Case":

A method of applying BIM during a facility's lifecycle to achieve one or more specific objectives

Respond "yes/no" if Agency Plans to use BIM/3D Modeling for the Following Purposes/Use Cases (in Investment Case):

	Project Delivery	
More Common	Capture Existing Conditions Will you be using BIM authoring software to develop a 3D object model of the existing conditions for a site, roads/bridges on a site, or a specific area within a road or bridge?	yes
	Author Design Model Will you be using BIM authoring software to develop a 3D model and assigning attribute information for an asset design, leveraging a library of parametric design elements?	yes
	Analyze Engineering Performance Will you be using intelligent modeling software and the BIM model to determine the most effective engineering solutions, based on design specifications?	yes
	Coordinate Design Models Will you be using 3D coordination software to compile a federated model of design models for performing automated 3D collision detection to identify potential coordination issues along with performing a visual analysis to identify potential spatial design issues?	yes
	Review Design Models Will you be reviewing a BIM model with discipline expert reviewers to gain their feedback and to validate the design, construction, and/or operational aspects of a project?	yes
	Inspect Constructed Assets Will you be using the 3D model(s) to verify location, elevation and quantities of installed assets against contract requirements?	yes
	Create Quantities and Cost Estimates Will you be using BIM software to automate the generation of accurate quantity take-offs and cost estimates throughout the lifecycle of a project?	no

1. Start | 2. UserInputs | 3.1 StaffData | 3.2 BenefitsData | 3.3 CostData | 3.4 Parameters | ROIResults_Default | ROIResults_Detailed | Investigate | Refe

Using the ROI Tool

Step 3.1: Enter Staff Data

Instructions:

1) Fill out information below in green cells
2) Where avaialble, 'suggested values' will be used if agency input is left blank
3) Proceed to next sheet using the navigation arrow on the upper right corner

Legend: Only enter values in green cells

A. Staff Wages

State	U.S.	1.00
Year of data	2020	1.00

Average Annual Salary (inclusive of benefits)

Role	Active	Agency Input	Suggested Value
Geotechnical Engineers	$119,600		$119,600
Transportation/Design Engineers	$93,600		$93,600
Transportation Planners	$81,100		$81,100
Structural Engineers	$96,200		$96,200
Project Managers	$131,500		$131,500
Construction Inspectors	$83,800		$83,800
IT/ CADD Staff	$75,600		$75,600
Computer Network Architects	$155,500		$155,500
BIM Managers	$191,500		$191,500
Cost Estimators	$90,000		$90,000
Surveyors	$87,500		$87,500
Construction Maintenance	$45,700		$45,700
	$0		
	$0		
	$0		

Source:
Wages are U.S. national average wages. From BLS and other online salary resources
Wages are adjusted for the state context based on state selected for analysis

Average Hourly Wage Rates (inclusive of benefits)

Role	Active	Agency Input	Suggested Value
Geotechnical Engineers	$57.00		$57.00
Transportation/Design Engineers	$42.00		$42.00
Transportation Planners	$29.00		$29.00
Structural Engineers	$42.00		$42.00
Project Managers	$63.00		$63.00
Construction Inspectors	$40.00		$40.00
IT/ CADD Staff	$36.00		$36.00

1. Start | 2. UserInputs | 3.1 StaffData | 3.2 BenefitsData | 3.3 CostData | 3.4 Parameters | ROIResults_Default | ROIResults_Detailed | Investigate | Re

Using the ROI Tool

Step 3.2: Enter Benefits Data

Instructions:

1) Review each benefit and update with agency-specific data by entering values in green cells.
To exclude benefit, enter values of 0. Some benefits have suggested values in blue cells for reference.
2) Proceed to next sheet using the navigation arrow on the upper right corner

Legend: Only enter values in green cells

Assumption for range spread: 20% 20%

Code	#	Benefit	Benefit Description	Variables	Units	ACTIVE Mid	ACTIVE Low	ACTIVE High	User Override Mid	User Override Low	User Override High	Suggested Values Mid	Suggested Values Low	Suggested Values High	Source / Notes
In-House Agency Benefits															
BA1	1	Cost savings from reduced paper, printing and distribution	This benefit refers to reduced spending on the production and distribution of plan sheets plus printing and shipping of bid tabs that results from moving to a digital approach. Agencies that have already implemented "e-construction" or only issue electronically signed and sealed PDFs of the plans will not experience this cost savings.	Percent reduction in agency costs associated with paper, printing and distribution (due to BIM)	% reduction	32.5%	5.0%	60.0%				32.5%	5.0%	60.0%	Expert panel, and NCHRP Report 866
				Average annual spending on paper, printing and distribution (without BIM)	$ per year	$1,200,000						$1,200,000			Expert panel
BA2	2	Cost savings from reduced physical storage needs and office space/ elimination of leased building space	This benefit is the cost savings from reduced use of office space and leased building space for storage of paper plans and other physical files due to digital conversion. Agencies that have already implemented "e-construction" or only issue electronically signed and sealed PDFs of the plans will not experience this cost savings will not experience this cost savings.	Reduction in office space required for storage due to BIM digital files	sqft	20,000	16,000	24,000				20,000	16,000	24,000	Case Studies
				Price of office rental space	$ per sqft	$16						$16			U.S. average per sqft, PriceItHere.com
BA3	3	Avoided vehicle crashes due to safety simulation with BIM (Advanced Users)	This benefit results from avoiding potential vehicle crashes due to improved safety simulations during project design. Specifically, this benefit is monetized by the avoided operational costs to the agency (e.g., cleanup and property repair costs, such as guardrail replacements) that would have resulted from vehicle crashes.	Percent reduction in maintenance workorders for post-crash cleanup/repair due to BIM safety simulations	% reduction	17.0%	13.6%	20.4%				17%	14%	20%	CMFs for treatments to reduce poor sight distance. Not specific to BIM (FHWA-SA-11-08)
				Average spending on maintenance workorders for post-crash cleanup/repair, without BIM	$ per year	$12,000,000						$12,000,000			MNDOT, Statewide Highway Systems Operation Plan (2012)
BA4	4	Improved worker safety during construction	This benefit represents the value of reduced worker accidents during	Percent reduction in worker accidents during construction	% reduction										Expert panel, and Dodge Data & Analytics

1. Start | 2. UserInputs | 3.1 StaffData | 3.2 BenefitsData | 3.3 CostData | 3.4 Parameters | ROIResults_Default | ROIResults_Detailed | Investigate | References | Calcs>> | ListsLookups ...

Using the ROI Tool

Step 3.3: Enter Cost Data

Instructions:

1) Review each cost and update with agency-specific data by entering values in green cells. To exclude a cost, enter values of 0. Some costs have suggested values in blue cells for reference.
2) Proceed to next sheet using the navigation arrow on the upper right corner

Legend: Only enter values in green cells

Assumption for range spread: 20% 20%

Code	#	Cost	Variables Required to Monetize Cost	Units	ACTIVE Mid	ACTIVE Low	ACTIVE High	User Override Mid	User Override Low	User Override High	Suggested Values Mid	Suggested Values Low	Suggested Values High	Source / Notes
Initial / One-Time Costs														
CI1	1	Initial cost of BIM, Asset Management software or system configuration and customization (Professional services to setup system solution)	Average cost of professional service contractor visit to setup, program, configure, and/or customize system solution	$	**$575,000**	$400,000	$750,000				**$575,000**	$400,000	$750,000	Expert panel, cost research, and estimates by BIM personnel
CI2	2	Initial BIM hardware investments or upgrades required (e.g., computer workstations, tablets, GPS rovers, drones, robotic stations 'RTS')	Cost of equipment required											
			Computers	$/ computer	**$1,500**	$1,000	$2,000				**$1,500**	$1,000	$2,000	Case studies
				quantity	**10**						10			User Input- enter value appropriate for agency context
			Tablets	$/ tablet	**$850**	$650	$1,050				**$850**	$650	$1,050	Cost research
				quantity	**10**						10			User Input- enter value appropriate for agency context
			Total Stations and/or GPS rover systems (equipment + accessories)	$ (total)	**$27,500**	$15,000	$40,000				**$27,500**	$15,000	$40,000	Agency data received and cost research. A system includes the entire set up, the instrument, the data collector and the pole and the software to run it
			Drones/UAS	$ (total)	**$21,040**	$3,000	$39,079				**$21,040**	$3,000	$39,079	ODOT, 2018 and agency data received

1. Start | 2. UserInputs | 3.1 StaffData | 3.2 BenefitsData | 3.3 CostData | 3.4 Parameters | ROIResults_Default | ROIResults_Detailed | Investigate | References | Calcs>> | ListsLook

Using the ROI Tool

Step 3.4: Update Parameters

Instructions:
1) Review parameter values in 'ACTIVE'. If desired, enter override value in green cells.
2) Proceed to next sheet using the navigation arrow on the upper right corner

Legend: Only enter values in green cells

Variable Name	Unit	ACTIVE	User Override	Suggested Value	Source/Notes
Model Parameters					
Base Year		2021		2021	Current Year
First Year of Investment		2022			Adjust in UserInputs
Analysis Period (years after First Year of Investment)	years	10		10	Assumption
Last Year of Analysis		2034			Calculated
Real Discount Rate	%	4.0%		4.0%	
General					
Number of work days per month	days per month	21		21	
Ramp-up factors & Benefit delay					
Years After Investment for Benefits to be Realized (Project Delivery)	years	3		3	Assumption: takes 3 years after investment to setup all tools/technology
First Year of Realizing Full Benefits (Project Delivery)		2025			Calculated
Years After Investment for Benefits to be Realized (Asset Management)	years	5		5	Assumption: takes 5 years to receive data for models used for asset
First Year of Realizing Full Benefits (Asset Management)		2027			Calculated
Additional Years of Delay before Realizing Full Benefits for:					
BS3: Time savings from design efficiency	years	1		1	Assumption
Safety Data					
Value of U Injury (Severity Unknown)	$/injury	$199,994		$199,994	USDOT BCA Guidance, 2021. Inflated from $2019 to $2020

1. Start | 2. UserInputs | 3.1 StaffData | 3.2 BenefitsData | 3.3 CostData | 3.4 Parameters | ROIResults_Default | ROIResults_Detailed | Investigate | References | Calcs>>

Using the ROI Tool

Results Summary - Analysis with Default Parameters

Return to Start

SUMMARY METRICS

Total Discounted Benefits

Mid	$15,468,710
Low	$5,253,487
High	$25,683,934

Total Discounted Costs

Mid	$2,264,452
Low	$1,613,533
High	$2,915,371

Net Present Value

Mid	$13,204,258
Low	$3,639,954
High	$22,768,563

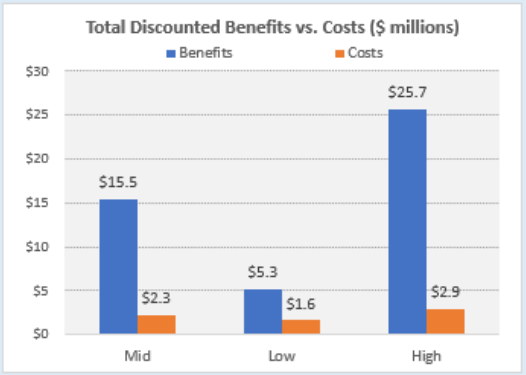
Benefit-Cost Ratio

Mid	6.83
Low	3.26
High	8.81

Payback Period (years)

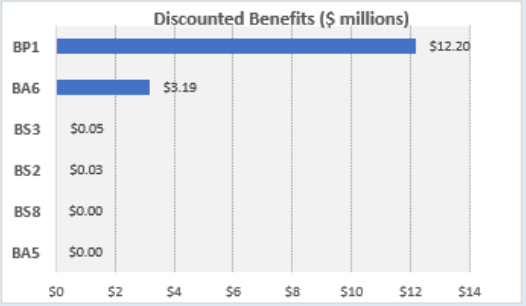
Mid	2
Low	4
High	2

Based on discounted series. A value of 0 indicates investment is paid back in same year of investment.



TOTAL DISCOUNTED BENEFITS

		Mid	*Low*	*High*
Agency Cost Savings				
BA5	Improved worker safety during maintenance inspections	$0	$0	$0
BA6	Cost savings on inspections due to use of drones	$3,190,277	$1,160,101	$5,220,453
Project Cost Savings				
BP1	Cost savings from avoided change orders	$12,203,381	$4,067,794	$20,338,968
Staff Time Savings				
BS2	Time savings during project scoping	$25,293	$712	$49,873
BS3	Time savings from design efficiency	$49,759	$24,880	$74,639
BS8	Time savings completing design quantities	$0	$0	$0
		0.00	0.00	0.00



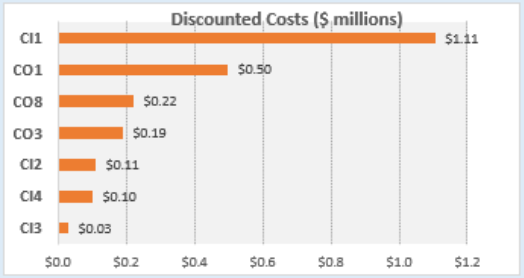
TOTAL DISCOUNTED COSTS

	Mid	Low	High

Using the ROI Tool

TOTAL DISCOUNTED COSTS

		Mid	Low	High
CI1	Cost of initial BIM software configuration/customization	$1,105,769	$769,231	$1,442,308
CI2	Cost of initial BIM hardware investments/upgrades	$112,201	$52,692	$171,711
CI3	Cost of initial comprehensive staff training	$31,410	$25,128	$37,692
CI4	Opportunity cost of staff time for initial comprehensive training	$102,945	$102,945	$102,945
CO1	Incremental costs of BIM-related software subscription	$499,282	$399,426	$599,139
CO3	Cost of semi-regular hardware replacement	$190,836	$86,505	$295,168
CO8	Cost increase of professional services contracts requiring BIM	$222,007	$177,606	$266,409
		0.00	0.00	0.00



1. Start | 2. UserInputs | 3.1 StaffData | 3.2 BenefitsData | 3.3 CostData | 3.4 Parameters | ROIResults_Default | ROIResults_Detailed | Investigate | References | Cal

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