Digital Twin Guidelines

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COLUMBIA | CBIPS
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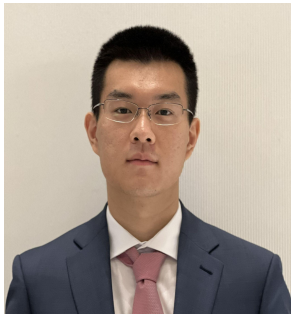

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BIM and Digital Twin

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Background

1. Case Studies
   - 138th Street Bridge - NYSDOT
   - Digital twin for Bridge inspection in Minnesota
2. Software Availability Study
   - Bentley
   - Autodesk
3. Site Visit
4. Benefits & Challenges

Digital Twin Overview

About Digital Twin

- First voiced in 1991, with the publication of *Mirror Worlds*, by David Gelernter
- A virtual model designed to accurately reflect a physical object
- Help monitor production systems to achieve and maintain peak efficiency
- The future is nearly limitless since increasing amounts of cognitive power devoted

What is a digital twin? | IBM,2019

Digital Twin Overview

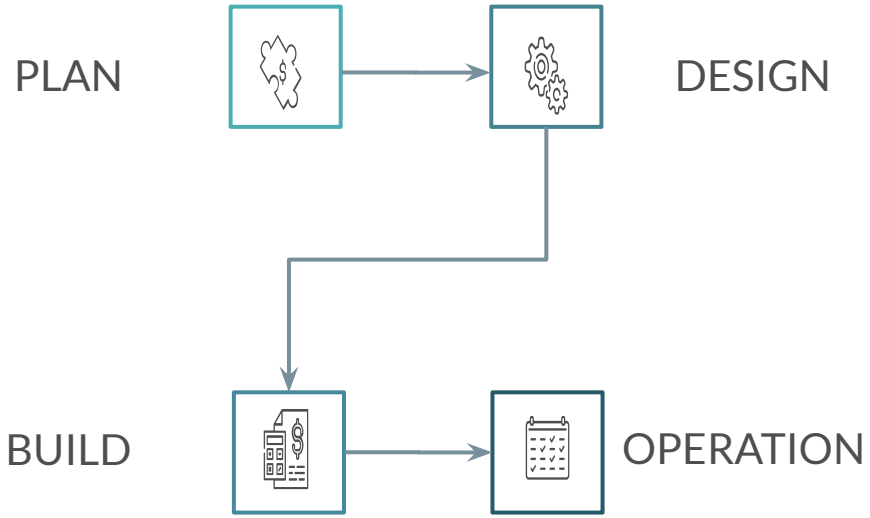
Digital Twin's Types Graphics

- Component twins/Parts twins
- Asset twins
- System or Unit twins
- Process twins

What is a digital twin? | IBM 2019

BIM Introduction

- Building Information Modeling (BIM) is the process of creating and managing information for a built asset.
- Based on an intelligent model and enabled by a cloud platform, BIM integrates structured, multi-disciplinary data to produce a digital representation of an asset across its lifecycle, from planning and design to construction and operations.

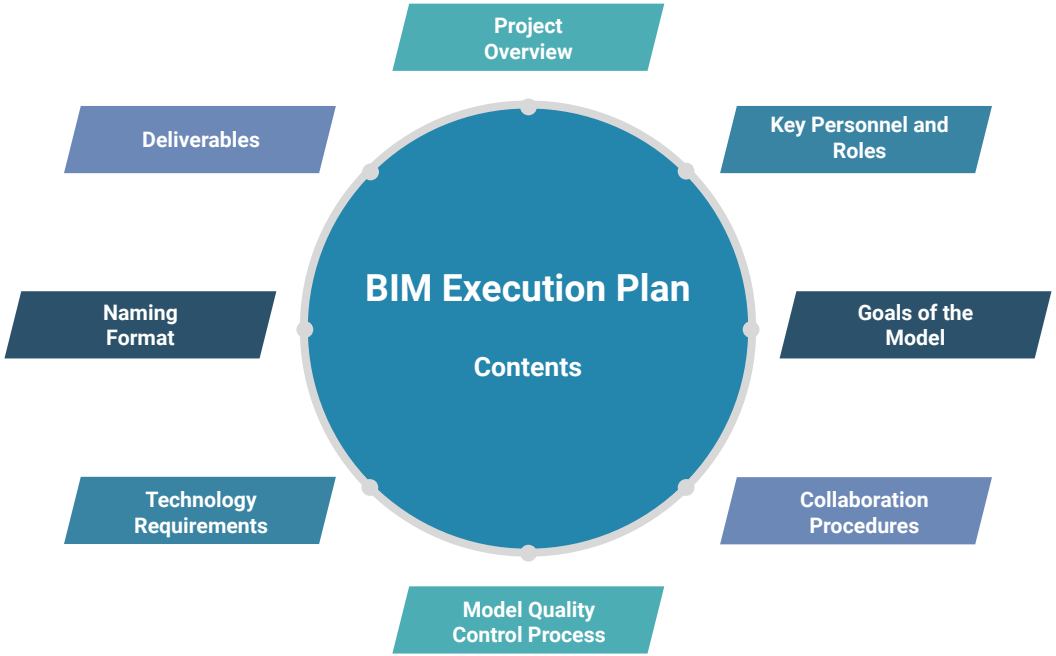


BIM Benefits, Autodesk, 2022

BIM Execution Plan

- A BIM Execution Plan is a document which gives the project participants a clear understanding of their roles.
- It establishes standards about communication, Milestones, Deliverables, file naming formats, etc
- Project Goals and BIM uses are specified for the project in the BEP

BIM Execution Plan



PRIORITY	GOAL DESCRIPTION	POTENTIAL BIM USES
Medium	Assess feasibility of the project	Feasibility Analysis
High	Maximize efficiency of design & coordination process	3D Coordination, Design Authoring
High	Minimize clashes both in frequency and severity on-site	3D Coordination
High	Ensure there are no cost over-runs	Cost Estimation
High	Ensure pre-fab components are dead accurate	Digital Fabrication
High	Ensure project is completed within the schedule	Phase Planning
Medium	To evaluate the feasibility of the schedule	4D modeling
Medium	Improve the communication protocol	3D Coorination

X	PLAN	X	DESIGN	X	CONSTRUCT	X	OPERATE
		X	DESIGN AUTHORING				
			3D COORDINATION	X	3D COORDINATION		
			DIGITAL FABRICATION	X	DIGITAL FABRICATION		
X	4D MODELING	X	4D MODELING	X	4D MODELING		4D MODELING
X	COST ESTIMATION	X	COST ESTIMATION	X	COST ESTIMATION	X	COST ESTIMATION
X	EXISTING CONDITION MODELING	X	EXISTING CONDITION MODELING	X	EXISTING CONDITION MODELING	X	EXISTING CONDITION MODELING

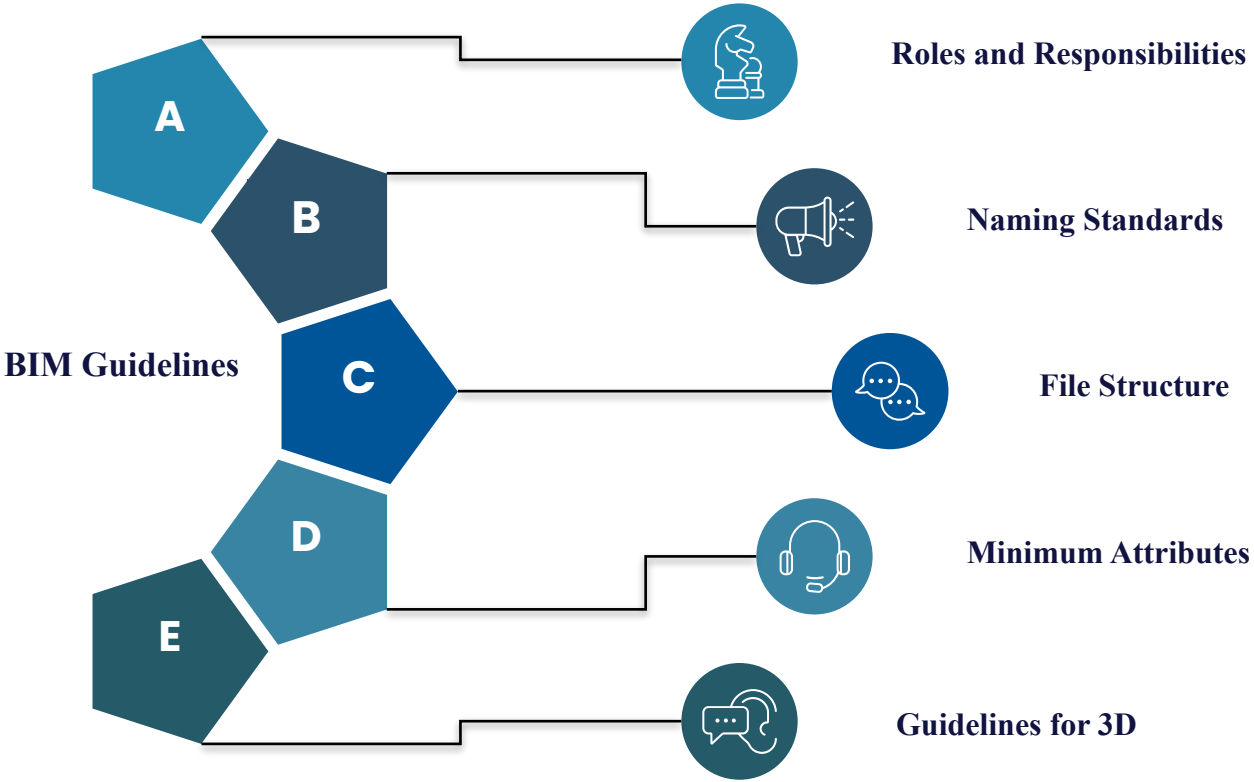
BIM Execution Plan

Implementation:

- Planning team which includes representatives from the owner, designers, contractors, engineers, major specialty contractors, facility manager.
- The lead party for coordinating and compiling the BIM Plan should be clearly identified.
- Identify the BIM goals of the project and decide the Digital Twin functions to be included.
- Determine who is responsible for generating the model.
- Setting requirements for the involved parties in the project.

BIM GUIDELINES

Guidelines for BIM overview



1. Roles & Responsibilities

1. Project Integrator:

- Lead the Project Coordination Meetings
- Collect and assemble the primary integration model
- Ensure the BIM data is fulfilling all project requirements
- Facilitate the distribution of the model, supporting reports and logs
- Track issues and resolutions and distribute to team

2. Quality Control Representative:

- Routinely audit all models to ensure they are meeting all required standards
- Ensure proper software and versions are being used
- Document and report to the project team any quality related issues as part of the Project Integration Meetings
- Ensure that all 2D drawings are derived directly from the model and that no changes have been made to the 2D sheets that would in anyway invalidate the model

https://www.gsa.gov/real-estate/design-excellence-program/3d4d-building-information-modeling/bim-software-guidelines/gsa-bim-guidelines-for-revit (2019)

2. Naming Standards

There are two main ways that BIM design software platforms manage files: the conventional approach, in which only one sheet, floor, or model will exist per file; and the more recent software generation, which can hold an entire project within one file.

Design Software	File Management Type
AutoCAD (including Architecture, MEP and all other verticals)	Drawing-based file platform
MicroStation (including Architecture, Building and all other verticals)	Drawing-based file platform
Revit (all versions)	Project-based file platform
Archicad (all versions)	Project-based file platform

https://www.gsa.gov/real-estate/design-excellence-program/3d4d-building-information-modeling/bim-software-guidelines/gsa-bim-guidelines-for-revit (2019)

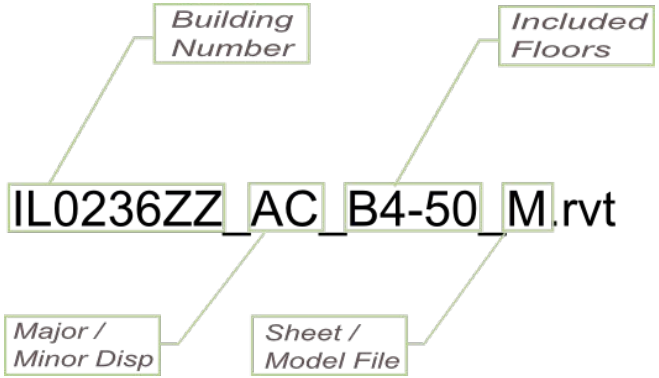
2. Naming Standards

1. Drawing Based (Sheets):

- They will use the most current “PBS CAD standard” for all file naming.
- This document makes no changes to the existing standards for drawing-based file platforms.

2. Project Based (3D Models):

- Project-based file platforms will use a four part file name consisting of:
  - The assigned site ID
  - 1 character major discipline / trade designator
  - 1 character minor discipline / trade designator
  - Few characters to define contained floors/site location
  - 1 character type designator M/S/C (model, sheets, combined)



Example 1

https://www.gsa.gov/real-estate/design-excellence-program/3d4d-building-information-modeling/bim-software-guidelines/gsa-bim-guidelines-for-revit (2019)

3. File Structure & Organization

- Data Structure
  - Phasing and 4D planning should be contained within single files, where possible.
  - When working on a site which has existing BIM data, the structure developed by previous teams should be used. Modifications to the existing data structure should only be made in cases where not doing so would adversely affect the project.
  - Data structure should be established using some logical breakdown of the project data. This should take into account both immediate project needs and future use as part of the building information life-cycle. Some examples of data separations are:
    - Floor by floor or logical groups of floors
    - Trades (e.g. cladding, steelwork, plumbing, electrical)
    - Construction Joints
    - East Wing / West Wing
    - MEP Systems

https://www.gsa.gov/real-estate/design-excellence-program/3d4d-building-information-modeling/bim-software-guidelines/gsa-bim-guidelines-for-revit (2019)

3. File Structure & Organization

- Origin point, Northing & Elevation
  - A common project or site base point is to be agreed upon by all team members as part of the BEP.
  - The selection of the origin point must take into account the numerous software platforms used and also be compatible with as many as possible.
  - If there are conflicting existing origin points, the building with the largest square footage shall be used to establish the origin point.
  - True North and Project North will be defined within the BEP and will be implemented consistently across all BIM data.

https://www.gsa.gov/real-estate/design-excellence-program/3d4d-building-information-modeling/bim-software-guidelines/gsa-bim-guidelines-for-revit (2019)

3. File Structure & Organization

- Folder structure

  The final data submittal is to have all data organized into a folder structure.Each included file should be linked to its respective element in the model using the parameters for URLs, as outlined in the Minimum Attributes Standard

- Globally Unique Identifier

  Globally Unique IDentifier or GUID is a universally unique number assigned by the BIM authoring software to every element within the BIM. The standards only apply to projects which have existing BIM data actively being used to support a building data life-cycle program

https://www.gsa.gov/real-estate/design-excellence-program/3d4d-building-information-modeling/bim-software-guidelines/gsa-bim-guidelines-for-revit (2019)

4. Minimum Attributes

- URL Data

URL data is to be added to all projects as a TYPE level parameter or attribute. The URL data will link to either a specific file or a folder based on whether the target data is a single file, such as an MSDS sheet, or multiple files, such as photos. The targeted data is to follow the structure outlined in the Data Submittal Standard

Attribute / Parameter	Data Type	Description
URL As-Built Drawings	URL	A URL link pointing to one or more as-built drawings, typically either DWGs or PDFs
URL MSDS	URL	A URL link pointing to one or more MSDS, typically a single PDF
URL Op and Maint Manuals	URL	A URL link pointing to one or more operation or maintenance manuals, typically PDFs
URL Owner Manual	URL	A URL link pointing to one or more owner manuals, typically PDFs
URL Photos	URL	A URL link pointing to one or more digital photographs, typically JPGs. This may link to a sub-folder of the divisions Photos folder when required.
URL Product Data	URL	A URL link pointing to one or more product data or information documents, typically PDFs
URL RFIs	URL	A URL link pointing to one or more scanned RFIs from the project, typically PDFs, although sometimes JPGs

https://www.gsa.gov/real-estate/design-excellence-program/3d4d-building-information-modeling/bim-software-guidelines/gsa-bim-guidelines-for-revit (2019)

4. Minimum Attributes

- Url Guidelines
  - URL to Local Files:
    - All URLs used in submitted data must be of the relative and never pathed to a absolute network location.
    - URLs should always go deeper into the folder structure. Backlinking should be avoided whenever possible.
  - URL to Internet Address:
    - Care must be used when linking to internet based resources. It is unlikely that they will be available, with address unchanged, for the life-cycle of the building.
    - Internet URLs must only be used when there is no means of making the content local to the data submittal.

https://www.gsa.gov/real-estate/design-excellence-program/3d4d-building-information-modeling/bim-software-guidelines/gsa-bim-guidelines-for-revit (2019)

4. Minimum Attributes

- Omniclass Data

  Design components used to generate the virtual model must be associated with an Omniclass Number and Omniclass Title. This allows for organization and understanding of design intent. This effort occurs in all design and construction phases. Within a Revit environment, it can be addressed in the family. The family templates have this information already, however, if the predetermined information is not accurate to the component, it is the responsibility of either AE or GC (based on LOD) to be corrected.

https://www.gsa.gov/real-estate/design-excellence-program/3d4d-building-information-modeling/bim-software-guidelines/gsa-bim-guidelines-for-revit (2019)

5. Guidelines for 3D

The rapid collection of 3D information serves several purposes including:

- historical documentation
- facility condition documentation and audits
- construction as-built development
- BIM development.

Implementation:

Identify contexts and projects

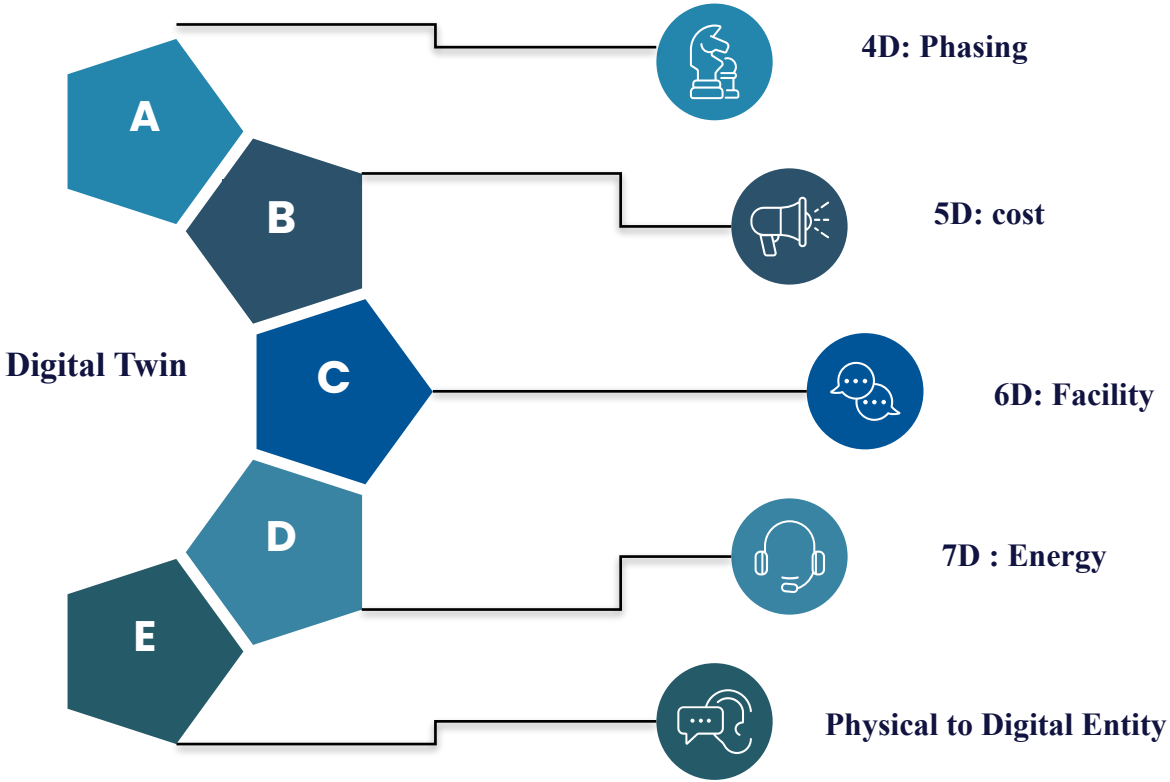
evaluate contractor submissions throughout the project

proper specification of the deliverables, communication and coordination

https://www.gsa.gov/real-estate/design-excellence-program/3d4d-building-information-modeling/bim-guides/bim-guide-03-3d-imaging (2019)

Guidelines for Digital Twins

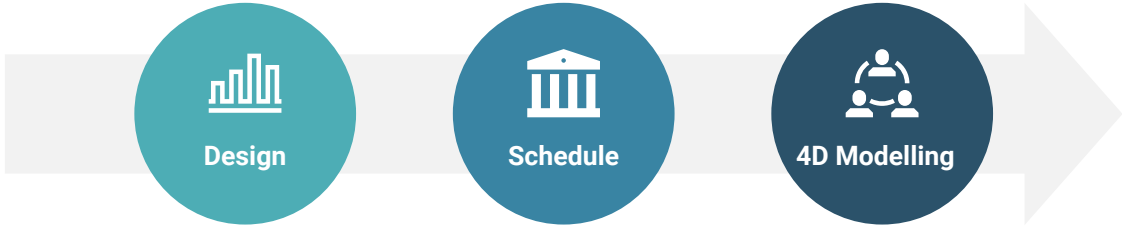
Guidelines for Digital Twins overview



6. Guidelines for 4D : Phasing

- 3D model with the dimension of time is a 4D model. It is used to show construction sequence and space requirements on a building site
- It helps everyone better understand the project milestones and construction plans.

Implementation requirements:



Design Authoring	Scheduling	4D Modeling
Software: Revit, Civil 3D	Software: P6, MS P	Software: Navisworks, SYNCHRO

6. Guidelines for 4D : Phasing

First Roles and Responsibilities must be assigned.

Define Scope and Level of Detail to be used for the 4D model.

The team should have sufficient knowledge on

- Scheduling and general construction process.
- Ability to use 3D model
- Knowledge about 4D software: Importing Geometry, Managing schedule Links, Making Animations, etc.

7. Guidelines for 5D: Cost

Overview

- Cost Management (BIM 5D) brings many opportunities and challenges associated with the need of local workflows modification in accordance to information modeling needs

(PDF) BIM for Cost Estimation (researchgate.net), 2018

7. Guidelines for 5D: Cost

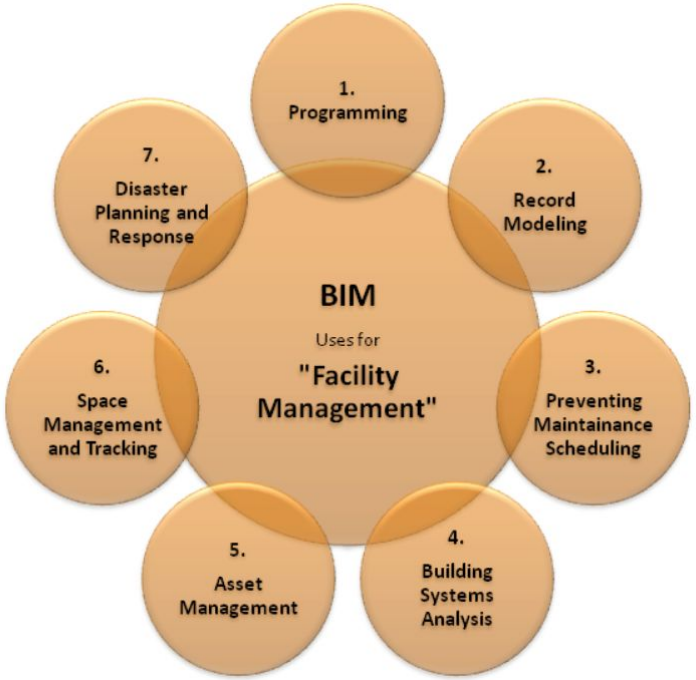
Implementation

- a well-developed information model according to the given data standard
- Transfer parameters and attributes (structure, volume, area) to the spreadsheet
- Use the conventional software tools to process the data
- Program through the Application Programming Interface (API) for cost estimation

(PDF) BIM for Cost Estimation (researchgate.net), 2018

8. Guidelines for 6D : Facility Management

- 6D BIM involves the addition of relevant information that supports the facility management
- A model created by the designer is updated throughout the course of construction. This model can be submitted to the owner as an “as-built” model.
- The as-built model helps with the maintenance of the structure after it has been constructed.



Facility Management Uses

BIM Guide For Facility Management, GSA, 2015

8. Guidelines for 6D : Life Cycle Integration

Implementation:

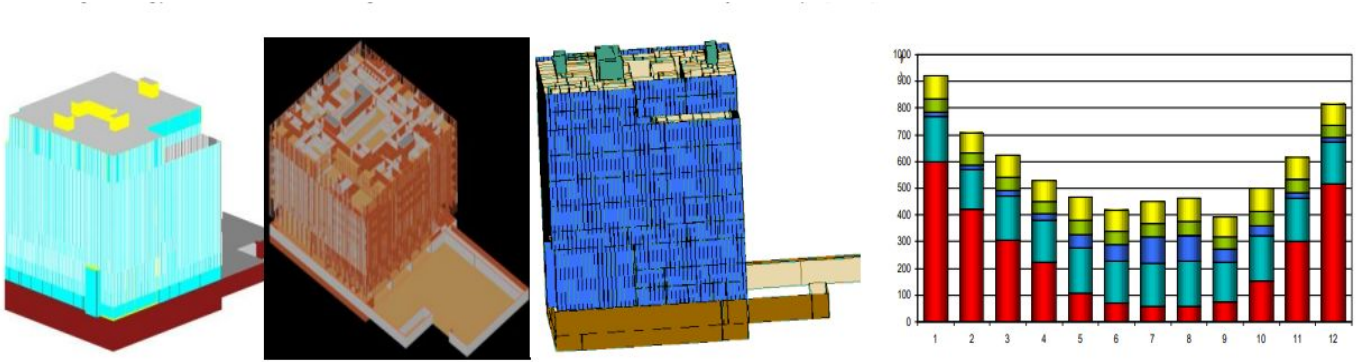
- Identify the lifecycle of the project : Existing Building, Small Project under construction, new construction, or for Major Renovations of a facility
- Facility Management and Life Cycle Integration must be included in the BEP's BIM Goals.
- Determine when and by whom the model is created. Usually the A/E is responsible for the model production.
- Verify that all the Models are actual representations of the structure
- Connect to the facility management system of the structure based on the requirements.

BIM Guide For Facility Management, GSA, 2015

9. Guidelines for 7D: Energy

Overview

- Energy performance in buildings is the result of a complex set of interrelationships among the external environment, the shape and character of the building components, equipment loads, lighting systems, mechanical systems, building envelope, air distribution strategies, renewable energy options, operational protocols, and the building occupants.



GSA_BIM_Guide_05_Version_2.1.pdf, 2019

9. Guidelines for 7D: Energy

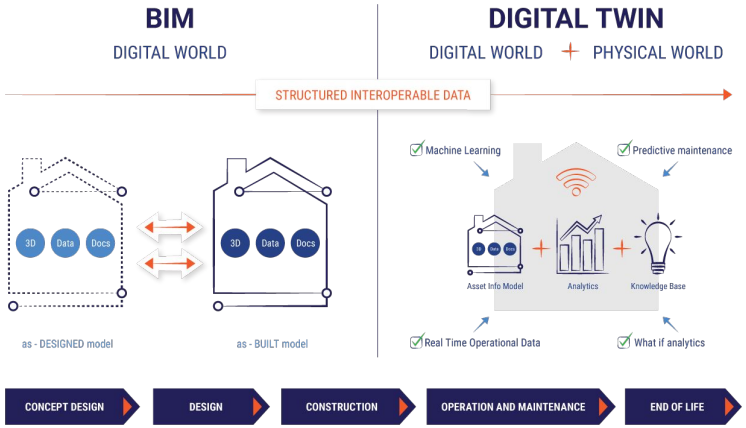
Decision Process

- Identify the stakeholders and their energy goals
- Define the business needs and energy considerations of the project
- Identify the opportunities where energy performance information can help guide the project
- Identify the project team's capabilities and resources, including time, budget, and skill for using energy modeling effectively
- Identify the energy modeling tools that will generate useful information for the team

GSA_BIM_Guide_05_Version_2.1.pdf, 2019

Connecting the Physical to Virtual Entity

- The flow of information should be bidirectional between the Virtual and Physical entities
- Using the digital twin for simulations to predict the behaviour of the physical entity
- Sensors are used to connect the two entities together
- Using IoT connects the physical entities to their Virtual counterparts



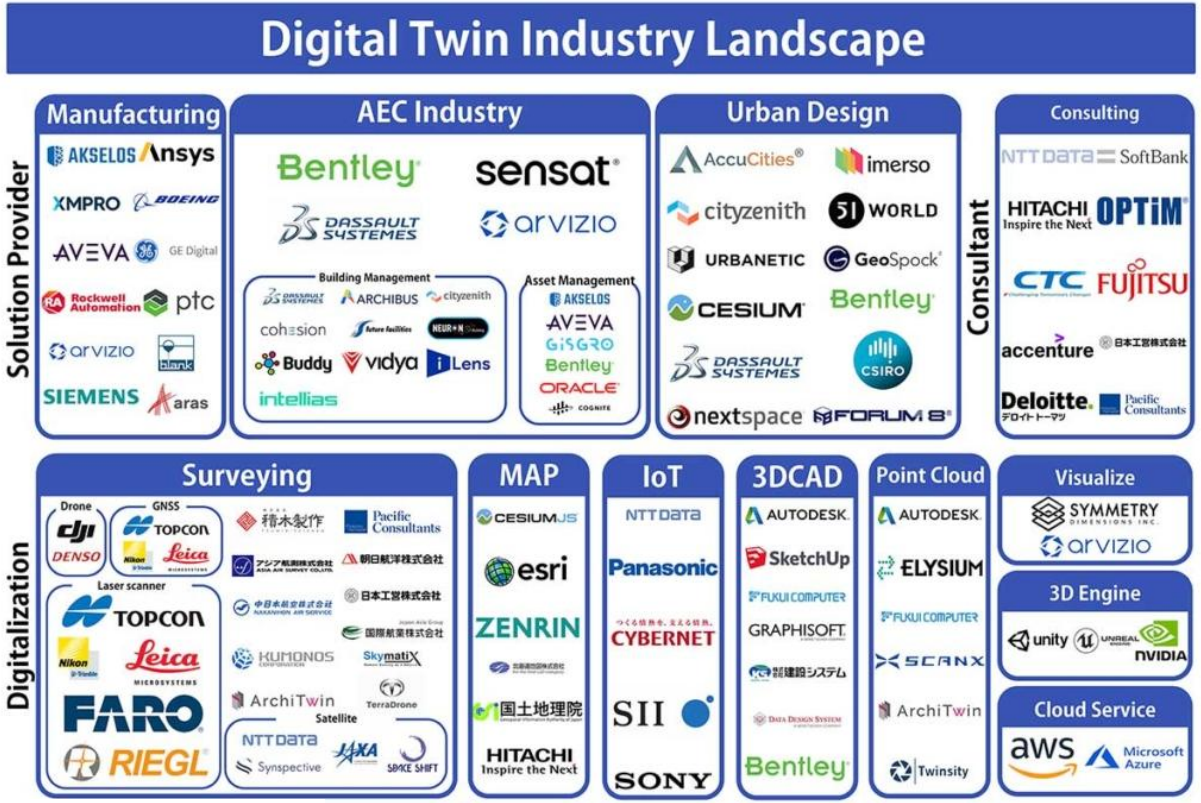
BIM to Digital Twin, Source: CoBuilder

BIM to Digital Twin, CoBuilder, 2020

Best in Class Softwares

Softwares Available

Softwares Available



Accucities Digital Twin Industry Map by Symmetry Dimensions, 22 Nov. 2020,

10. Software Version

- Some software versions are not compatible with their older versions as well as new ones
- The specific version of software to be used must be agreed upon by the project team as part of the BEP.

- - Autodesk Revit Architecture
  - Autodesk Revit Structural
  - Autodesk Revit MEP
  - Autodesk Navisworks
  - Industry Foundation Class (IFC)

https://www.gsa.gov/real-estate/design-excellence-program/3d4d-building-information-modeling/bim-software-guidelines/gsa-bim-guidelines-for-revit (2019)

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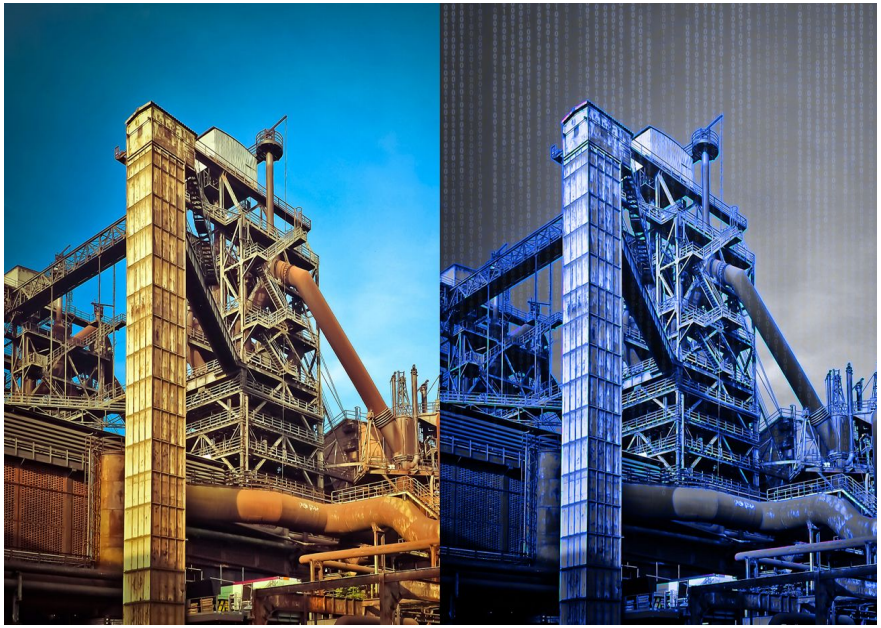
Thank You
Q&A

APPENDIX

Digital Twins Presentation 1, Oct 11th, 2022

Contents

DIGITAL TWINS



A Digital Twin is an Exact Replica of a physical asset. It can also be defined as a virtual representation of a system that spans its lifecycle, is updated from real-time data and helps with decision making.

Types of Digital Twins

Descriptive

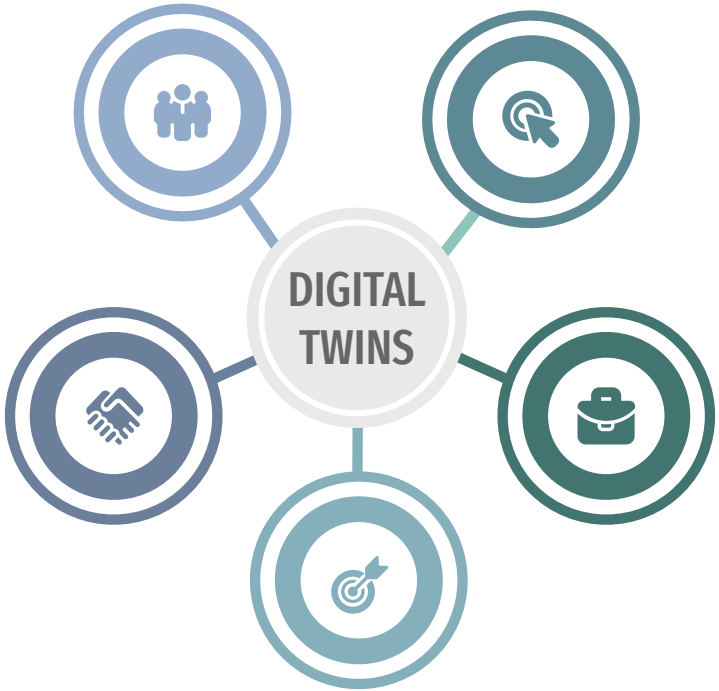
A live, editable version of design and construction data

Autonomous

Ability to learn and act on behalf of users

Comprehensive

Simulation for future what-if scenarios



Informative

Additional operational and sensory data

Predictive

Using operational data for insights

Source : Digital Twins in Built Environments: An Investigation of the Characteristics, Applications, and Challenges 25 January 2022

CASE STUDY I

Revitalization of Roadway in Cedar Falls, Iowa

BIM vs Digital Twin

PARAMETERS	BIM	DIGITAL TWIN
Focuses on	Building Information & Tools	People, Processes & Behaviors
Benefits	Project Management & Risk Analysis	Predicts potential failure and prevents accidents & damages
Simulation of Operations	No real time synchronization	Real time operational response
Prediction of Data	Only accuracy and and completeness can be comprehended	Anticipates information such as weather forecasts, energy demand, etc

Tools


BricsCAD®


AUTODESK®
REVIT®


AUTODESK®
NAVISWORKS®


Bentley®
Advancing Infrastructure


AUTODESK®
CIVIL 3D® 2021


KREO


Tekla®
Structures


AUTODESK®
INFRAWORKS®

Development Process

Data, 3D design, Doc

Real time operational data/Big Data

Machine learning algorithms

Predictive maintenance & What if Analysis

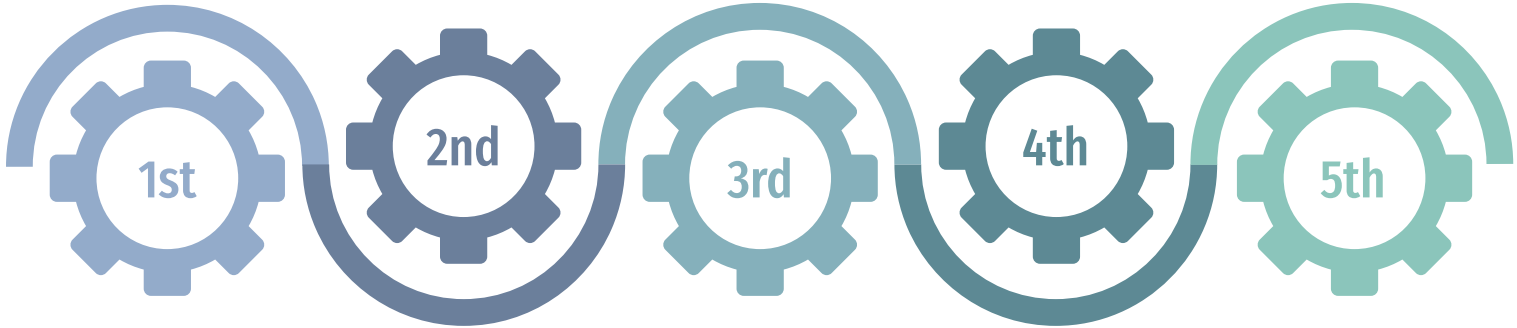
Application

DESIGN DECISION-MAKING

Provide the opportunity to test design intent for its functionality or compliance

REAL-TIME CONSTRUCTION PROGRESS MONITORING

Automate resource allocation and waste management, and reproduce the real conditions of the site, materials, machinery, and workers' behavior



SMART CITY

Create state-of-the-art AI algorithms, which can be used for digital twin-enabled city management applications

PRODUCT MANUFACTURING

Curtail the production of unwanted items and result in sustainable construction.

MAINTENANCE & OPERATION

Offer improved data-driven decision making during asset operation and management

Source : Digital Twins in Built Environments: An Investigation of the Characteristics, Applications, and Challenges 25 January 2022

Case Study I : Overview

A

ABOUT

Roadway Revitalization in Cedar Falls, Iowa

B

AIM

To improve roadway conditions & Traffic flow flow,provide non-vehicular access

C

TECHNOLOGY

Drones and Bentley Applications

D

RESULT

Successfully delivered the project

While Revitalizing a Roadway, Foth Team Honed Collaboration Processes That Ease Remote Work, 6 May, 2020

Case Study I : Process

DATA ACQUISITION	Drones and Mobile Scanning applications.
MODELING	MicroStation, LumenRT, OpenRoads, OpenFlows
SIMULATIONS, UTILITY COORDINATION	Bentley Applications
COLLABORATION PLATFORM	ProjectWise

While Revitalizing a Roadway, Foth Team Honed Collaboration Processes That Ease Remote Work, 6 May, 2020

Case Study I : Result

TIME

Using open applications **reduced** the **design phase** by **50%**, saving **1,600 hours of design time** which enabled construction to begin a **full year ahead of schedule**

COST

Including the **BIM** model as part of the **bidding documents** ultimately resulted in costs at **3% below total contract bid amounts**, saving the city more than **$500,000**

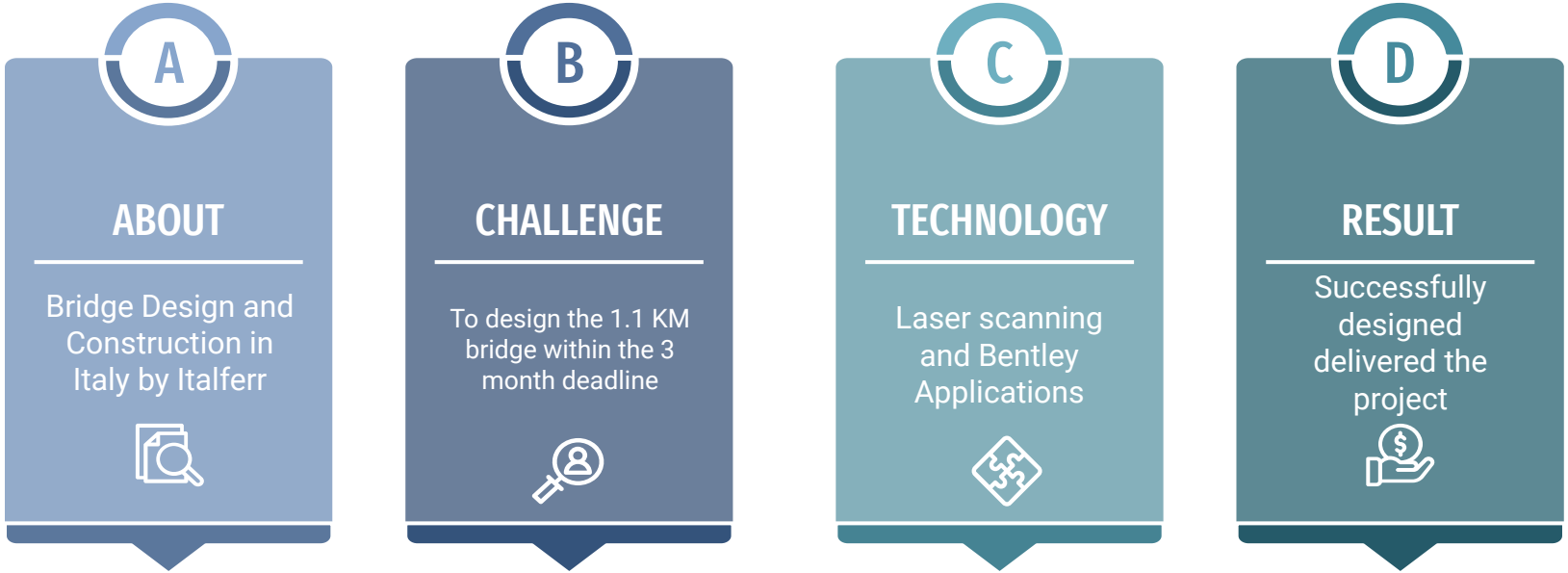
ROI

Foth's safe, efficient, and modern design delivered a **return on investment estimated at US$32 million** in savings for the community to be realised over the next 25 years

CASE STUDY II

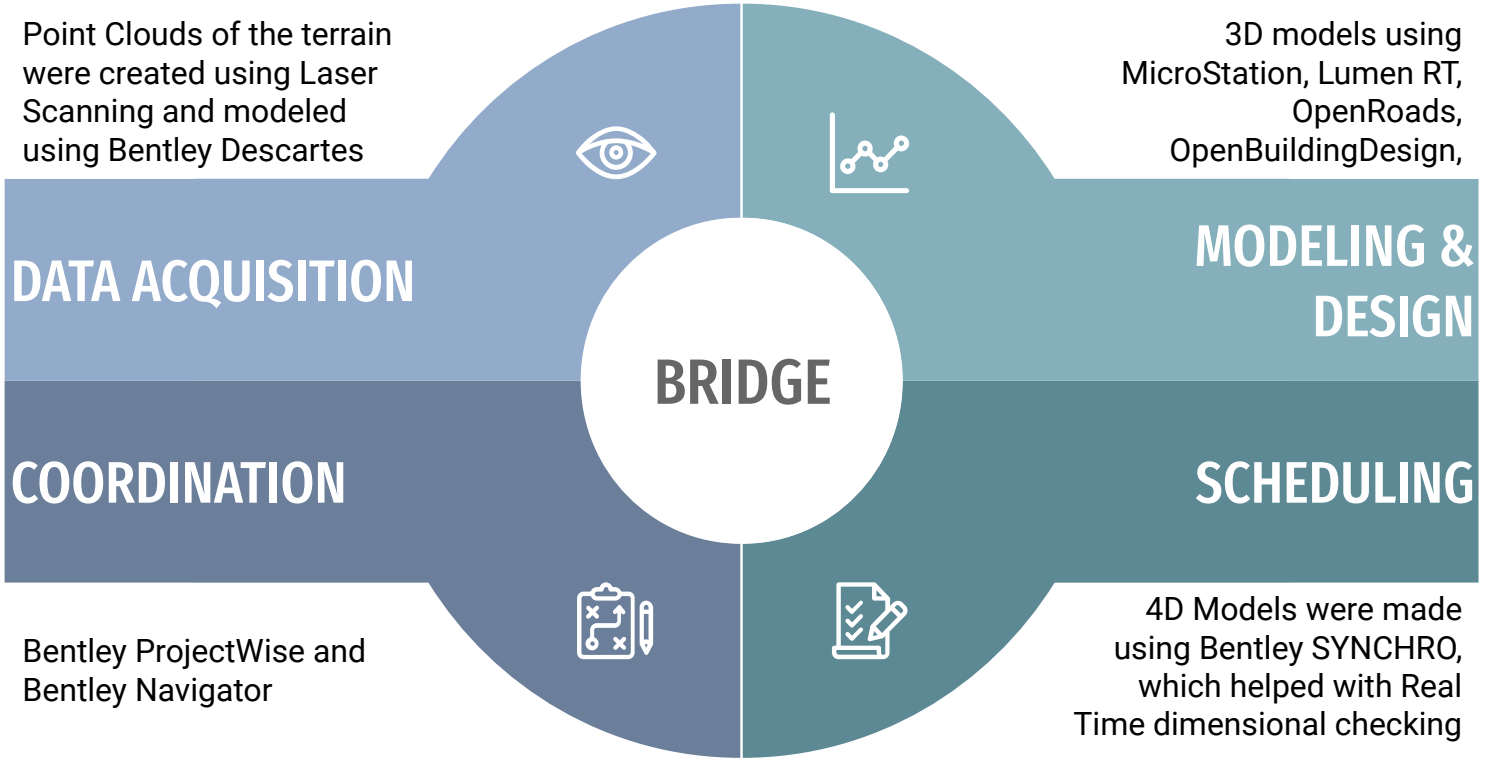
Building the Ponte Morandi Bridge, Italy

Case Study II : Overview



Source:https://www.abcmagazine.eu/news/italferr-uses-digital-twins-to-streamline-workflows-and-improve-accuracy-on-genoa-bridge-redesign 2018

Process



https://www.abcmagazine.eu/news/italferr-uses-digital-twins-to-streamline-workflows-and-improve-accuracy-on-genoa-bridge-redesign 2018

Results

DESIGN

With the help of multiple tools, many of the design processes were automated and the 3 month deadline to design the bridge was met

TIME

3D models helped visualise the end product and scheduling tools helped set deadlines for tasks, because of which the designers and contractors completed the project sooner

COORDINATION

Using tools, the clashes between various disciplines were determined and resolved before reaching the site and, which improved coordination in the project

Source:https://www.abcmagazine.eu/news/italferr-uses-digital-twins-to-streamline-workflows-and-improve-accuracy-on-genoa-bridge-redesign
2018

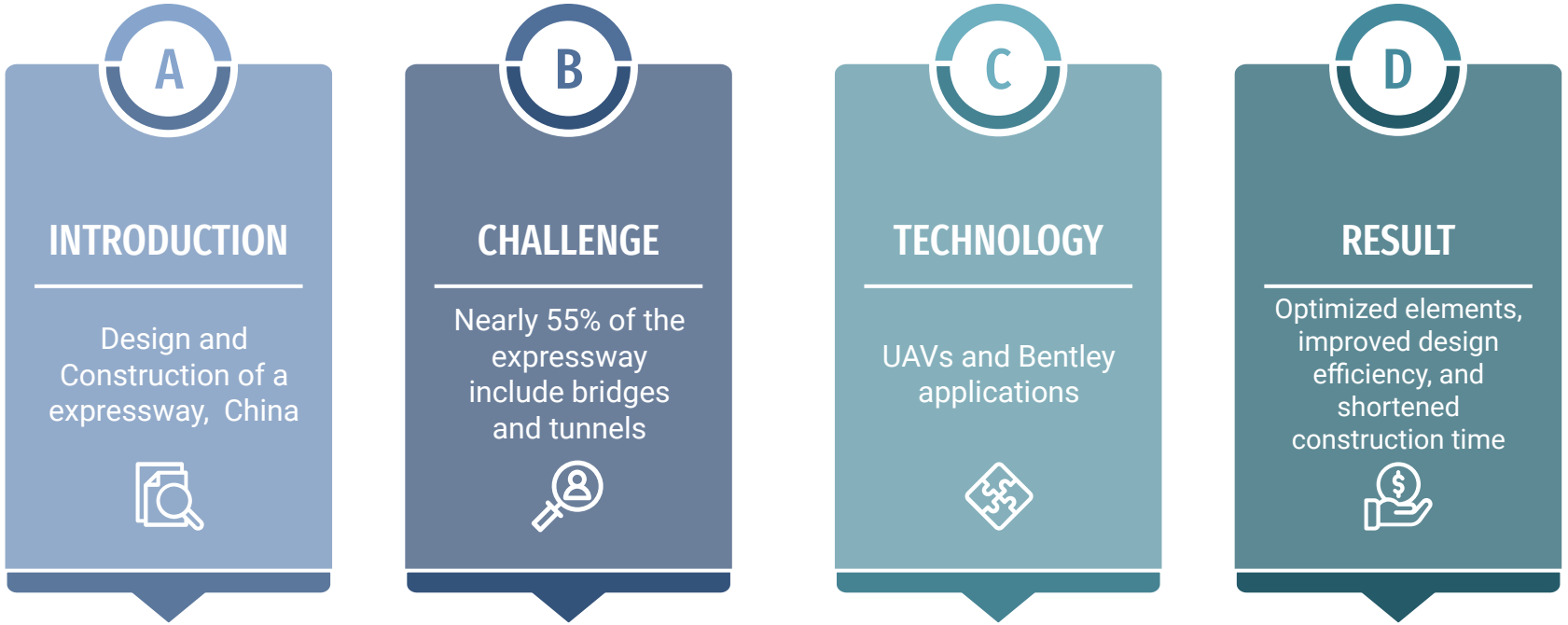
Lessons Learned

- Digital Twins can help shorten the time taken to design a structure
- Parts of the design process can be automated using software tools like OpenRoads and OpenBuilding Design
- Terrain Surveying is done using drones and laser scanning
- Bentley is a leader in the BIM and DT industry

CASE STUDY III

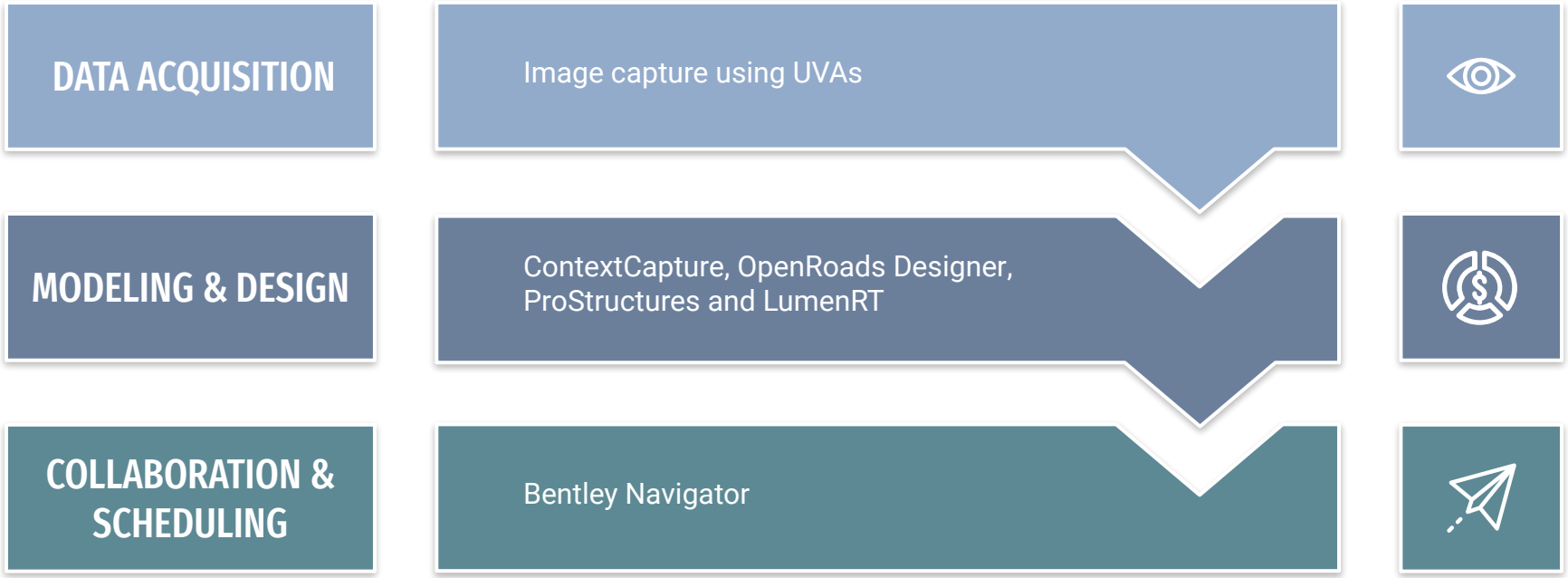
Meitan-Shiqian Expressway in Guizhou Province, China

Case Study III: Overview



Source : https://blog.virtuosity.com/success-story-chongqing-traffic-planning-survey-and-design-institute-meitan-shiqian-expressway-in-guizhou-province
Dec 11, 2019

Process



Source : https://blog.virtuosity.com/success-story-chongqing-traffic-planning-survey-and-design-institute-meitan-shiqian-expressway-in-guizhou-province
Dec 11, 2019

Results

1st	Optimized all elements in the expressway, improved design efficiency	DESIGN
2nd	Shortened construction time by 89 days	TIME
3rd	Detected more than 100 clashes and issues, including some that were not visible prior to construction.	CONSTRUCTION

Source : https://blog.virtuosity.com/success-story-chongqing-traffic-planning-survey-and-design-institute-meitan-shiqian-expressway-in-guizhou-province
Dec 11, 2019

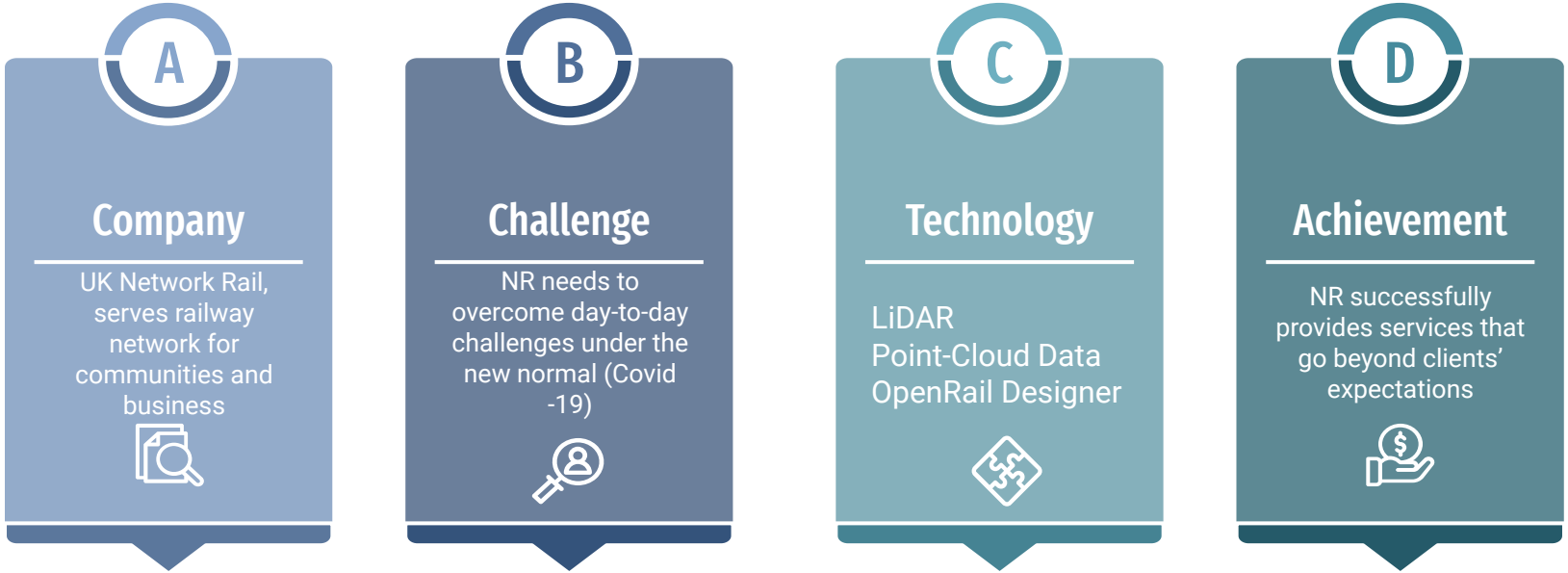
Lessons Learned

- Digital twin can be used to benefit the whole process of a project
- For bridges, it may face difficulty in obtaining correct and enough data
- Digital twin offers a better approach for the communication between project's team and clients.

Case Study IV:

Network Rail Overcomes COVID-19 Obstacles with Digital Twins of Railway Stations

Case Study: Overview



Source: [Network Rail Overcomes COVID-19 Obstacles with Digital Twins of Railway Stations | Cadalyst](), 23 Oct, 2020

Case Study: Process (Part 1: Exeter)

Goal	Build 3D model of station and signal lighting
Solution	Use MicroStation to collect information
Ideology	Digital Terrain Model + Cross-Checking Result = A comprehensive Station Model
Future Impact	Perform digital site visits for design review Allow further stakeholders' engagement

Source: Network Rail Overcomes COVID-19 Obstacles with Digital Twins of Railway Stations | Cadalyst , 23 Oct, 2020

Case Study: Process (Part 2: Paddington)

Goal	Improve signage visibility and commuter navigation
Solution	Collect over 100 existing signage elements Develop a new layout of station's signage
Ideology	Conduct extensive point-cloud scans + Manipulate data with varying densities = Model of right level of accuracy
Future Impact	Model's delivery a month ahead of the schedule Ensure future work and investment

Source: Network Rail Overcomes COVID-19 Obstacles with Digital Twins of Railway Stations | Cadalyst , 23 Oct, 2020

Case Study: Contribution

Employee

NR possessed more than 5000 employees, and this upgrade project for railway strongly support their business during the covid-19 pandemic

Transportation

With responsibility for 2700 miles of track, 5841 bridges, 1750 level-crossings, 4500 signals, NR provides a safe, reliable, and high-performing railway every day

Academic Manipulation

In terms of Digital twins, NR successfully use innovative thinking and agile digital transformation to adapt the new normal

Source: Network Rail Overcomes COVID-19 Obstacles with Digital Twins of Railway Stations | Cadalyst , 23 Oct, 2020

Case Study: Honor
Winners of the Year in Infrastructure 2020 Awards

Title	Special Recognition Award	Advanced Virtualization through digital twins of railway network

Source: Network Rail Overcomes COVID-19 Obstacles with Digital Twins of Railway Stations | Cadalyst , 23 Oct, 2020

Lessons Learned

1. Digital twin is the transformation between different types of the data
2. Digital twin connects the real site and theoretical model much closely
3. It also faces a potential risk which is the data encryption

Digital Twins: Pros and Cons

PROS

- Improve Efficiency and Productivity
- Manage Assets in Real Time
- Understand data to Provide Better Service

CONS

- Data Encryption
- Addressing Known Vulnerability
- Routine Security audit

Source: Digital Twin Technology Benefits and Challenges March 2019

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Cadalyst,Road and Bridge Digital Twins in Action: Four Case Studies, May 2020 https://www.cadalyst.com/collaboration/digital-twin/road-and-bridge-digital-twins-action-four-case-studies-75827 accessed Oct 2022

Digital Twins Presentation 2, Nov 1st, 2022

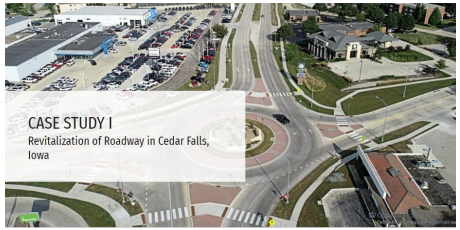
Overview

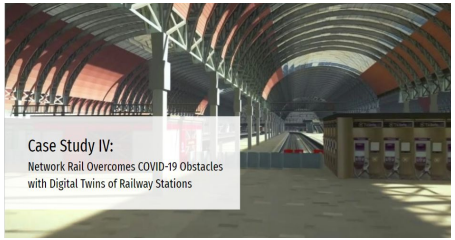
1. Introduction :

- BIM
- Digital Twin
- BIM vs Digital Twin
- Types
- Applications of Digital Twins
- Tools available to make Digital Twins

Overview

2. Case Studies
   - Revitalization of Roadway in Cedar Falls, Iowa
   - Building the Ponte Morandi Bridge,Genoa, Italy
   - Meitan-Shiqian Expressway in Guizhou Province, China
   - Network Rail Overcomes COVID-19 Obstacles with Digital Twins of Railway Stations, UK





Overview

3. Lessons Learned

- Bentley is one of the leaders in the BIM and DT industry and offers multiple integrated solutions for the same
- DTs can help to significantly reduce the duration of the design phase
- There may be some issues while procuring data for bridges
- DTs also helps with coordination between project team and owner
- It also faces a potential risk which is the data encryption

Software

Bentley Software:

1. Capital Improvement Software
   - Microstation
   - OpenBridges Designer
   - ProjectWise Integration

2. Operation and Maintenance Software
   - Assetwise
   - SUPERLOAD
   - ContextCapture
   - Orbit 3DM

"Roads & Bridges"*Bentley*, www.bentley.com/software/roads-and-bridges

Capital Improvement Software

SOFTWARE	APPLICATION	INTEGRATION	FILE FORMAT SUPPORTED
MICROSTATION	Modeling, Documentation, and Visualization Software	Autodesk, RealDWG, IFC, Esri SHP,3D, 3DS, Rhino 3DM, IGES, Parasolid, ACIS SAT, CGM, STEP AP203/AP214, STL, OBJ, VRML World, SketchUp SKP, and Collada	Google Earth KML, CALS, BMP, TIF, GeoTIFF, JPG,PDF,2D/3D DGN, DWG
OPENBRIDGES DESIGNER	Integrated Modeling, Analysis, and Design for Bridges	MicroStation, OpenRoads, OpenRail, AssetWise Inspections, ProStructures, gINT, and more AASHTO BRIDGEWare database	3D, PDF, MS Word, MS Excel, HTML, DGN, DXF, XML, and LandXML
PROJECTWISE INTEGRATION	BIM collaboration	Bentley and non-Bentley CAD, Microsoft Office 365	DGN or DWG, PDFs

"Roads & Bridges"*Bentley*, www.bentley.com/software/roads-and-bridges

Operations & Maintenance

SOFTWARE	APPLICATION	INTEGRATION	FILE FORMAT SUPPORTED
ASSETWISE	Capture, analysis, and management of data	ERP/EAM System Connectors, GIS Connector, Online Data Collection Connector,ProjectWise	DGN or DWG, PDFs
SUPERLOAD	Reduce time, optimize routes, and increase efficiency with real-time route validation	Prosteel, LARS Bridge and AASHTOWare Bridge Management software	N/A
CONTEXTCAPTURE	Improve how you design, construct, operate, and collaborate, add real-world digital context to your projects	SuperMap GIS, SkyDio 3D Scan	.3mx, .3mx, .3sm, .s3c
ORBIT 3DM	Platform to share 4D digital context	ArcMap, ArcGIS Online, ArcPro, MicroStation, QGIS,	N/A

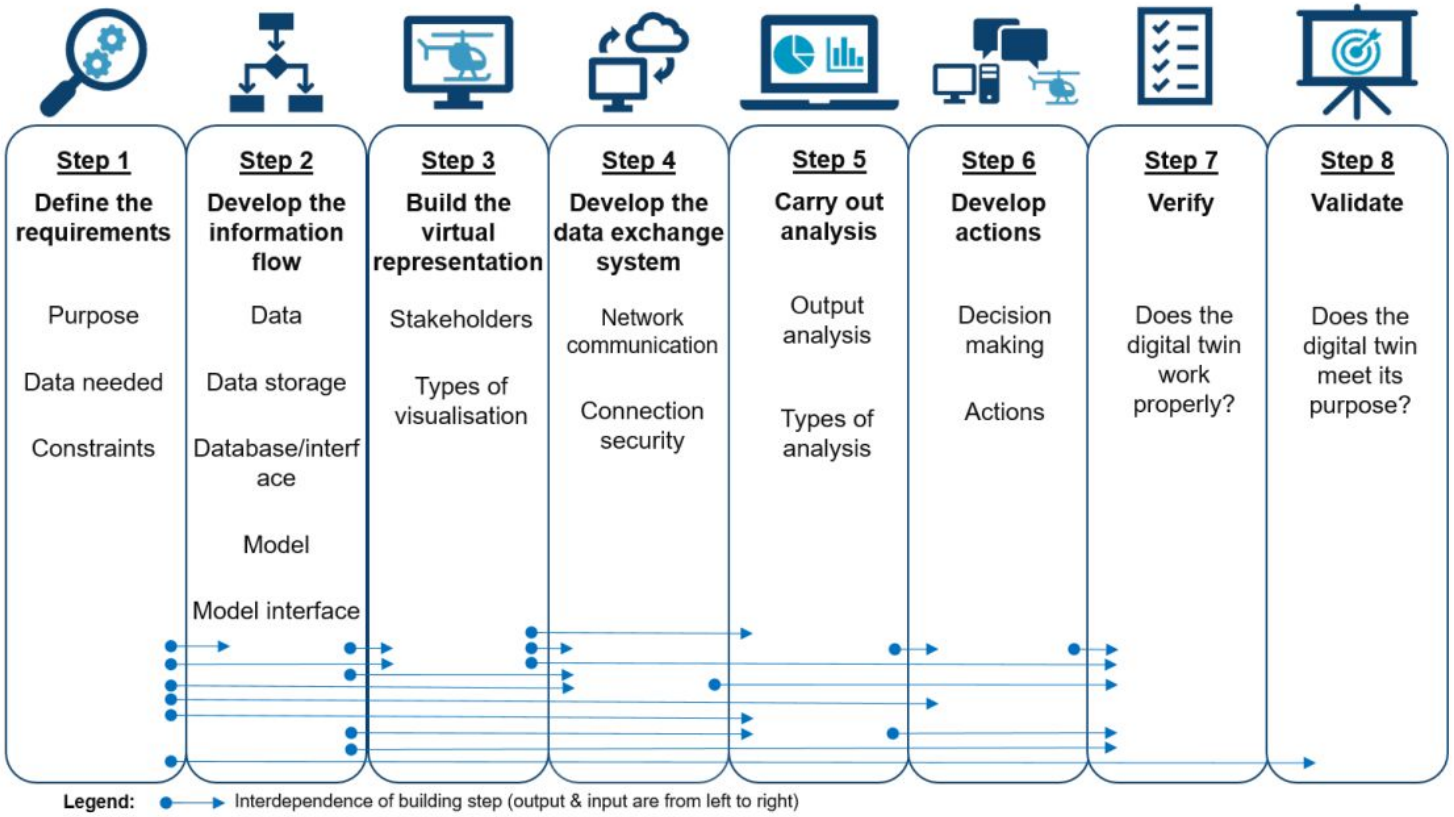
"Roads & Bridges"*Bentley*, www.bentley.com/software/roads-and-bridges

FIVE ELEMENTS OF A MODEL

Physical Entities	Virtual Entities	Data	Connection	Services
The bottom-most layer of the five-dimension model	The basis of all other capabilities	The driving force for digital twin	Support the interconnection of all components of the digital twin	The result of the digital twin

Wang K, Wang Y, Li Y et al. A review of the technology standards for enabling digital twin [version 1]. Digital Twin 2022, 2:4

BUILDING STEPS

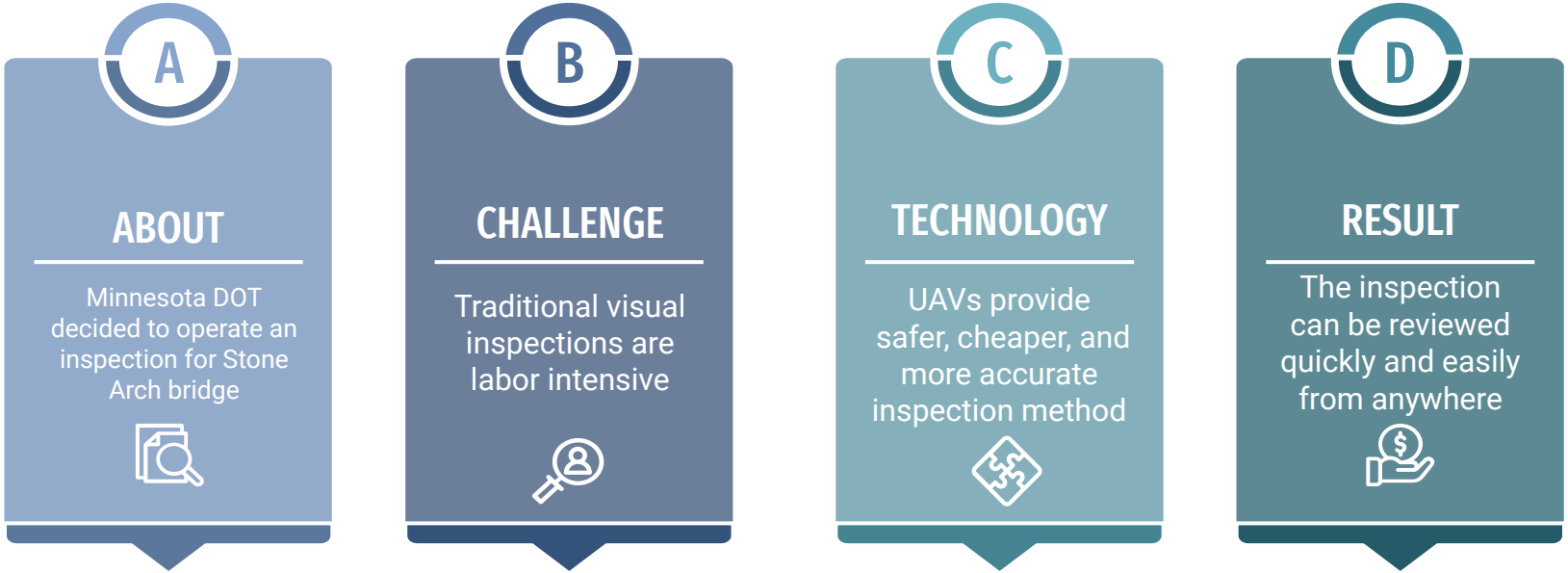


Dedy Ariansyah et al. Digital Twin Development: A Step by Step Guideline(2020)

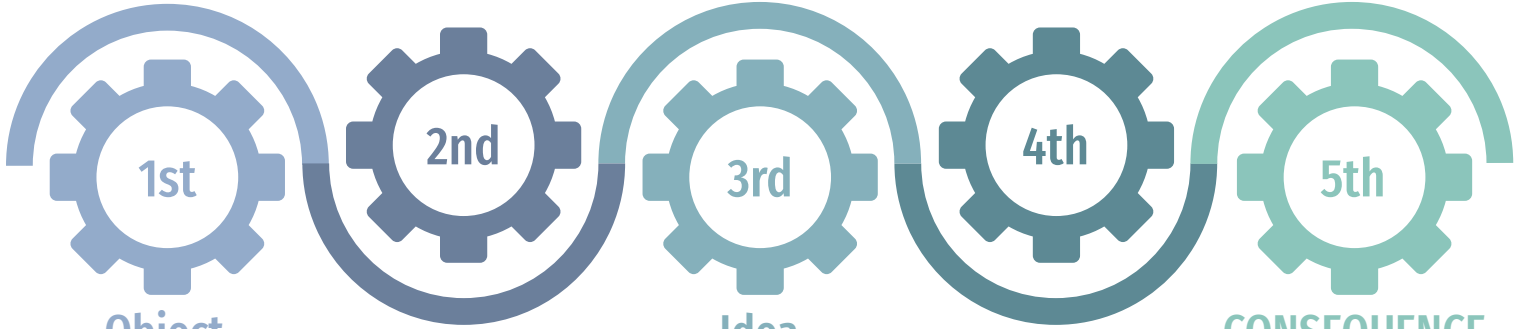
Case Study I:

Digital Twins Assist Bridge Inspection

Case Study I: Overview



Case Study I: Phase 1 (UAVs Take the Lead)



Object
Bridges have such a long lifecycle, often up to 75 to 100 years

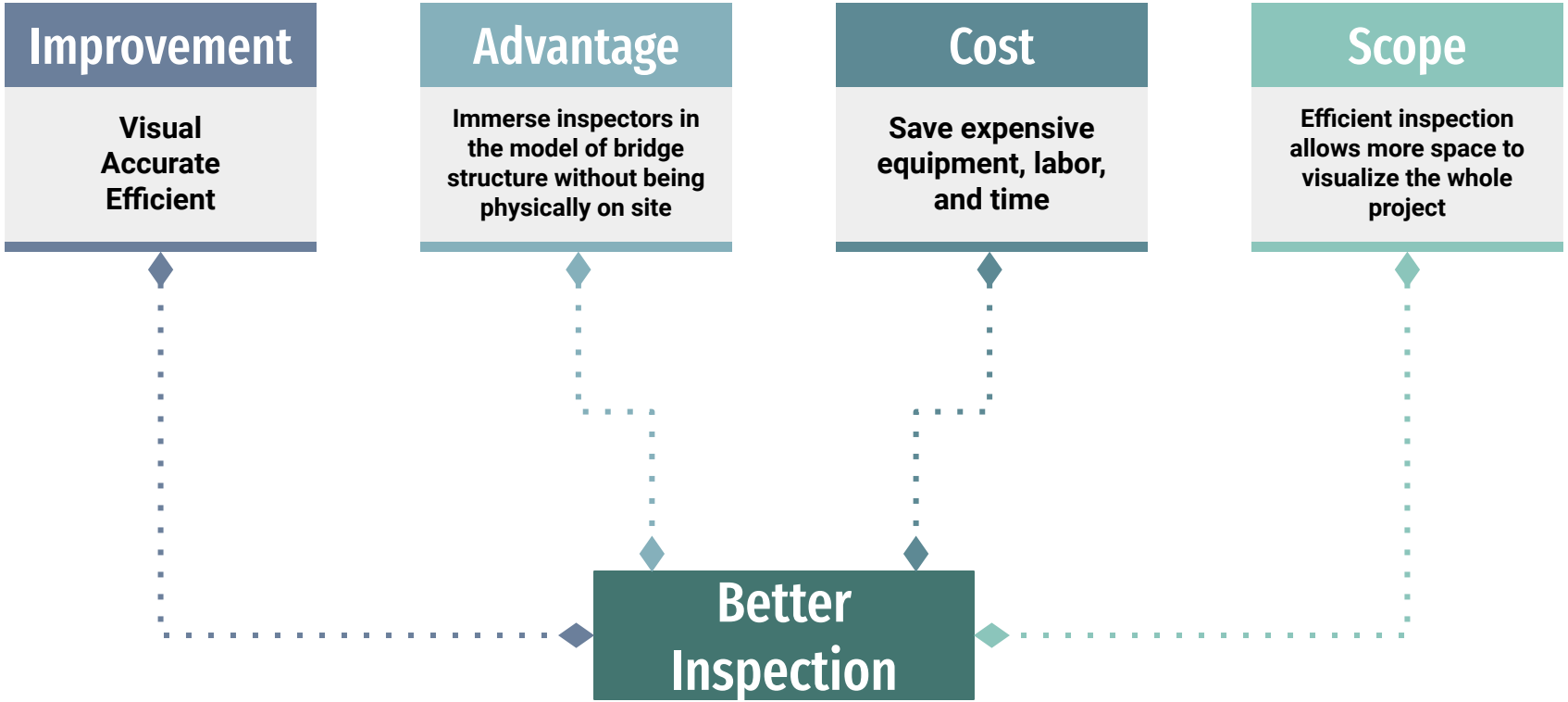
Difficulty
It was very hard to inspect the changes on bridges' structures over time

Idea
Digital Twin Technology-Unmanned Aerial Vehicles, UAVs

SET UP
Deploy UAVs to inspect the bridge from a holistic perspective

CONSEQUENCE
UAVs successfully completed the in-field inspections, and achieved 50% savings

Case Study I: Phase 2 (Virtual Inspection)



Case Study I: Phase 3 (Reality Mesh)

1	It gives another dimension to understand the infrastructure and surrounding topography	Visualization
2	It provides an intuitive and immersive way to navigate and view asset information	Recognition
3	It shows the real-world digital context for designs, constructions, and operations	Application
4	It decreases the amount of time for inspectors and achieves to 50% savings	Saving

Case Study I: Result

REVOLUTION

UAVs updated the inspection method, and made it more accurate and precise

COST

The new method achieved 50% of original savings as the traditional inspection

IMPACT

This technology improved safety for inspectors and help preserve bridge infrastructures in the future

Lessons Learned

1. Use of digital twin can be more economical than traditional method
2. Shared data can connect each office together
3. UAVs are helpful to inspect the real-time changes
4. Virtual inspection help preserve heavy infrastructures like bridges

Case Study II:

138th Street Bridge over Major Deegan Expressway

Case Study II : Overview

A

ABOUT

Increase the height , accommodate traffic on the bridge at 138th street over Major Deegan Expressway. Started march 2020

B

CHALLENGE

To replace the existing bridge while not affecting the Pedestrians, Utilities, Traffic.

C

TECHNOLOGY

Bentley Applications : Synchro, iTwin, OpenBridge Modeller

D

RESULT

Successfully designed and delivered the project

Bentley Advancing Infrastructure NYSDOT Industrializes East 138th Street Bridge Using Digital Twin, 2022

Case Study II : Process

MODELLING	MicroStation, OperBridge Modeller, ProSteel
SCHEDULING	SYNCHRO
SIMULATIONS (Stages and Animations)	SYNCHRO and Lumen RT
COLLABORATION PLATFORM	iTwin Design Review

Case Study II : Result

TIME

Using Digital Twin technology and Bentley Applications, NYSDOT saved time of the designers and the stakeholders time. iTwin Design Review helped contractors review the drawings and make updates easily

COST

Making the Digital Model a legal contract document helped the project bidders to make a bid which was 15% less than the original estimate made by the engineers

IMPACT

Using Bentley SYNCHRO, the local community was satisfied about the project by looking at animations and 3D models of the bridge

Bentley Advancing Infrastructure NYSDOT Industrializes East 138th Street Bridge Using Digital Twin, 2022

Lessons Learned

- SYNCHRO 4D and LumenRT facilitated visual construction sequencing, traffic control planning, and public outreach for better project coordination
- Digital Twins help reduce the cost of the project by helping contractors get a clear picture of the quantities of materials required
- Animations and Simulations can help with the community outreach and stakeholder engagement

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Digital Twins Presentation 3, Nov 29th, 2022

Contents

Overview

1. Softwares
   - Bentley softwares
2. Elements of a model
3. Model Building Steps
4. Case Studies
   - DT in Bridge Inspection, Minnasota
   - DT in bridge redevelopment, New York

Case Study I:
Digital Twins Assist Bridge Inspection

Case Study II:
138th Street Bridge over Major Deegan Expressway

IFC Format

- Industry Foundation Classes or IFC is a file format developed by the BuildingSMART company which is a consortium of various companies in the industry from across the world.

- Their aim is to develop standards, norms and tools supporting the flow of information among different platforms.

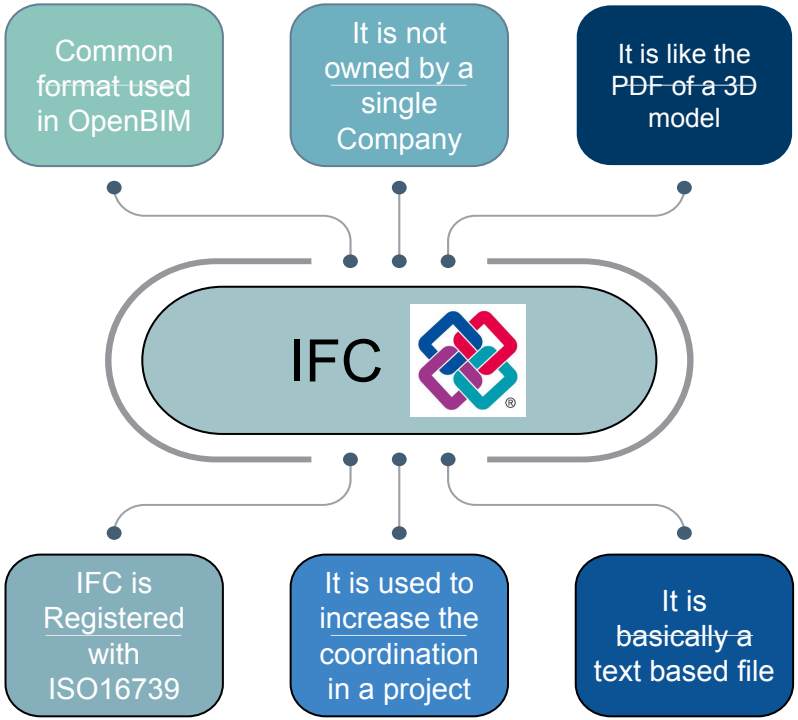
- Autodesk, Dassalt, Bentley, Tekla, Bosch, Arup, Siemens and many more companies are part of BuildingSMART International.

Source: BIMcorner

Working with IFC and Model View Definitions, BIM connect, 2018

IFC Format

- OpenBIM is an universal approach to design, construction and operation of buildings based on open standards.
- IFC is the basic standard for OpenBIM.
- IFC does not belong to any single software provider and can be used across different softwares.
- IFC is mainly used to share the model across various disciplines involved.



Everything worth knowing about the IFC format, BIM Corner, 2019

IFC Format

- IFC is Registered with ISO16739.
- An IFC file can be compared to a PDF. i.e. it is a frozen version of the model.
- A model generated using IFC contains data about some of the properties of the original model.
- The model generated using IFC format can be used for many purposes such as cost estimation, simulation and clash detection.

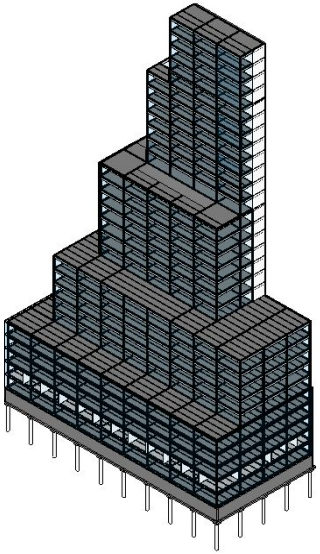


Fig1: IFC Model

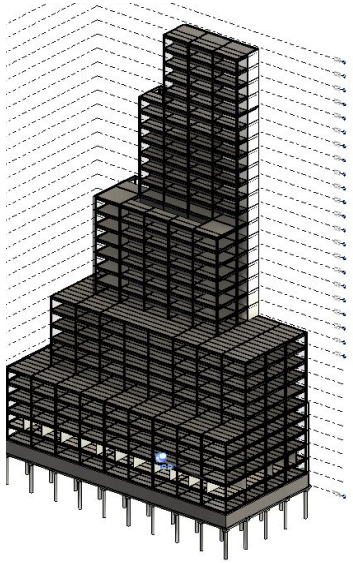


Fig 2: Revit Model

Everything worth knowing about the IFC format, BIM Corner, 2019

IFC Format

- A model when exported to IFC, gets converted to a text based model. This can be seen using a notepad.
- The text is generated using rules and specifications which are made by the BuildingSMART company.
- Every line in the text is used to define specific parts,objects or materials used in the model.
- There are 3 types of IFC exports:
  - .IFC
  - .ifcXML
  - .ifcXML ZIP
- IFC XML is in the form of a programming language. It can be viewed using an XML editor.

```
  <TheOrganization>
   <IfcOrganization xsi:nil="true" ref="i2"/>
  </TheOrganization>
 </IfcPersonAndOrganization>
 <IfcApplication id="i4">
  <ApplicationDeveloper>
   <IfcOrganization xsi:nil="true" ref="i2"/>
  </ApplicationDeveloper>
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  <ApplicationIdentifier>Multi material modeling</ApplicationIdentifier>
 </IfcApplication>
 <IfcOwnerHistory id="i5">
  <OwningUser>
   <IfcPersonAndOrganization xsi:nil="true" ref="i3"/>
  </OwningUser>
  <OwningApplication>
   <IfcApplication xsi:nil="true" ref="i4"/>
  </OwningApplication>
  <ChangeAction>nochange</ChangeAction>
  <CreationDate>1575233437</CreationDate>
 </IfcOwnerHistory>
```

Ifc XML file

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#19= IFCSIUNIT(*,.AREAUNIT.,$,.SQUARE_METRE.);
#20= IFCMEASUREWITHUNIT(IFCRATIOMEASURE(0.09290304),#19);
#21= IFCDIMENSIONALEXPONENTS(2,0,0,0,0,0,0);
#22= IFCCONVERSIONBASEDUNIT(#21,.AREAUNIT.,'SQUARE FOOT',#20);
#23= IFCSIUNIT(*,.VOLUMEUNIT.,$,.CUBIC_METRE.);
#24= IFCMEASUREWITHUNIT(IFCRATIOMEASURE(0.028316846592),#23);
#25= IFCDIMENSIONALEXPONENTS(3,0,0,0,0,0,0);
#26= IFCCONVERSIONBASEDUNIT(#25,.VOLUMEUNIT.,'CUBIC FOOT',#24);
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#34= IFCSIUNIT(*,.THERMODYNAMICTEMPERATUREUNIT.,$,.DEGREE_CELSIUS.);
#35= IFCSIUNIT(*,.LUMINOUSINTENSITYUNIT.,$,.LUMEN.);
#36= IFCUNITASSIGNMENT((#15,#19,#23,#27,#28,#29,#33,#34,#35));
#37= IFCPROJECT('3vQCgMnSj2$hlmsZB5TdK',#5,'Undefined',$,$,$,$,(#11),#36);
#38= IFCLOCALPLACEMENT($,#10);
```

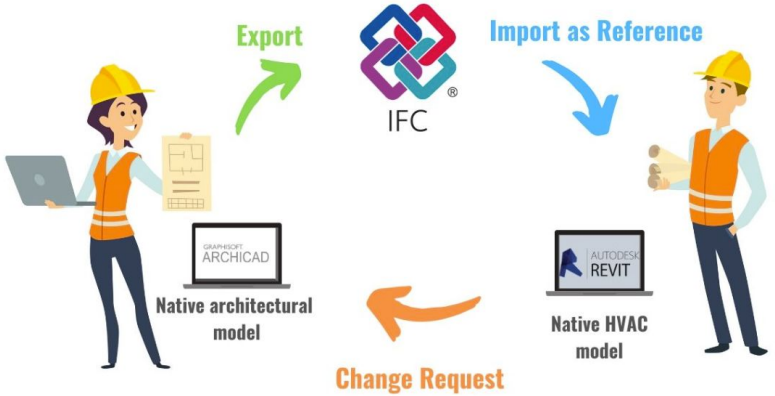
Ifc file

Everything worth knowing about the IFC format, BIM Corner, 2019

IFC Format

Intended Use -

- An IFC Model should be used as a reference model and not as the native model for editing.
- A model is created and sent to different disciplines using IFC format.
- The user(HVAC,Electrical, etc) should ask the generator(Architect) of the model to make any changes.
- The new model is sent to the user in order to complete their work.
- IFC can be edited on different softwares but that is not its intended purpose.



Source: BIMcorner

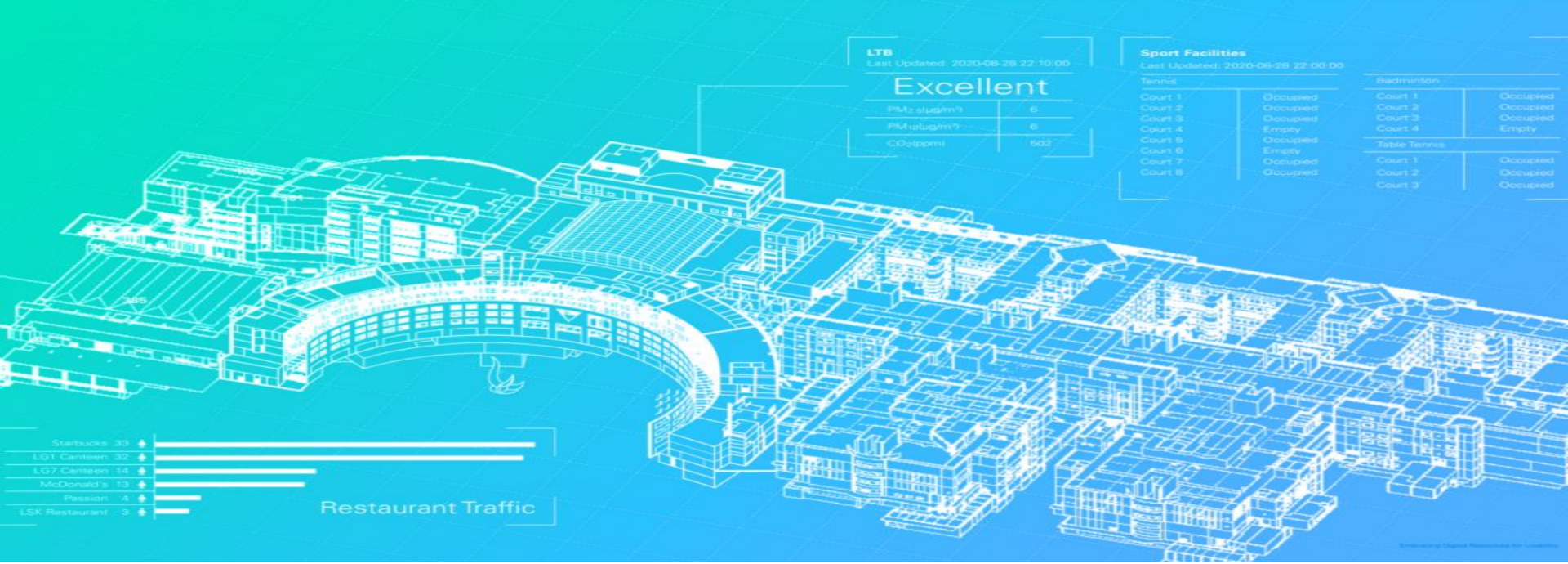
Everything worth knowing about the IFC format, BIM Corner, 2019

Software

SOFTWARE	TYPE	INTEGRATION
aPriori	Cost -Analysis & Control	Upload any CAD file and aPriori will automatically generate a detailed manufacturability analysis in real time. It provides your designers, engineers, sourcing specialists and cost engineers with valuable insight into how they can eliminate cost drivers
Robot Structural Analysis	Structural Analysis	Robot Structural Analysis Professional is structural load analysis software that verifies code compliance and uses BIM-integrated workflows to exchange data with Revit. It can help you to create more resilient, constructible designs that are accurate, coordinated, and connected to BIM.
ReCap Pro	Reality Capture	ReCap Pro software helps designers and engineers capture high quality, detailed models of real-world assets.

Software

SOFTWARE	TYPE	INTEGRATION
ABAQUS	Finite Element Analysis	With Abaqus/CAE you can quickly and efficiently create, edit, monitor, diagnose, and visualize advanced Abaqus analyses.
LISCAD	Surveying	It allows easy generation of virtually any design, while Survey Live can be used for real-time surveying and set-out with total stations or GNSS equipment. In addition, point clouds can be imported, viewed, edited and utilised for virtual surveying workflows.



Case Study :

The Hong Kong University of Science and Technology (HKUST) campus

Case Study : Overview

A

ABOUT

creating a digital twin, which digitizes the physical world with different facility systems integrated into a single hub

B

CHALLENGE

further extend the digital twin to major subcomponents and other SSC IoT projects such as aircon analytics and SCAN+ monitoring

C

TECHNOLOGY

BIM, GIS, IFC
DATA, IoT,
BMS

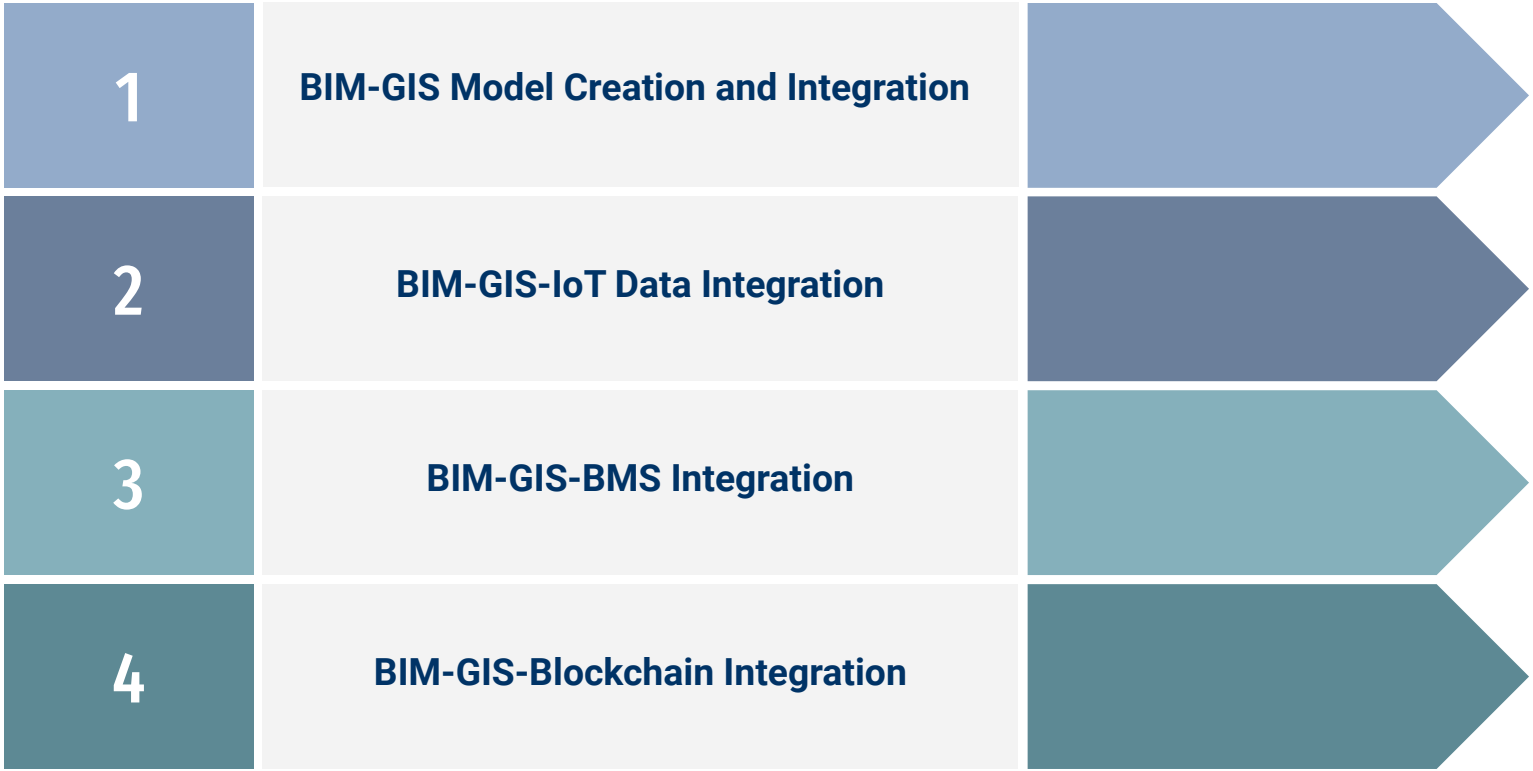
D

RESULT

Successfully delivered the project

https://digitaltwin.hkust.edu.hk/ProjectDetails.html 2022

Case Study : Four Integration



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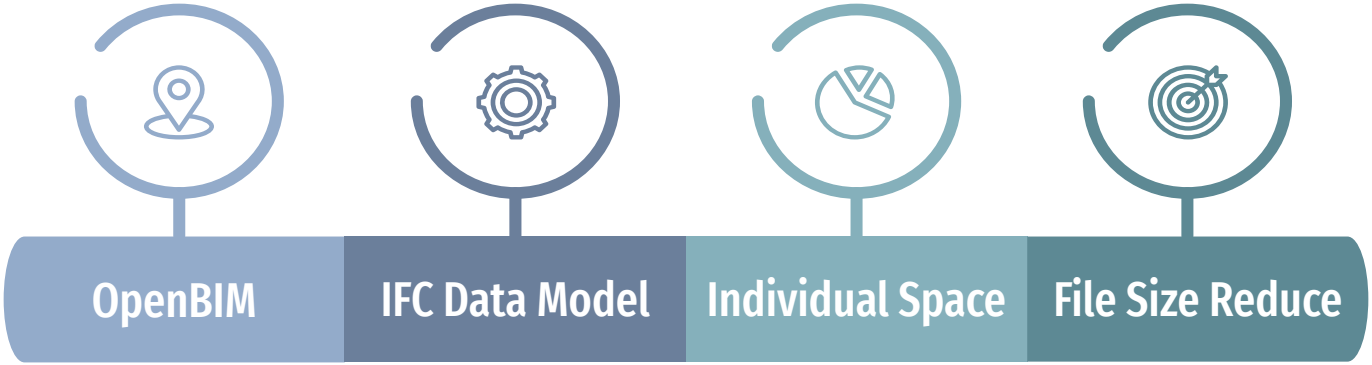
Case Study : Four Integration

- **BIM-GIS Model Creation and Integration**



a large-scale digital twin is generated to support both microscopic analyses and macroscopic management

govern the attribute modeling in BIM, as well as the data transfer to GIS

Based on the proposed IFC schema, individual buildings/spaces of an area are constructed

by combining architecture components, minimizing the graphical rendering loads for smoother visualization

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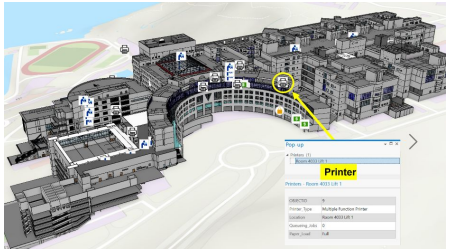
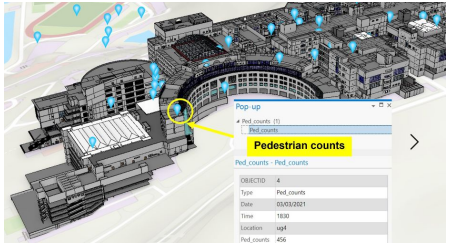
Case Study : Four Integration

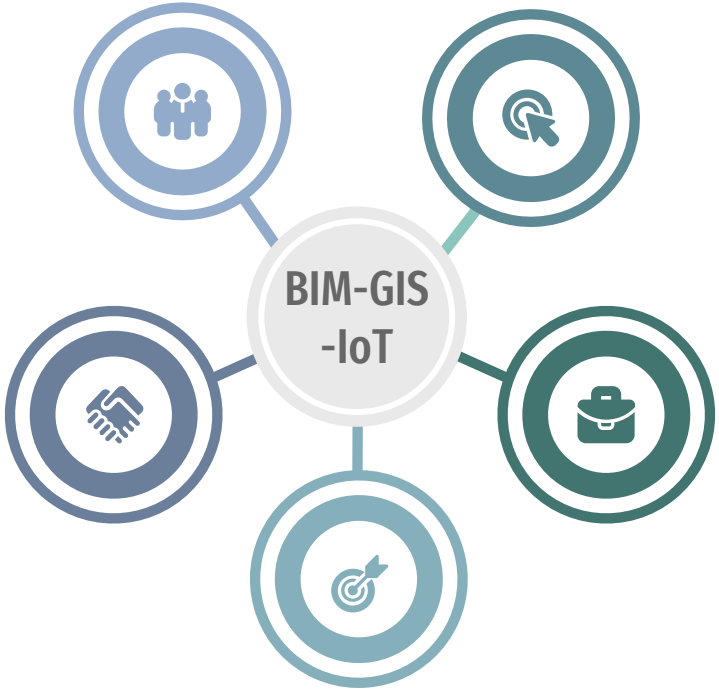
- **BIM-GIS-IoT Data Integration**

POIs-point of interest

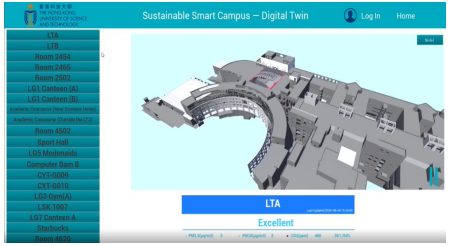


Pedestrian Counts

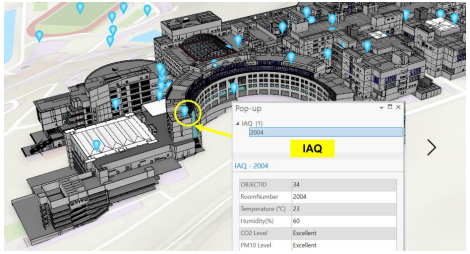




Mobile APP



IAQ



Virtual Tour

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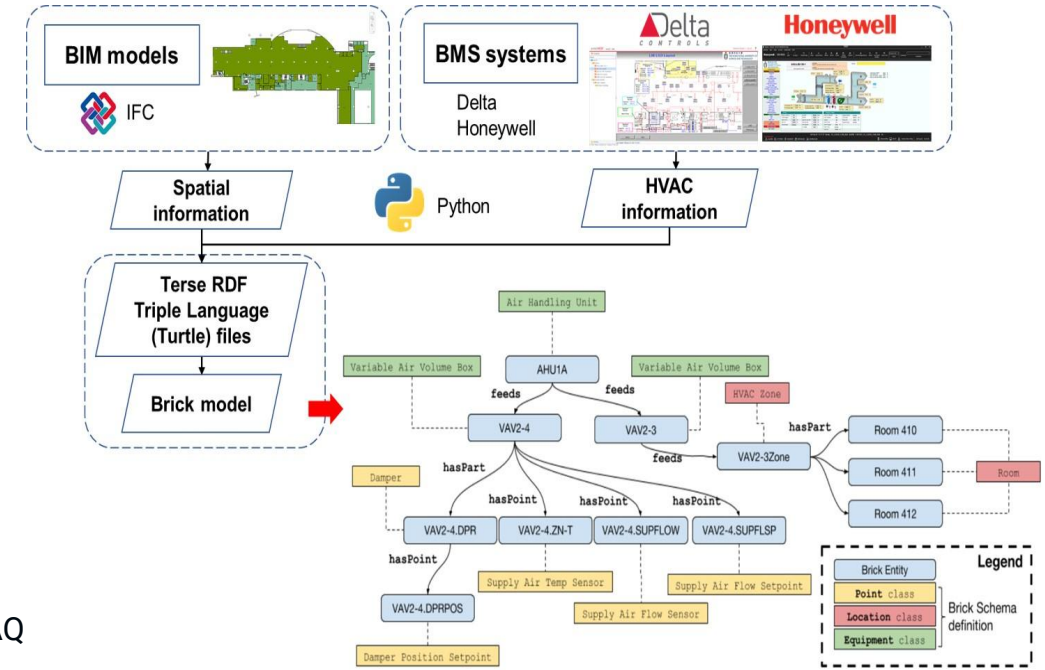
Case Study : Four Integration

- **BIM-GIS-BMS Integration**

- spatial information were extracted from BIM models based on IFC files to ensure data interoperability under openBIM standard.
- Python programming was implemented to automatically process the data sources and generate a Brick model



facility managers can effectively query necessary information for routine/ proactive/ predictive maintenance of the HVAC components, as well as IAQ assessment for optimizing occupant comfort or energy efficiency.

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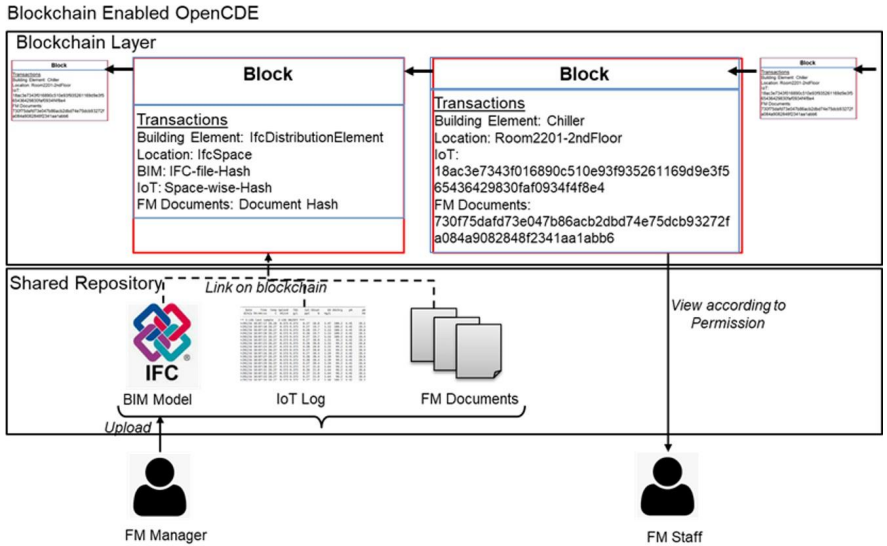
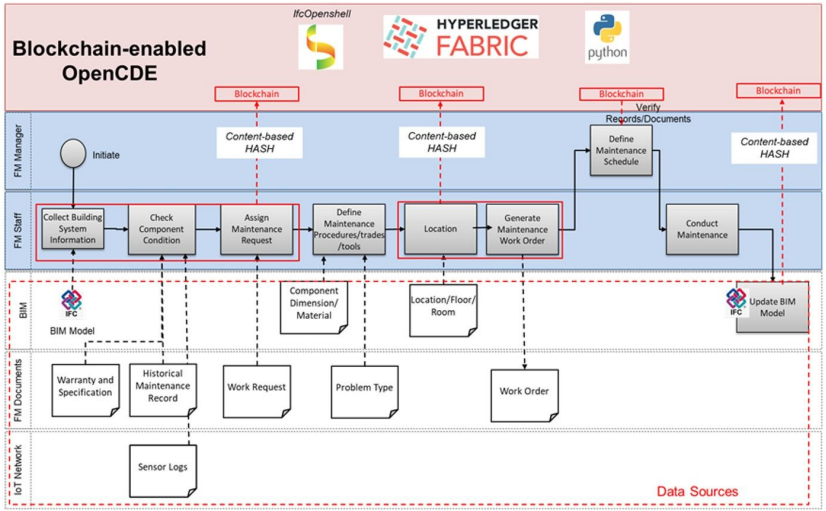
Case Study : Four Integration

- **BIM-GIS-BLOCKCHAIN Integration**
  - a blockchain layer for integrating graphical and non-graphical information from different data sources in a secure manner
  - a shared repository for the storage and graphical and non-graphical information



- a typical facility maintenance process supported by the blockchain-enabled openCDE



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Lessons Learned

- Digital twins significantly help to enhance facility management (FM) like engineering analyses, operation management and maintenance.
- IFC files can act as the base of the whole process to ensure data interoperability
- Blockchain is one of the ways of secure data management among different parties and facility management

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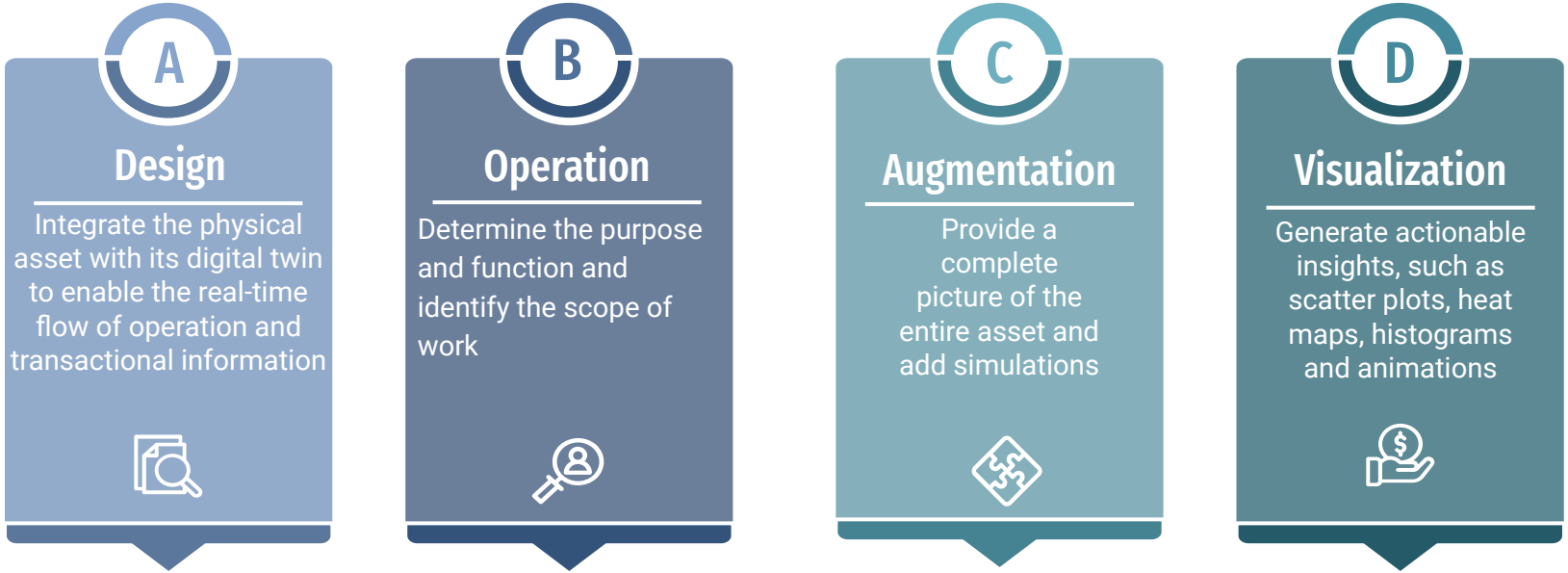
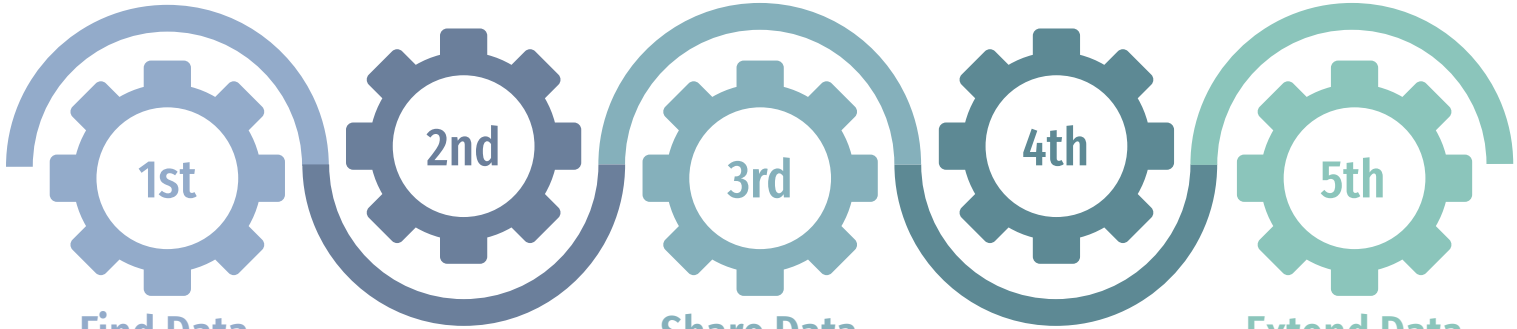
Digital Twins Implementation



Digital Twin: A Complete Knowledge Guide (leewayhertz.com)

How to Deal with Data?



Find Data
Visual access to models from any device make it easy to locate the correct information

Reuse Data
Function to clear out the choke points, then reuse

Share Data
Apply modern social technologies to encourage information exchanges

Control Data
Ensure all project members have wide-open access

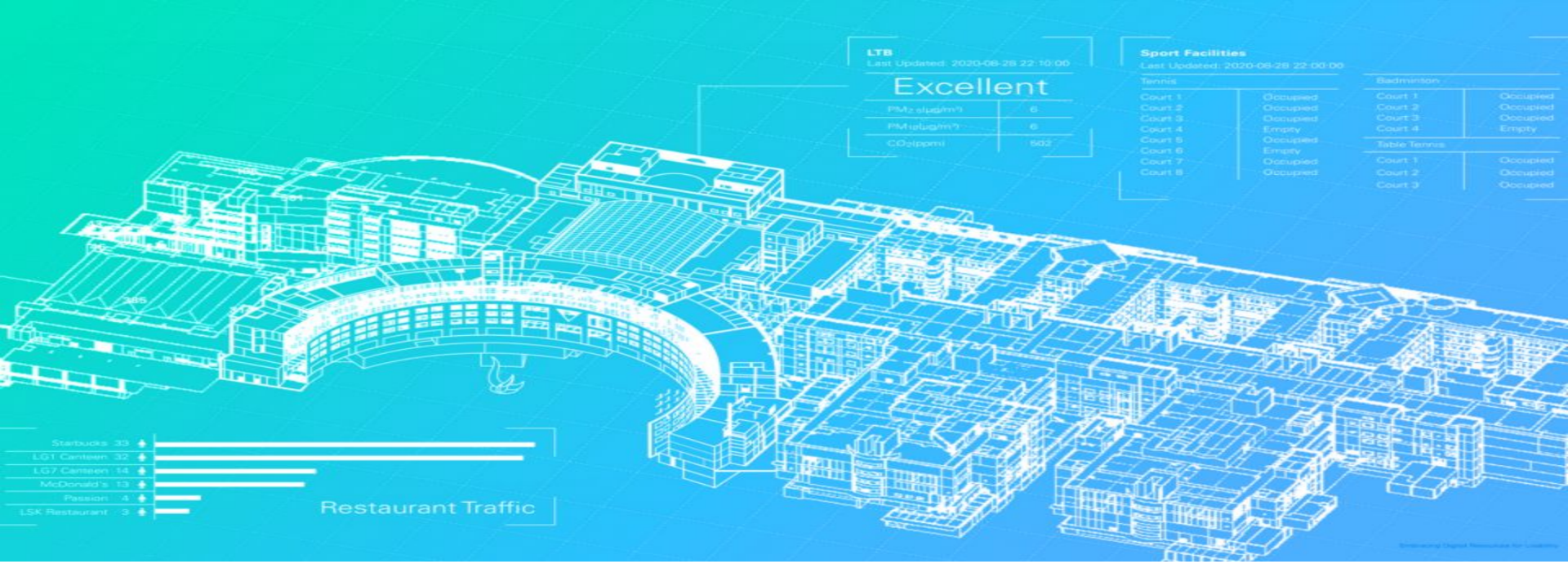
Extend Data
Improve collaboration, process data and share them with all stakeholders

[The Importance of Interoperability in Structural Engineering | Cadalyst]

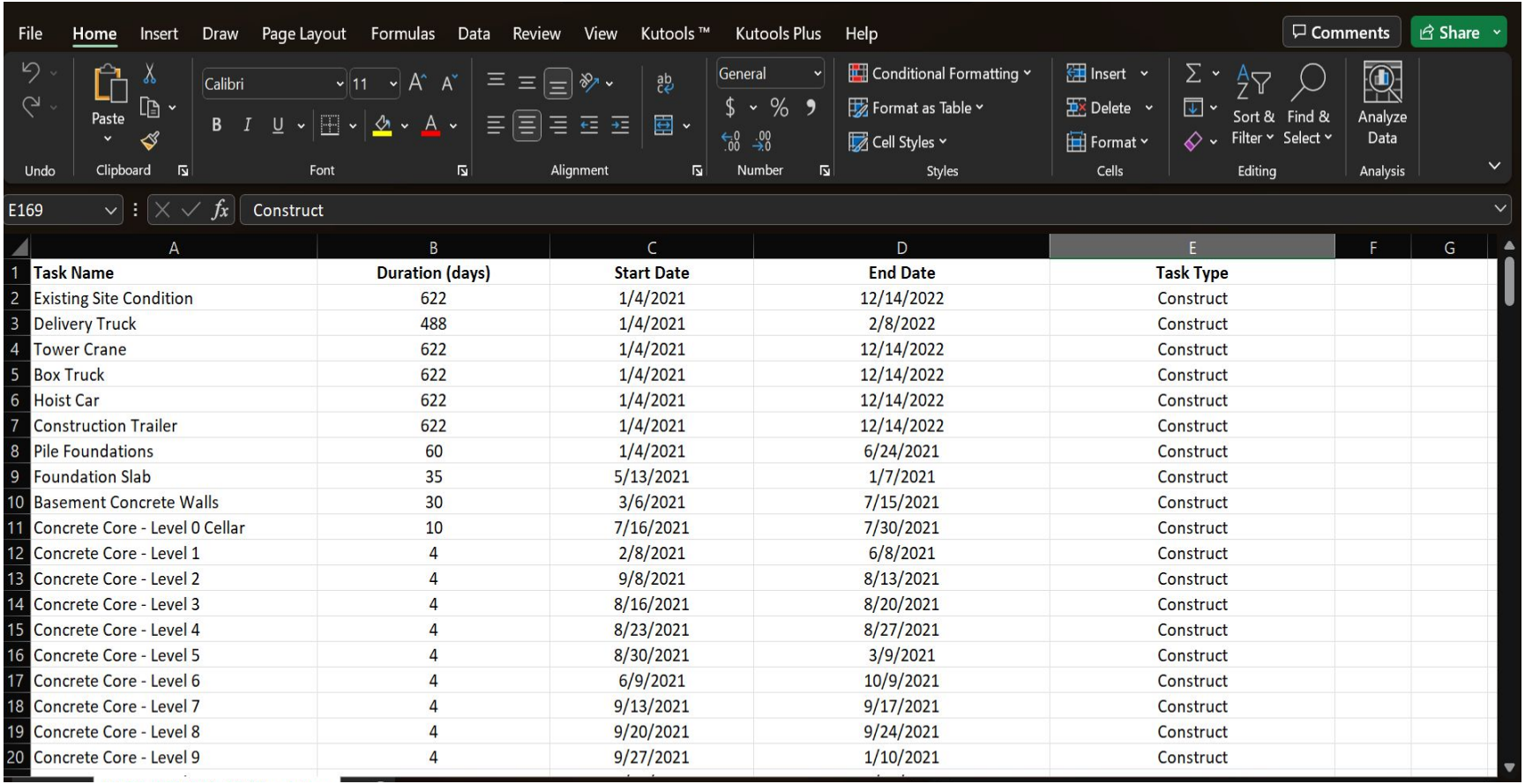
Project Deliverables

Part	Definition	Purpose
Quality Planning	A process to check whether the project meet established goals	Specify roles of quality management for the project
Quality Assurance	A procedure to assess adherence to specification after initial deliverable completion	Review the information exchanges to make sure a clear deliverable
Quality Control	A final checkpoint to review whether the project satisfy quality requirements as deliverables are being completion	Monitor the project is operated correctly to a standard quality

https://www.e-education.psu.edu/geog871/l7_p3.html



4D Simulation in Preconstruction



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Paste Calibri 11 General Conditional Formatting Format as Table Cell Styles Insert Delete Format Sort & Filter Find & Select Analyze Data

E169 Construct

	A	B	C	D	E	F	G
1	**Task Name**	**Duration (days)**	**Start Date**	**End Date**	**Task Type**		
2	Existing Site Condition	622	1/4/2021	12/14/2022	Construct		
3	Delivery Truck	488	1/4/2021	2/8/2022	Construct		
4	Tower Crane	622	1/4/2021	12/14/2022	Construct		
5	Box Truck	622	1/4/2021	12/14/2022	Construct		
6	Hoist Car	622	1/4/2021	12/14/2022	Construct		
7	Construction Trailer	622	1/4/2021	12/14/2022	Construct		
8	Pile Foundations	60	1/4/2021	6/24/2021	Construct		
9	Foundation Slab	35	5/13/2021	1/7/2021	Construct		
10	Basement Concrete Walls	30	3/6/2021	7/15/2021	Construct		
11	Concrete Core - Level 0 Cellar	10	7/16/2021	7/30/2021	Construct		
12	Concrete Core - Level 1	4	2/8/2021	6/8/2021	Construct		
13	Concrete Core - Level 2	4	9/8/2021	8/13/2021	Construct		
14	Concrete Core - Level 3	4	8/16/2021	8/20/2021	Construct		
15	Concrete Core - Level 4	4	8/23/2021	8/27/2021	Construct		
16	Concrete Core - Level 5	4	8/30/2021	3/9/2021	Construct		
17	Concrete Core - Level 6	4	6/9/2021	10/9/2021	Construct		
18	Concrete Core - Level 7	4	9/13/2021	9/17/2021	Construct		
19	Concrete Core - Level 8	4	9/20/2021	9/24/2021	Construct		
20	Concrete Core - Level 9	4	9/27/2021	1/10/2021	Construct		

Saturday 9:48:00 PM 1/9/2021 Day=6 Week=1

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