BUS GoCircular

Shaping a Circular Sustainable Future

Module 7

Digitalisation and Material Passports in the Design and Construction Sector

Circular Economy in the Construction Industry

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101033740

Summary

Within this module, trainers will explore a multitude of existing and new or emerging digitalization topics that support repairs, material reduction and training along with a number of other impacts. The trainee will also gain an understanding of material passports and why they are an important new element within the construction industry and their value. They will then relate all of this information to its application into Multi-functional Green Roofs Facades and Interiors Elements.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101033740

Objectives/Learning Outcomes

- 15 - Arrange a safe working environment and continuously consider health and safety requirements, especially for working on roofs and facades
- 46 – Apply digital tracking of materials to optimise maintenance, demolition, and recovery of multifunctional green roofs, façades, and interior elements
- 47 – Develop and apply material and building passports
- 57 – Employ BIM modelling to get insight into the effects and changes affiliated with upkeep, repair, or improvement of buildings
- 84 – Use drones and imaging technologies to collect data about roofs or facades for renovation purposes

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Objectives/Learning Outcomes

- 75 – Provide documentation as guideline to use the multifunctional green roofs, façades, and interior elements properly in order to stretch its lifetime
- 26 – Design multifunctional green roofs, façades, and interior elements for prefabrication so that as little waste as possible is produced during construction
- 70 - Apply sensor technology to green roofs and façades (e.g. for predicting maintenance, to facilitate water flow from roof when needed)

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Content

- Digitalization in Design and Construction
- BIM
- Drones
- 3D Modelling
  - VR (Virtual Reality)Headsets
- Exoskeleton Suits
- Digital Twins
- Material Passports
- 3D Printing and Prefabrication
- Application for Multi-functional Green Roofs Facades and Interior Elements

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Digitalization in design and construction

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What is Digitalization

Digitalization is the use of digital technologies to change a business model and provide new revenue and value-producing opportunities; it is the process of moving to a digital business.

Source: https://www.ie.edu/insights/articles/digitization-will-raise-construction-to-the-modern-day/

Source: https://www.gartner.com/en/information-technology/glossary/digitalization

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Digitalization in Construction

While the pace of digitalisation across the built and natural environments continues to gather momentum, there remains a significant opportunity for the construction sector to invest more widely in adopting model-centric and data-driven work processes and practices. The benefits of digitalisation (the adoption of digital technologies, such as as BIM and digital twins) are well understood by many market participants. Still, many barriers to adoption remain across a sector that is fragmented, under continual cost and time pressures, and frequently criticised for spending less on research and development than comparable industries. In addition, to support traditional construction processes such as cost estimation, prediction, planning and control; progress monitoring; and health, safety and well-being, the sector is now having to address other practices with some urgency. These include incorporating environmental, social and governance (ESG) principles; designing and measuring social value; implementing whole-life and whole-asset thinking; and carbon footprint calculation, benchmarking and reporting across projects.

*Source:*https://www.rics.org/globalassets/rics-website/media/knowledge/research/research-reports/rics0112-digitalisation-in-construction-report-2022-web.pdf

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Reasons for Digitalization

- Evolving client needs
- Increased technological capabilities
- Next-generation of workers and professionals
- Booming start-up environment
- Supportive policies and legal frameworks
- Increased market needs
- Up to the neck competition
- Launch of large infrastructure projects
- Need for integrated processes
- Better quality standards

Source: https://www.burohappold.com/articles/digitisation-is-revolutionising-the-construction-industry/

Source: https://www.digiqc.com/blog/digitalization-in-construction-industry

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Opportunities with Digitalization

- New Channels: A broader network of contacts.
- Better Visualization: Virtual tours and visits and 2D and 3D modeling.
- 3D Simulation Tool: Eliminating errors and risks via 3D simulation
- Simplified administrative work: Easy documentation and reactive workflow.
- Tracking feedback and improvement: Better and digital interaction with clients and evolving key performance indices.
- Enhances products: Smart and better buildings with improved infrastructure. Smart cities.
- New partnership models: Flexibility between builders, partners, and promoters.
- New financing options: Customized and tailored financing models.
- Multiple performance tracking: Transparent performance tracking and enhanced value in data.
- Management of large data: data analytics, simulations, analysis

Source: https://www.digiqc.com/blog/digitalization-in-construction-industry

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Benefits of Digitalization

- Safer operations
    a. With digital design and construction, the need for crews to enter dangerous situations and locations to get hard-to-reach information has reduced drastically.
- More innovation
    a. As a result of the rapid adoption of digital technologies on the construction project site, a virtuous cycle has begun, whereby innovation is becoming a core differentiator, fueling further adoption and investment.
- A new focus
    a. This digital transformation has enabled a renewed focus within the entire construction industry on what's most important – high-quality work safely done.

Source: https://www.digiqc.com/blog/digitalization-in-construction-industry

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Benefits of Digitalization

- Relevant communication
    a. The use of cloud-connected mobile apps has become the norm and is accepted on most projects in the field.
- Timely Intervention
    a. With digitalization, the exchange of information has become quicker and more effective.
- Big Data Handling
- Sophisticated Symptoms
- Automatisation

Source: https://www.digiqc.com/blog/digitalization-in-construction-industry

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BIM (Building Information Modeling)

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BIM Fundamentals

BACKGROUND

It’s impossible to build in a perfect way, so it’s impossible to resolve all the specific solutions that a project requires during the project stage or the construction one. There are a lot of issues to take into account and technology can help us to detect some issues that can compromise the quality of the project.

Source: https://bimzeed.eu/

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BIM Fundamentals

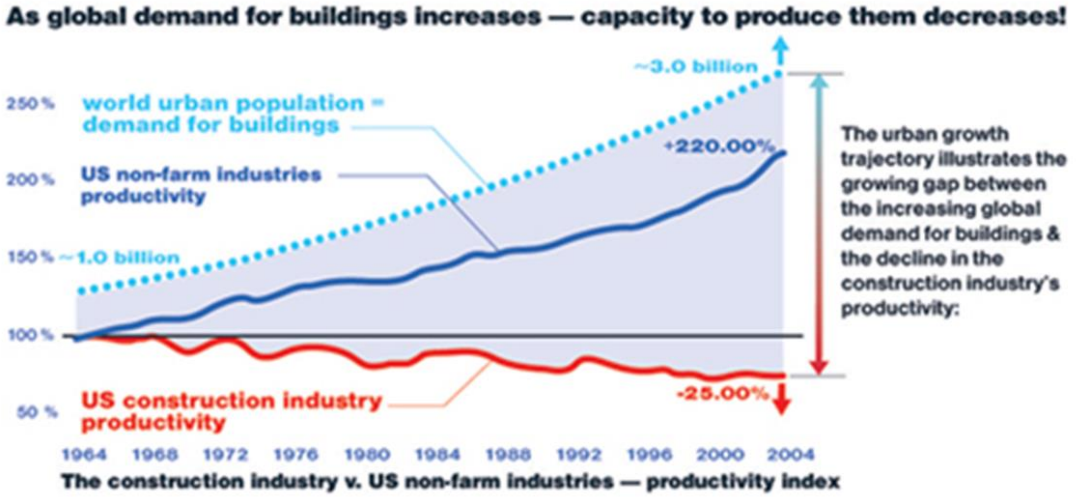
BACKGROUND

This graphic shows us the evolution of productivity in different industries in United States since 1964. It can be interpreted as the productivity evolution in industries in a developed country.

All industries but farm rose their productivity index from 1960s to 2000s.

In only 40 years world urban population increased 2 billion people.

US construction industry productivity falls a 25%.



Source: https://bimzeed.eu/

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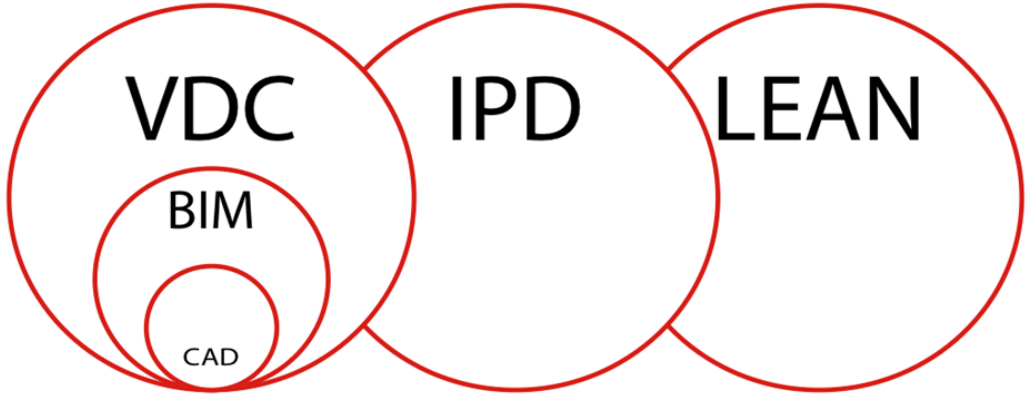
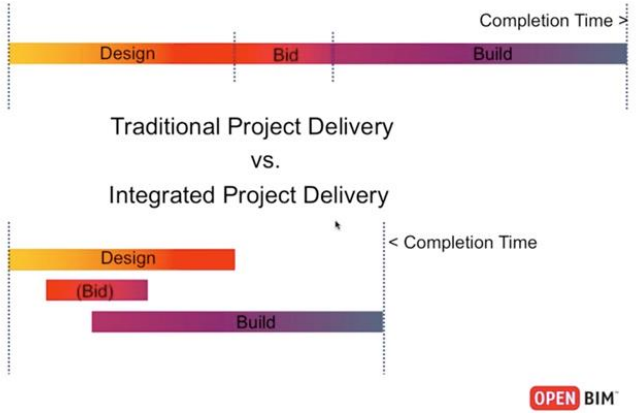
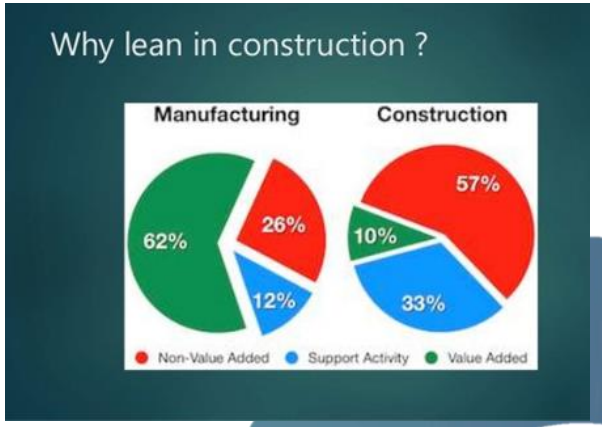
BIM Fundamentals

SOLUTION

To increase collaboration, the usage of new technologies in the construction industry and the implementing of new approaches such as Lean Construction methodology, it's supposed to be the point of inflection of the construction industry productivity.







Source: https://bimzeed.eu/

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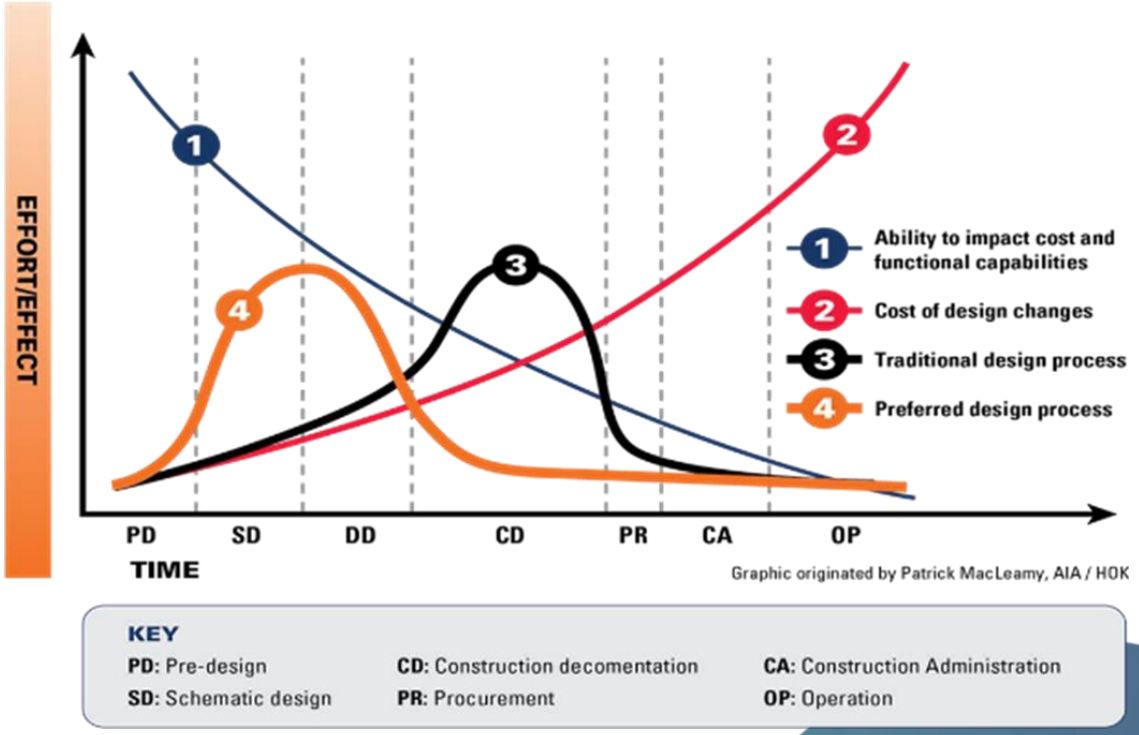
BIM Fundamentals

BIM APPROACH

The use of the BIM methodology requires that we anticipate certain decisions at an early stage.

We need to further define the documentation that will be used to build as we are building it digitally at 1:1 scale. That is, at real size.

This allows us to analyze the build, without leaving room for error of interpretation in the documentation. Because we have a 3D model, we are able to analyze it from different aspects.



Source: https://bimzeed.eu/

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BIM Fundamentals

BIM APPROACH

BIM is a methodology that allows us to implement a process of creating and managing the information (graphic and non-graphic) of a project throughout all the phases of the life cycle of an asset.

Source: https://bimzeed.eu/

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BIM Fundamentals

CAD vs BIM

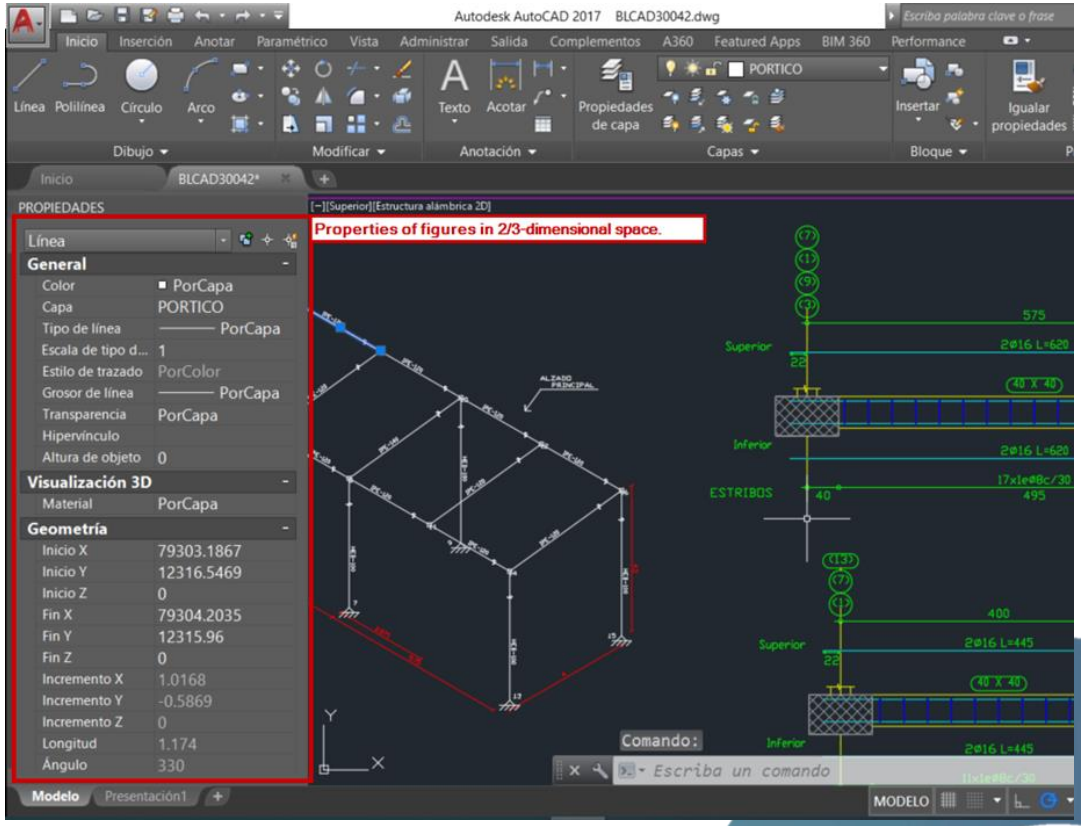
CAD (Computer Aided Design)

Computer Aided Design (CAD) is based on the graphic representation of vectorial geometric entities (such as: lines, points, arcs and polygons).

The software does not interpret what is being represented, the information has to be managed by the user through support tools such as layers, line styles, etc.

CAD programs:

AutoCAD, MicroStation, Catia, Sketchup, etc



Source: https://bimzeed.eu/

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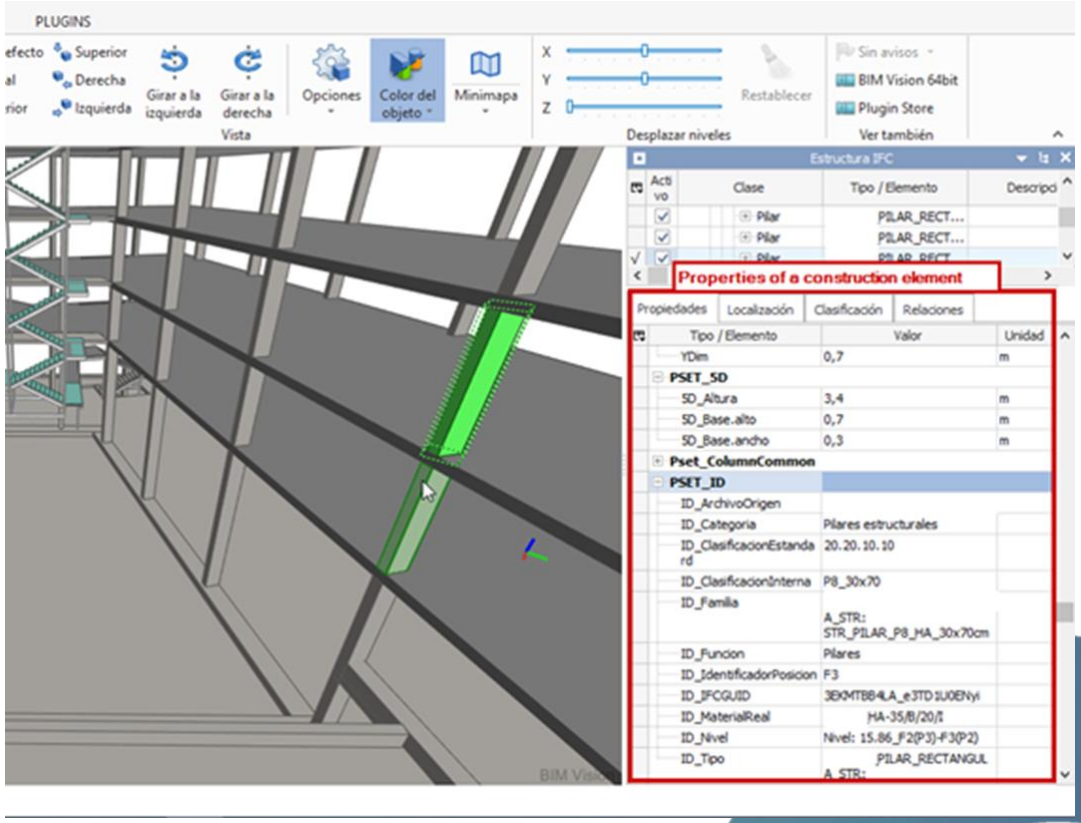
BIM Fundamentals

CAD vs BIM

While CAD is based on geometric vector entities, BIM is based on Parameterizable Objects.

The digitization of assets in BIM Objects, allows us to create parameterizable objects in which we can embed any type of information and benefit from it once the project is completed.

In addition, BIM software interprets that a wall and a pillar are different elements (CAD interprets that they are two rectangles) thus allowing the association of specific parameters according to the construction family to which each element belongs.



Source: https://bimzeed.eu/

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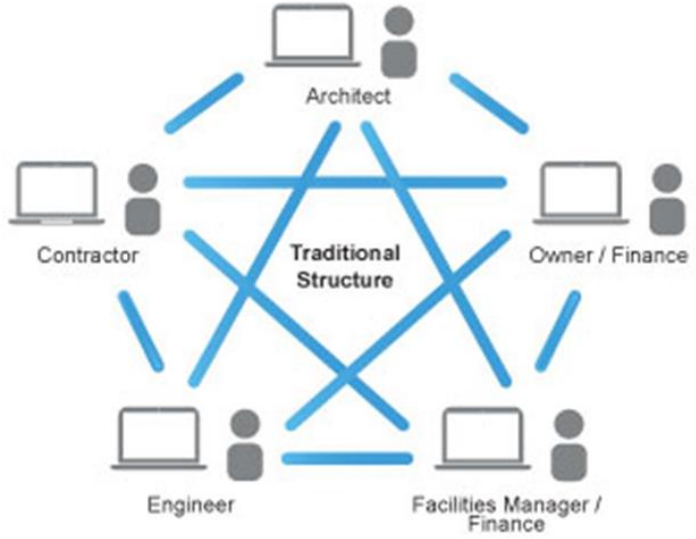
BIM Fundamentals

CAD vs BIM

Other key difference between CAD and BIM is the fact of using a centralized model data that you share with your project partners. There is only a model, a single source of information that is shared with all partners at the same time, so they all have access to the last model version.



Source: https://bimzeed.eu/

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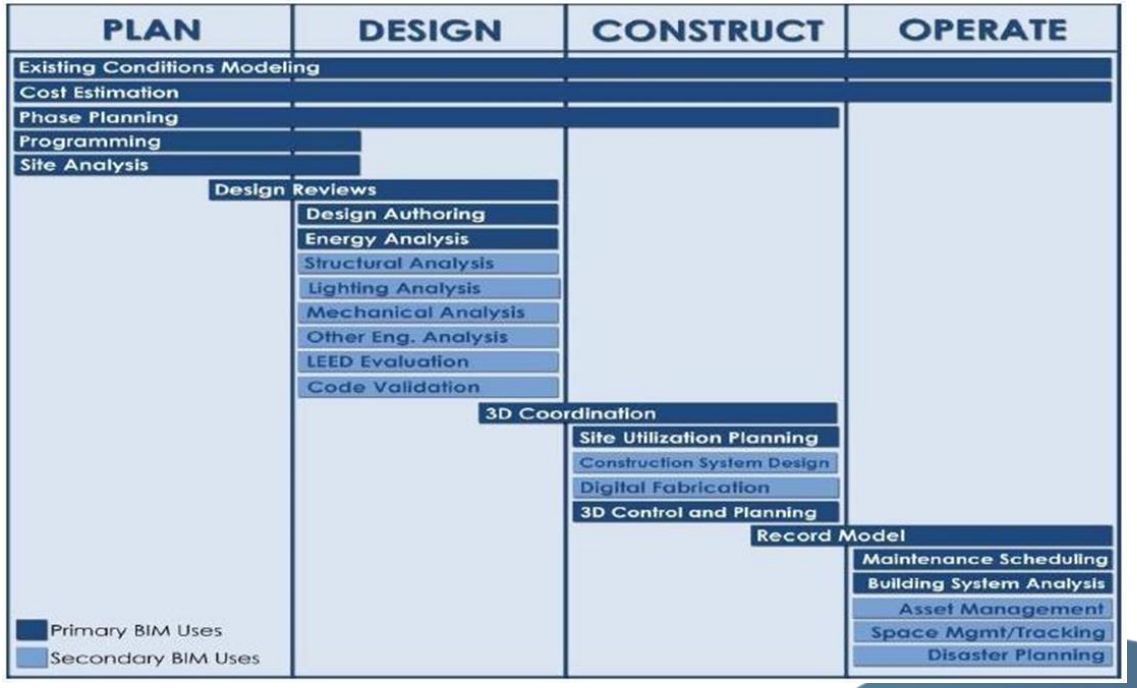
BIM Fundamentals

BIM Model exploitation: BIM Uses

Each of the actions we perform through a model are BIM Uses.

The first BIM Uses were defined in "The Uses of BIM" by PENN State University.

This document defines BIM uses, primarily by the purpose that they fulfil on a project, along with additional attributes for each BIM Use, e.g., the scope of work includes, the phase within the lifecycle, the level of development of the model, and the discipline to perform the modelling.



Source: https://bimzeed.eu/

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BIM Fundamentals

BIM Uses: Programming

Process in which a spatial program is used to efficiently and accurately assess design performance regarding spatial requirements.

Potential Value

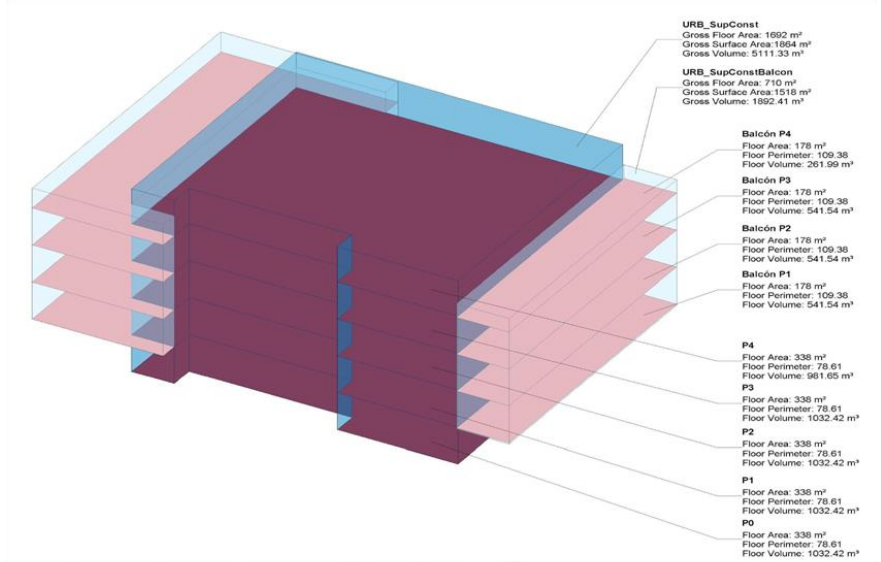
- Efficient and accurate assessment of design performance regarding spatial requirements by the owner.

Resources Required

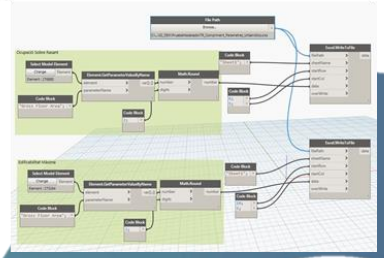
- Design Authoring Software
- Programming Software

Team Competencies Required

- Ability to manipulate, navigate, and review a 3D model.
- Knowledge of regulations and spatial requirements.



		PLANEJAMENT		PROJECTE	
Qualificació Urbanística					
Ordenació					
Ús del Sòl					
Superfície Parcel·la		1.319,48 m2			m2
Ocupació Sobre Rasant	40%	527,79 m2		512,84	m2
Espai Lliure d'Edificació	Mínim	791,69 m2			m2
Ocupació Sota Rasant					
Índex Edificabilitat		1,60			
Edificabilitat Màxima		2.111,17 m2		517,73	m2
Nº Màxim de Plantes	PB+4	5,00			
Sup. Const. Màx. Planta		422,23 m2		421,56	m2
Sup. Const. Màx. Balcons Planta		105,56 m2		103,26	m2
Sup. Màx. Pavimentada	30%				
Sup. Mín. Inalterada Parcel·la	10%	131,95 m2			m2
Alçada Reguladora		16,70 m			m
Alçada Planta Baixa		+/-1 m			



Source: https://bimzeed.eu/

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BIM Fundamentals

BIM Uses: Design Review

A process in which stakeholders view a 3D model and provide their feedbacks to validate multiple design aspects.

Potential Value

- Eliminate costly and timely traditional construction mock-ups
- Different design options can be changed in real-time during meetings based on owner feedbacks
- Create shorter and more efficient design and design review process
- Get instant feedbacks on owner's needs.
- Increases coordination and communication between different parties.

Resources Required

- Design Review Software
- Hardware which is capable of processing potential large model files

Source: https://bimzeed.eu/

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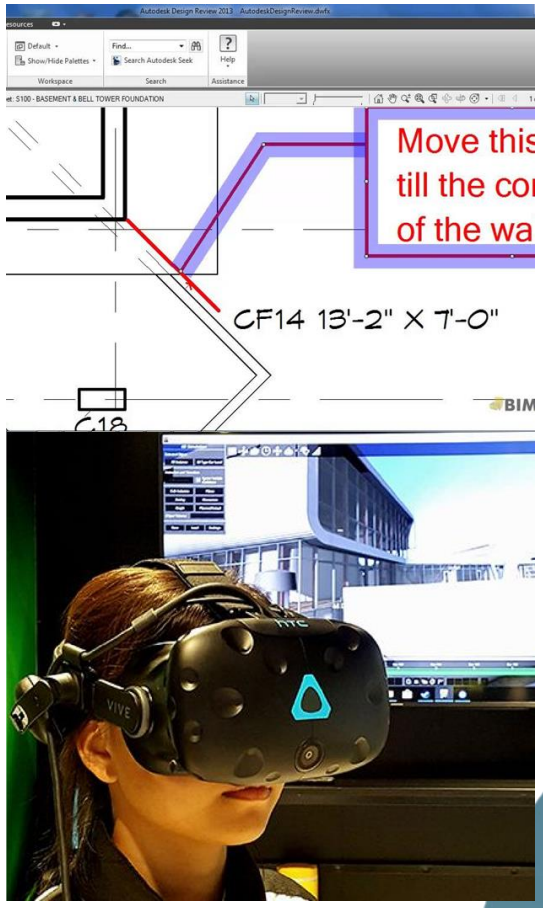
BIM Fundamentals

Team Competencies Required

- Ability to manipulate, navigate, and review a 3D model
- Ability to model photo realistically including textures.
- Strong sense of coordination. Understanding roles and responsibilities of team members and understanding how building systems integrate with one other.



Source: https://bimzeed.eu/

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BIM Fundamentals

BIM Uses: Cost Estimation

This process allows the project team to see the cost effects of their changes during all phases of the project.

Potential Value

- Precisely quantify modelled materials
- Quickly generate quantities to assist in the decision-making process and generate more cost estimates at a faster rate
- Provide cost information to the owner during the early decision-making phase of design and throughout the lifecycle, including changes during construction
- Easier exploration of different design options and concepts within the owner's budget

Resources Required

- Model-based estimating software
- Design authoring software and accurately built design model
- Cost data (classification systems used in cost estimation workflows)

Source: https://bimzeed.eu/

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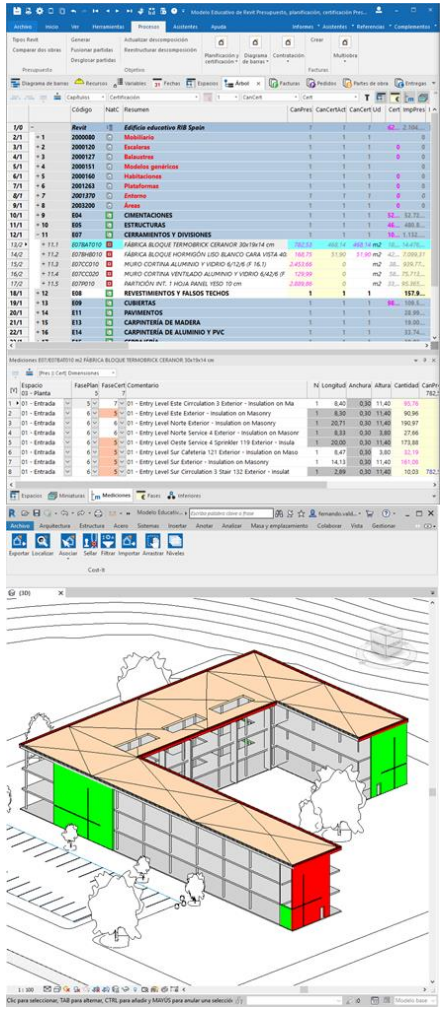
BIM Fundamentals



Team Competencies Required

- Ability to define specific design modelling procedures which yield accurate quantity take-off
- Ability to identify quantities for the appropriate estimating level
- Ability to manipulate models to acquire usable quantities

Source: https://bimzeed.eu/

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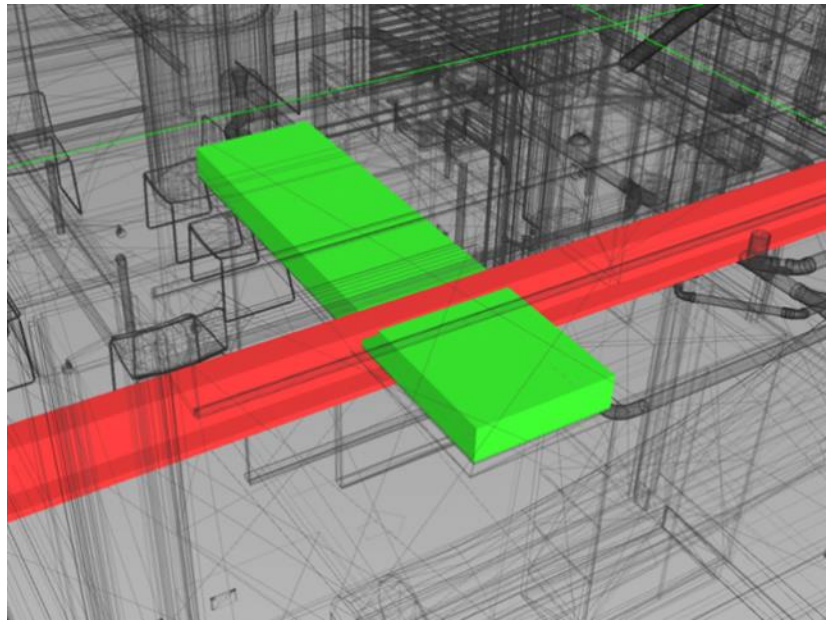
BIM Fundamentals

BIM Uses: 3D Coordination also known as Clash Detection

The 3D coordination allows the professionals involved to assimilate the complexity of the design which translates into greater efficiency in its resolution.

Potential Value

- Coordinate building project through a model
- Reduce and eliminate field conflicts.
- Reduced construction cost; potentially less cost growth (i.e. less change orders) and decrease construction time and increase productivity on site
- More accurate as built drawings



Source: https://bimzeed.eu/

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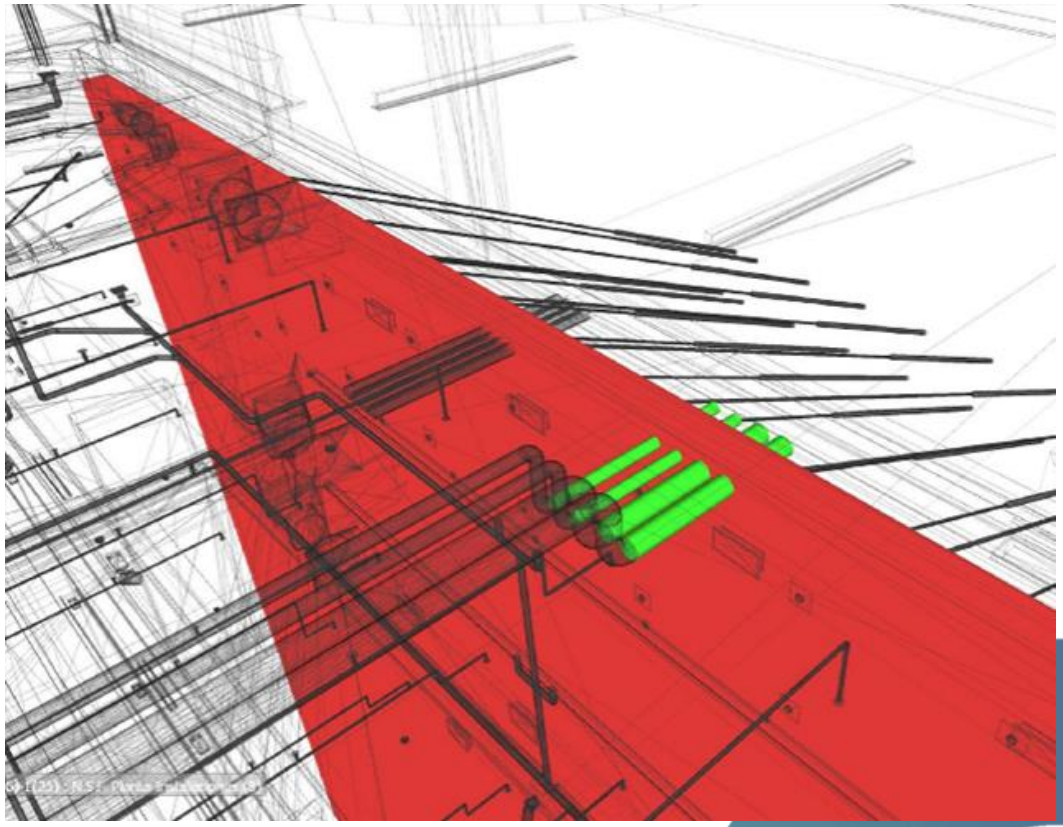
BIM Fundamentals

Resources Required

- Design Authoring Software
- Model Review Software

Team Competencies Required

- Ability to deal with people and project challenges
- Ability to manipulate, navigate, and review a 3D model
- Knowledge of building systems



Source: https://bimzeed.eu/

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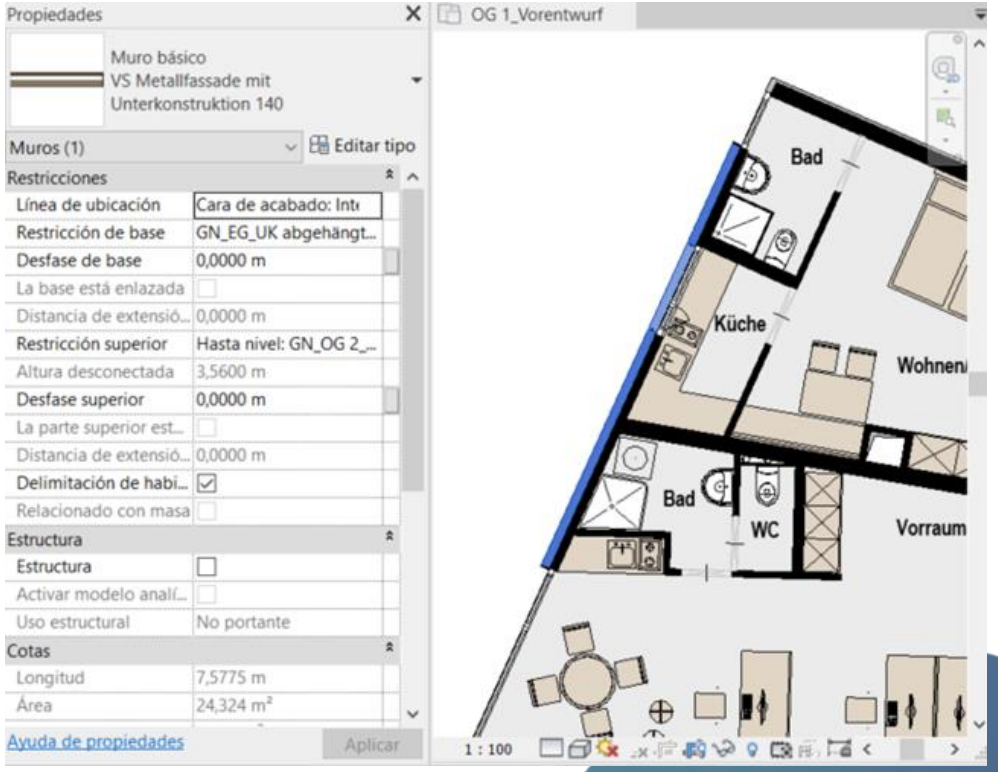
BIM Fundamentals

BIM Uses: Design Authoring

A process in which 3D software is used to develop a Building Information Model based on criteria that is important to the translation of the building's design.

Potential Value

- Transparency of design for all stakeholders
- Better control and quality control of design, cost and schedule
- Powerful design visualization
- True collaboration between project stakeholders and BIM users
- Improved quality control and assurance



Source: https://bimzeed.eu/

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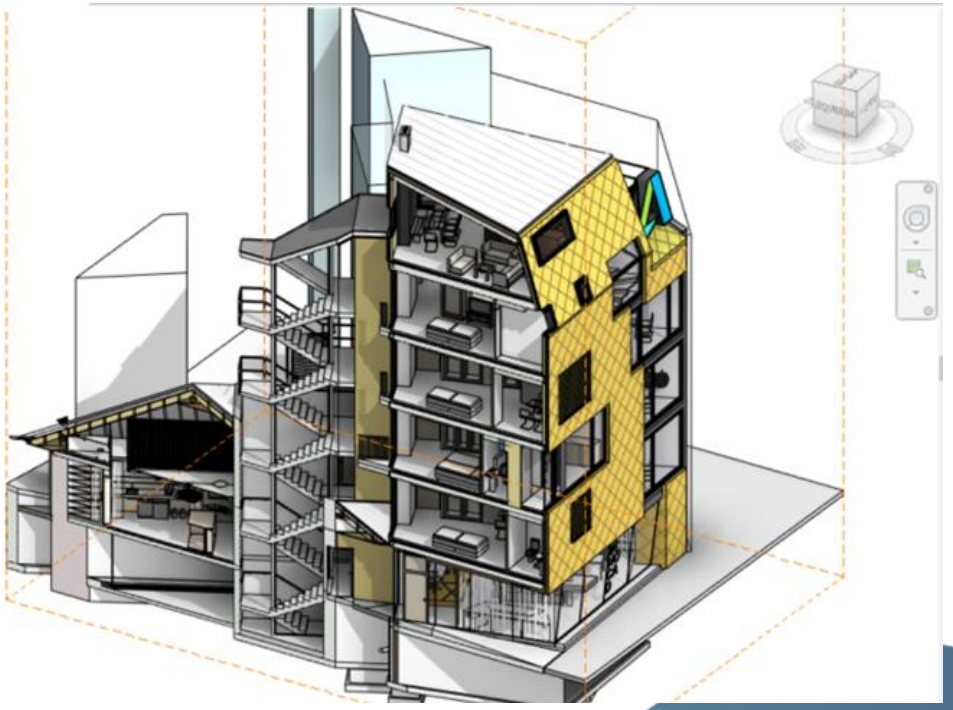
BIM Fundamentals

Resources Required

- Design Authoring Software

Team Competencies Required

- Ability to manipulate, navigate, and review a 3D model
- Knowledge of construction means and methods
- Design and construction experience



Source: https://bimzeed.eu/

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BIM Fundamentals

BIM Uses: Energy Analysis

A process in the design phase which one or more building energy simulation programs use a properly adjusted BIM model to conduct energy assessments for the current building design.

Potential Value

- Save time and costs by obtaining building and system information automatically from BIM model instead of inputting data manually twice. For example: geometries, volumes precisely from BIM model
- Help with building energy code verification
- Optimize building design for better building performance efficiency and reduce building life-cycle cost

Source: https://bimzeed.eu/

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BIM Fundamentals

Resources Required

- Building Energy Simulation and Analysis Software(s)
- Well-adjusted Building 3D-BIM Model
- Detailed Local Weather Data
- National/Local Building Energy Standards

Source: https://bimzeed.eu/

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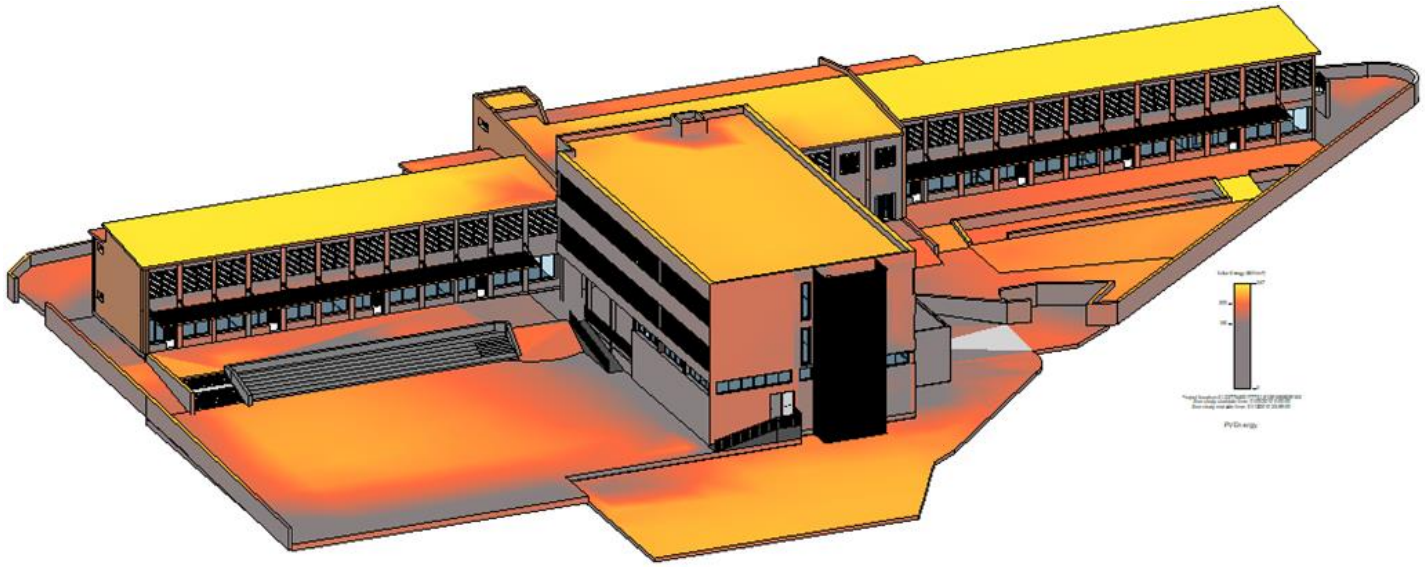
BIM Fundamentals

Team Competencies Required

- Knowledge of basic building energy systems
- Knowledge of compatible building energy standard
- Knowledge and experience of building system design
- Ability to assess a model through engineering analysis tools



Source: https://bimzeed.eu/

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BIM Fundamentals

BIM Uses: Phase Planning

A process in which a 4D model (3D models with the added dimension of time) is utilized to effectively plan the phased occupancy in a renovation, retrofit, addition, or to show the construction sequence and space requirements on a building site.

Potential Value

- Better understanding of the phasing schedule by the owner and project participants and showing the critical path of the project
- Space and workspace conflicts identified and resolved
- Identification of schedule, sequencing or phasing issues
- Increased productivity and decreased waste on job sites

Resources Required

- Design Authoring Software
- Scheduling software
- 4D Modelling Software

Source: https://bimzeed.eu/

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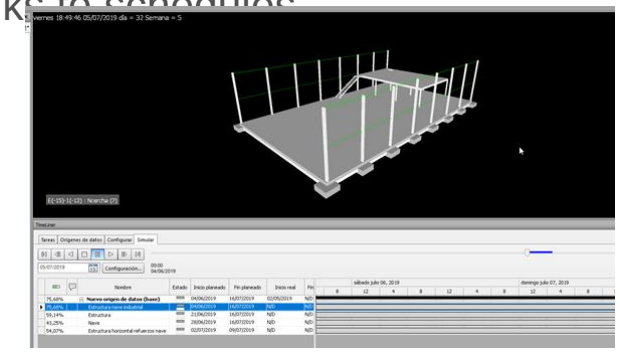
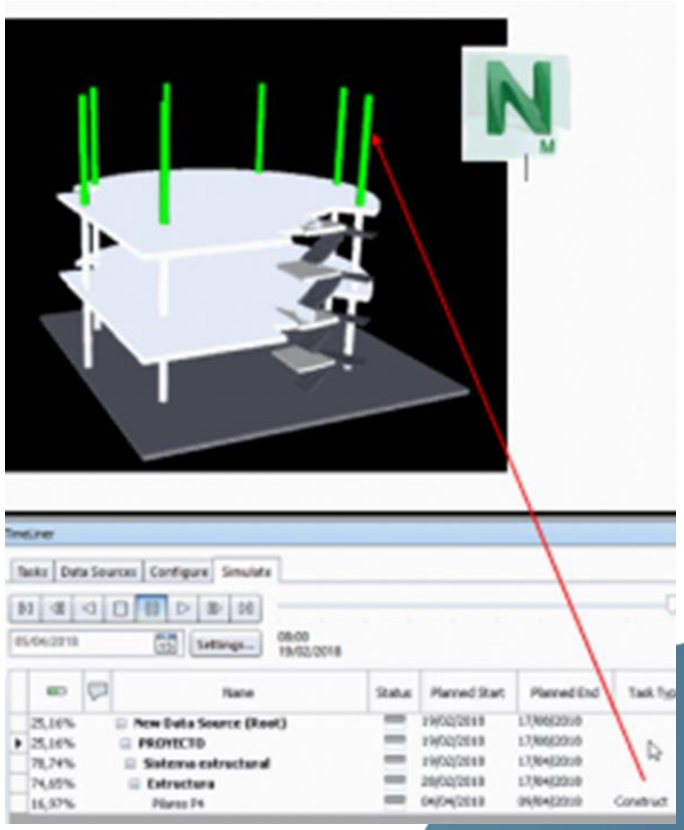
BIM Fundamentals

Team Competencies Required

- Knowledge of construction scheduling and general construction process.
- Ability to manipulate, navigate, and review a 3D model.
- Knowledge of 4D software: import geometry, manage links to schedules





Source: https://bimzeed.eu/

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BIM Fundamentals

BIM Software

Authoring tools create models while audit and analysis tools study or add to the richness of information in a model.

We can have a huge amount of analysis tools depending on the type of analysis that they do.

It can be:

- Structural Analysis
- Energetic Analysis
- Clash detection analysis
- Virtual Reality and Visualization analysis
- Etc

Source: Parametric monkey

Source: https://bimzeed.eu/

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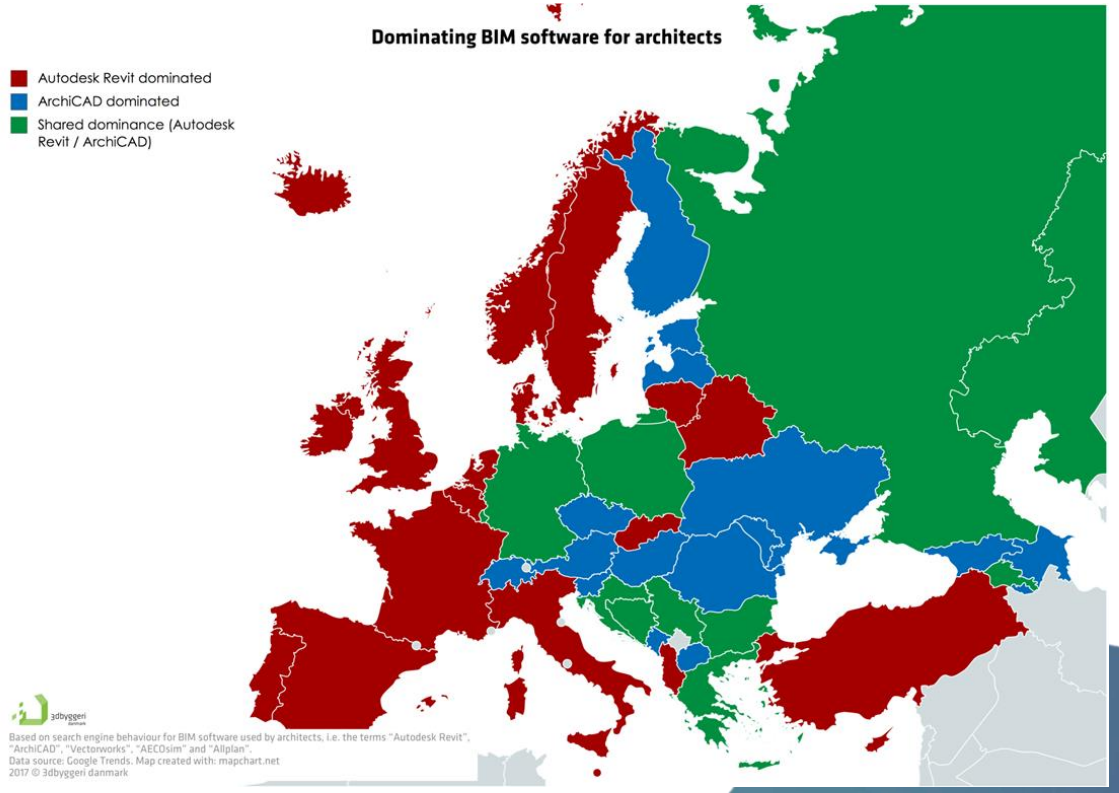
BIM Fundamentals

BIM Authoring tools

There are a lot of design authoring tools, some of them are:

- Autodesk Revit
- Archicad
- Allplan
- AECOsim Building Designer
- Tekla Structures



Source: Google trends. Graphics: 3dbyggeri Danmark ApS

Source: https://bimzeed.eu/

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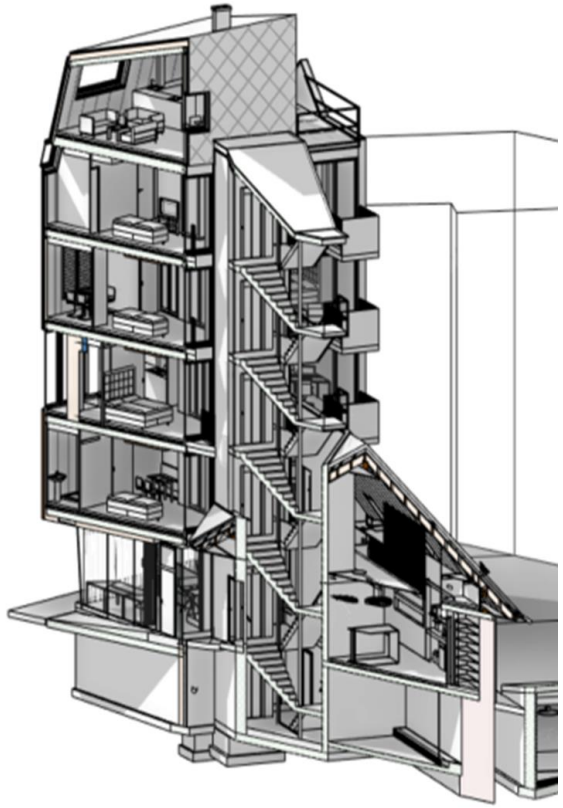
BIM Fundamentals

Considerations in the use of Design Authoring Tools

The use of these design authoring tools is critical for the BIM project, because you will condition the usability of the models for other purposes.

When we are creating building models, we need to do it in a proper and planned way and:

- Use the correct tool that fits with the purpose of the project.
- Use the correct modelling strategy
- Define the scope of the model and don't waste time with useless information



Source: https://bimzeed.eu/

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101033740

BIM Fundamentals

LOD

It is used to define information delivery a reference library of definitions is required. These levels of “definition” may be either described in terms of geometry or information requirements. Geometric also is described as graphic data and information as non-graphic data.

Source: https://bimzeed.eu/

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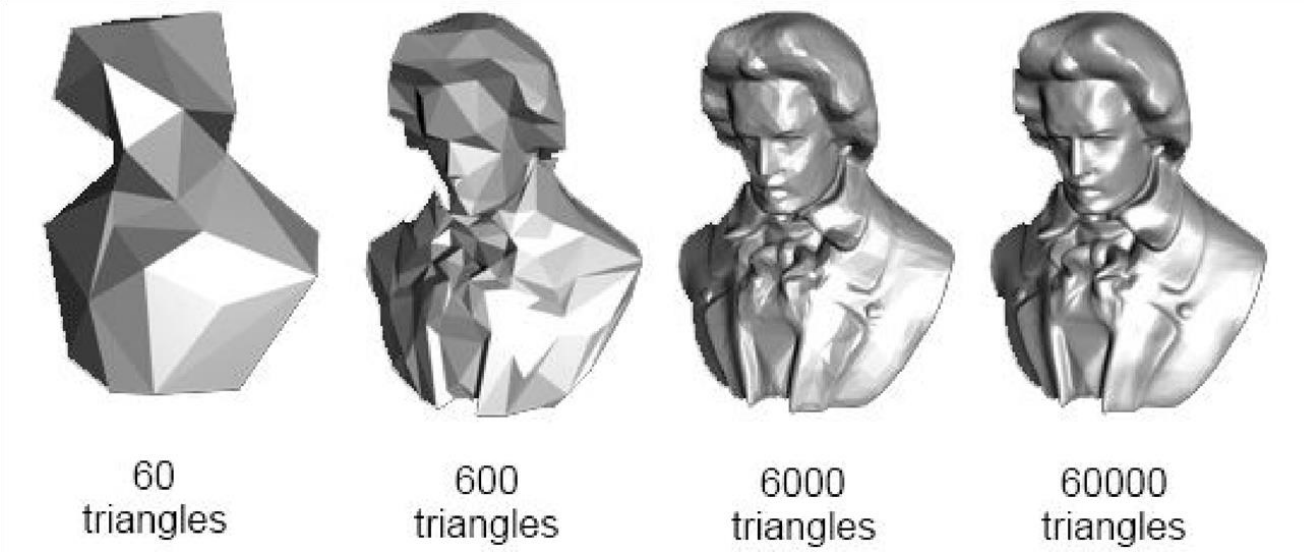
BIM Fundamentals

LOD: GEOMETRY

Geometrical accuracy of the element that will be installed on site.



Source: https://bimzeed.eu/

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BIM Fundamentals

LOD: INFORMATION

Information levels of the product that will be installed on site.

Concept (Presentation)	Design Development	Documentation	Construction	Facilities Management
DESCRIPTION: Office Chair Arms, Wheels WIDTH: DEPTH: HEIGHT: MANUFACTURER: Herman Miller, Inc. MODEL: Mirra LOD: 100	DESCRIPTION: Office Chair Arms, Wheels WIDTH: 700 DEPTH: 450 HEIGHT: 1100 MANUFACTURER: Herman Miller, Inc. MODEL: Mirra LOD: 200	DESCRIPTION: Office Chair Arms, Wheels WIDTH: 700 DEPTH: 450 HEIGHT: 1100 MANUFACTURER: Herman Miller, Inc. MODEL: Mirra LOD: 300	DESCRIPTION: Office Chair Arms, Wheels WIDTH: 685 DEPTH: 430 HEIGHT: 1085 MANUFACTURER: Herman Miller, Inc MODEL: Mirra LOD: 400	DESCRIPTION: Office Chair Arms, Wheels WIDTH: 685 DEPTH: 430 HEIGHT: 1085 MANUFACTURER: Herman Miller, Inc MODEL: Mirra PURCHASE DATE: 01/02/2013

(Only data in red is useable)

practicalBIM.net © 2013

Source: https://bimzeed.eu/

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101033740

BIM Fundamentals

LOD PROGRESSION AND LOD MATRIX

To establish the information (graphic and non-graphic information from now on) requirements in every phase commonly use a resource or tool called LOD Matrix.

Here we define the different levels of information in different phases according with the BIM project strategy.

					GRAPHICAL LOD	Proyecto Basico/ Design Intent Model	Proyecto Ejecutivo/ Coordinated Design	Trade Coordination/ Construction Phase
REF	REF				ELEMENT	LOD	LOD	LOD
01.02.03	1	2	3		Beam demolitions	200	200	300
01.02.03.01	1	2	3	1	Steel beams demolition	200	200	300
01.02.03.02	1	2	3	2	Reinforced concrete beams demolition	200	200	300
01.02.04	1	2	4		Slabs demolitions	200	200	300
01.02.04.01	1	2	4	1	Pre-cast slabs demolition	200	200	300
01.02.04.02	1	2	4	2	In-situ reinforced concrete slabs demolition	200	200	300
01.02.04.03	1	2	4	3	Composite slab demolition	200	200	300
01.02.05	1	2	5		Floors demolitions	200	200	300
01.02.06	1	2	6		Walls demolitions	200	200	300
01.02.06.01	1	2	6	1	Reinforced concrete wall demolition	200	200	300
01.02.06.02	1	2	6	2	Masonry/blockwork wall demolition	200	200	300
01.02.06.03	1	2	6	3	Plasterboard wall demolition	200	200	200
01.02.06.04	1	2	6	4	Glazed wall demolition	200	200	200
01.02.06.05	1	2	6	5	Others	200	200	200
01.02.07	1	2	7		Openings demolitions	200	200	200
01.02.07.01	1	2	7	1	Wood doors demolitions	200	200	200
01.02.07.02	1	2	7	2	Steel doors demoltiions	200	200	200
01.02.07.03	1	2	7	3	Glazed doors demolitions	200	200	200
01.02.07.04	1	2	7	4	Windows demolitions	200	200	200
01.02.08	1	2	8		Wall finishes demolitions	200	200	200

Source: https://bimzeed.eu/

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BIM Fundamentals

LOD VS LOD

There are two principle standards for this concept. Level of Development (AIA+BIM FORUM - USA) and Level of Definition (NBS – UK).

LEVEL OF DEFINITION – NBS

LEVEL OF DEVELOPMENT – BIM FORUM

Source: https://bimzeed.eu/

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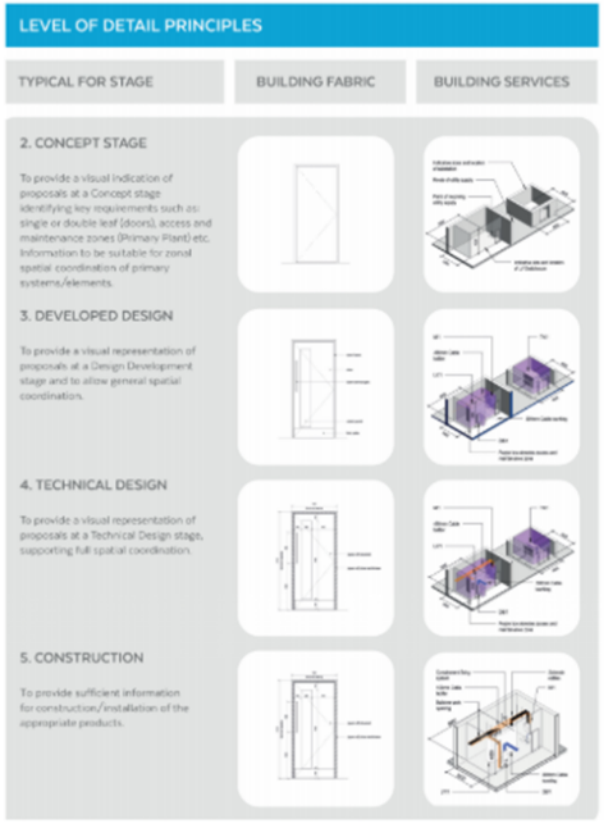
BIM Fundamentals

LOD VS LOD

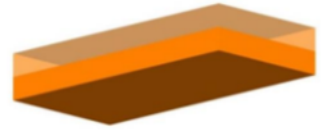
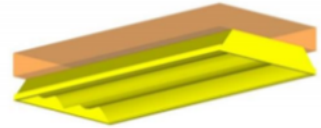


Source: https://bimzeed.eu/

D5040.50 21-04 50 40 50 Lighting Fixtures

Includes: Luminaires, lighting equipment, ballasts, and accessories. Includes fluorescent, high intensity discharge, incandescent, mercury vapor, neon, and sodium vapor lighting.

Associated Masterformat Sections: 26 50 00 / 26 51 00 / 26 52 00 / 26 53 00 / 26 54 00 / 26 55 00 / 26 55 23 / 26 55 29 / 26 55 33 / 26 55 36 / 26 55 39 / 26 55 53 / 26 55 59 / 26 55 61 / 26 55 63 / 26 55 70

100	See D50	
200	See D5040	
300	Modeled as design-specified size, shape, spacing, and location of lighting fixtures; approximate allowances for spacing and clearances required for all specified hangers, supports and seismic control; access/code clearance requirements modeled.	 *205 D5040.50-LOD-300 Lighting Fixtures*
350	Modeled as actual size, shape, spacing, and location of lighting fixtures. actual size, shape, spacing, and location for supports and seismic control. actual access/code clearance requirements modeled.	 *206 D5040.50-LOD-350 Lighting Fixtures*
400	Supplementary components added to the model required for fabrication and field installation.	

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BIM Fundamentals

BIM Classification

Classification is fundamental to achieving effective information management and has been identified as one of seven components required for Level 2 building information modelling (BIM).

This process of deciding what 'things' are called is causing some issues in the BIM world. If you have a vast quantity of data or information, that can be a very powerful resource.

Classification can be defined as, 'The act or process of dividing things into groups according to their type.'

OMNICLASS™
A Strategy for Classifying the Built Environment

Source: https://bimzeed.eu/

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BIM Fundamentals

BIM ROLES

Carrying out a project in BIM implies having to take care of the models we make. Because if they are not made with the right strategy, they can be useless and the effort dedicated to make them would be in vain.

That is why new responsibilities must be acquired in order to guarantee the success of the application of the BIM methodology.

These new roles are:

- BIM Manager
- BIM Coordinator
- BIM Modeler

	Strategic						Management				Production	
Role	Corporate Objectives	Research	Process + Workflow	Standards	Implementation	Training	Exceution Plan	Model Audit	Model Coordination	Content Creation	Modelling	Drawing Production
BIM Manager	Y	Y	Y	Y	Y	Y	Y	N	N	N	N	N
BIM Coordinator	N	N	N	N	N	Y	Y	Y	Y	Y	Y	N
BIM Modeler	N	N	N	N	N	N	N	N	N	Y	Y	Y

Source: https://bimzeed.eu/

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BIM Fundamentals

BIM ROLES

BIM Manager responsibilities

- To define the BIM Uses and Objectives of the project.
- To create the project standards, define the workflows and reflect them in the BIM Execution Plan (BEP) according to the phase of the project.
- To create and manage the CDE.
- To establish audit and control processes to ensure compliance with customer BIM requirements.
- Technical support in the detection of interference or Clash Detection.
- To ensure interoperability and communication.

Source: https://bimzeed.eu/

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101033740

BIM Fundamentals

BIM Coordinator responsibilities

- To assist the BIM Manager in drafting the BEP.
- To ensure compliance with the BEP or BIM Implementation Plan.
- To coordinate the work within his own discipline (or phase).
- To carry out the processes of checking the quality of the BIM model at a geometric and non-geometric level.
- To upload models in the CDE when appropriate.

Source: https://bimzeed.eu/

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BIM Fundamentals

BIM ROLES

BIM modeler responsibilities

- To model the project within your own discipline.
- To embed and extract information from the model in the specified formats. PDF, DWG, IFC, NWC
- To solve detected conflicts in clash detection reports.
- To read the BEP and model it according to your requirements.

Source: https://bimzeed.eu/

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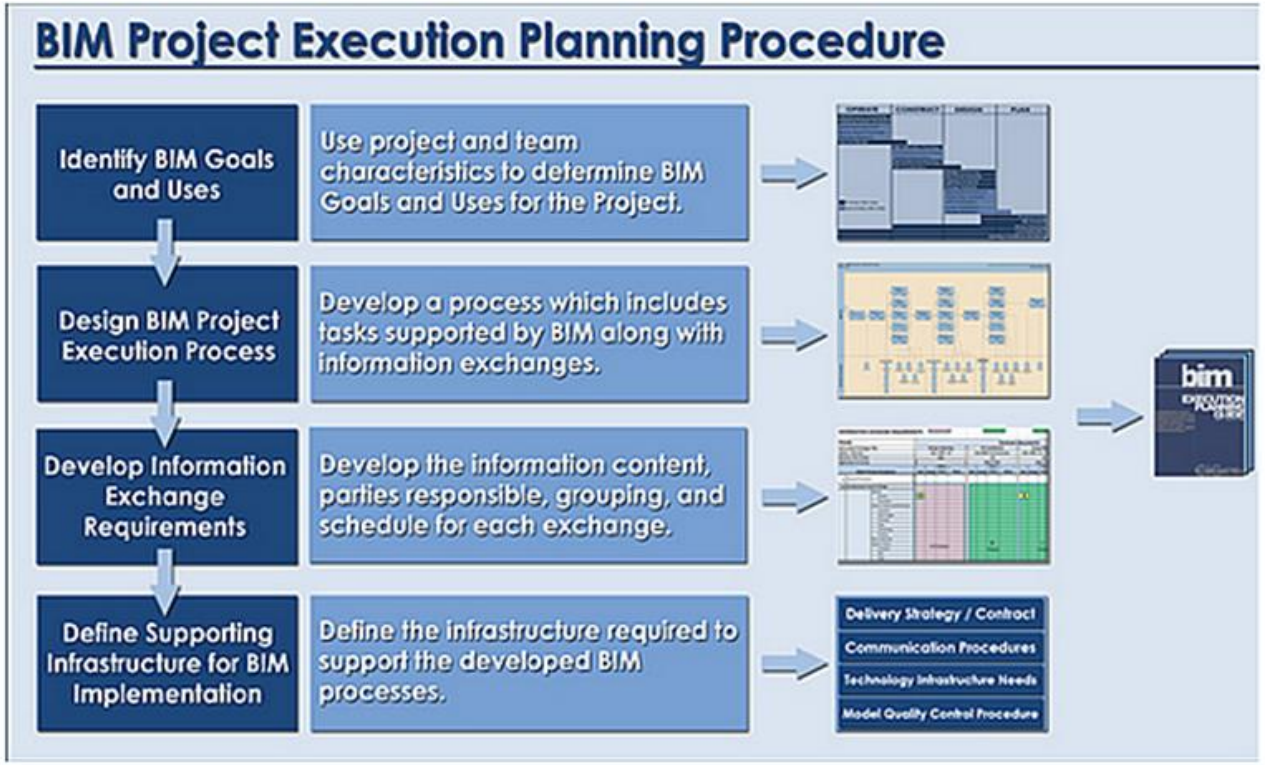
BIM Fundamentals

BIM EXECUTION PLAN

All these responsibilities, decisions, etc... must be agreed upon by all members of the Project team. Once agreed it is necessary to write them all in a contractual document where each individual agent can find their responsibilities and information requirements to ensure interoperability (and other workflows) and to achieve the Project BIM objectives.



Source: BIM Project Execution Planning Guide (PSU)

Source: https://bimzeed.eu/

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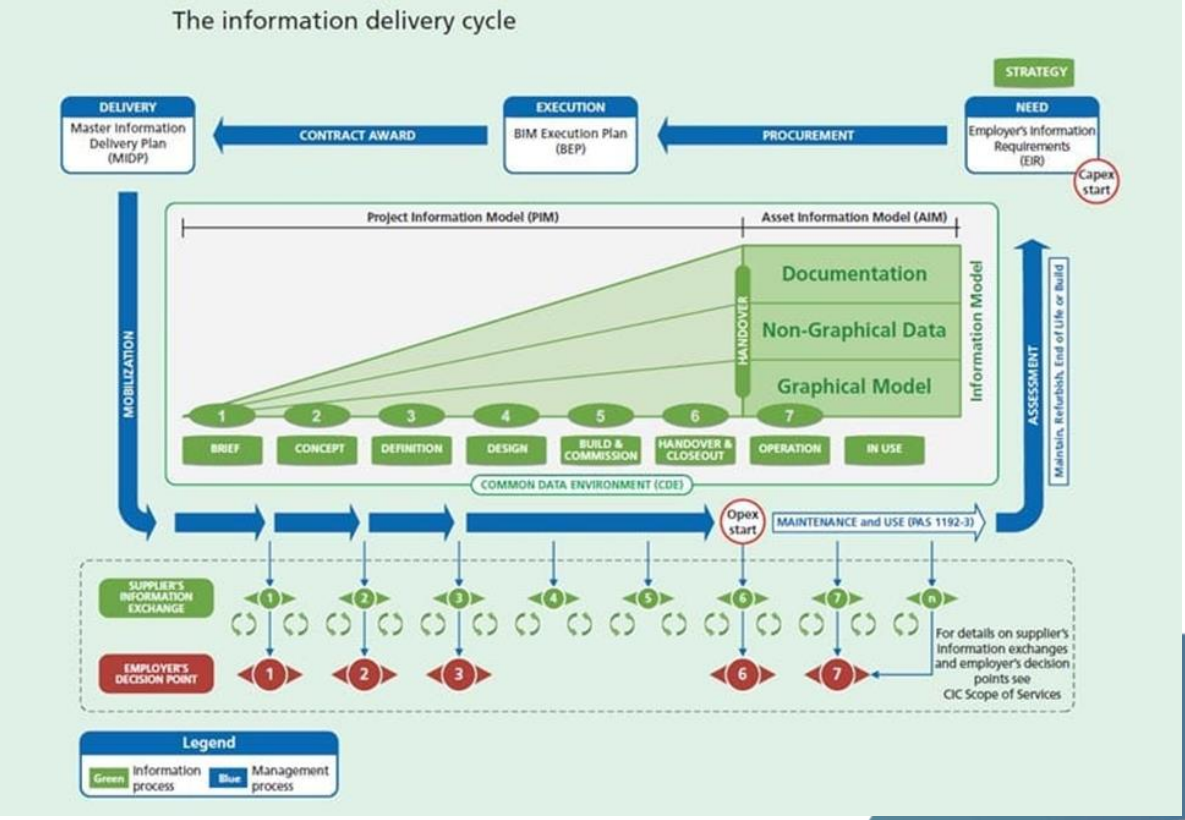
BIM Fundamentals

BIM EXECUTION PLAN

At tender stage, before a contract is agreed, a prospective supplier will develop a BEP with the aim of demonstrating their proposed approach, capability, capacity and competence to meet the EIR in general terms.

Once a contract has been awarded then the winning supplier is required to submit a further BIM Execution Plan. The focus of this post-contract document is to confirm the supply chain's capabilities.



Source: PAS 1192-2:2013

Source: https://bimzeed.eu/

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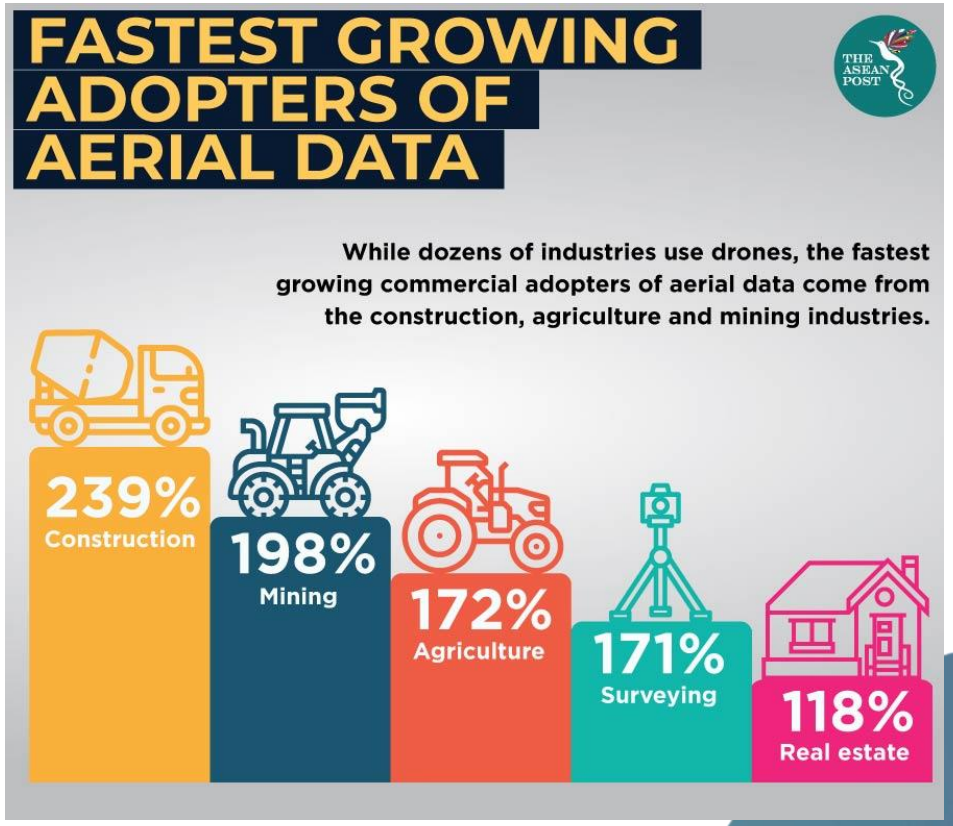
Drones

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101033740

Drones

In 2018, this sector saw a 239% increase in the adoption of drone technology. In its report on the impact of drones, PwC states that the use of drones throughout a construction project provides an unparalleled record of all activities; cuts planning and survey costs; increases efficiency and accuracy, and eliminates disputes over the status of a project at a given point in time.



Source: 27 Advisory and Aerial Ascent

Source: https://wingtra.com/drone-mapping-applications/drones-in-construction-and-infrastructure/

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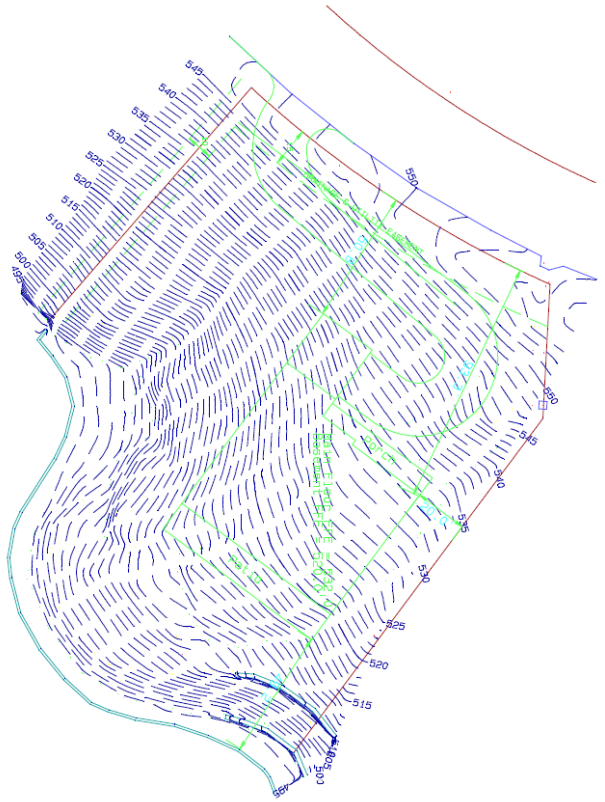
Drones Used in Construction

Topographic Mapping and Land Surveys

Due to their ability to map vast quantities of land, drones can exponentially cut down on time spent visualizing a site's topography. This helps to keep the project on schedule and on budget and ensures accuracy before the project is initiated. Gathering this information can help determine feasibility and assist with design.



Source: https://landsurveyorsunited.com/almanac/topographic-survey

Source: https://www.bigrentz.com/blog/drones-construction

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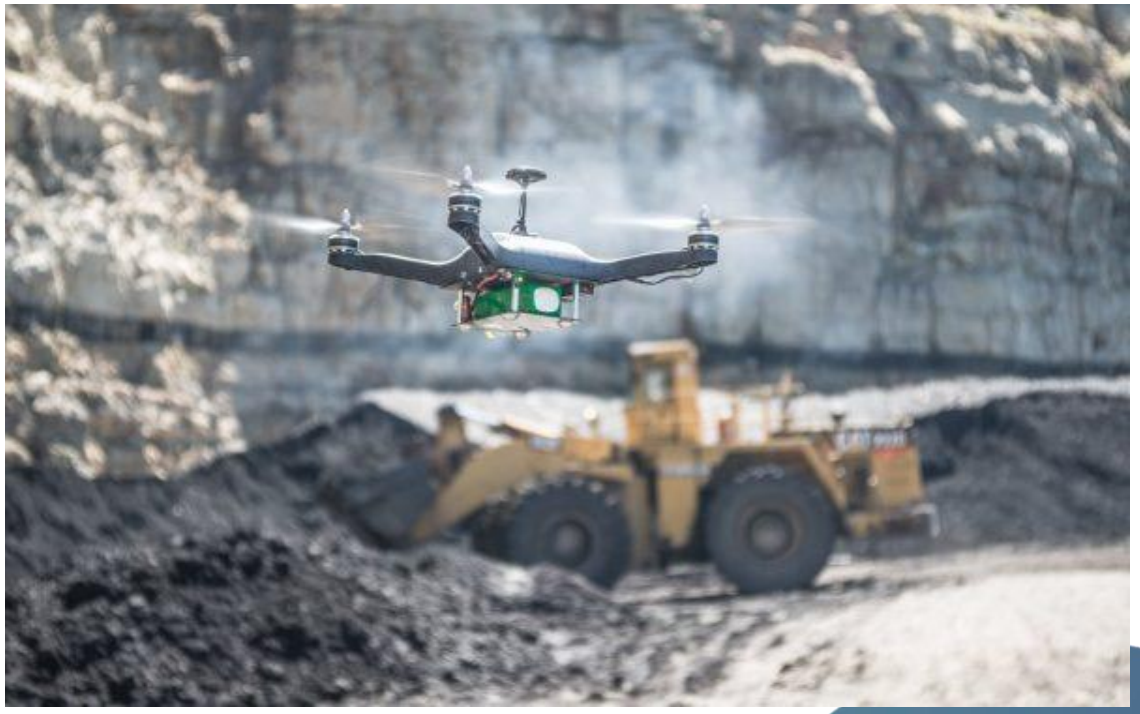
Drones Used in Construction

Equipment Tracking

With a drone, you can do a flyover and quickly assess whether the equipment is where it needs to be. They can quickly recognize if a piece of equipment that should be terminated is still on-site.

Equipment malfunctions are a common issue. Drones' recording functionality could be used to identify issues remotely and provide visual representations that aid in communicating those issues.



Source: https://trackem.com.au/asset-tracking-from-the-sky/

Source: https://www.bigrentz.com/blog/drones-construction

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Drones Used in Construction

Remote Monitoring and Progress Reports

Another valuable feature of construction drones is the visibility they can provide for clients. Drones can produce impressive aerial views and give clients a grasp of the project's progression, especially when they cannot be physically present on a site. This helps assure clients that their spend is being utilized efficiently.

Source: https://wingtra.com/drone-mapping-applications/drones-in-construction-and-infrastructure/

Source: https://www.bigrentz.com/blog/drones-construction

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Drones Used in Construction

Security Surveillance

A drone operator can conduct a flyover to quickly see if a piece of equipment is in a secure enough location. They can also use the surveillance camera to see if unauthorized individuals are on the site. This can help prevent damage or theft and identify any trespassers.

Source: https://www.bigrentz.com/blog/drones-construction

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Drones Used in Construction

Personnel Safety

Construction managers can also use drone video cameras to monitor the job site for safety concerns, ensuring workers are properly balanced and that no structures or equipment are loose or unstable.

Source:https://www.forconstructionpros.com/construction-technology/article/21295561/six-factors-to-consider-when-adding-drones-to-your-construction-business

Source: https://www.bigrentz.com/blog/drones-construction

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Drones Used in Construction

Structure Inspection and Photography

Drones can also be used for planned maintenance of larger-scale structures like bridges, towers, roofs, and scaffolding. A task that would take an entire team of surveyors to do would only take a few hours with a drone operator.

*Source:*https://www.geospatialworld.net/blogs/drones-to-propel-new-technological-innovations-in-the-construction-industry/

Source: https://www.bigrentz.com/blog/drones-construction

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Drone Applications Throughout the Construction Cycle

1. Bidding and pre-planning

- DTMs and DSMs of a site generated with drone data can show possible drainage points, changes in elevation and other factors that can assist in selecting the best locations for building, digging or storing materials.

2. Planning and design

- With drone orthophotos and 3D models, you can overlay buildings onto their environment to get a clear sense of how a new building might look next to an existing one.

Source: https://wingtra.com/drone-mapping-applications/drones-in-construction-and-infrastructure/

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Drone Applications Throughout the Construction Cycle

3. Execution

Earthworks

- From drone images, you can generate a point cloud consisting of thousands of points, each containing geospatial (X, Y, Z) and color information. Then, with a photogrammetry software, you can get precise volume measurements and run a cut/fill analysis.

As-built vs. as-design

- One of the most striking advantages of accurate site visualization is the ability to overlay the CAD on the orthophoto. This allows you to compare what was actually built with the plan and make sure that they fit together.

Source: https://wingtra.com/drone-mapping-applications/drones-in-construction-and-infrastructure/

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Drone Applications Throughout the Construction Cycle

Site progress monitoring

- During the construction phase, site managers have to control and validate completed work in order to permit continued work.

Communication tool

- The visual data from regular drone surveys assists in on-demand (could be daily, weekly) operational planning.

Minimize rework and litigation documentation

- Having up-to-date visual data can help you catch a mistake before it takes shape and avoids demolition and the waste of time and materials related to it.

Source: https://wingtra.com/drone-mapping-applications/drones-in-construction-and-infrastructure/

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Drone Applications Throughout the Construction Cycle

Handover

- The owner can look carefully through the documentation before agreeing to the handover, and contractors can prove that the work has been conducted as per requirements, including details on who did what.

4. Maintenance and asset inspection

- By sending drones in the air, companies can visually inspect large assets or those located in hard-to-reach areas more quickly and cost-effectively.

Source: https://wingtra.com/drone-mapping-applications/drones-in-construction-and-infrastructure/

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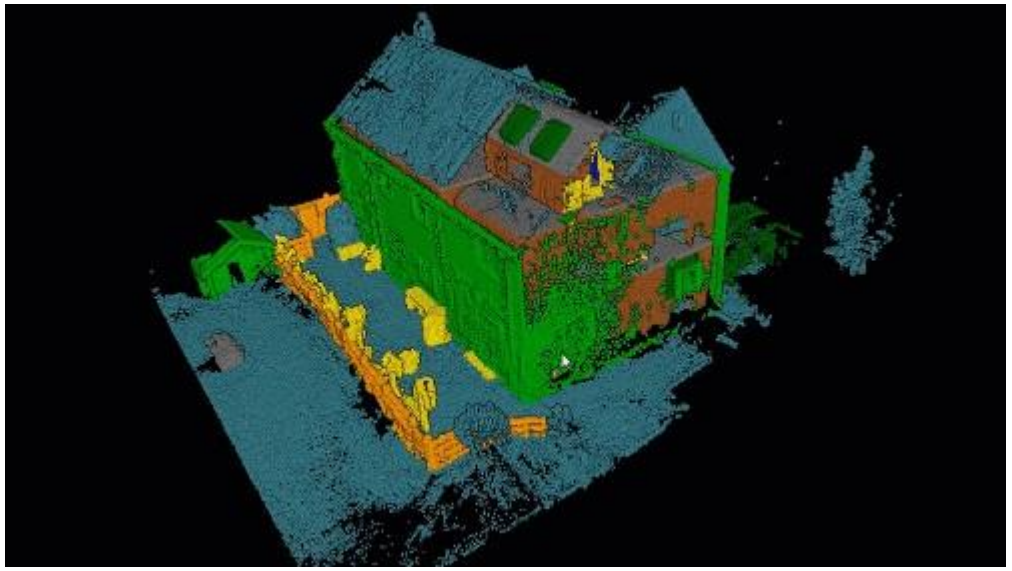
Types of Drone Outputs

- Orthophotos and orthomosaics
- Point clouds
- Digital surface models (DSMs) and digital terrain model (DTMs)
- 3D models
- Raw images



Source: https://towardsdatascience.com/the-future-of-3d-point-clouds-a-new-perspective-125b35b558b9

Source: https://wingtra.com/drone-mapping-applications/drones-in-construction-and-infrastructure/

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3D Modeling

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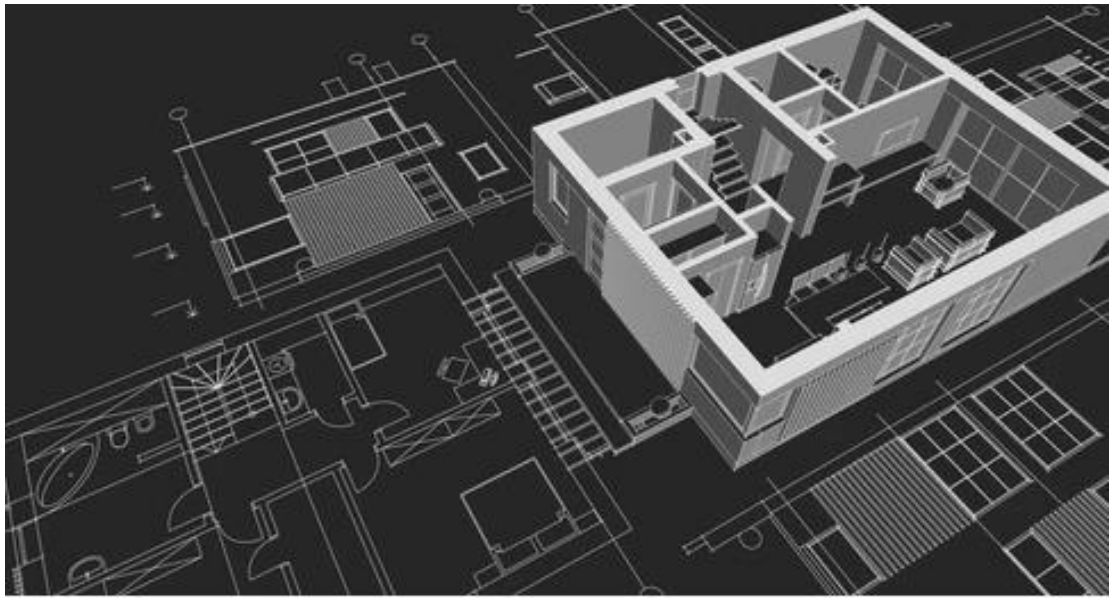
3D Modelling

3D modeling refers to the process of creating a mathematical representation of a 3-dimensional object or shape. This is done using software. 3D models are now widely used in a variety of industries. Motion pictures, video games, architecture, construction, product development, medical, all these industries are using 3D models for visualizing, simulating and rendering graphic designs. 3D modeling in construction is widely gaining popularity due to the plethora of benefits it offers.



*Source:*https://www.shutterstock.com/search/3d-modeling-building

*Source:*https://www.geospatialworld.net/blogs/3d-modeling-construction-benefiting/

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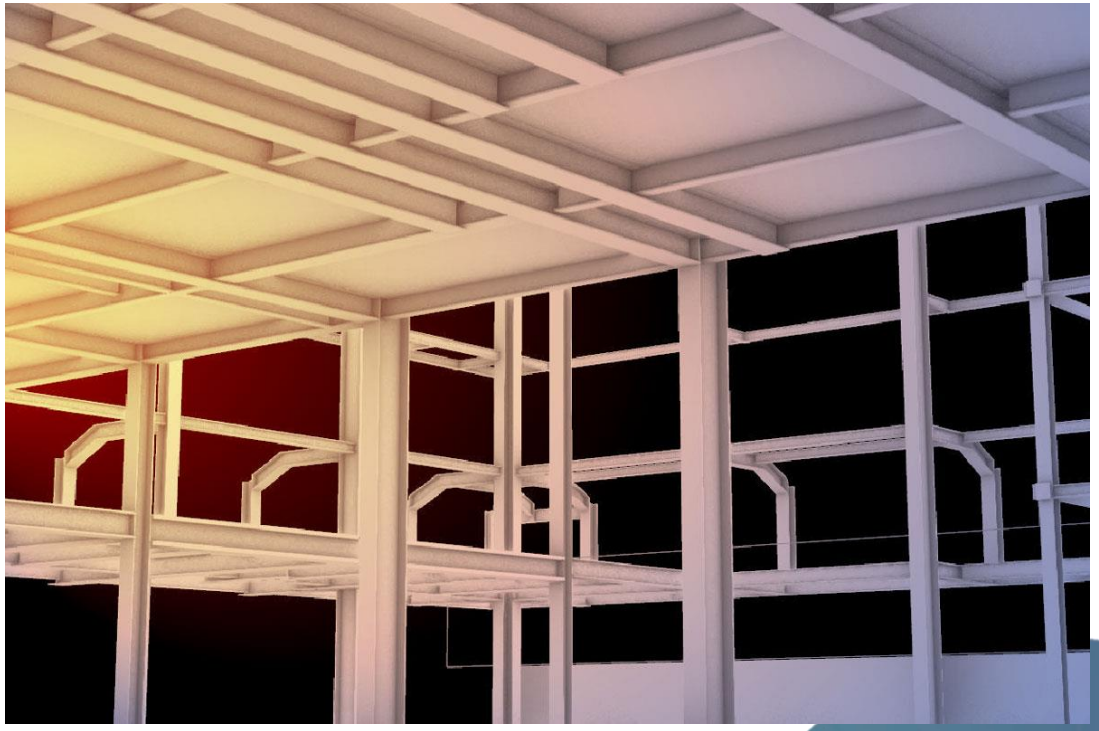
3D Modelling

1. Enable more realistic visualisations
2. Enable collaboration with easy-to-review designs
3. Ensure projects are completed on time
4. Greater control of machinery
5. Help to communicate site layout
6. Enhanced designs
7. Promotion of team synergy
8. Reduced lead time, errors and costs



*Source:*https://www.thecadroom.com/what-is-3d-modelling-in-architecture/#:~:text=Adopting%203D%20modelling%20has%20enabled,that%20entail%20multiple%20moving%20parts.

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VR (Virtual Reality)

Virtual Reality (VR) in relation to construction is the ability to take a computer-generated 3-dimensional model and provide the ability to view, walkaround and interact with the model prior to construction.

Virtual Reality is an extension of the BIM process and whilst we all know BIM can optimise the delivery of buildings by providing greater efficiencies at all stages of the building lifecycle, BIM does not encourage exploration of form, space and aesthetics as VR can.

VR can also play an important role at all stages of the design-to-construction process, from evaluating design options and showcasing proposals, to designing out errors and ironing out construction and serviceability issues before breaking ground on site.

*Source:*https://www.letsbuild.com/blog/vr-in-construction-management

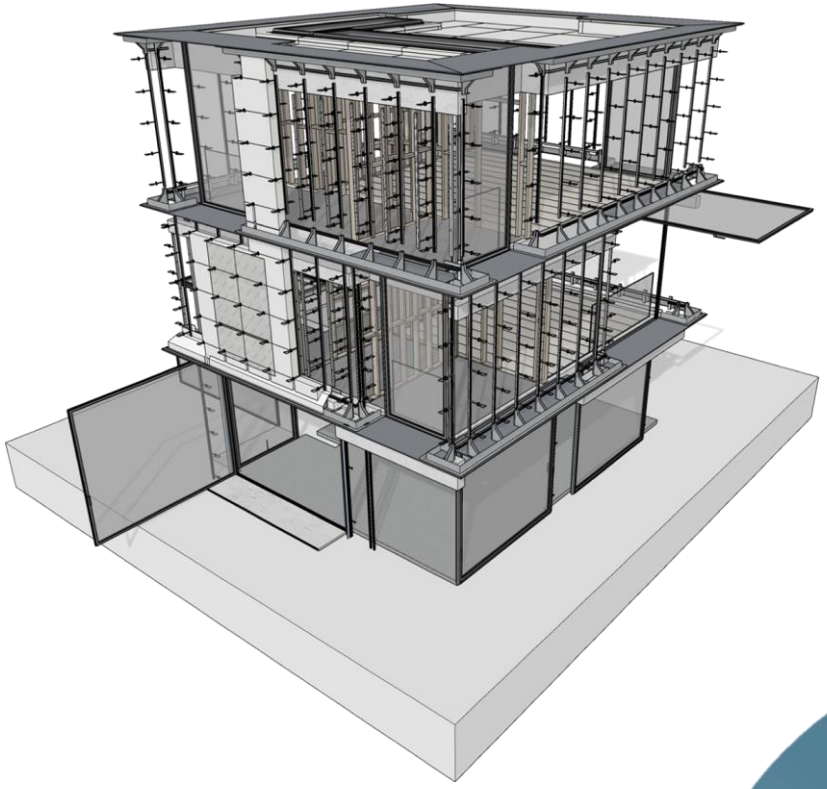
*Source:*https://www.symetri.co.uk/insights/blog/virtual-reality-in-construction/#:~:text=Virtual%20Reality%20(VR)%20in%20relation,the%20model%20prior%20to%20construction

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101033740

How VR Technology is Being Used in the Construction Industry

Design and 3D modelling

Virtual reality takes the design process to the next level. By creating a realistic digital twin of a proposed construction project, plans can be rigorously examined at the design stage. Being able to walk around a virtual site means that issues can be flagged and addressed at an earlier stage. This can help to significantly minimise costly and time-consuming alterations further down the line.



*Source:*https://www.capterra.com/resources/popular-free-3d-modeling-software-options/

*Source:*https://www.futurevisual.com/blog/construction-vr-training/

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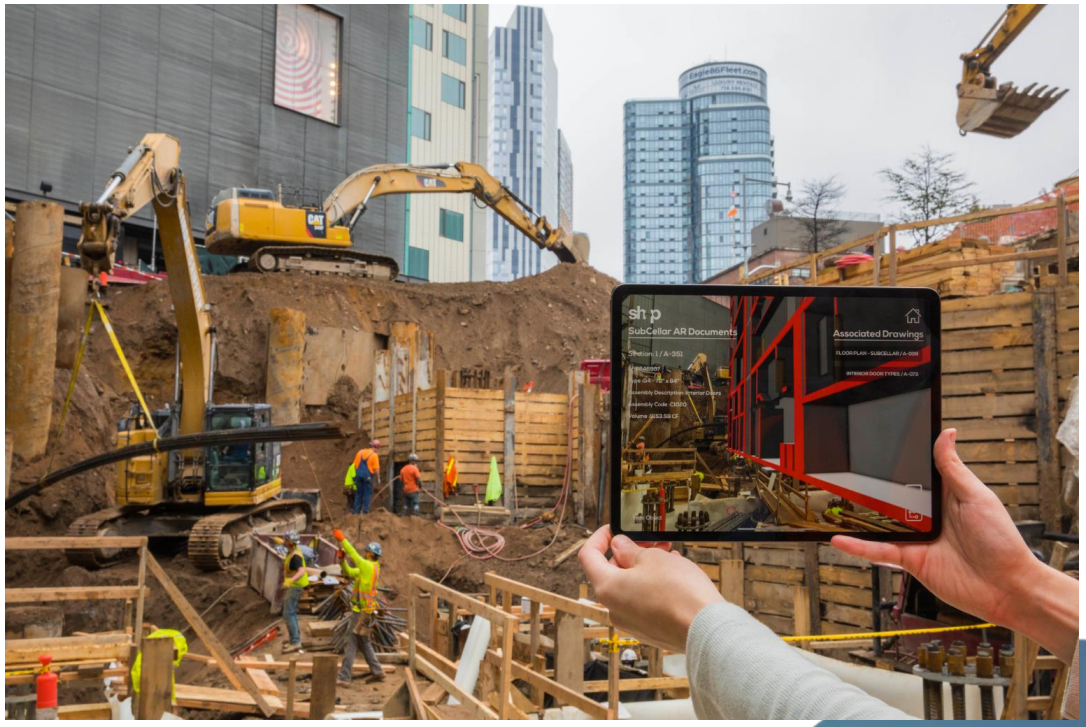
How VR Technology is Being Used in the Construction Industry

VR tours – improving communication with clients

Client relationships can also benefit from visiting finished constructions in the virtual world at the design stage, and has been adopted by leading innovators in the built environment, such as Arup. By creating a virtual completed site before it's been built allows clients to not only visualise, but tour, experience and scrutinise it from the very start of the project. This will help to realise their vision more accurately, as virtual reality helps to remove any ambiguities around their expectations and allows adjustments to be made before construction begins.



*Source:*https://www.nytimes.com/2019/11/08/realestate/how-virtual-reality-is-augmenting-realty.html

*Source:*https://www.futurevisual.com/blog/construction-vr-training/

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How VR Technology is Being Used in the Construction Industry

Supporting collaborative working

One thing that all constructions projects have in common is that they rely on collaborative working for completion of interdependent tasks. But often these relationships are challenged by fragmented working practices; for example, with workers being on site at different times, or consultants working remotely. Virtual reality can help to improve communications throughout the project's lifespan, from sharing the finished vision in minute detail, through to providing site updates to those unable to visit the site regularly.

*Source:*http://accordantco.com/wp-content/uploads/construction-collaboration.jpg

*Source:*https://www.futurevisual.com/blog/construction-vr-training/

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101033740

How VR Technology is Being Used in the Construction Industry

Training

One of the key areas where immersive technology is making a real impact is in construction VR training. Immersive learning experiences give employees the chance to get hands-on and practical experience in a safe, risk-free environment. From health & safety training through to training in intricate technical tasks, virtual reality can help to hone skills, boost performance and improve collaborative working practices.

*Source:*https://www.build-review.com/wp-content/uploads/2019/10/Virtual-reality.jpg

*Source:*https://www.futurevisual.com/blog/construction-vr-training/

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101033740

VR (Headset)

Virtual Reality Training is the digital simulation of lifelike scenarios for training purposes. Trainees enter a 360°, active learning environment, experiencing sights and sounds that dissolve the barrier between virtual and actual reality. Using the headset and controllers, trainees look, speak, and move about freely in a 3D virtual setting, interacting with simulated real-world tools, machinery, and other trainees and instructors.

*Source:*https://www.equipmentworld.com/technology/article/14969105/this-vr-training-simulator-is-the-first-for-construction-equipment

*Source:*https://pixovr.com/what-is-virtual-reality-training/#:~:text=PIXO%20VR%20Training-,What%20is%20Virtual%20Reality%20Training%3F,between%20virtual%20and%20actual%20reality.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101033740

Benefits of VR Training

- Improvements in job performance of 70+%
- Dramatic reductions in on-the-job human errors
- Increases in learning retention of up to 80%
- 40-60% reductions in time needed to train compared to traditional training methods
- Elimination of the cost and risk of unnecessary travel
- Enhanced team decision-making, workplace safety, and collaboration
- Inclusive of all four major learning styles, (Visual, Auditory, Reading/Writing, and Kinesthetic)

*Source:*https://pixovr.com/what-is-virtual-reality-training/#:~:text=PIXO%20VR%20Training-,What%20is%20Virtual%20Reality%20Training%3F,between%20virtual%20and%20actual%20reality.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101033740

Exoskeleton Suits

A robotic exoskeleton is a mechanical device worn by a human being for certain purposes or applications. An exoskeleton is generally considered to be a hard mechanical frame with joints that allow movement of the human operator.

*Source:*https://www.nbcnews.com/mach/innovation/robotic-exoskeletons-are-changing-lives-surprising-ways-n722676

*Source:*https://www.iberdrola.com/innovation/what-are-exoskeletons

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101033740

Exoskeleton Benefits

1. ***Injury and Strain Prevention***

Exoskeletons cut down on overexertion by supporting workers' upper limbs when performing monotonous activities.

2. ***Withstanding Repetitive Tasks***

Reduces strain for repetitive activities such as painting ceilings.

3. ***Increased Productivity***

Exoskeletons have been proven to increase workers' endurance by reducing the amount of energy exerted on repetitive tasks.

4. ***More Work Accuracy***

You can practically maintain most of your attention and focus on the task at hand without the distraction of strain and fatigue.

5. **More Opportunities For Aged Contractors**

With a construction exoskeleton, all workers are able to handle more strenuous work effectively.

*Source:*https://eksobionics.com/5-amazing-ways-to-use-exoskeletons-for-construction/#:~:text=You%20can%20enjoy%20many%20benefits,joints%2C%20and%20increasing%20work%20efficiency.&text=Exoskeletons%20cut%20down%20on%20overexertion,limbs%20when%20performing%20monotonous%20activities.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101033740

Benefits of VR for Circular Economy

Utilising Virtual Reality headsets and exoskeletons, waste can be reduced throughout training and building.

During training less materials must be used for Virtual on site training which can add value to the training that is provided. This can also reduce the number of mistakes or mishaps on site as the worker will have added training and added efficiency, leading again to a reduction in material use and waste.

*Source:*https://www.theengineer.co.uk/content/opinion/comment-how-ar-vr-is-helping-construction-go-green/

*Source:*https://eksobionics.com/5-amazing-ways-to-use-exoskeletons-for-construction/#:~:text=You%20can%20enjoy%20many%20benefits,joints%2C%20and%20increasing%20work%20efficiency.&text=Exoskeletons%20cut%20down%20on%20overexertion,limbs%20when%20performing%20monotonous%20activities.

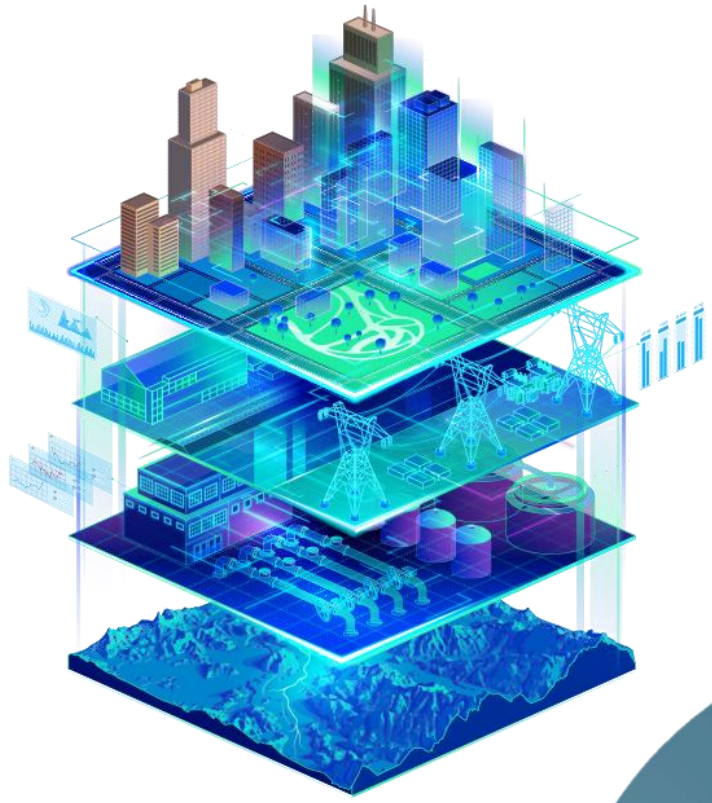
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101033740

Digital Twins

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101033740

What is a Digital Twin

A Digital twin is the creation of an online model that will act as a pair with the physical building through tools such as BIM and CAD. These models will allow the user to explore and test the buildings usability, track the building life (can be paired with material passports and increase the sustainability of the building). This can be done by insuring that material use is optimised, tracking materials for repair and service and allowing for material passports and other such documents to be completed.



Source:https://www.esri.com/en-us/digital-twin/overview

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101033740

What are the Levels of Digital Twins

DESCRIPTIVE TWIN

- A live, editable version of design and construction data

INFORMATIVE TWIN

- Additional operational and sensory data

PREDICTIVE TWIN

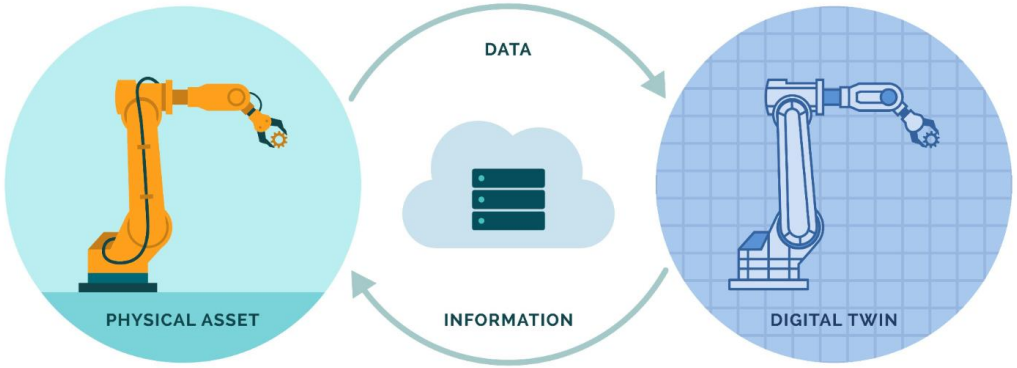
- Leverage operational data for insights

COMPREHENSIVE TWIN

- Simulation for future what-if scenarios

AUTONOMOUS TWIN

- Ability to learn and act on behalf of users



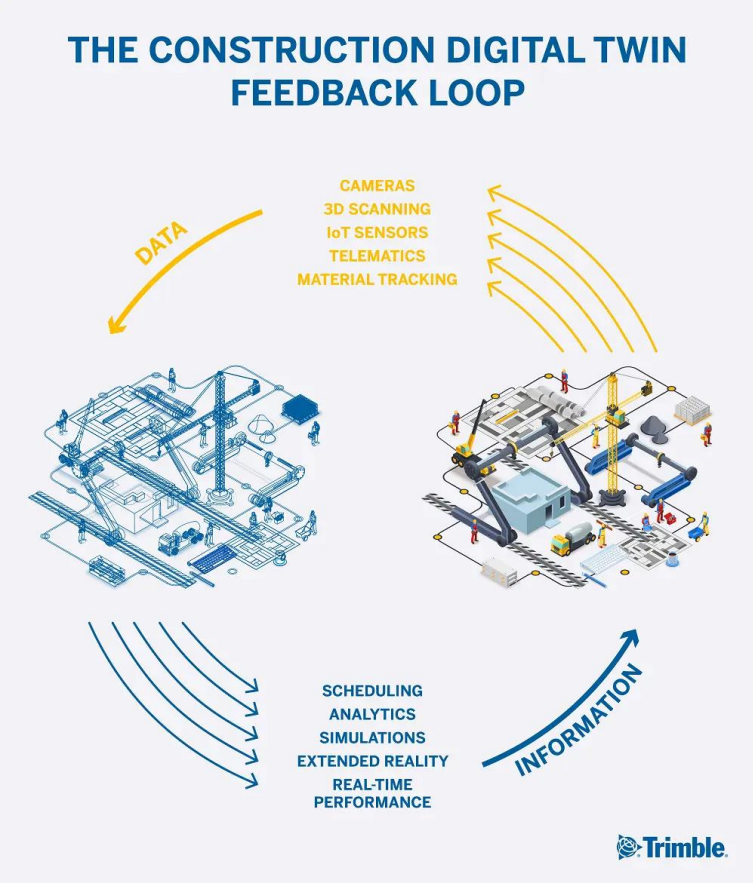
*Source:*https://www.datacenterknowledge.com/security/how-secure-digital-twin-technology-your-data-center

*Source:*https://damassets.autodesk.net/content/dam/autodesk/www/solutions/digital-twin/architecture-engineering-construction/pdf/adsk-aec-digital-twin-ebook.pdf

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101033740

Benefits of Digital Twins

Resource Management: Digital twins make it possible to create an information pipeline between the office and the field. With the aid of automatic data delivery, project stakeholders can predict allocation issues and help balance labor costs with budgets. This helps the jobsite run more efficiently and affordably.



*Source:*https://constructible.trimble.com/construction-industry/what-are-digital-twins

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Benefits of Digital Twins

Connectivity: Digital twins deliver information in a centralized platform. This technology takes BIM a bit further by automatically updating 3D models with constructible data. Component dimensions, model details, working conditions, and more can be added to content-enabled models. This way, no details get lost as a model evolves with the building over the years.

The benefits of digital twins don’t end when the initial construction is complete. They continue to offer smart solutions to everyday asset use.

*Source:*https://constructible.trimble.com/construction-industry/what-are-digital-twins

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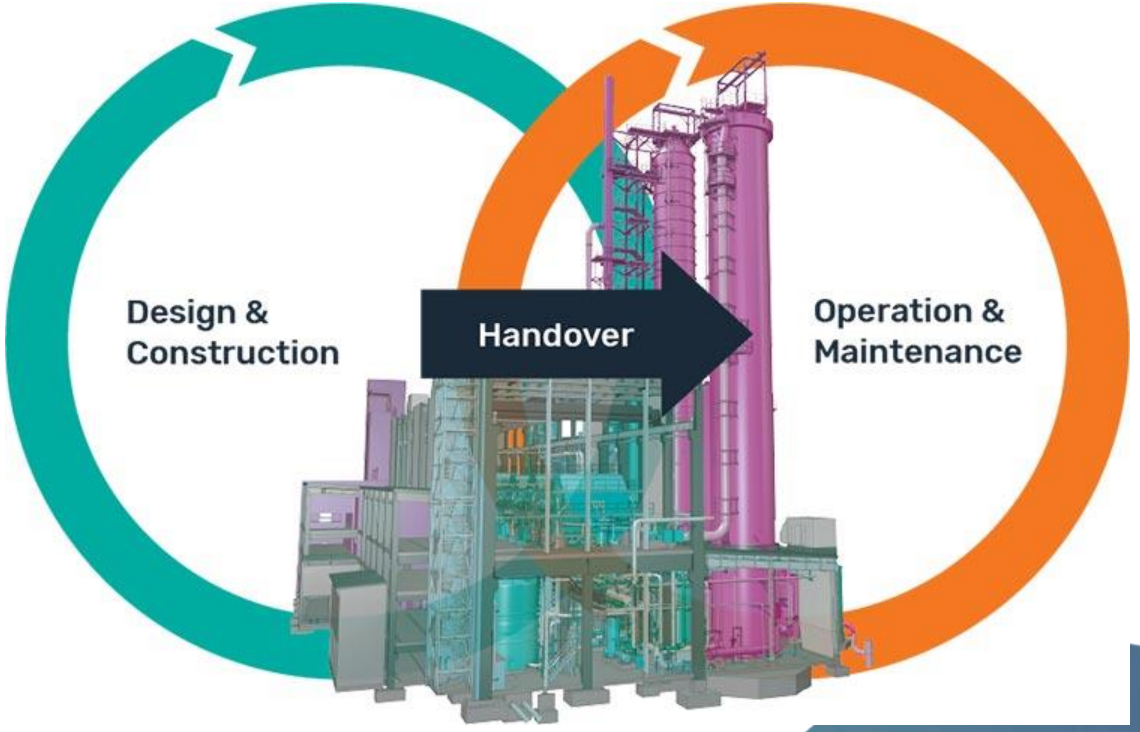
Benefits of Digital Twins

Value-added deliverable: Digital twins can be handed over to the project owner to help support ongoing structural enhancements. The insight they provide can help inform future decision making and offer invaluable insight into day-to-day operations. A digital twin can also be a value-added asset for clients looking to leverage data in future optimization projects.



*Source:*https://www.cadmatic.com/en/solutions/digital-twin/digital-twins-driving-digital-transformation/

*Source:*https://constructible.trimble.com/construction-industry/what-are-digital-twins

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Benefits of Digital Twins

Streamlined facility management: Digital twins can offload much of the burden of asset management. For example, when a repair is needed, a digital twin can pinpoint problem areas and share necessary specs with techs. It can even keep track of who to bill for the work.

*Source:*https://constructible.trimble.com/construction-industry/what-are-digital-twins

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Benefits of Digital Twins

Ongoing improved efficiencies: To truly increase efficiency, you need to know how the facility is being used. KONE recently used digital twins to analyze how people are using elevators. Sensors were used to track how people moved through buildings. The goal: cut down elevator wait times, especially during busy mornings.

*Source:*https://www.reutersevents.com/supplychain/technology/digital-twins-way-improve-efficiency-logistics

*Source:*https://constructible.trimble.com/construction-industry/what-are-digital-twins

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Disadvantages of Digital Twins

Lack of connectivity: Digital twin methods help elevate BIM to something more than CAD display. Unfortunately, BIM models are often created without use of as-built data. This results in a digital representation that isn't a true twin — one that can't be connected to the internet of things (IoT).

Outdated information: Too often, contractors don't update design models with change orders. Without accurate, real-time data, a digital twin can't work as intended.

*Source:*https://constructible.trimble.com/construction-industry/what-are-digital-twins

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Digital Twins and BIM

The BIM process incorporates data created during the planning and design phases. Digital twin extends data capture to the construction and operational phases of the asset—and can also inform planning and design for future projects.

Realizing the full promise of digital twin requires multidisciplinary models at the core and an integration of systems and data across workflows and between organizations. BIM is the most efficient path to the creation of an accurate, high-value digital twin.

*Source:*https://www.autodesk.com/solutions/digital-twin/architecture-engineering-construction

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Material Passports

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101033740

Material Passports - The Aim

- Increase the value or keep the value of materials, products and components over time
- Create incentives for suppliers to produce healthy, sustainable and circular materials/building products
- Support materials choices in Reversible Building Design projects
- Make it easier for developers, managers and renovators to choose healthy, sustainable and circular building materials
- Facilitate reversed logistics and take back of products, materials and components

*Source:*https://www.bamb2020.eu/topics/materials-passports/

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101033740

Orms - Material Passport

Orms created a material passport guideline which walks users through the creation one.

https://orms.co.uk/insights/materialpassports/

*Source:*https://www.bamb2020.eu/topics/materials-passports/

*Source:*https://www.bamb2020.eu/topics/materials-passports/

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Barriers to Material Reuse

Cost

It’s typically cheaper to demolish and buy new, rather than deconstruct and refurbish

Design

Contemporary construction favours chemical fixing over mechanical. Making it time consuming to remove materials and often damages them in the process.

Risk

There is often a lack of knowledge about an existing material, and therefore a lack of confidence in it. How can we trust the material will perform as we need it to?

*Source:*https://www.bamb2020.eu/topics/materials-passports/

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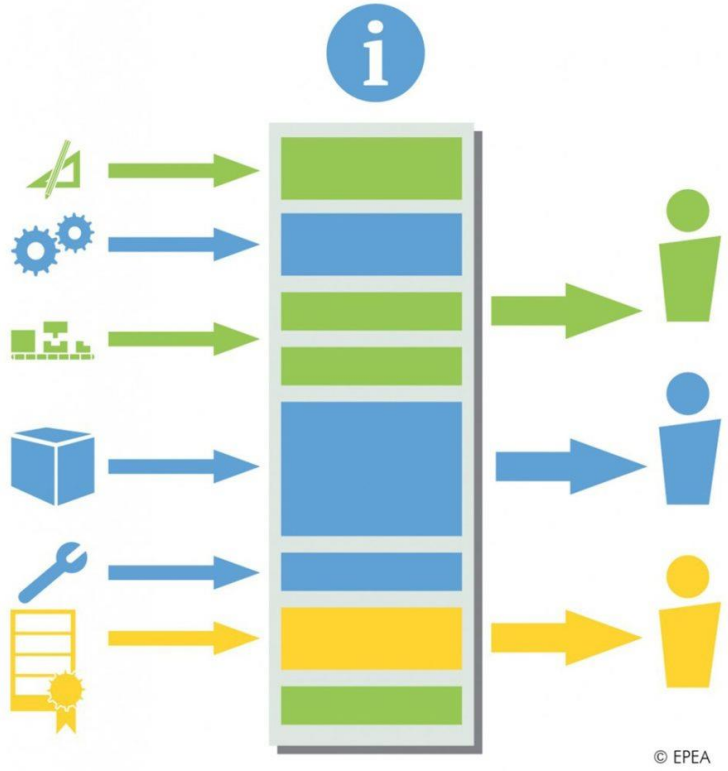
What is a Material Passports

Waste is a material without an identity

Thomas Rau

A passport gives that material an identity. Knowledge about a material gives us confidence in it, enabling successful reuse



*Source:*https://www.bamb2020.eu/topics/materials-passports/

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Material Passports - Steps

Material Identification

For most existing Buildings as Material Banks, it is unlikely that we will have sufficient data records to assess the reuse potential of the existing materials.

We recommend that a series of comprehensive surveys are carried out at an early stage, to identify the existing materials within the Material Bank. This allows for informed design decisions to be made.

*Source:*https://www.bamb2020.eu/topics/materials-passports/

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Material Passports - Steps

The Material Database

We recommend that Material Passporting is carried out along with the implementation of BIM, to ISO Standard 19650-1/2. BIM offers a standardised process to manage large quantities of data. It also ensures a higher quality 3D model and potential for a digital twin.

*Source:*https://www.bamb2020.eu/topics/materials-passports/

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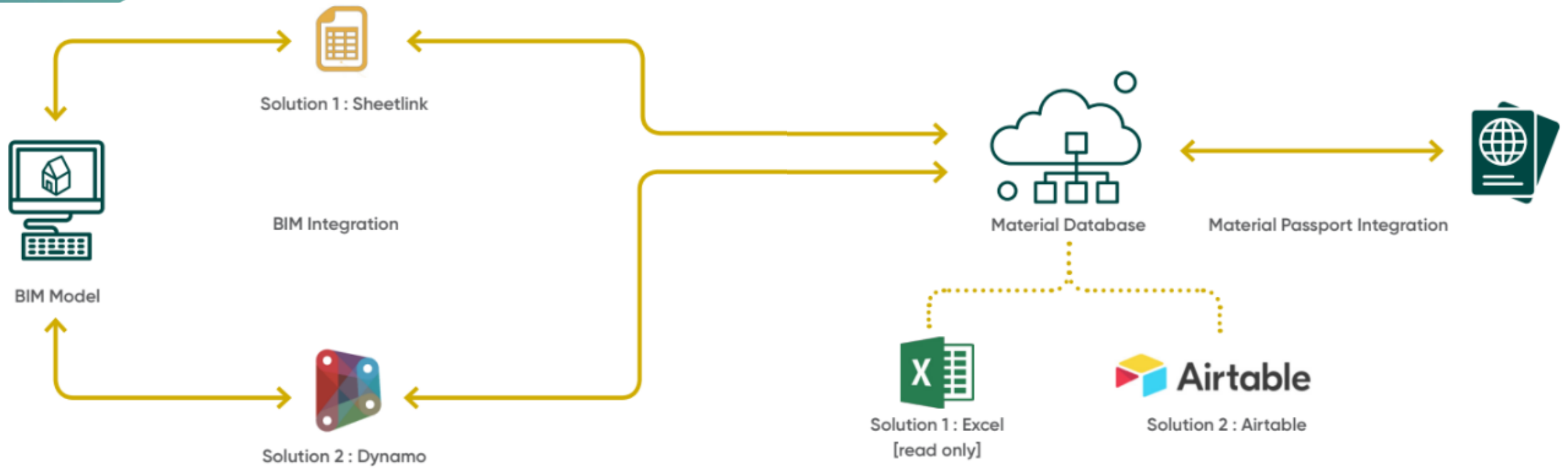
Material Passports - Overview



*Source:*https://www.bamb2020.eu/topics/materials-passports/

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Material Passports - The Tools Available

Tool 1 - Implementation Guide

- This guide provides step by step instructions on how to get started.

Tool 2 - Naming Conventions

- To facilitate cross referencing between the database, revit file and physical tags on built assets, we have implemented a human friendly naming format.

Tool 3 - Shared Parameters for Revit

- A Shared Parameters file contains the parameters included in the sample excel database.

Tool 4 - Dynamo Script for Revit

- This is provided as a starting point for teams capable of implementing the Dynamo scripting for creating a bidirectional link between the Material Database and Revit.

Tool 5 - Sample Excel Database

- For teams using Revit, this is a reference file only. The actual database file must be generated by Revit using either Sheetlink or Dynamo, as this sets up the bidirectional link.

*Source:*https://www.bamb2020.eu/topics/materials-passports/

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Material Passports - Future opportunities

Interface with BIM Model

This is the area of greatest opportunity. We imagine the creation of a Revit plug in to replace the Dynamo script. This would give greater control over the fields that are imported for each element category, and increase automation.

Material Warehouse

A technical challenge of phasing within Revit could be addressed by creating a virtual Material Warehouse. Deconstructed elements in the ‘Existing Phase’ are temporarily stored and reused in the ‘New Construction Phase’.

Material Database

We are in the process of creating a cloud based database system. This will improve functionality, allow for some automations and deliver an interactive Material Passport which can be accessed by scanning the physical tag in the building.

Interface with Wider Portfolio

Digital Twins have the potential to unlock greater information sharing across a portfolio. Linking or consolidating Material Databases of projects will support future material reuse and insight into real time value of each Material Bank.

*Source:*https://www.bamb2020.eu/topics/materials-passports/

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Material Passports - Summary

Our goal was to develop an open source methodology to Material Passporting for existing buildings, that would be accessible to design teams of all sizes and capabilities.

As an industry, we must do better, and the fastest way to achieve this is by sharing our knowledge and collaborating on meaningful solutions.

Therefore we invite you to implement Material Passporting on your project, please get in touch to join our network. In return, all we ask is that you share your experience, findings and solutions back with us, so that the research can continue to evolve.

This is an exciting time, and we look forward to collaborating with partners as we advance towards a Circular Economy.

*Source:*https://www.bamb2020.eu/topics/materials-passports/

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Material passports - Learn More

Orms -

https://orms.co.uk/insights/materialpassports/

BAMB -

https://www.bamb2020.eu/topics/materials-passports/

https://www.youtube.com/watch?v=9pB6axd7gQk&t=1s

Madaster -

https://madaster.com/platform/

Metabolic -

https://www.metabolic.nl/publications/materials-passports/

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101033740

3D Printing and Prefabrication

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101033740

3D Printing

3D printing in construction has some limitations due to the scale of both the aspects that need to be printed and the scale of the printer. The opportunities in construction can be identified when pairing 3D printing with concepts such as Design for Disassembly and Product-as-a-service. This can allow for easy replacements of minor elements of products or slight alterations to original designs by printing these pieces when necessary.

Source:https://www.liteworldllc.com/3d-printed-replacement-parts/

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101033740

Benefits of 3D Printing

Flexible Design

3D printing allows for the design and print of more complex designs than traditional manufacturing processes.

Rapid Prototyping

3D printing can manufacture parts within hours, which speeds up the prototyping process.

Print on Demand

Print on demand is another advantage as it doesn’t need a lot of space to stock inventory, unlike traditional manufacturing processes.

Fast Design and Production

3D printing can print objects within hours, which is much faster than moulded or machined parts.

*Source:*https://www.twi-global.com/technical-knowledge/faqs/what-is-3d-printing/pros-and-cons

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Benefits of 3D Printing

Minimising Waste

Little or no wastage as compared to alternative methods which are cut from large chunks of non-recyclable materials.

Cost Effective

3D printing saves time and therefore costs associated with using different machines for manufacture.

Ease of Access

3D printers are becoming more and more accessible with more local service providers offering outsourcing services for manufacturing work.

Environmentally Friendly

This technology reduces the amount of material wastage.

*Source:*https://www.twi-global.com/technical-knowledge/faqs/what-is-3d-printing/pros-and-cons

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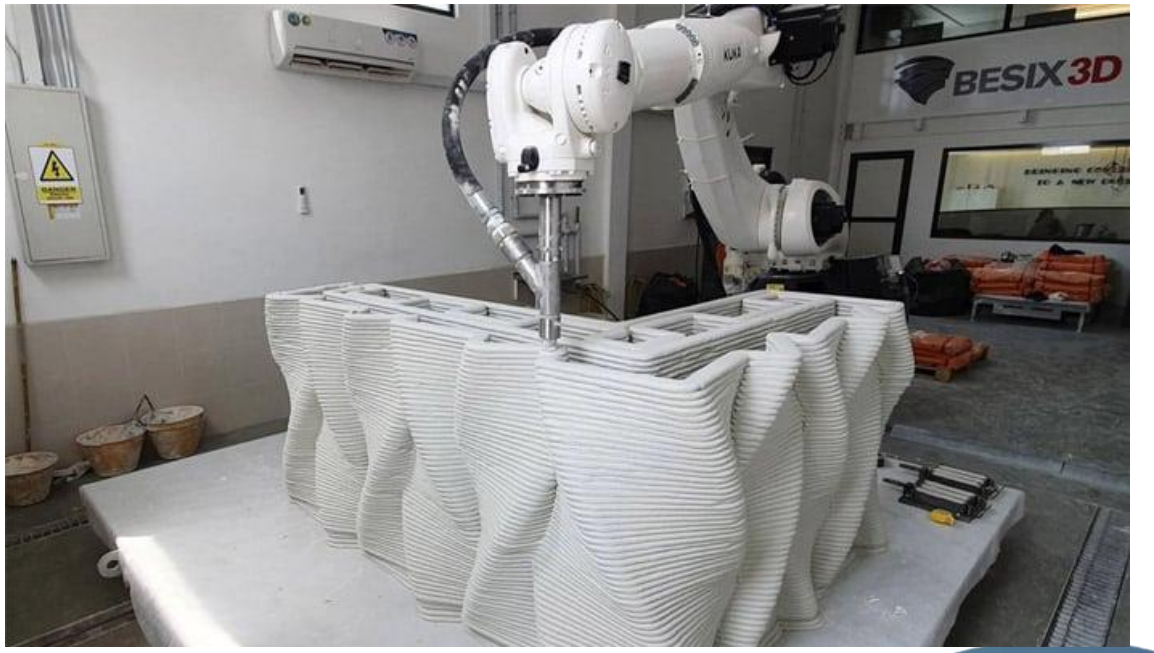
Types of 3D Printing in Construction

Robotic arm extruders

The rails are arranged to let the robotic arm move, and within the limits of the rails, the arm will build the house layer by layer by extruding concrete material from the nozzle. This is the most popular 3D printing technology used to build XL structures.



*Source:*https://www.3dnatives.com/en/robotic-arms-3d-printing-141020226/

*Source:*https://www.sculpteo.com/en/3d-learning-hub/applications-of-3d-printing/construction-and-architecture/

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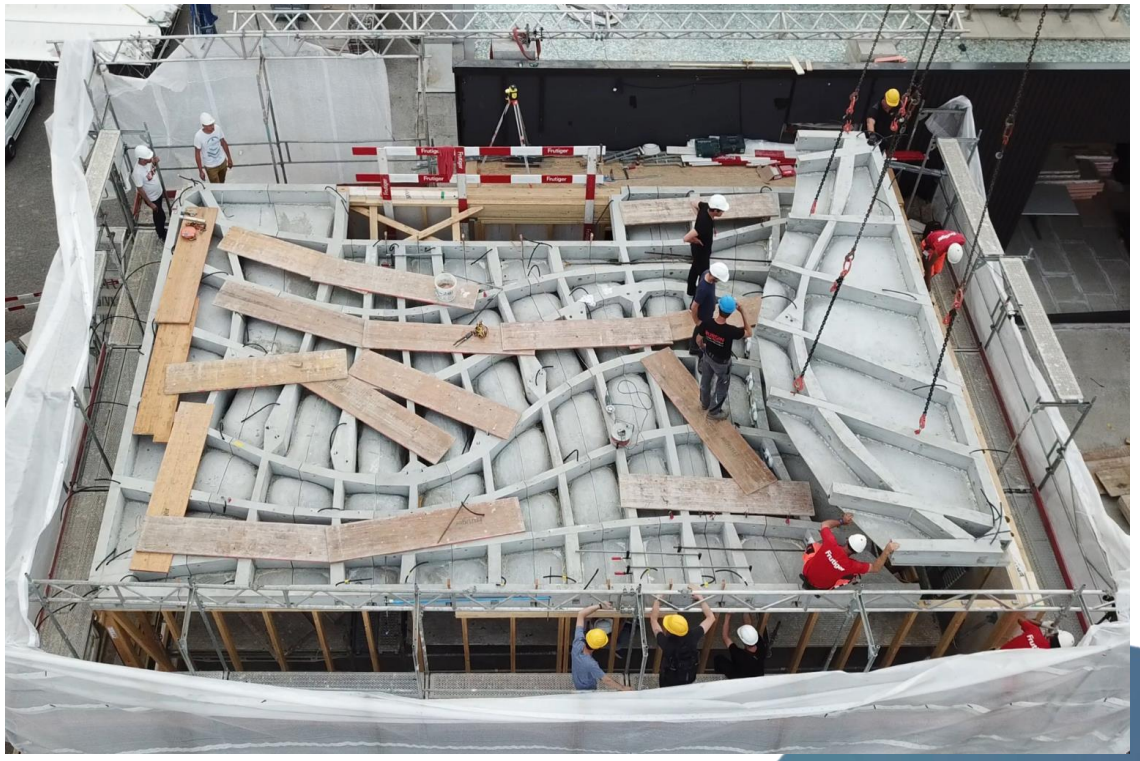
Types of 3D Printing in Construction

Sand 3D printing

The pioneer who tested it was the Italian architect Enrico Dini, who built his D-Shape 3D printer. The machine spreads a layer of sand powder, then hardens the structure's shape with a binder.



*Source:*https://blog.drupa.com/en/pioneers-in-3d-printing-eth-zurich-uses-3d-sand-printing-for-real-scale-architectural-project-2/

*Source:*https://www.sculpteo.com/en/3d-learning-hub/applications-of-3d-printing/construction-and-architecture/

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Types of 3D Printing in Construction

Metal technology

For structures such as bridges, which have to withstand more stress, Dutch company MX3D developed Wire Arc Additive Manufacturing (WAAM). The team described the technology: “we combined an industrial robot with a welding machine to turn it into a 3D printer that works with our software”. The robot allows for 3D printing metal structures in 6-axes.

*Source:*https://www.sculpteo.com/en/3d-learning-hub/applications-of-3d-printing/construction-and-architecture/

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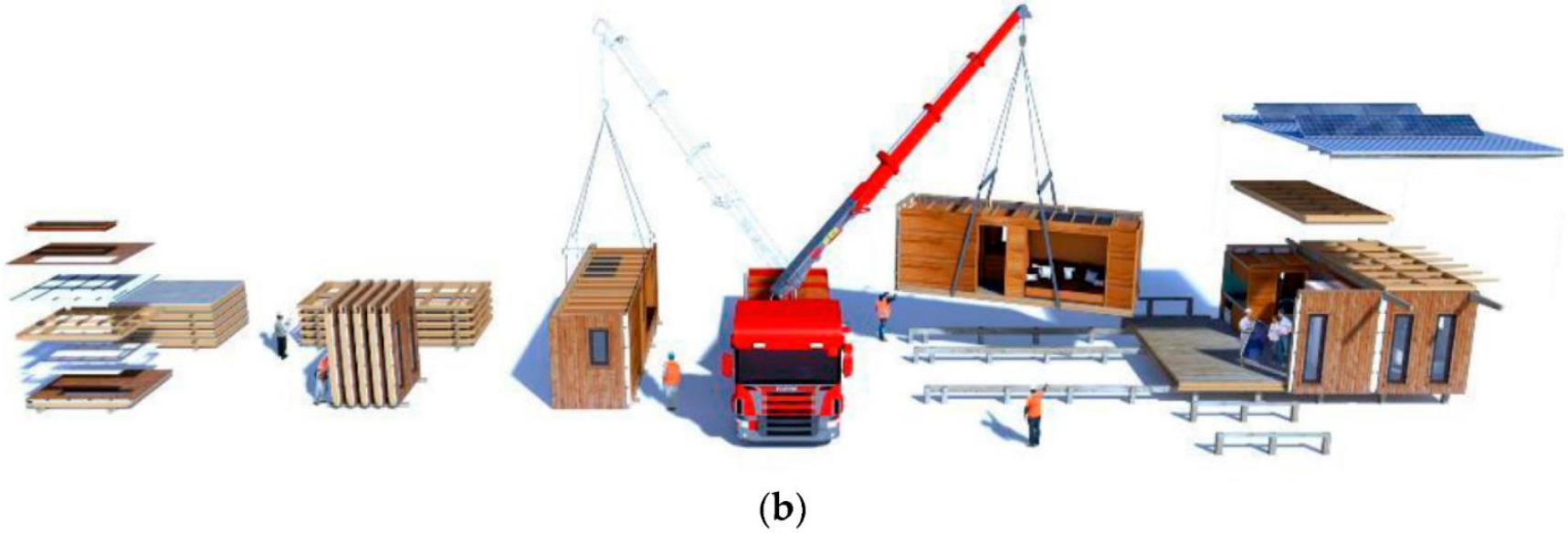
Prefabrication

prefabrication, the assembly of buildings or their components at a location other than the building site. The method controls construction costs by economizing on time, wages, and materials. Prefabricated units may include doors, stairs, window walls, wall panels, floor panels, roof trusses, room-sized components, and even entire buildings.



(b)

*Source*https://www.mdpi.com/2071-1050/8/6/558

*Source:*https://www.britannica.com/technology/prefabrication

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101033740

Benefits of Prefabrication

1. Impacts Technology Trends with Advanced Design Tools

The construction industry has reinvented prefabrication and modularization due to the innovations in construction technology. BIM (Building Information Modeling) technology is a useful tool that is making the construction industry more environmentally sustainable and economical.

2. Better Safety & Security

Construction is a hazardous industry to work in, so companies want to implement safer processes. With prefabrication, there is less risk for problems with dirt, moisture, and other environmental hazards because workers create subassemblies in factory-controlled environments

*Source:*https://esub.com/blog/7-benefits-prefabrication-construction/

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Benefits of Prefabrication

3. Cost-effectiveness

Prefabrication reduces the cost of labor, further offsetting the rising costs of materials.

4. Consistency & Quality Control

Factory tools used in prefabrication offer additional quality assurance compared to repeated construction on-site. Sub-assemblies in prefabricated construction are produced in a controlled manufacturing environment and follow specified standards, therefore built to a uniform quality.

*Source:*https://esub.com/blog/7-benefits-prefabrication-construction/

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Benefits of Prefabrication

5. Flexibility

Without difficulty, workers disassemble and relocate sub-assemblies to different sites.

6. Green Construction

Compared to traditional construction, prefabricated and modular buildings are more eco-friendly in both the short-term and long-term. Traditional construction processes require more materials that lead to more waste. Prefabrication has a lower environmental impact because extra materials are recyclable. Whereas, on a traditional site, waste goes directly to a landfill. A factory's controlled environment allows for better air filtration for better wall insulation, which directly increases efficiency for energy.

*Source:*https://esub.com/blog/7-benefits-prefabrication-construction/

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Benefits of Prefabrication

7. Saving Time and Accelerating Construction Process

With prefabrication, it takes a significantly less amount of time to build compared to on-site construction. In fact, it takes less than half the time compared to traditional on-site construction.

*Source:*https://esub.com/blog/7-benefits-prefabrication-construction/

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Application for Multi-functional Green Roofs Facades and Interior Elements

Presentation

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101033740

Application for Multi-functional Green Roofs Facades and Interior Elements

All of the above applications can be applied to MGRFIE to allow for easy implementation, reduced waste , increased speed and digital tracking.

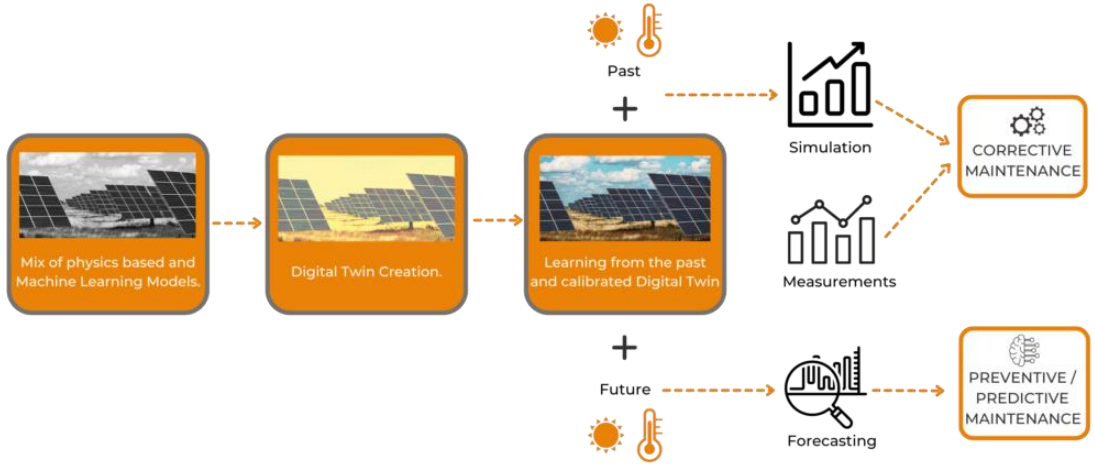
What other opportunities are possible with Digitalization of MGRFIE?

*Source:*https://www.mvrdv.nl/projects/30/the-couch
THE COUCH, Amsterdam, Netherlands, MVRDV

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101033740

Example -Digital Twins for Multi-functional Green Roofs Facades and Interior Elements

Digital twins can be a major positive for MGRFIE as it can allow for digital tracking of the building from less easy to access areas. i.e. green walls can be monitored and it can be very straight forward to monitor what must be updated or replaced or if there are leeks or damages.



Source:https://smarthelio.com/decoding-digital-twin-for-solar-plants/
Digital Tracking of Solar Panels

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QUIZ/ASSIGNMENT/ACTIVITY

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EXTRA READING/STUDY

Activity

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EXTRA READING/STUDY

For Further Case Studies and Training Material Please Follow the Link Below

https://docs.google.com/spreadsheets/d/1DTte4Ph8pQ4lKzYGFt2_S-d1Z_Rmd9-i/edit?usp=sharing&ouid=112148808974461842163&rtpof=true&sd=true

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EXTRA READING/STUDY

BIMzeED

https://bimzeed.eu/

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https://busgocircular.eu/

Follow us

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https://www.linkedin.com/company/busgocircular

https://www.youtube.com/channel/UCXu4Rjs5WDXBE-yqda5kt5A

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101033740

Colophon

BUS GoCircular

Partners

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