1.3 Computer modelling and BIM software

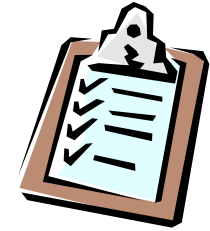*Ir Dr. Sam C. M. Hui*

Department of Mechanical Engineering
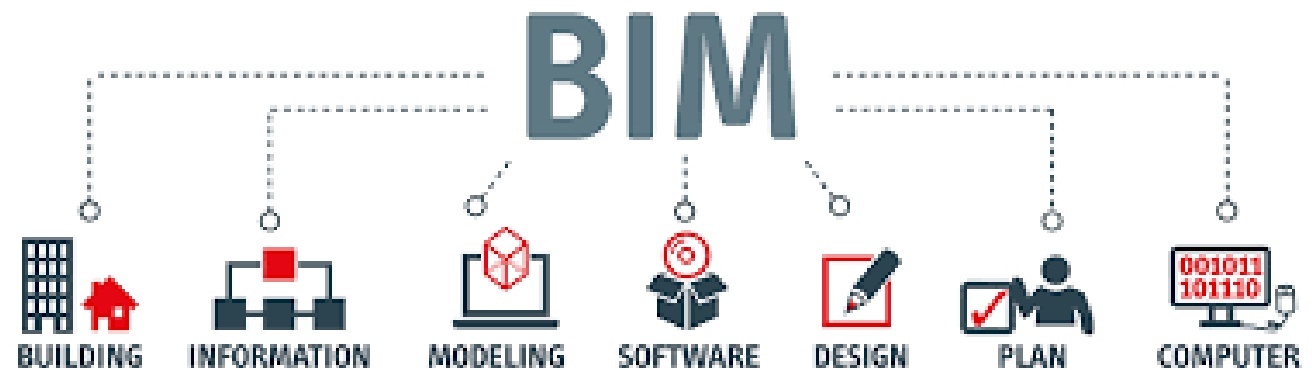The University of Hong Kong
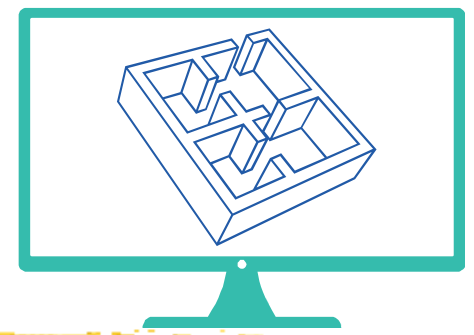E-mail: cmhui@hku.hk

May 2023

Contents

- Modelling

- Purpose of the model

- Hardware and software requirements

- Computer modelling techniques

- BIM software

- Latest trends

Modelling

- In BIM, every project is built TWICE
  - Once in a virtual environment to make sure that everything is just right and once in a real environment to bring the project to life

- BIM model is the overview of every other aspect of the building and its information
  - It provides an analogy or smaller-scale representation of the final appearance and effect
  - It will continue to model this representation throughout the building's lifespan
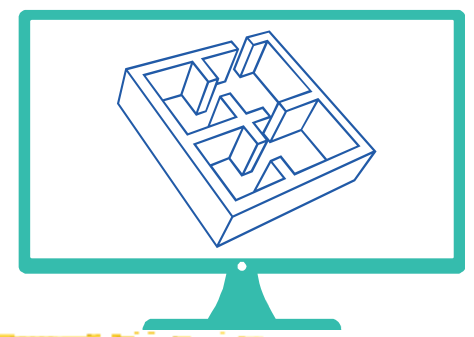
Modelling
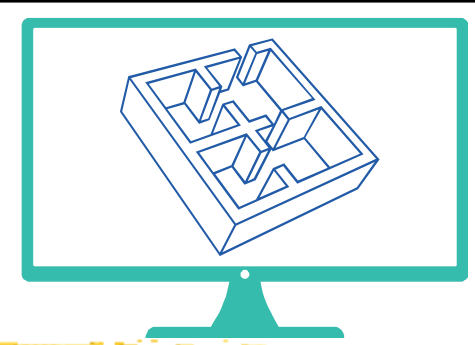
- Information modelling for BIM:
  - 3D model
  - 4D model - time
  - 5D model - time and cost
  - Energy model
  - Business model
  - Financial model
  - Safety plan
  - Maintenance plan
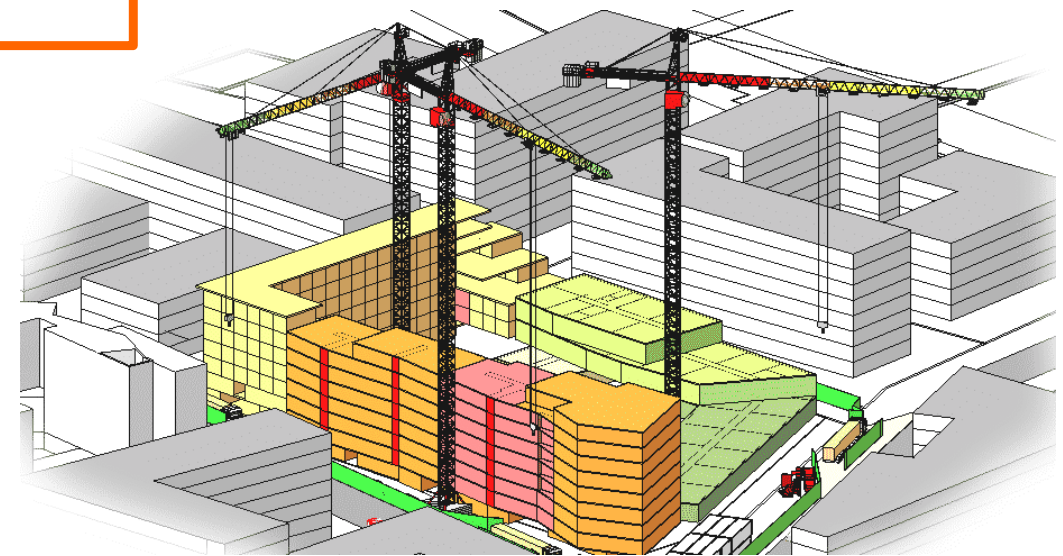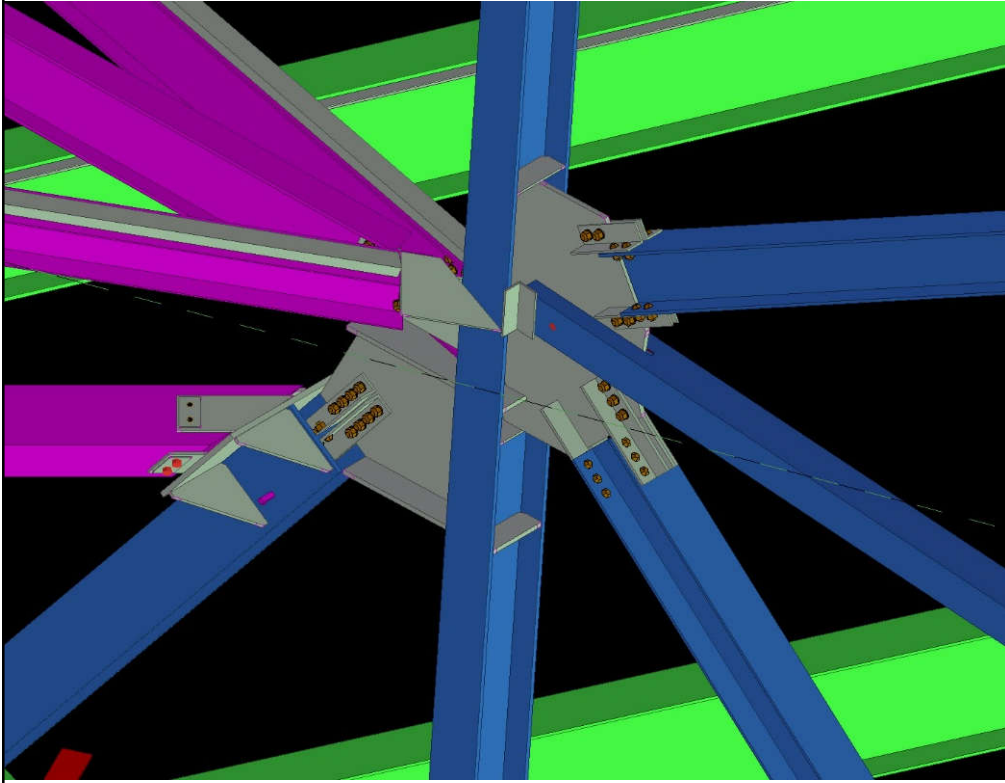
Modelling

- Practical types of BIM models:
  - Design models
    - Arch, Structure, MEP, Civil/Infrastructure
  - Construction document models
    - Arch, Structure, MEP, Civil/Infrastructure
    - Specifications
  - Contractor model (for construction & installation)
  - Facility management model (for O&M)
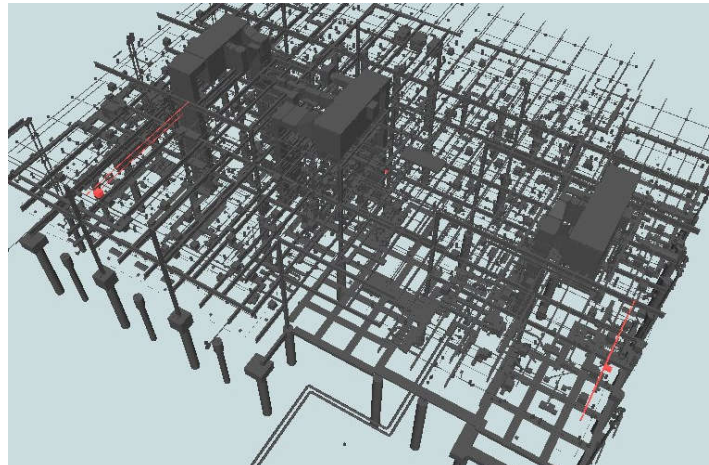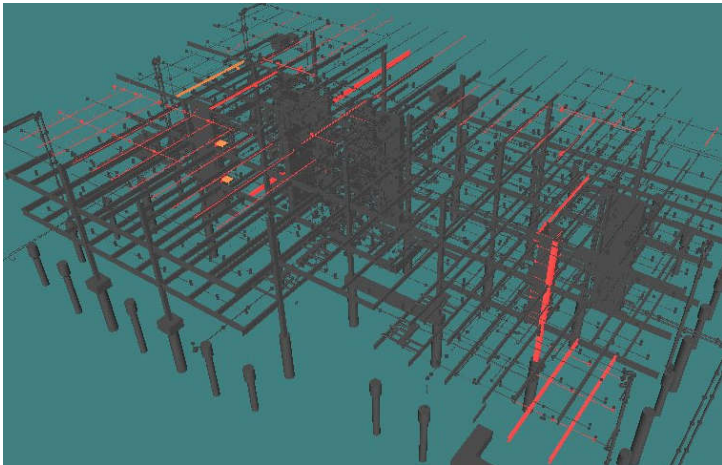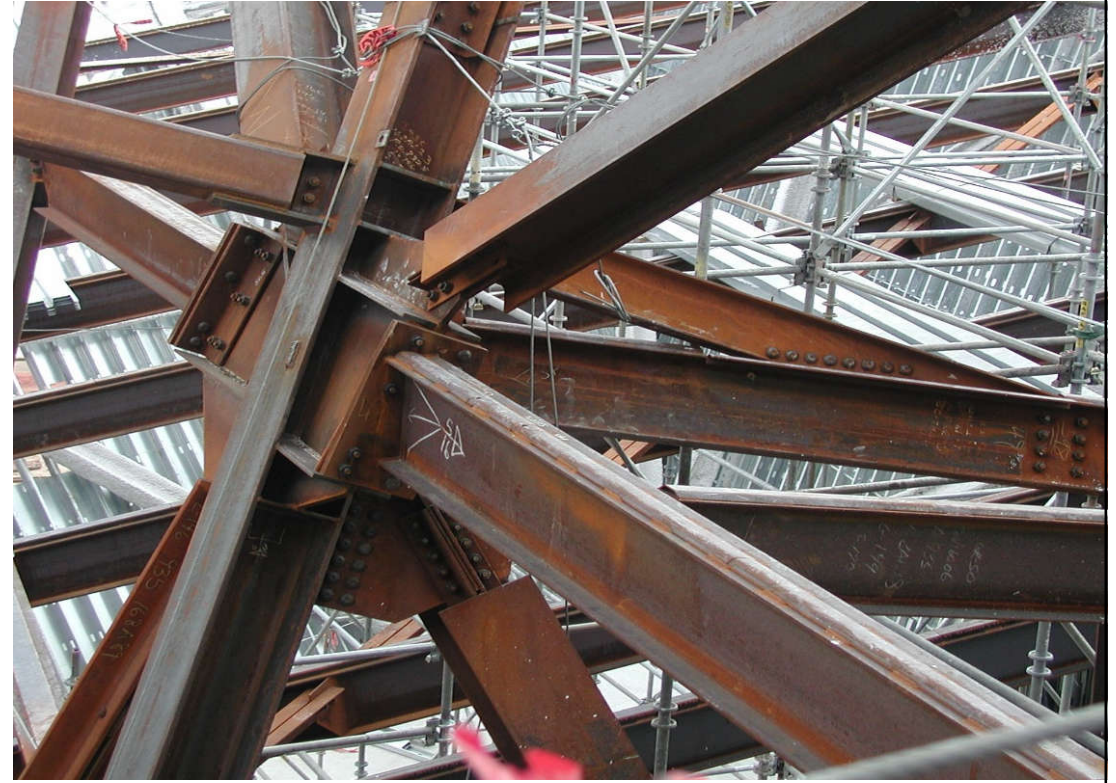 - Green/Sustainable design model

(Example: Video: Building Information Modelling - BIM (3:02) https://youtu.be/MWmJtqP1_XA)

BIM design models for structural engineering and clash analysis
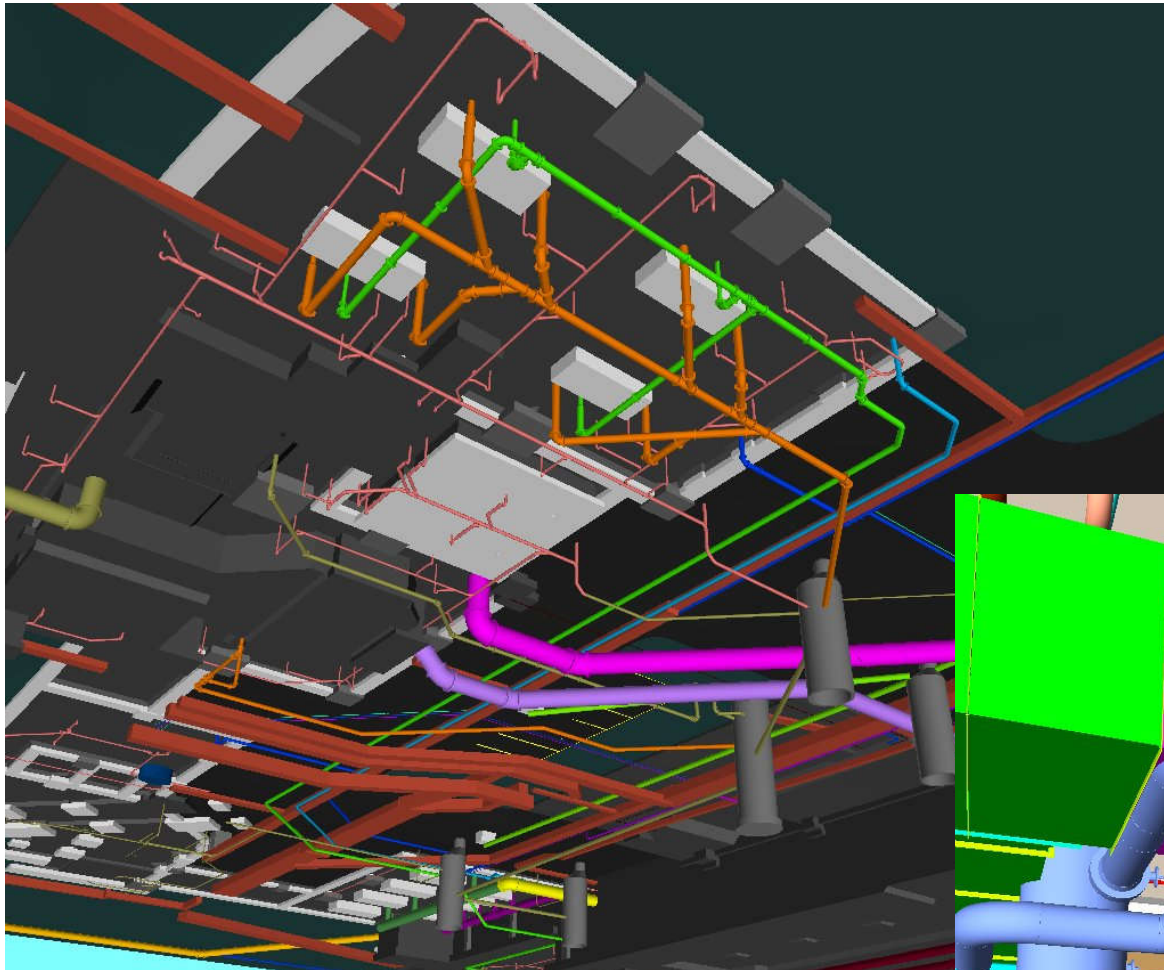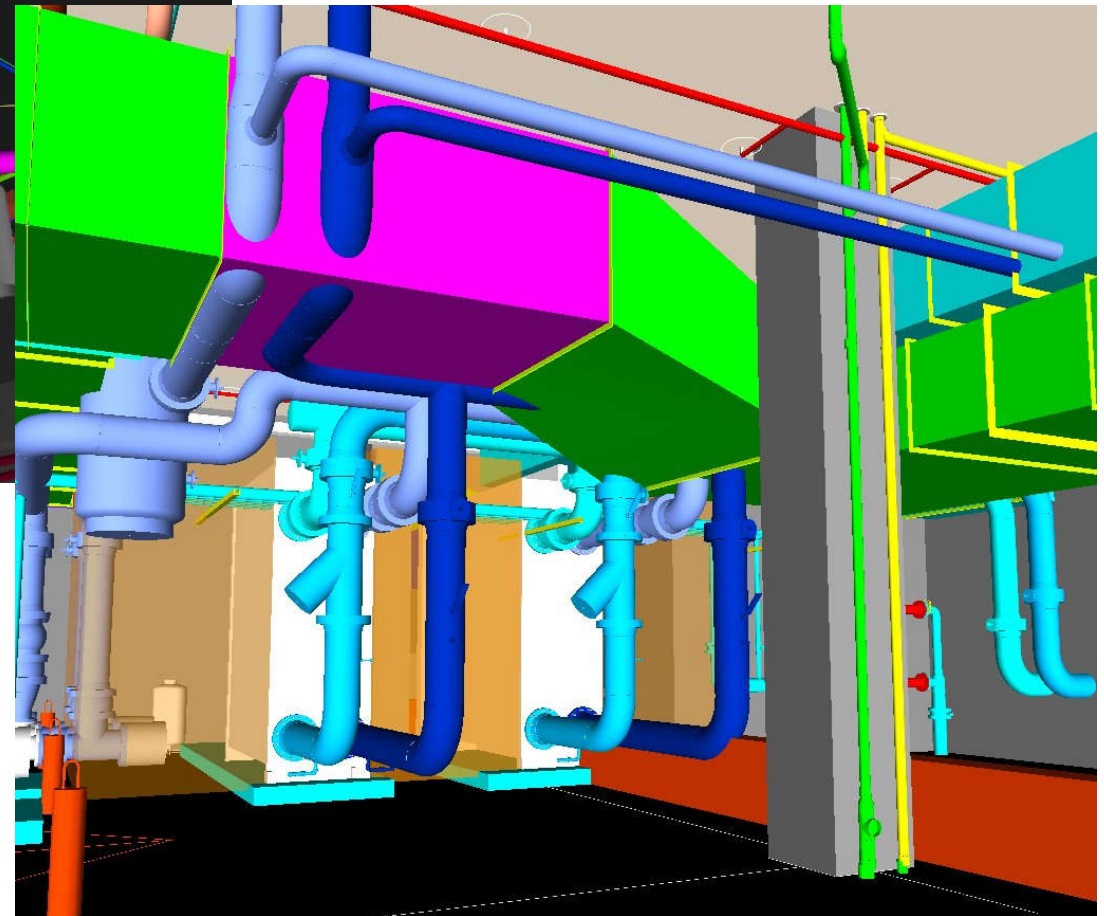
BIM 3D model

Actual installed

Clash analysis and coordination

BIM design models for building services engineering

On the ceiling

Inside plantroom

(Source: Butler Treatment Plant and Cronkite School of Journalism, UK)

Modelling
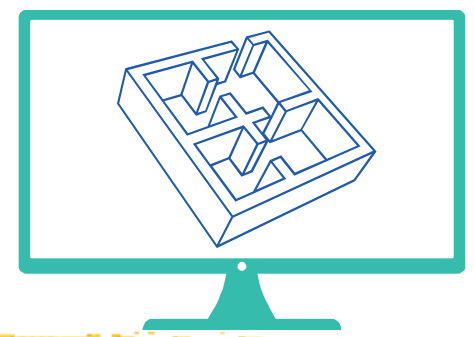
- Common uses of BIM for Building Services:
  - 1. <u>Collaboration and access</u>
    - Clash detection and coordination
    - Conceptual design and feasibility evaluation
    - Field management (on-site)
  - 2. <u>Simulation and analysis</u>
    - Mechanical/HVAC simulation
    - Air, fluid, flow, and thermal comfort
    - Energy analysis, green building design
  - 3. <u>Visualization</u> (rendering)

Collaborated model for BIM and common software tools
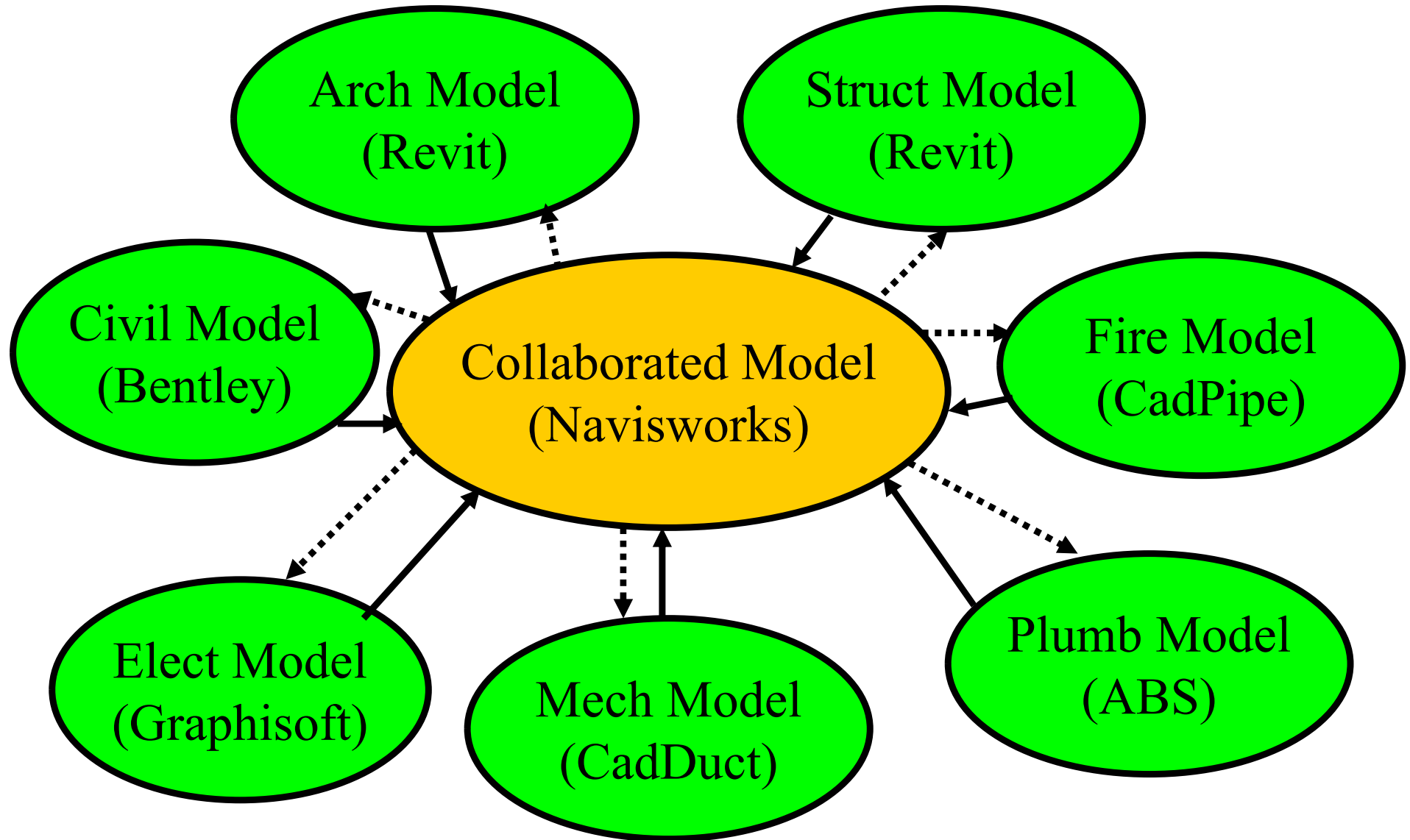
Individual scopes to consolidated model
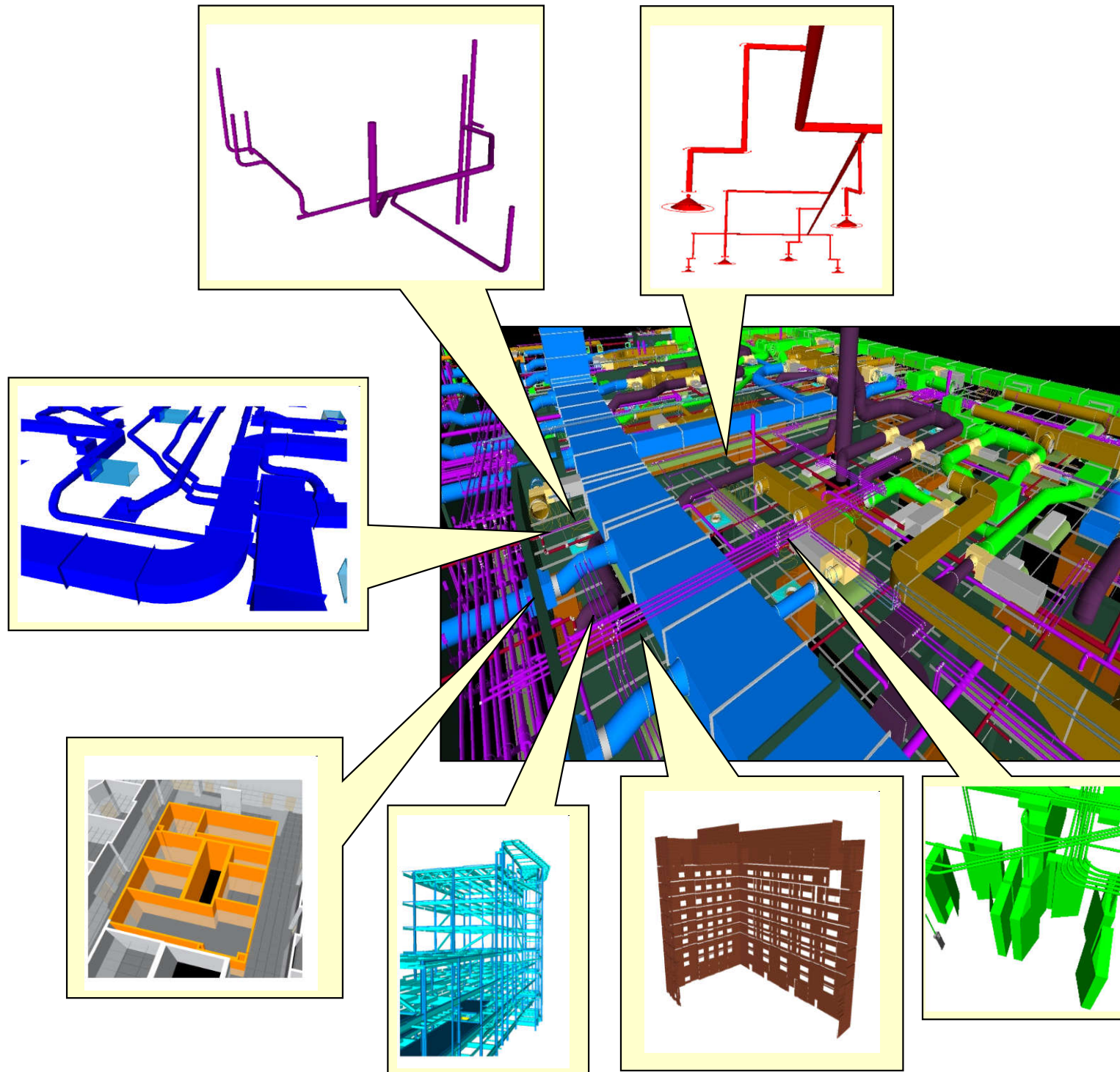
Modelling
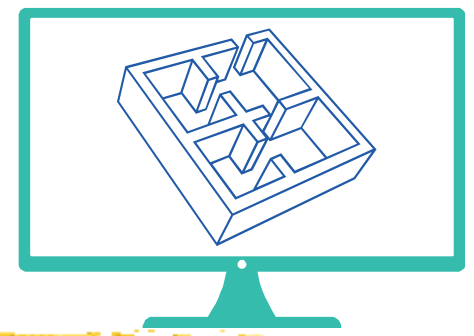
- Simulation 模擬
  - The process of developing a representative model of a system and using it to analyze and predict system behaviour and performance

- Modelling 建模 / 建立模型
  - Deals primarily with the relationship between actual dynamic processes and models
  - Usually involves iterations

- >> Support decision making

> Do you know the difference between simulation and modelling?

Building energy simulation and modelling

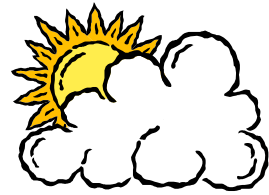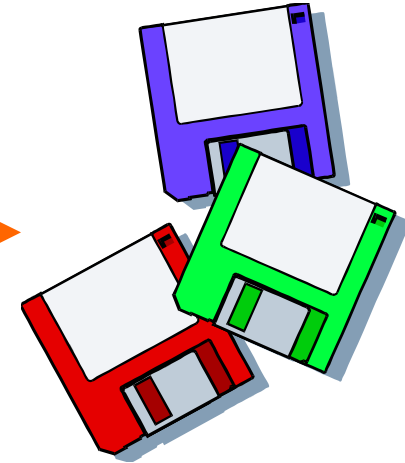(Building energy simulation - Wikipedia https://en.wikipedia.org/wiki/Building_energy_simulation)

Weather data
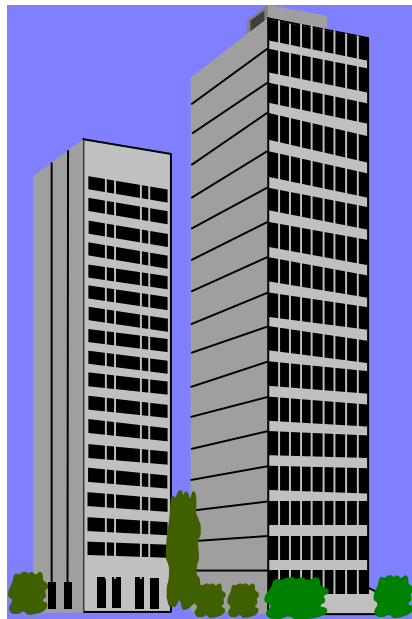
Building description

- physical data
- design parameters

Simulation tool (computer program)

Simulation outputs

- energy consumption (MWh)
- energy demands (kW)
- environmental conditions

Decisions

The following factors largely influence the successful modelling approach:

- Purpose of the model

- Complexity

- Model Size

- Hardware
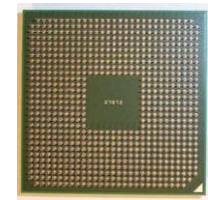
Purpose of the Model

Conceptual
Design

Visualization

Site
Planning

BIM
Modelling
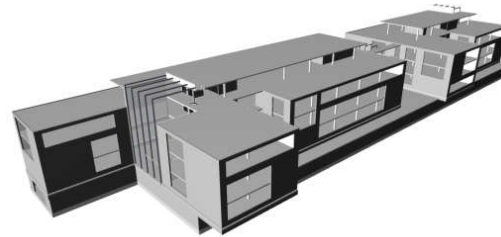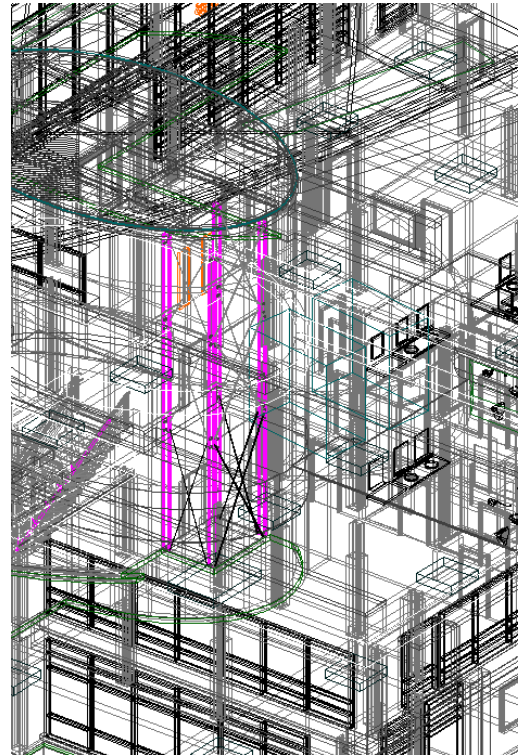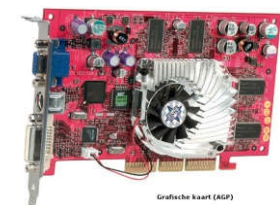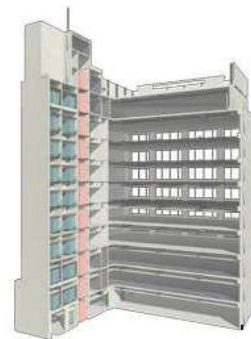

Construction
Coordination
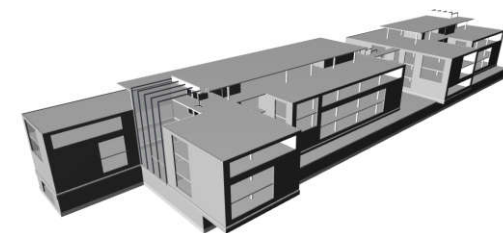
Structural
Design

Digital Surveys

- Direct import of site survey data from XYZ coordinates automatically convert into a mesh element.

- Refurbishment projects typically start with 3D laser scanning, which generate "point-clouds". Some BIM software, like ARCHICAD, can read the most commonly used point-cloud file formats and create the corresponding 3D geometry instantly.
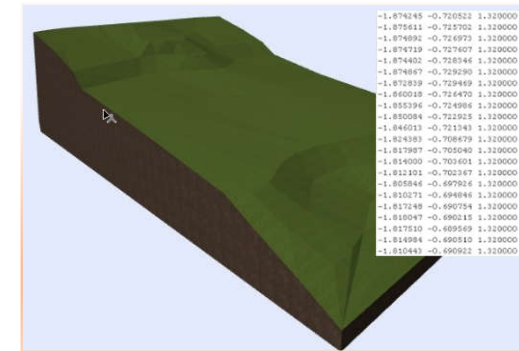
How to put 3D laser survey and **point-clouds** to work:

- Modelling existing buildings before renovation.

- Modelling the surroundings prior to creating a new building.

- Modelling the "as-built" structure to detect deviations from plan.

Scan to BIM by digital survey and laser scanning
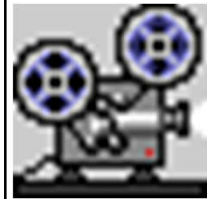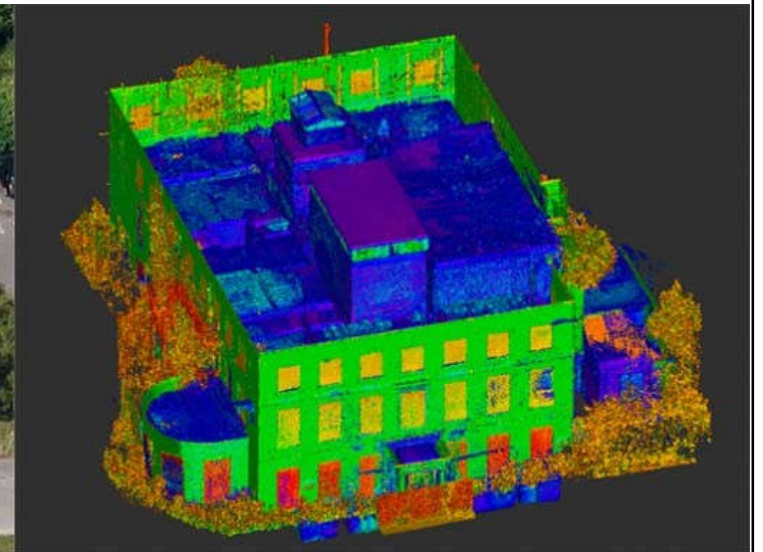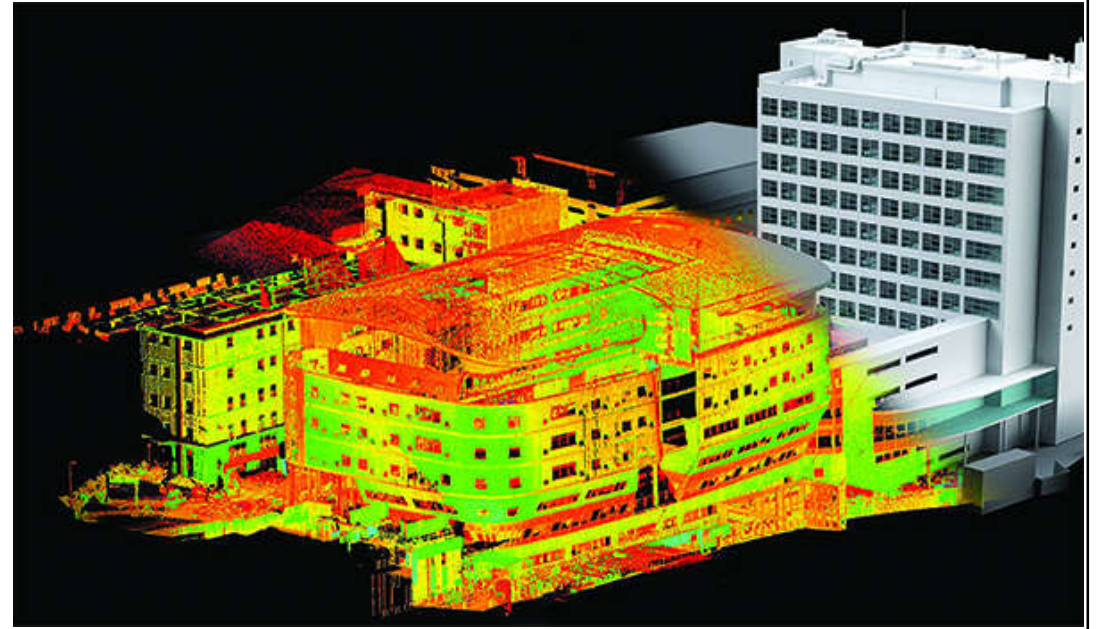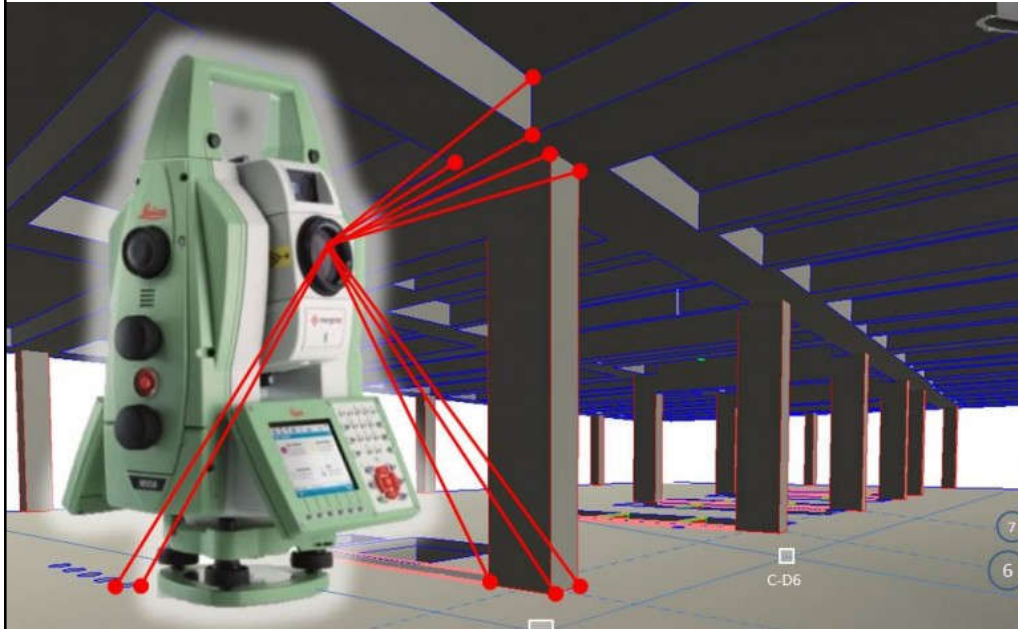
(Video: Laser Scanning & BIM or Scan-to-BIM (4:41) https://youtu.be/fqoNXUymGko)

Conceptual Modelling

- Main purpose of the model is to help making design decisions
- The model not neccessary includes the entire building (e.g. internal structures can be missing)
- Accuracy is not relevant
- Level of detail is typically lower then in BIM models (mass modelling)
- Materials can be symbolic or missing

http://www.sketchup.com
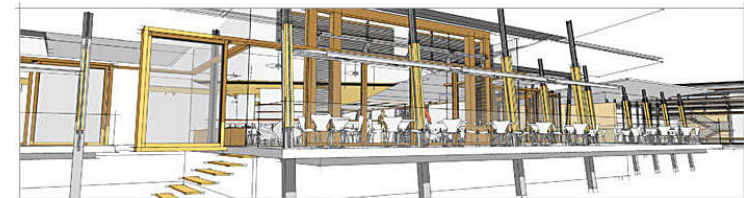
Modelling for Visualization

- Not necessary to model the entire building

- Only the elements of the actual view need to be shown

- Level of modelling detail should depend on the image quality and the distance from the camera

- Accurate texture coordination and lighting is essential
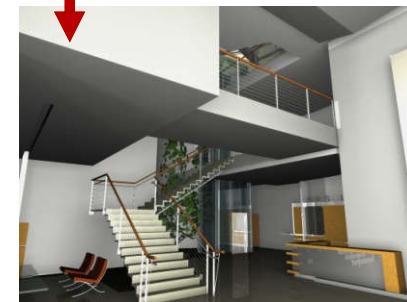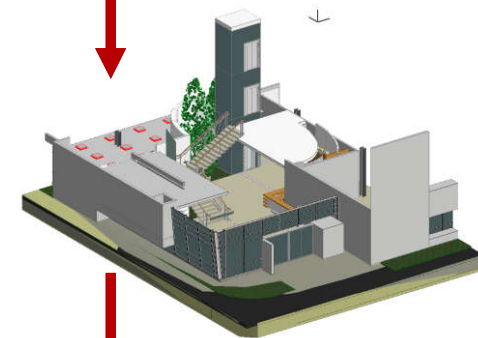
NHS Building, paastudio.com

BIM Modelling for Architecture

- The entire building has to be modeled with the corresponding **architectural information** (materials, components etc.).

- The model has to be made of
- **real architectural elements**
- (walls, slabs, roofs etc.) for
- correct calculation results.

- Modeling **detail level** should be appropriate for the required drawing representations.
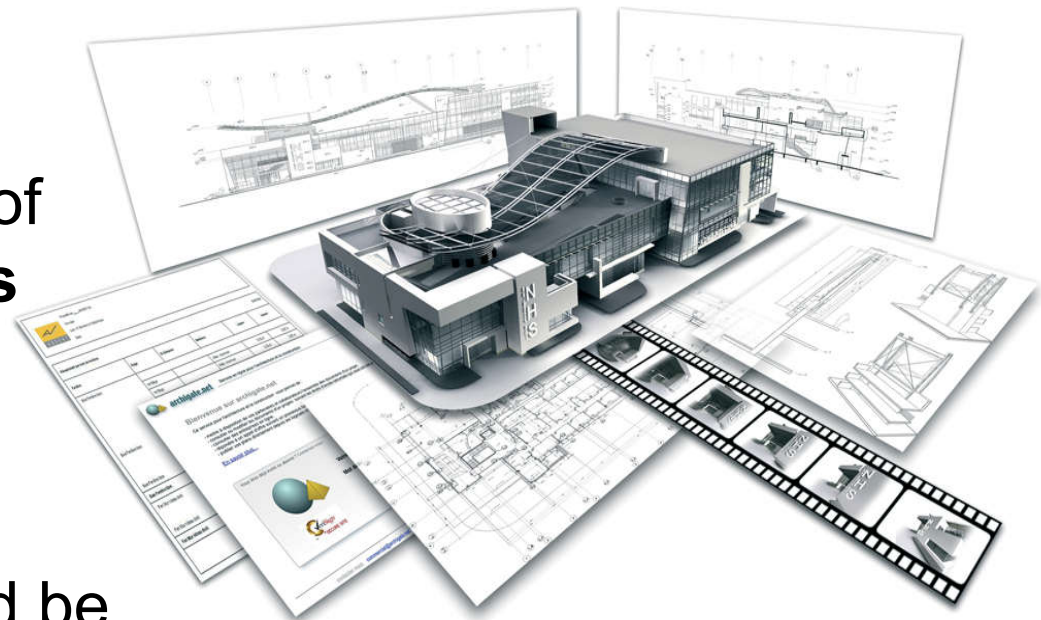
NHS Building, paastudio.com

Example of BIM architecture model and information
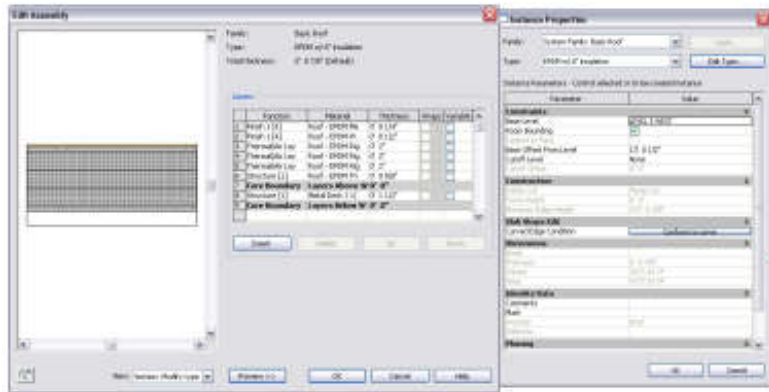
Wall information
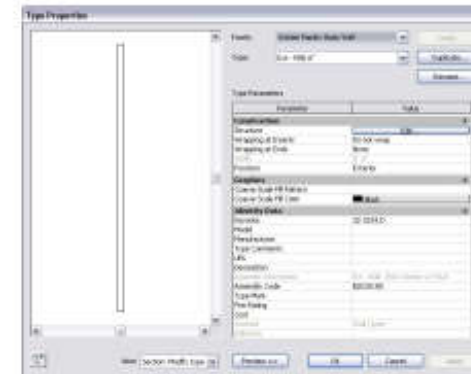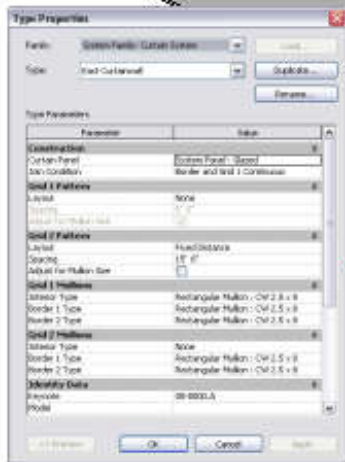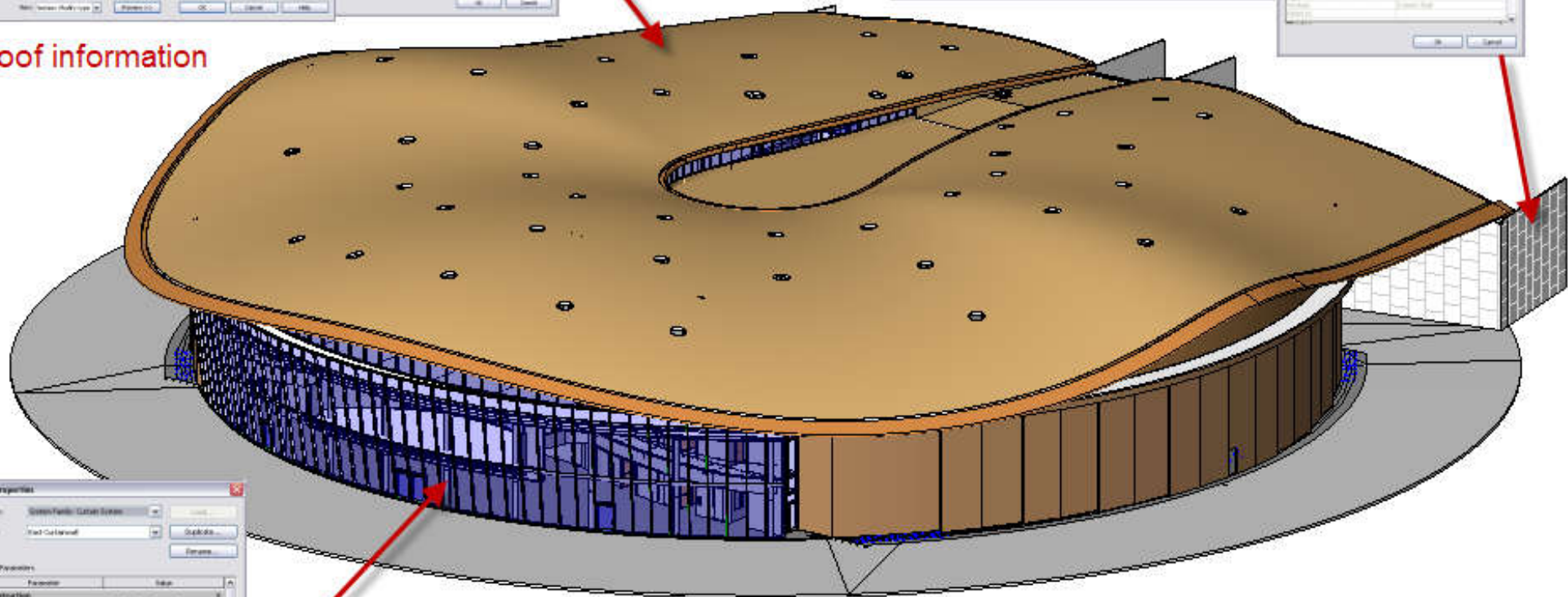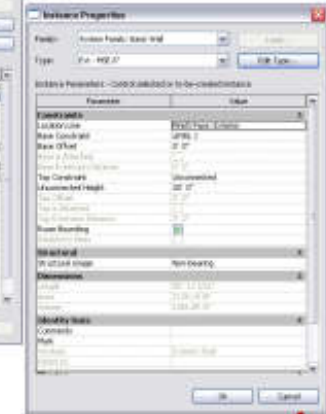
Roof information

Curtain Wall iinformation

Real Building Materials

Priority Based Connections automatically provide construction documentation level sections and details.
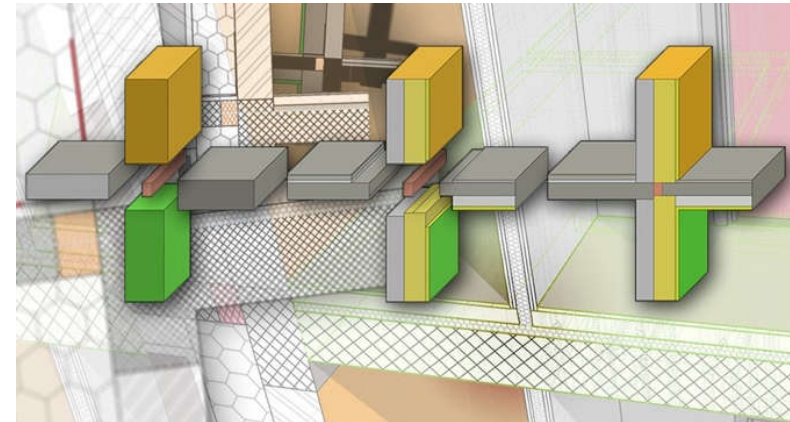
Intelligent Building Materials ensure correct graphical representation of materials in sections, element surfaces in 3D views, and thermal properties throughout the building energy evaluations.

Modelling for Construction Coordination

•Time and cost information is attached to the BIM model by linking schedules and estimating recipes (4D-5D).

•The main purpose of the 3D model is to calculate the exact quantities of materials and to identify any conflicts, collisions in the construction. Thus model accuracy is critical.

•Elements of composite building structures can be described in estimating recipes instead of modeling them in 3D.

Time

(Linked schedules)
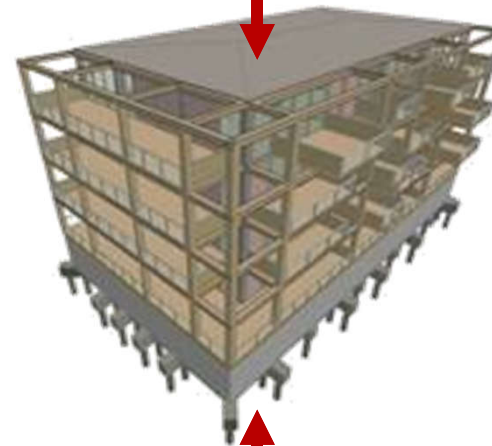
BIM model

Cost

(Linked estimating recipes)

Virtual Construction Model

BIM
Model

Estimating
Recipe

Methods

Resources

Model Complexity

Model Complexity

Traditional   Organic
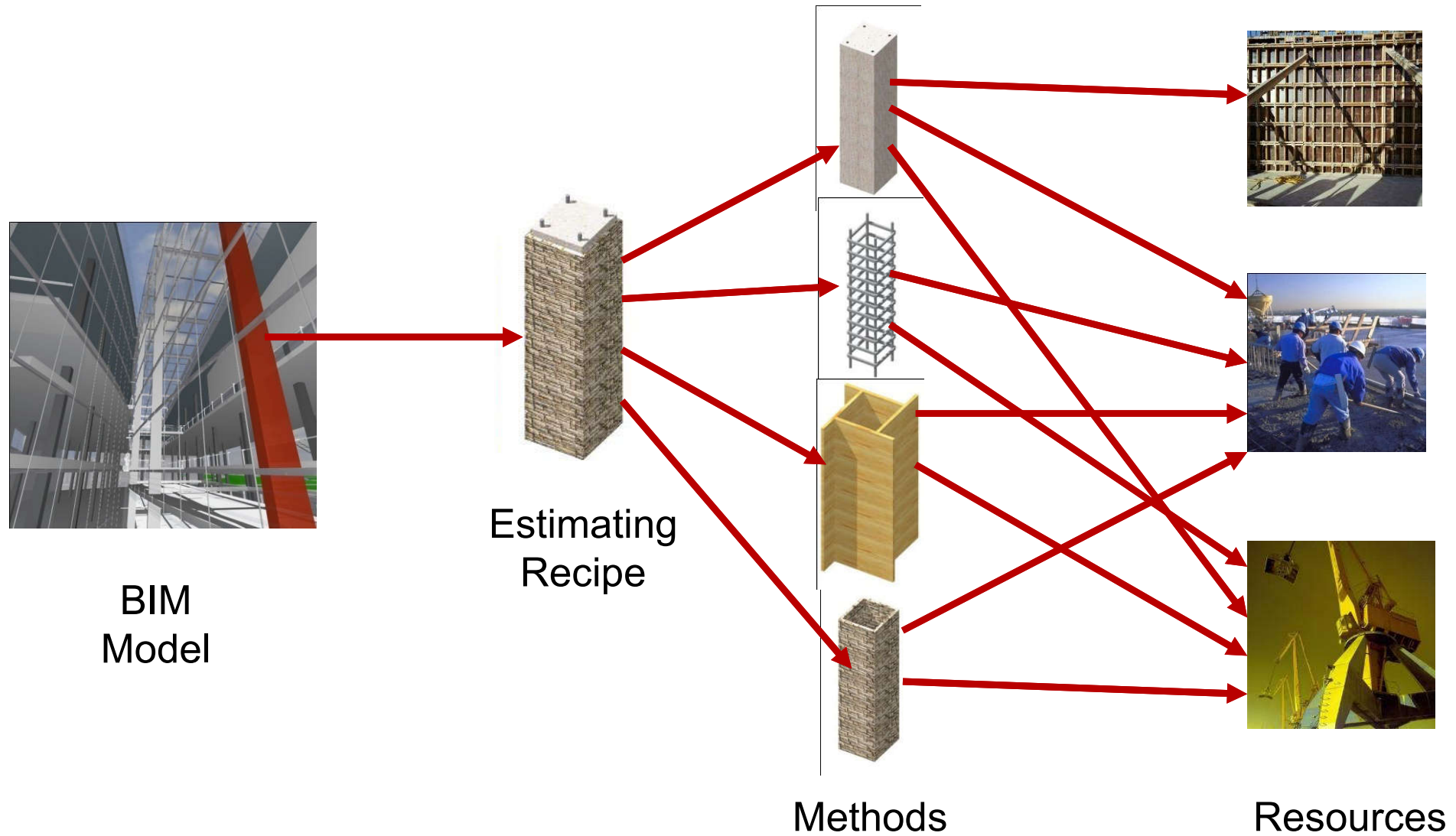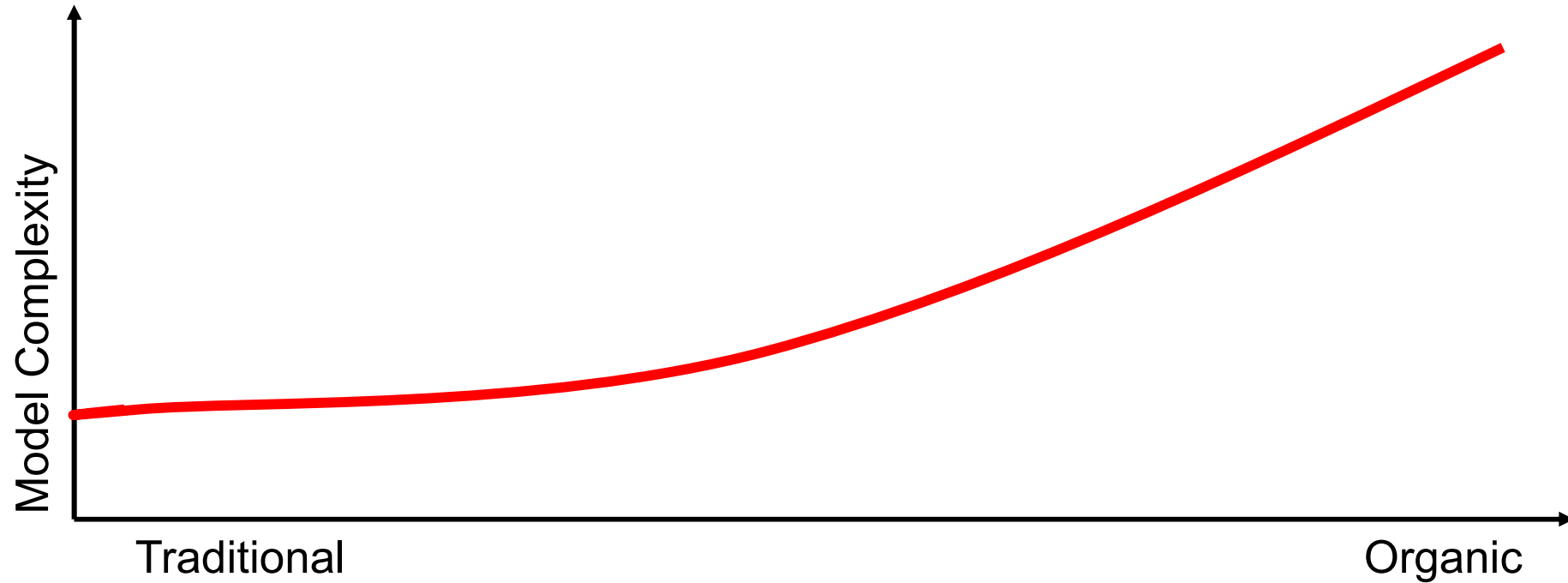
Le Corbusier   Zaha Hadid   Frank O. Gehry

Complexity

- How can you model these buildings?

- **Simplify**
  - The level of detail shouldn't exceed the actual requirements

- **Divide**
  - Share the building model between the project team members

- **Use the appropriate tools**
  - Combine several applications for the best result

Herzog & de Meuron

Frank O. Gehry

Santiago Calatrava

Model Size

- What makes a model big?

- No of building elements

- No of 3D model polygons

- Size of the project

- Lack of teamwork

- Inappropriate computer hardware

- Inappropriate software usage
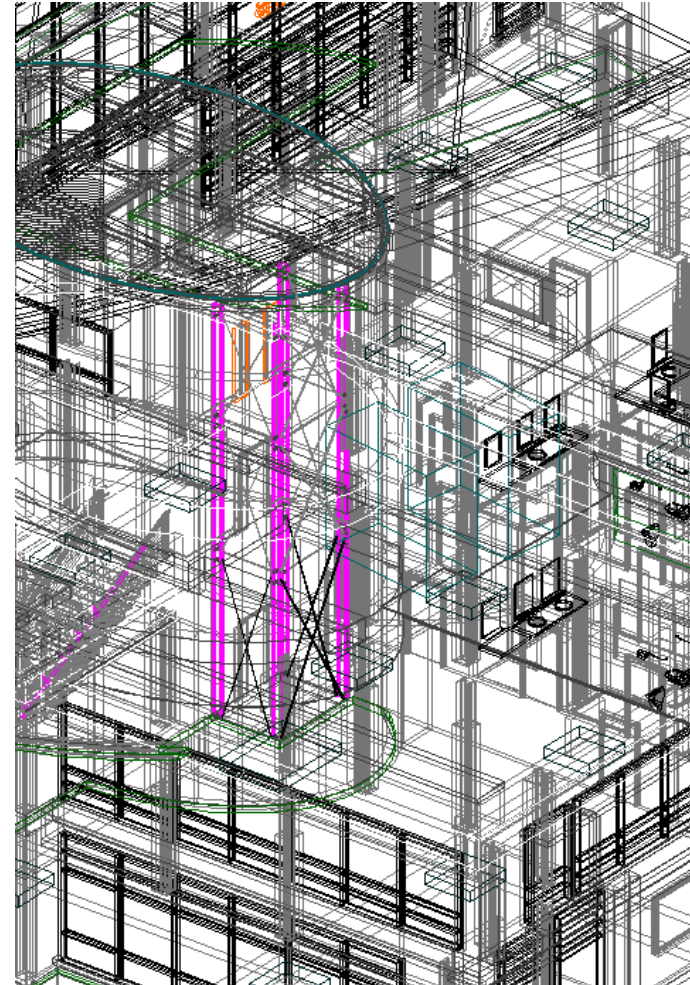
Model Size

- How can you work effectively with big buildings?

- Reduce the number of 3D model polygons: simplify the memory excessive model elements

- Turn off the invisible elements: filter the model with layer combinations and selections

- Divide the project: file hotlinking and teamwork solutions help to share the work with other project team members

- Use appropriate hardware

Hardware Requirements

- The computer configuration has to match with the hardware requirements of the CAD software

- CPU
- Speed: General latency
Cores: Complex computations
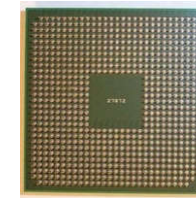
- Memory
- Size: Project size limit
Size and Speed: Complex 3D operations
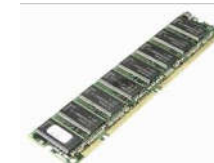
- Hard Disk
- Size: Amount of projects, backups, resources
Quality: Data safety

- Graphic Card
- Latency in 2D and 3D navigation.

Software Solutions

Classic BIM modeling approach for small to medium scale projects:

All in one application:
- modeling
- documentation
- visualization

BIM Application

Documentation

BIM model
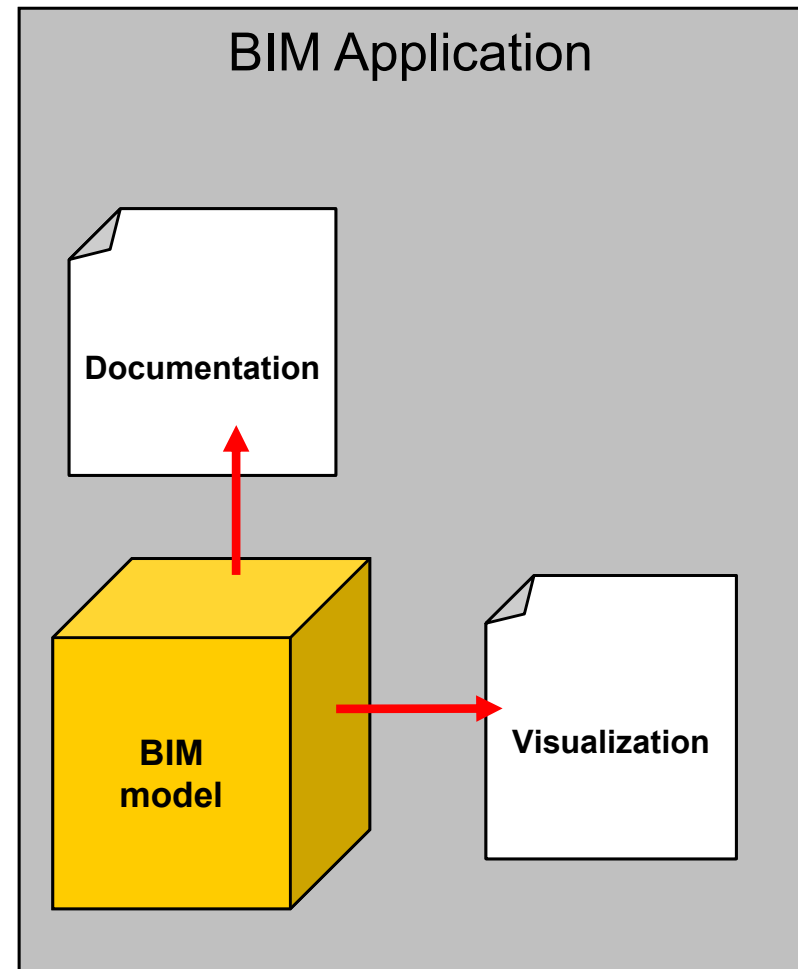
Visualization

Software Solutions

Complex modeling and visualization solution
for large or complex projects:

Specialized applications combined
with BIM software

Parts of the 3D model
are created in external
modeling applications

Documentation

Visualization

BIM application

Conceptual modeler

Rendering application

Conceptual Visualization

Freeform modeler
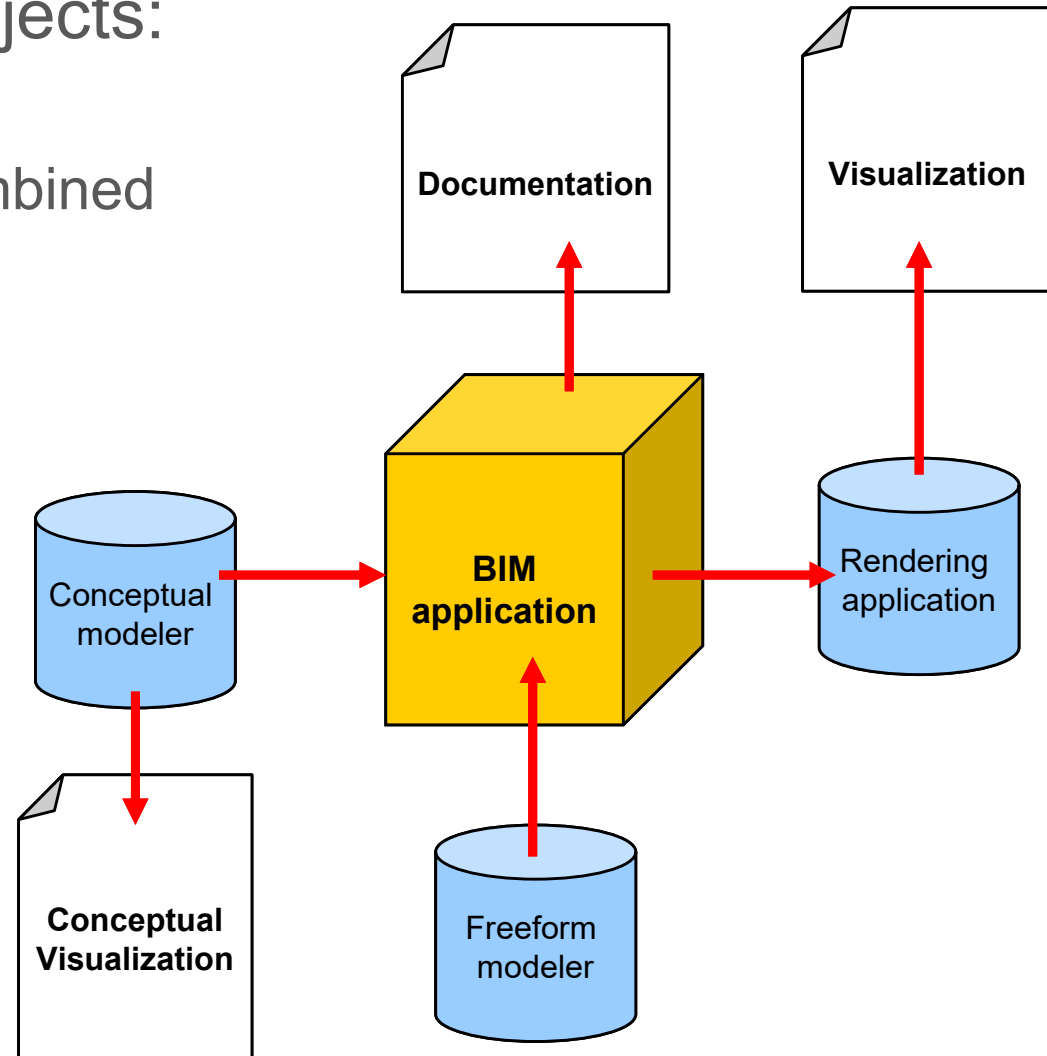
Computer Modelling Techniques

•**Polygonal modeling** is an approach for modeling objects by representing or approximating their surfaces using polygons.

•The main advantage of polygons are that they are faster than other representations.

•

•Polygons are incapable of accurately representing curved surfaces, so a large number of them must be used to approximate curves.
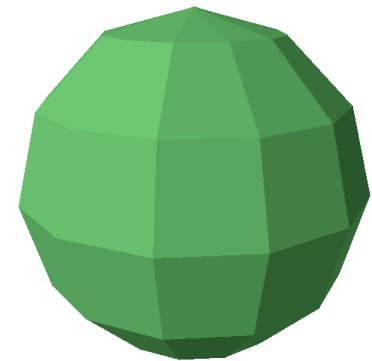
Low Resolution Model
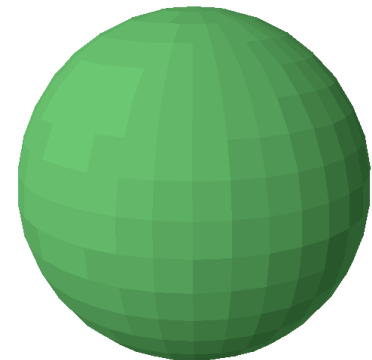
High Resolution Model

Computer Modelling Techniques

• **NURBS**, short for non-uniform, rational B-spline, is a mathematical model commonly used for generating and representing curves and surfaces. A NURBS curve is defined by its **order**, a set of weighted **control points**, and a **knot vector.**

• They are invariant under affine as well as perspective transformations.

• They offer one common mathematical form for both standard analytical shapes (e.g., conics) and free-form shapes.

• They provide the flexibility to design a large variety of shapes.

• They reduce the memory consumption when storing shapes (compared to simpler methods).

Control Point

Control Polygon
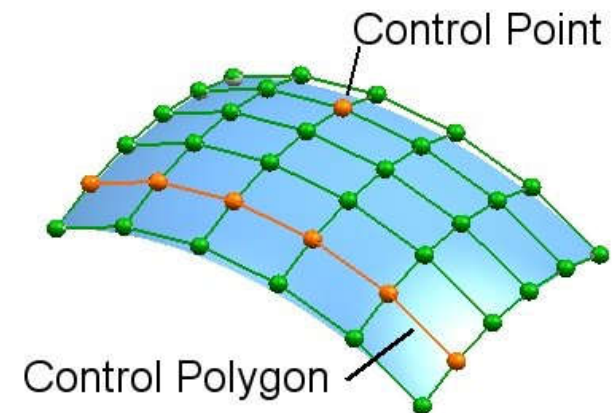
Computer Modelling Techniques

•**Solid modeling** is the unambiguous representation of the solid parts of an object suitable for computer processing.

•**Constructive solid geometry (CSG)** is a technique used in solid modeling. Constructive solid geometry allows a modeler to create a complex surface or object by using Boolean operators to combine objects.

•It is used in cases where simple geometric objects are desired, or where mathematical accuracy is important.

•CSG is popular because a modeler can use a set of relatively simple objects to create very complicated geometry.

•CSG models require strong processing capabilities.
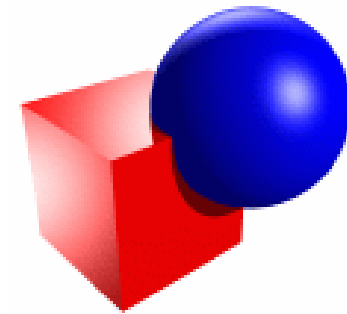
Addition
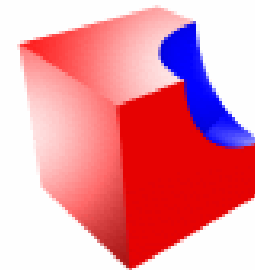
Subtraction

Intersection

BIM software

- Three common BIM software packages
  - ArchiCAD by Graphisoft
  - Microstation by Bentley System
  - Revit by Autodesk

- Usually the BIM software packages have distinct environments for architectural, structural, and mechanical, electrical and plumbing (MEP) objects that can all be referenced into a single file

BIM software

- Most popular drawing tools:
  - Autodesk Revit (Architecture/Structure/MEP) 41%
  - Graphisoft ArchiCAD 15%
  - Autodesk AutoCAD 14%
  - Autodesk AutoCAD LT 12%
  - Nemetscheck Vectorworks 9%
  - Bentley Microstation 2%
  - Trimble Sketchup (formerly Google Sketchup) 2%
  - Bentley AECOsim Building Designer 1%
  - Nemetscheck Allplan 0%

Which one you have learnt or used before?

BIM software

(Source: BIM Software guide https://www.buildingincloud.net/en/bim-software-guide/)

Overview of software for BIM design

Planning

LOD Planner

Authoring

SketchUp
bimobject®
REVIT
ClashMEP
VECTORWORKS® A NEMETSCHEK COMPANY
GRAPHISOFT. ARCHICAD
Tekla
INTERGRAPH®

Analysis

BIMTRACK™
NAVISWORKS
BIM Assure
SCIA A NEMETSCHEK COMPANY
BIMcollab®
SOLIBRI
BIM 360

Use

SYNCHRO SOFTWARE
assemble
Trimble Connect
BUILDING OPS
DAQRI
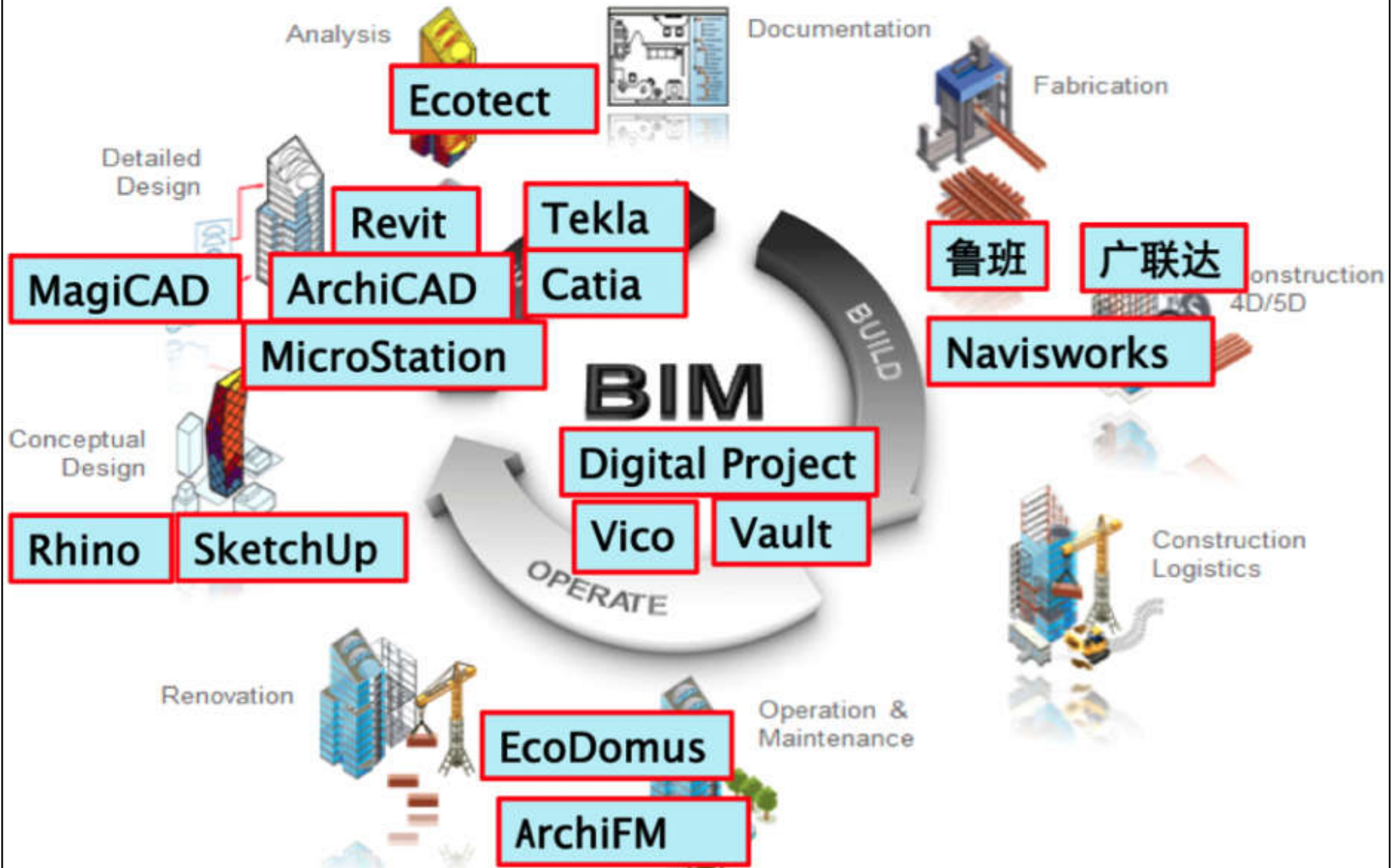ecodomus
VICO OFFICE
Microsoft HoloLens

Not an exhaustive list

BIM software

- Types of software based on BIM dimensions:
  - 3D Modelling
  - 4D Scheduling
  - 5D Cost
  - 6D Sustainability
  - 7D Maintenance & Operation
- 15 Best BIM Software [2023 Updated BIM Software List]
  - https://www.constructionplacements.com/bim-software/

Choice of BIM software for different phases

Analysis — Ecotect

Documentation

Fabrication

Detailed Design — Revit, ArchiCAD, MagiCAD, MicroStation, Tekla, Catia

Conceptual Design — Rhino, SketchUp

BIM

BUILD

鲁班 广联达

Construction 4D/5D — Navisworks

Digital Project

Vico Vault

OPERATE

Construction Logistics

Renovation

EcoDomus
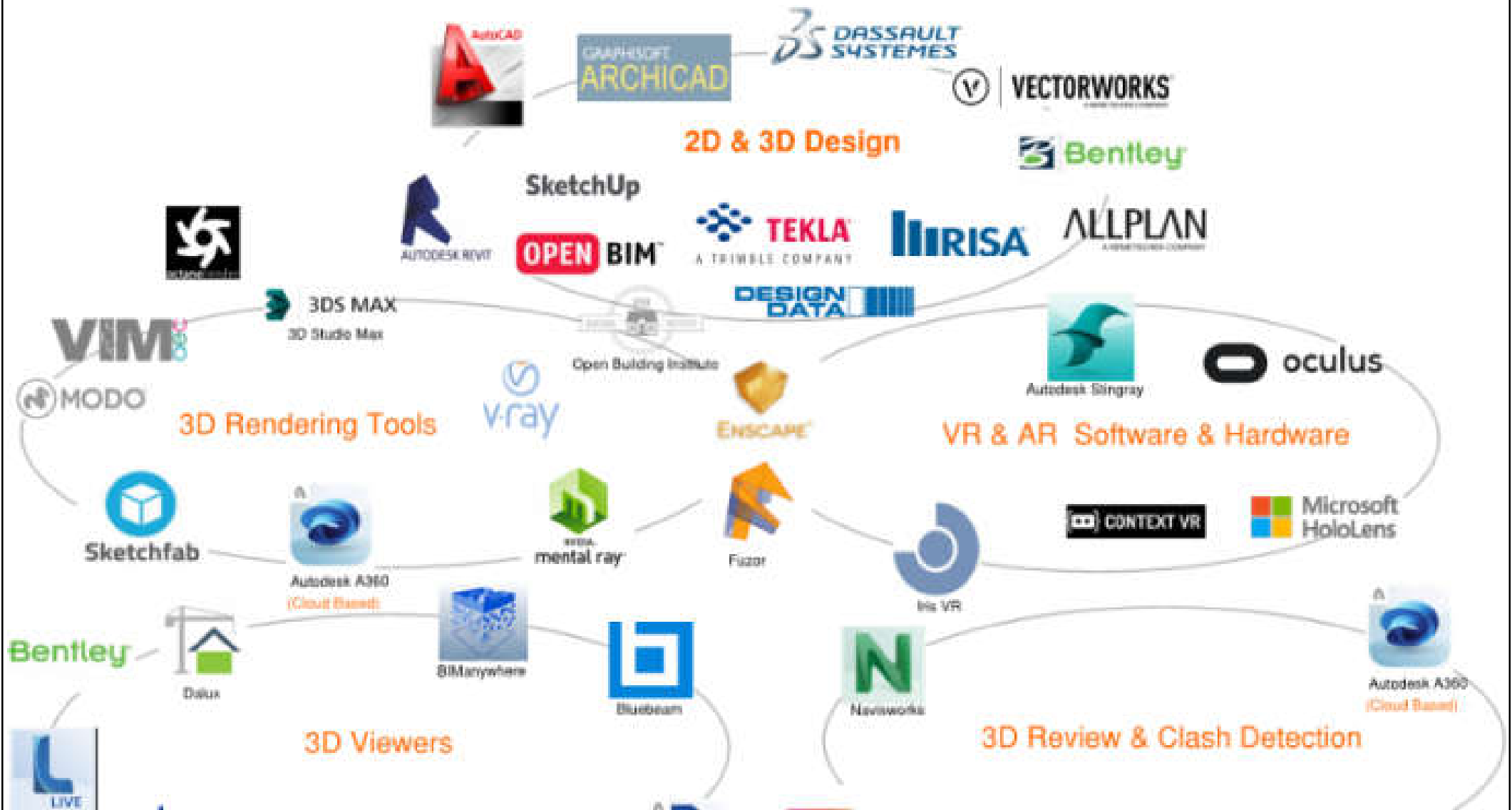
ArchiFM

Operation & Maintenance

BIM software

- Types of software based on disciplines and functions:
    - Design authoring tools (2D, 3D)
        - Architecture, Structure, MEP (Building Services)
    - Rendering tools (for visualization)
    - Viewers & clash review (for CAD and 3D models)
    - Management (for documents or projects)
    - Virtual reality (VR) & augmented reality (AR)
- Other building analysis & simulation software
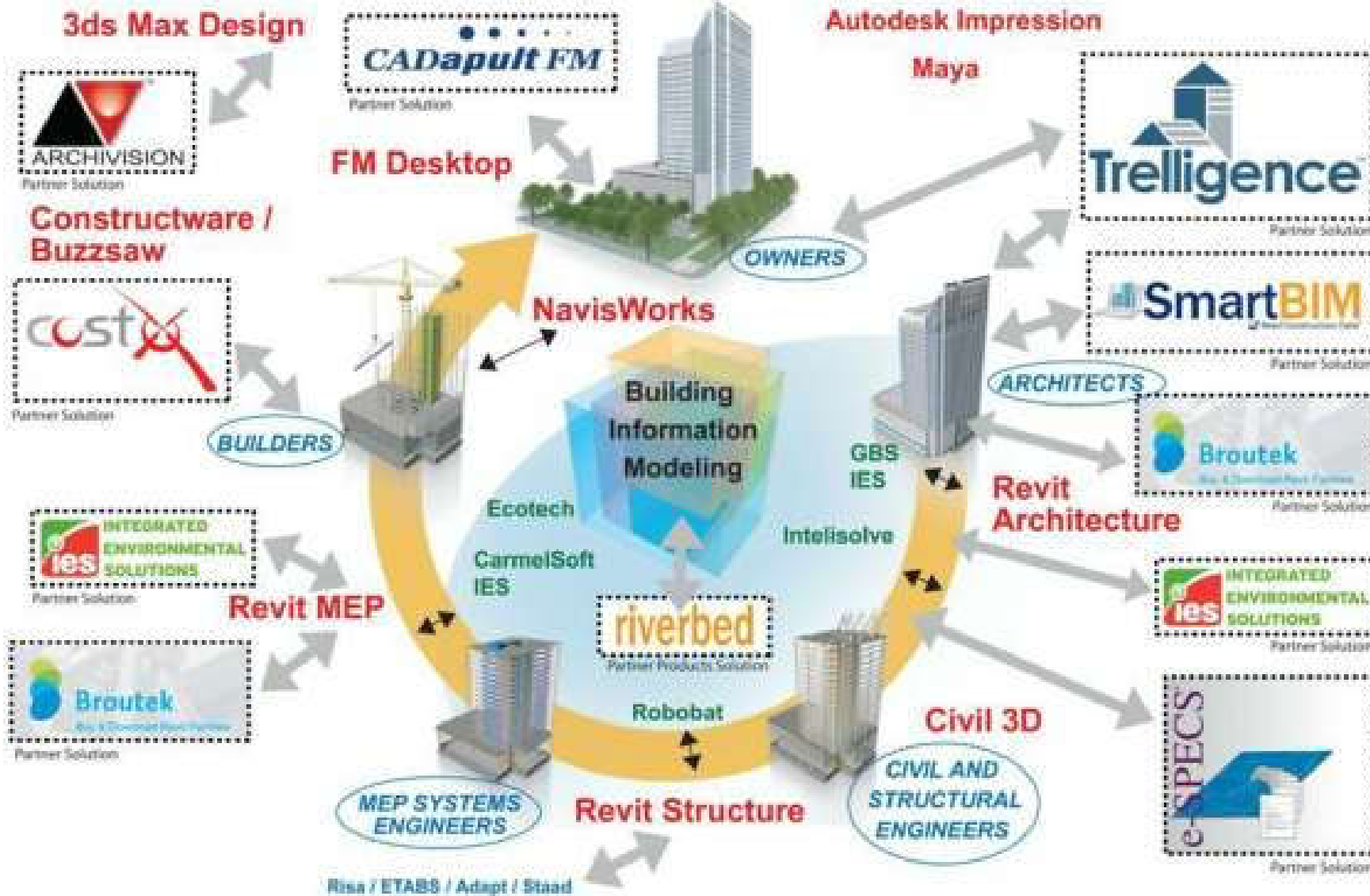
BIM software classification

AutoCAD · GRAPHISOFT ARCHICAD · DASSAULT SYSTEMES · VECTORWORKS

2D & 3D Design

Bentley

SketchUp

AUTODESK REVIT · OPEN BIM · TEKLA A TRIMBLE COMPANY · RISA · ALLPLAN

DESIGN DATA

VIM#

3DS MAX · 3D Studio Max

Open Building Institute

ENSCAPE

Autodesk Stingray · oculus

MODO

3D Rendering Tools

V·ray

VR & AR Software & Hardware

Sketchfab

Autodesk A360 (Cloud Based)

NVIDIA mental ray

Fuzor

Iris VR

CONTEXT VR · Microsoft HoloLens

Bentley · Dalux

BIManywhere

Bluebeam

Navisworks

Autodesk A360 (Cloud Based)

3D Viewers

LIVE

3D Review & Clash Detection

(Source: BIM Software guide https://www.buildingincloud.net/en/bim-software-guide/)

Design authoring and analysis tools for BIM

Examples of software tools for supporting the BIM process
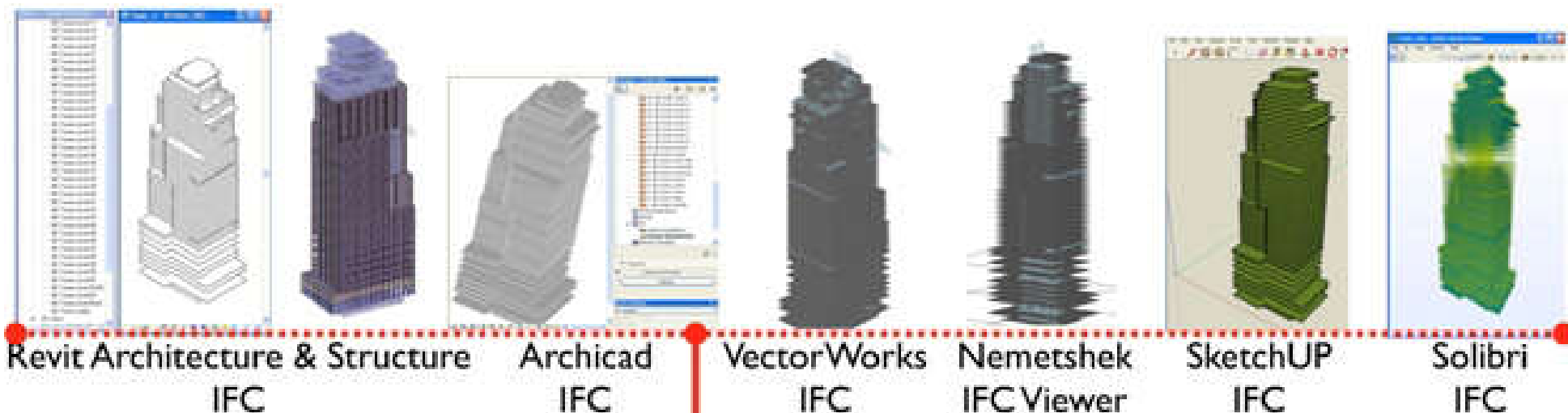
Revit Architecture & Structure
IFC

Archicad
IFC

VectorWorks
IFC

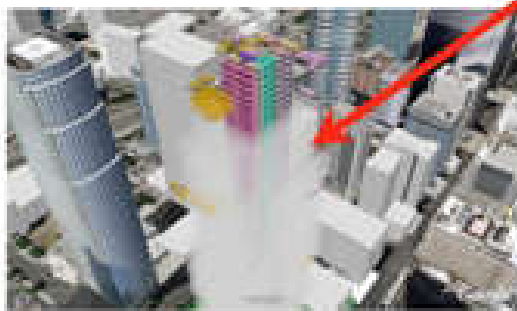Nemetshek
IFC Viewer

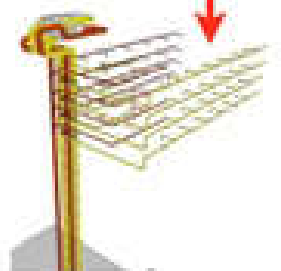SketchUP
IFC

Solibri
IFC
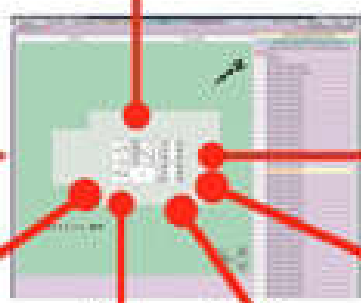
Excel

Onuma Planning System
IFC, KML, GBXML, CSV

OPS Reports

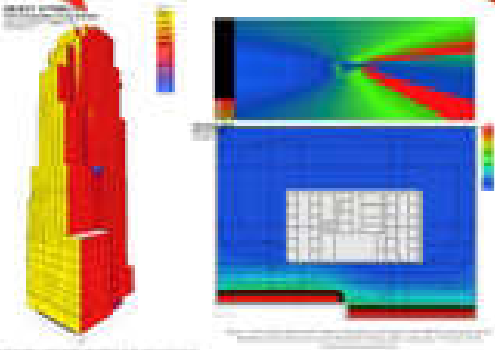Summary
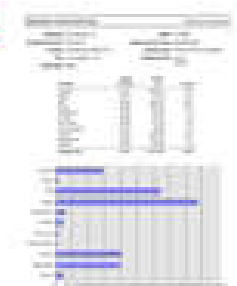Total Space NSF: 341,788 SF
Total Energy Use: 6,459,784 kWh

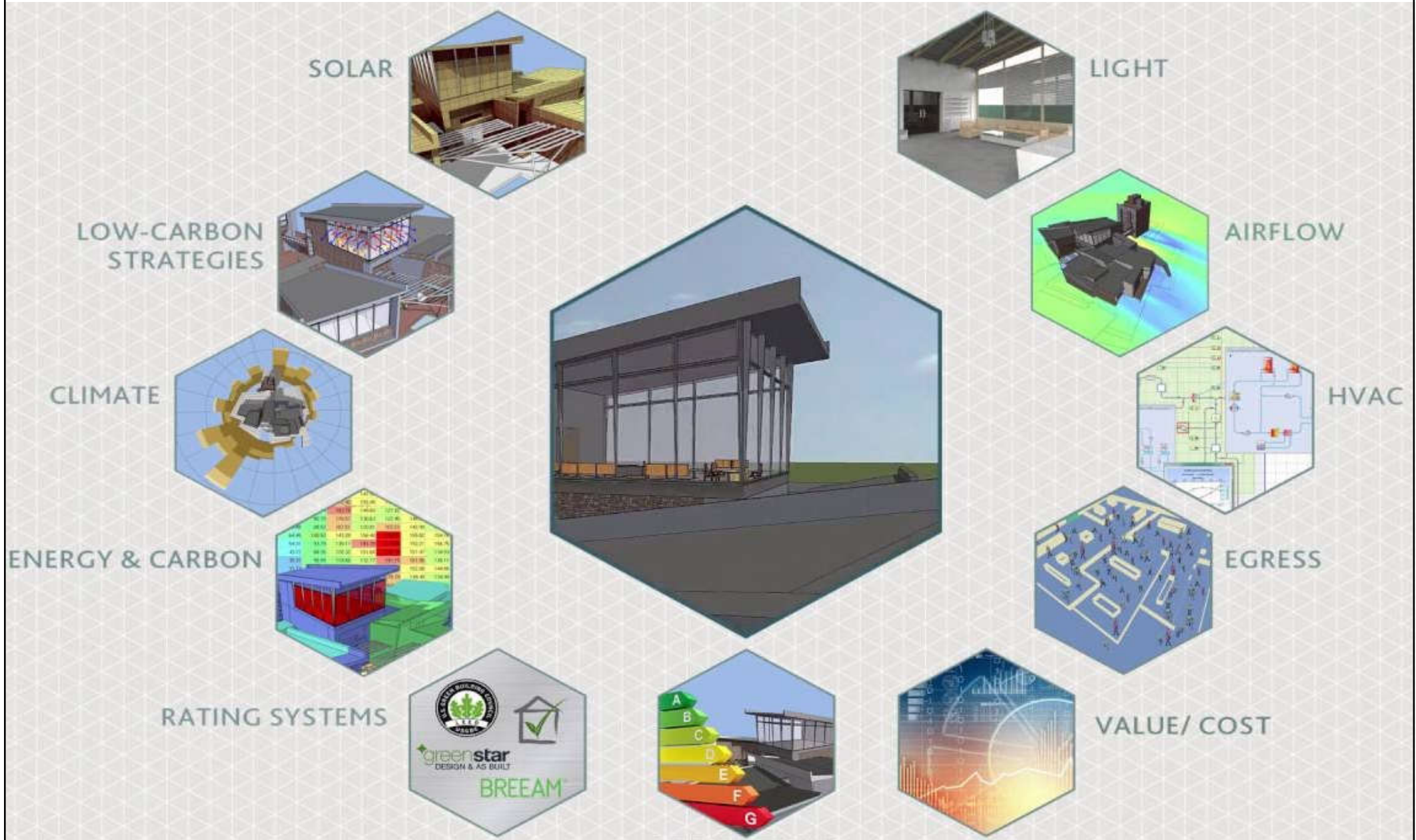Google Earth - KML

Elite CAD
IFC

Ecotect
GBXML & IFC

Whitestone
O&M
PDF and Excel

# Analyses using software in the BIM process

Latest trends

- Latest trends of BIM software
  - 4D & 5D estimating
  - Code compliance & checking
  - Links to building performance simulation engines
  - E-specifications & tendering
  - Digital prototyping (industrial design, 3D printing)
  - Fabrication information model (automation)
  - Graphical programming for design (e.g. Dynamo)
  - Artificial intelligence (AI) BIM for optimization

Typical BIM process and software tools

(Source: Garber, R., 2014. *BIM Design: Realising the Creative Potential of Building Information Modelling*)
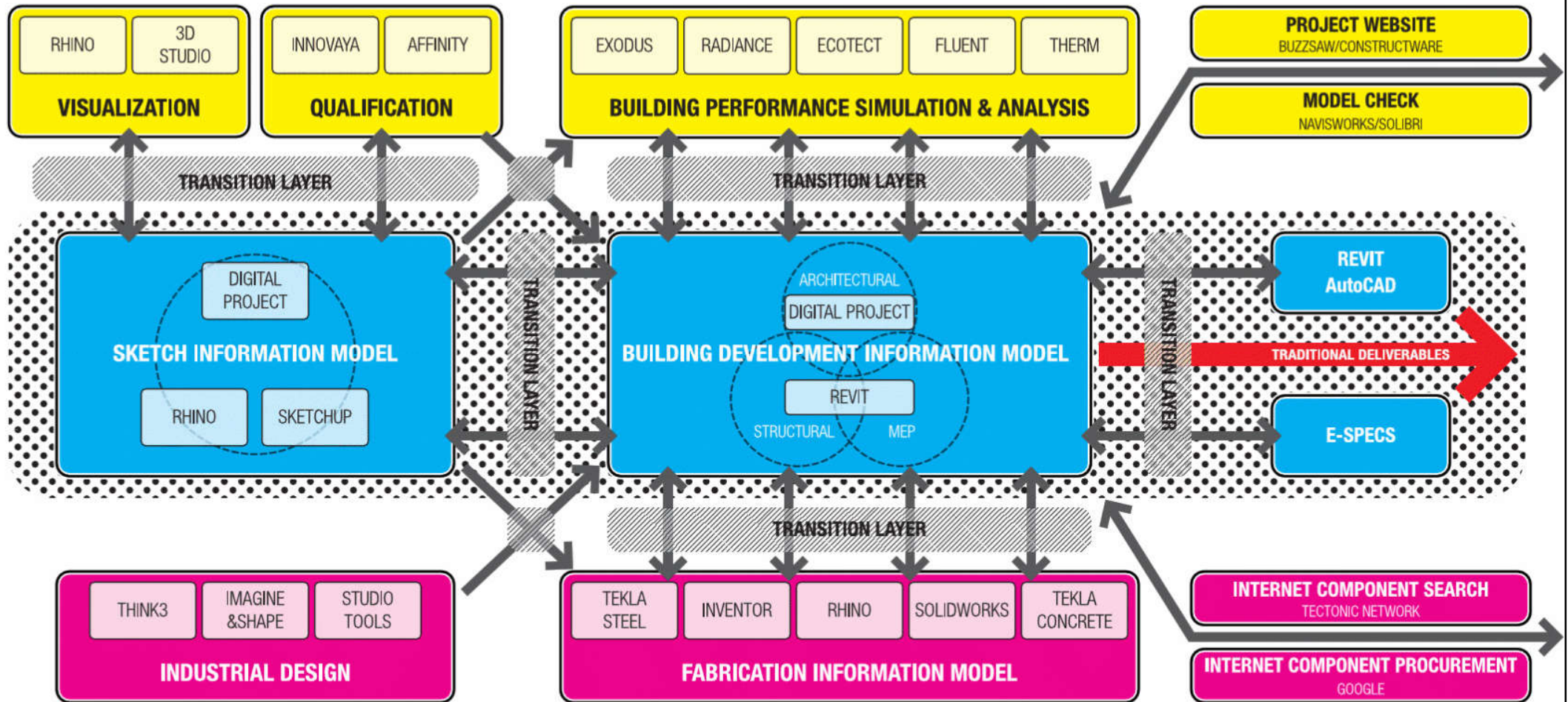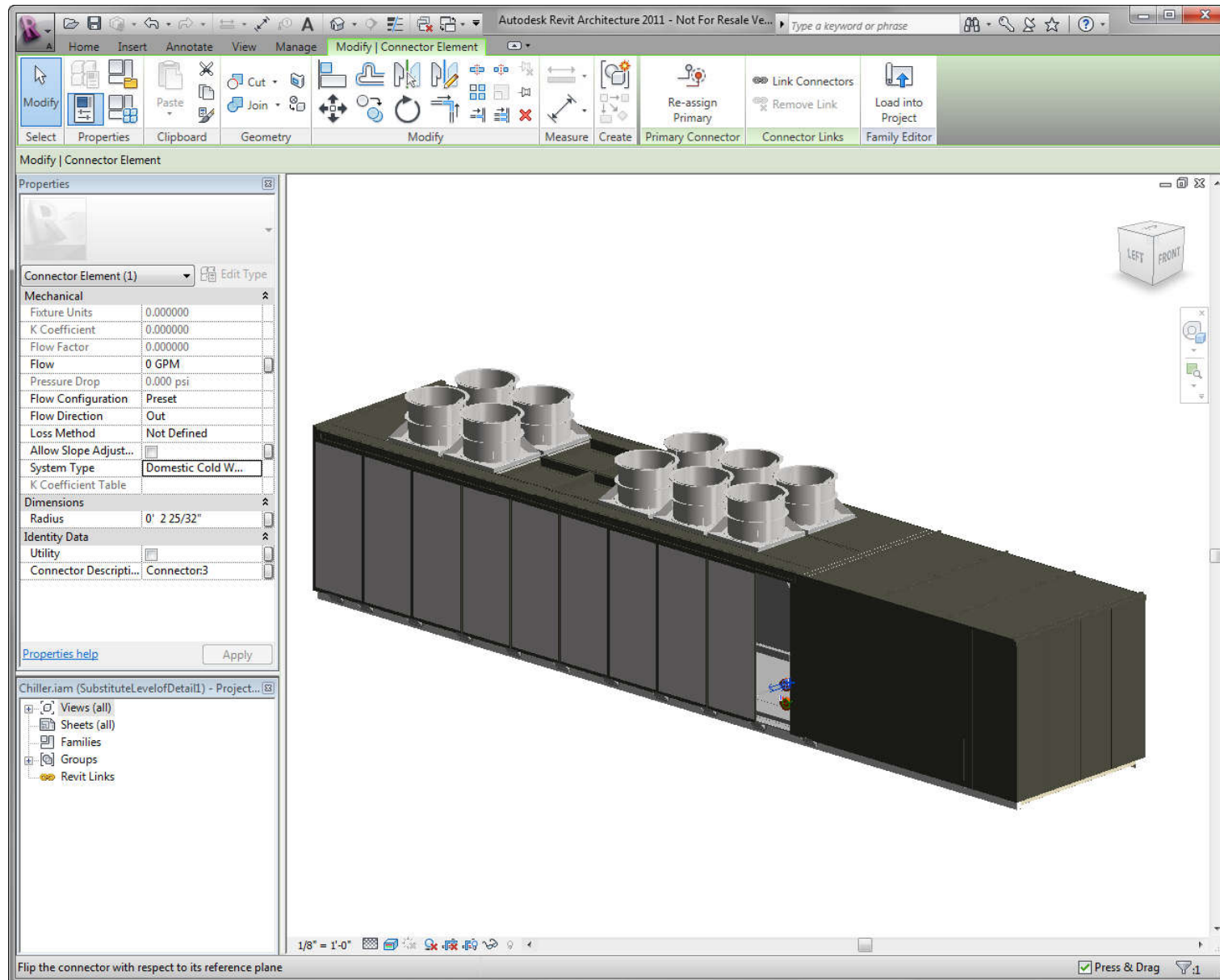
(See also: Linking BIM, manufacturing and digital prototyping https://redstack.com.au/support/blog_posts/the-link-between-bim-and-digital-prototyping)

Use of MS Excel with Dynamo and Revit
(graphical programming for design or parametric modelling)
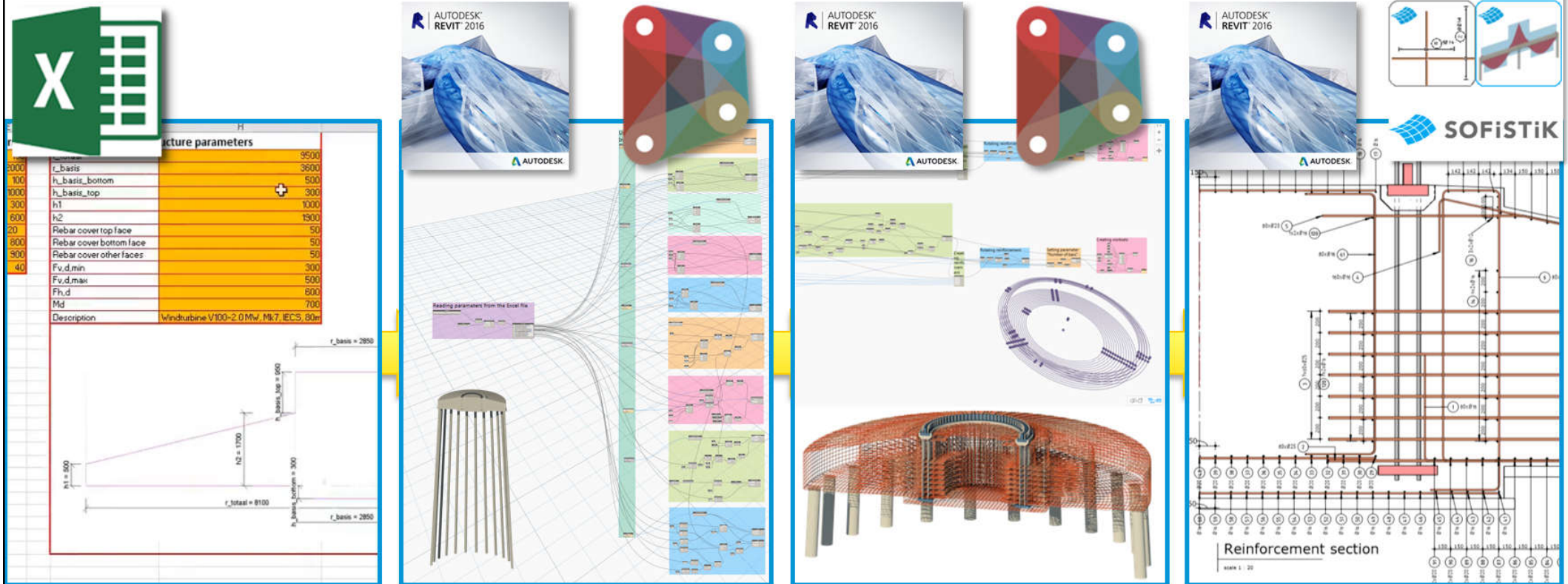
| Set parameters for geometry in Excel | Read Excel values and create initial geometry with Dynamo and Revit | Drive Revit geometry and generate rebar | Generate detailed output drawings |

See also: Dynamo BIM http://dynamobim.org/

(Source: Autodesk)