NET UBIEP

Network for Using BIM to Increase the Energy Performance

TRAINING MATERIAL

for Professionals

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Introduction

Why Net-UBIEP?

Net-UBIEP aims at increasing energy performance of buildings by wide spreading and strengthening the use of BIM, during the life cycle of the building. The use of BIM will allow to simulate the energy performance of the building using different materials and components, both to be used in the building design and/or in building design refurbishment.

BIM, which stands for Building Information Modeling, is a process that lasts for all the building life cycle from the design phase through the construction, management, maintenance, refurbishment and reuse/demolish. In each of this phase is very important to take into account all the energy aspects in order to decrease the environmental impact of the building during its life cycle.

Any professional needs to understand his/her role in the lifecycle of the building and has to gain additional competences related to the digitalization of the building process, that is to work to the development of the BIM model for any of dozens uses, which the customers will decide to entrust them.

The competences needed to implement BIM, taking into account the energy performance, vary depending on the phase of the building life cycle (1), on the target (2) and on BIM Profile (3).

This information has been put in a three-dimensional matrix which can be navigated through internet so that it is clear, for instance, which competence an architect (2) with a specific BIM role (3) should have in the design phase (1) in the construction of NZEB and provide an Energy Performance Certificate.

There is the need for engineers and architects to be ready to increase their capability to simulate, through BIM, the use of new technologies and materials to improve the energy performance of buildings and satisfy the needs of their customers with better quality at reduced cost.

BIM has diffused into construction industry and new digital technologies allow competitors from other countries to enter markets. The first professional who will be able to respond to this challenge will gain important advantage in the building market.

The first step consists in a **preparatory phase**, where the engineers and architects need to rethink their processes to manage the BIM models together with any other player of the building life cycle. They need to follow specific training to obtain knowledge of the following subjects:

- To know what's BIM and why it is useful to know the terminology
- Recognize the advantages of BIM compared to traditional methods
- To know the life cycle of the project information; in particular how the information is specified, produced, exchanged and maintained
- To know the added value of using open solutions to ensure interoperability
- To know how to collaborate in the Common Data Environment
- To know the national legislation for the digitalization of the building sector
- To know which normative are considered important in their Regional/Local environment in relation to:
    - Sustainable Energy Action Plan (SEAP) or Sustainable Energy and Climate Action Plan (SECAP)
    - Thermal Plant cadaster
    - Energy performance certification cadaster
    - Green products comprehension of energy carriers compulsory according to green public procurement

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The majority of SMEs working in the design and/or construction of buildings either as suppliers of big company and/or working autonomously, are not at all ready for this "digital revolution" and they need to acquire the right competences to put in place and manage the digital environment necessary for collaborating with other professionals along the life of a building starting with the preliminary design and lasting till the end of life cycle of the building.

The role of Professionals

Focusing on the energy aspects, the engineers and architects, need to be prepared for NZEB both in the case of new buildings as well as for the refurbishment of the existing one. To achieve this important result, they need not only to respect national, regional, local legislation, but they need to change their perspective and design and construct keeping the "end in mind". This means that they need to consider, from the beginning of the project, the requirements of the final users in relation to the energy performance and building comfort during the lifecycle of the project. They also need to consider the maintenance requirements and information during the life cycle of the building and its components/equipment.

Preliminary phase

Tasks:

1. Know how to manage the geo-referenced territorial maps, seismic maps, climatic maps where the building will be built
2. Identify SECAP indicators applied in the specific territory and the required format
3. Identify the indicators that can be checked through code checking and their format
4. Identify the requirements according to minimum environmental criteria to define the building sustainability (as energy and water consumption, …) during the life cycle of the building
5. Define the methods to manage, exchange, store the files in the CDE
6. Prepare the PIM on the bases of EIRs

Preparation and brief

Tasks:

1. Identify the energy performance requirements defined in the EIRs
2. Identify the energy performance requirements foreseen in the location where the building will be built/refurbished
3. Define the requirements for the maintenance delivery plan to ensure the foreseen energy performance of the building
4. Identify the professional skills required to implement BIM for the best energy performance to obtain NZEB
5. Define the requirements for all the supply chain that will work within the project
6. Prepare the preliminary BIM Execution Plan (BEP)
7. Make highly accurate visual reference of the existing condition of an existing building
8. Make highly accurate reference of the HVAC systems of an existing building
9. Propose different solutions for improving the energy efficiency of a building

Concept design

Tasks:

1. Develop the design taking into consideration any new requirements proposed by the client during the previous phase

2. Review the preliminary BEP to take into consideration any new issues coming from supply chain or from other professionals working in the same project
3. Review the building service design to ensure the maximum energy performance
4. Consider post-occupancy and operational issues for a better design of the buildings
5. Foresee the best mixture of technologies like RES installations, HVAC systems, etc. for the best energy performance
6. Ensure the presence of a system for the management and integrated control of the HVAC services (BACS - Building Automation and Control Systems)
7. Ensure the presence of devices for the reduction of water consumption
8. Ensure the "dynamic" behavior of the building envelope, preferably adopting solutions with movable elements (shielding, sliding panels, etc.)
9. Represent the level of information maturity of the models according to predefined LOD/LOI indicators for each model object in relation to the detail required by the definitive design
10. Design the CDE for exchanging, sharing and storing the information coming from different professionals and suppliers

Developed and Technical design

Tasks:

1. Ensure the sustainability requirements for energy performance contained in the developed design
2. Ensure the handover strategy for the correct maintenance and operational instructions
3. Integrate into one federated model the designs coming from HAVC and any other plant installation
4. Review the BIM Execution Plan, if changed
5. Ensure that the supply chain is able to provide the right information for the final Information Delivery
6. Ensure the accomplishment of all the requirements for NZEB or for the refurbishment of existing building
7. Ensure that the continuity of insulation has been considered
8. Foresee the preparation of a non-technical guide for the energy performance control in a format that is readable for the end user
9. Develop BIM 3D and 4D for planning time and costs of the work to simulate different solutions and evaluate the RoI for any refurbishment work
10. Develop BIM 6D to simulate different plant and illumination systems to obtain the best comfort and the lowest energy use
11. Perform clash detection to avoid any interference among plants and building structure
12. Perform code checking to ensure the respect of all legislative and technical requirements
13. Provide a CDE for exchanging, sharing and storing the information coming from different professionals and suppliers.
14. Ensure the correct digitalization and management of all graphical and non-graphical information

Construction

Tasks:

1. Transform the BIM model of the technical design in “as built”, that is, ensure that the information contained in the model correspond to the actual building.
2. Ensure that all the information of any building element, also provided by the suppliers, are correctly reported in the handover strategy

Handover and close out

Tasks:

1. Perform all activities foreseen in the handover strategy
2. Ensure the fine-tuning of the building services to ensure the best energy performance.
3. Control and verify that all the plants are correctly installed and that their user manual are provided together with the BIM model
4. Transfer the BIM model to the BIM facility manager and/or to the owner

In use and recycling

Tasks:

1. Check the in-use energy performance
2. Ensure the correct registration of the plants to the cadaster and to the owner
3. Ensure to provide the indicators necessary for SEAP and/or SECAP
4. Ensure the maintenance of the plant for the best performance
5. Ensure that any major modification is correctly reported in the BIM model
6. Ensure that recycling and dismissing of plants are performed correctly

Learning outcomes of Professional

The learning outcome can be viewed in the deliverable: D15.A – D3.2.A Requirements for Learning Outcomes for Target Groups. The deliverable can be downloaded by the web site www.net-ubiep.eu.

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0. Introductory Module – Basic BIM knowledge and skills

0.1 Introduction: what is BIM?

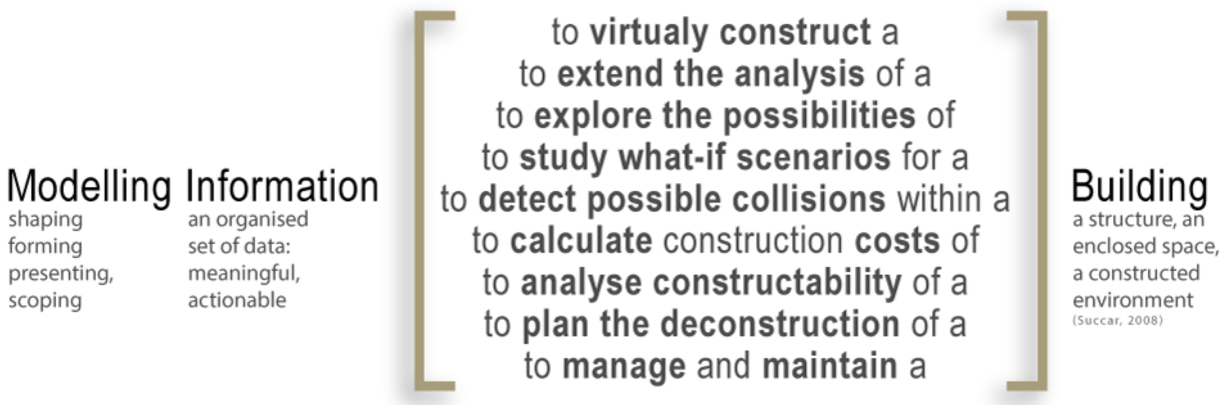
The boundaries of Building Information Modelling as a term-definition, set of technologies and group of processes is fast changing even before being widely adopted by the industry. As a term, BIM seems to have somehow stabilized now but as a set of technologies/processes, its boundaries are rapidly expanding. This boundary expansion (and sometimes mutation) is disconcerting in several ways as BIM continues to lack an agreed definition, process maps and regulatory frameworks. However, these concerns are offset by sheer potentials of BIM (as an integrated process) to act as a catalyst for change poised to reduce industry's fragmentation, improve its efficiency/effectiveness and lower its high costs of inadequate interoperability.

For industry stakeholders (like designers, engineers, clients, construction companies, facility managers, governments...) BIM represents the digitalization of the building industry. BIM's prominence, as a re-emerging concept, is being fueled by the increasing availability of processing power, maturing applications, interoperability discussions (IAI, NIST and GSA) and proactive regulatory frameworks.

BIM, how to read the term:

- Building: a structure, an enclosed space, a constructed environment...
- Information: an organized set of data: meaningful, actionable
- Modelling: shaping, forming, presenting, scoping...

To best understand this inadequate array of meanings, let's flip the order of the words:



The conceptual frameworks of Building Information Modelling stems from the mid 1980's but the term itself is a recent incarnation. As an acronym, BIM appears to be gradually wining over many competing terms representing mainly similar concepts.

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0.2 BIM Glossary

2

2E Index: An objective index that includes time, cost and a suitable evaluation obtained by means of a simulation process of a virtual prototyping able to determine its Eco Efficiency.

3D: Detailed geometric representation of each part and the totality of a building or facility, inside of an integrated information instrument.

3D Scanning: Collecting data from a physical object, building or any place by means of a laser scanning — normally with point clouds — to, subsequently, generate a BIM model.

4.0 Construction: Transformation and development of the construction industry supported by emergent technologies modifying established business models through the people, on the basis of interoperability of human means and materials, processes virtualization, decentralization of decision-making, real time exchange of information and focused on customer service.

4D: A dimension involving the use of some models in order to allow all the activities and time management process (planning, assessment and time controlling).

5D: A dimension involving the use of some models in order to allow all the activities and cost management process (cost estimates, determination of the budget, cost control).

6D: A dimension involving the use of some models in order to make energy and sustainability analyses.

7D: A dimension involving the use of some models in order to carry out activities and management process and operations throughout the entire building or facility lifecycle.

A

AEC (Architecture, Engineering and Construction): Acronym referring professionals and enterprises related to Architecture, Construction and engineering industry.

AECO (Architecture, Engineering, Construction and Operation): An extension of the AEC acronym which includes professionals and enterprises related to the operations and maintenance of buildings and infrastructures.

Agile movement: It is an incremental, iterative work cadence-based project management approach where requirements and solutions evolve over the time according to the need for the project. The work is realized by means of teams' collaboration self-organized and multidisciplinary, immersed in a process shared of short term policy-making.

AIA (American Institute of Architects): Association of Architects of the United States. Among their contributions to BIM, they have developed a BIM protocol that establishes a series of standards that are part of the documentation of contracts.

AIM (Asset Information Model): Information model (documentation, graphic model and non-graphic data) that supports the maintenance, management and operation of an asset throughout its life cycle. It is used as a repository for all the information about the asset, as a means to access and link with other systems and as a means to receive and centralize information of all the participants throughout the project stages.

As-Built, model: A model that gathers all changes experienced by projects in the construction process in such a way that it may be possible to obtain an accurate reality BIM model.

Augmented reality: Vision of a physical environment of the real world through a technological device through which tangible physical elements are combined with virtual elements, thereby creating a mixed reality in real time.

Authoring Software: Software applications providing for creation of 3D models enriched with its set data and its different parts which are used to build the original BIM model. They are usually known as modelling platform.

B

BCF (BIM Collaboration Format): It's an open file format which allows the submission of comments, screenshots and other information in the IFC file of a BIM model in order to promote communication and coordination of the different parts participating in a developed project through the BIM method.

Benchmarking: A process whose objective is to acquire useful information that helps an organization to improve its processes. Its aim is to achieve the maximum learning effectiveness from the bests, helping the organization to move from where it is to where it wants to arrive.

BEP (BIM Execution Plan) or BPEP (BIM Project Execution Plan): A document defining in an overall shape details of the BIM methodology implementation through all Project phases, by defining implementation achievement, BIM processes and tasks, information exchange, necessary infrastructure, roles, responsibilities and model applications, among other aspects.

Big Data: A concept that makes reference to storage of big quantities of database as well as to used procedures to find repetitive patterns within these data.

BIM (Building Information Modelling): A work methodology to manage, comprehensively, construction projects throughout all its lifecycle, based on virtual models related to databases.

BIM Applications: BIM application method during an active lifecycle to meet specific targets.

BIM, Big: Exchanging of BIM path between companies in the building life cycle.

BIM, Coordinator: A profile that coordinates tasks, responsibilities and accountabilities that each part has in the BIM project, in addition to delivery times. It also liaises with team leaders from the different disciplines, coordinating and monitoring Project models.

BIM, Friendly: Those processes and tools that did not grow under a BIM methodology entirely, they do allow certain participation in processes or interoperability within BIM tools.

BIM Implementation Plan: Strategic plan to implement BIM into an Enterprise or organisation.

BIM, Little: BIM processes and methodology implemented in organizations.

BIM, Lonely: The use of BIM tools in a Project by stakeholders without interoperability or information exchange between them.

BIM Manager: A profile which is responsible for guaranteeing the right flow of the information generated by BIM methodology, just as the effectiveness of processes and the accomplishment of the specification laid down by the client. It Is the Manager of the Project database creation.

BIM Maturity Level: An indicator, normally a static or interactive table which evaluates the knowledge level and the BIM practices of an organization or Team Project.

BIM Modeller: A profile whose function is the BIM elements modelling in order to make them represent faithfully, the Project or the building, both graphically and constructively, according to the design criteria and the generation of documents fixed for the Project.

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BIM Modelling: Construction or generation action of a virtual tri-dimensional model of a building or facility, adding information beyond geometry to the model in order to smooth the use in the different phases of the life cycle of the project and the building or facility.

BIM Model: Virtual tri-dimensional model of a building or facility, adding information beyond geometry to the model in order to smooth use in the different life cycle phases of a project and building or facility.

BIM Objectives: Objectives set to define BIM employment potential value for a Project or a Team Project. BIM objectives help to define how and why BIM should be applied in a Project or in an organization.

BIM, Open: Overall proposal to promote design collaboration, implementation and maintenance of buildings, based on standards and open workflows.

BIM Requirements: General term concerning all the requirements and the prerequisites which BIM models must meet, as clients, regulatory authorities or similar parts demand.

BIM Role or Profile: The role played by an individual inside an organization (or an organization inside a Team Project) which implies the generation, modification or management of BIM models.

BIM, Super Objectives: BIM parametric objectives that can be programmed with many variations on its inside.

BoQ (Bill of Quantity): A set of measurement of all the work units integrating a Project.

BREEAM Certification: An evaluation method and certification of the building sustainability which manage the Building Research Establishment (BRE), an organization devoted to research in the building sector in the world.

BSSCH (Building Smart Spanish Chapter): Spanish chapter about the Building Smart Alliance.

Building Life Cycle: The view of a building over the course of its entire life, taking into account the designing, construction, operation, demolition and waste treatment.

Building Smart Alliance: International non-profit organisation that aims to improve the health efficiency in the building sector through interoperability open standards about BIM and business models focused on the cooperation for achieving new levels in cost reduction and deadlines.

C

CAMM (Computer-Aided Maintenance Management): Computer system that manages maintenance activities of a property.

CDE (Common Data Environment): Digital central repository where all the information related to a Project is hosted.

Classification systems: Classes and category distribution for the construction industry including, among others, elements, spaces, disciplines and materials (Uniclass, Uniformat, Omniclass, are some of the most commonly used international classification standards).

Clash Detection: A procedure that involves locating the interferences produced within the objects of a model or when leading models of different disciplines in a single model.

COBie (Construction Operations Building Information Exchange): International standard for information Exchange about construction data focused from a BIM methodology point of view. The most popular representation is the progressively development of a calculation sheet throughout the construction process.

Concurrent engineering: It is a systematic effort to make an integrated and convergent product design and its correspondent manufacturing and service process. Designed to make responsible for the development take into account, from the beginning, all the product life cycle elements; from the conceptual design until its availability; including quality, cost and user requirements.

Construction planning: Activities and documentation that plans the execution of the different parts of the work in time. In a BIM model it is possible to assign a parameter to each element or object thereof, so that it is possible to simulate the state of the work at a given time if the planned has been followed.

D

Data Conundrum: A problem area when imposing standards in different cultures with particular circumstances in each of them.

DB (Design-Build): A way of managing a procurement of a construction Project in which the client establishes a single agreement for the design and the construction of the project.

DBB (Design-Bid-Build): Management mode of a construction Project procurement in which the client establishes separated procurements for the design and the construction of the project.

Deliverable: Any product, result or unique and verifiable capability to perform a certain service that must be created to complete a process, phase or project.

Digital twin: A visual representation of the building construction.

Discipline: Each of the main areas in which BIM model objects can be assembled according their main function. The most general disciplines are: architecture, structure and MEP.

E

Eco-Efficiency: Distribution of goods with competitive prices and services meeting human needs and providing quality of life as it progressively reduce goods environmental impacts and the intensity of consumed sources during the entire life cycle, taking this to a level in line with carrying capacity of the earth.

EIR (Employer´s Information Requirements): A document whose content defines customer requirements at each stage of the constructive Project in terms of modelling. It shall form a basis to produce the BEP.

Exemplary parameter: A variable that acts over a specific object independently of the rest.

Extraction: Data collection of a model.

F

Family: A set of objects that belong to the same category that have generation parametric rules to obtain analogic geometric models.

Federated model: A BIM model that links, does not generate different disciplines models. The federated model does not create a data base with data from individual models, unlike an integrated model.

FM (Facility Management): A set of services and interdisciplinary activities developed during the operation phase to manage and provide the best performing of a property by integrating people, spaces, processes, technologies and own installations of properties, such as maintenance or management of spaces.

G

GbXML: A format used in order to allow a smooth transfer of BIM model properties to energy calculation applications.

GIS (Geographical Information System): Information system able to integrate, store, edit, analyse, share and show geographically referenced information.

Global Unique Identifier: Unique number that identifies a certain object in a software application. In a BIM model, every object has its GUID.

Green Building Council: A non-profit association that join representatives from the entire building sector in order to encourage the sector transformation towards sustainability by promoting initiatives that provide methodologies as well as updated and internationally compatible tools to the sector, which allow, objectively, the assessment and certificate of building's sustainability.

H

HVAC (Heating, ventilating and air conditioning): By extension, acronym that makes reference to all referring to air-conditioning systems of buildings**.**

I

IAI (International Alliance for Interoperability): Predecessor organisation of the Building Smart.

ICT: Information and Communication Technologies

IDM (Information Delivery Manual): Standard referring to the processes specified when a certain type of information is required during a property life cycle, and the one that must deliver such information.

IFC (Industry Foundation Classes): A standard filing system made with BuildingSMART to smooth the information Exchange and interoperability between software applications in a BIM workflow.

IFD (Information Framework Dictionary): the International Framework for Dictionaries, is, in simple terms, a standard for terminology libraries or ontologies and is in continuous development by BuildingSMART.

Integrated model: A BIM model that links different discipline models, generating a federated model with a unique data base with individual model data.

Internet of Things: A concept that makes reference to digital interconnection of everyday objects with internet.

Interoperability: The ability of several systems (and organizations) to work together in a fluent manner without any data or information loss. Interoperability can refer to systems, processes, file formats, etc.

IPD (Integrated Project Delivery): It is a contractual relation that has a balanced focus in risk and sharing distribution between the main participants of a project. It is based on shared risks and rewards, the early involvement of all interveners in a project and opened communications between them. It involves the use of appropriate technology such as the BIM methodology.

IT: Information technology

IWMS (Integrated workplace management system): Integrated workplace management system that works through a corporate management platform which allows to plan, to design, to manage, to explode and to remove assets located in the spaces of an organization. It allows to optimize the use of sources in the working area including the management of property assets, facilities and installations.

K

KPI (Key Performance Indicator): Performance indicators that help organizations to understand how work is being realized in relation to its goals and objectives.

L

Last Planner LPS (Last Planner System) is a planning, monitoring and control system that follows lean construction principles. It is based on increasing accomplishment of construction activities by decreasing uncertainty associated to planning, creating mid-term and weekly planning's framed within initial settings or the master plan of the project, analysing restrictions preventing normal development of activities.

Lean Construction: Construction management method, a Project management strategy and a production theory focalized on waste minimization in materials, time, effort and maximizing value with the continuous improvement throughout design phases and project construction.

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LEED (Leadership in Energy & Environmental Design): Sustainable building certification system, developed by the United States Green Building Council, which is an agency with chapters in different countries.

Life cycle: A concept referring to the appearance, development and completion of the functionality of a particular item, project, building or work.

LOD (Level of Detail): Quantity and wealth of information evolution of a constructive process. It is defined for each stage of development of the project.

LOD (Level of Development): It defines the development or maturity level of information that a BIM model has, and this one is the composing part, constructive system or assembly of the building. The AIA has developed a numeral classification (LOD100, 200, 300, 400, 500).

LOD 100: The object that can be represented by a symbol or generic representation. Its geometric definition is not needed although it can depend on other objects defined graphically and geometrically. Certain elements can remain in this development level in advanced phases of the project.

LOD 200: The element is defined graphically, specifying quantities, size, shape or location regarding the set of the project. It can include non-graphic information.

LOD 300: The element is defined graphically, specifying quantities, size, shape and/or location accurately, regarding the set of the project. It can include non-graphic information.

LOD 350: It is equivalent to LOD 300 but it indicates interference detection between different elements.

LOD 400: The target element is geometrically defined in detail, as well as its position, which belongs to a specific constructive system, use and assembly in quantity terms, dimensions, shape, location and complete detailed orientation, specific product information for the project, commissioning work and installation. It can include non-graphic information.

LOD 500: The target object is geometrically defined in detail, as well as its position, which belongs to a specific constructive system, use and assembly in quantity terms, dimensions, shape, location and complete detailed orientation, specific product information for the project, commissioning work and installation. It can include non-graphic information. It is the same definition as in LOD 400 but for element which really have been implemented on work.

LOI (Level of Information): Is the level of non-modelled information that a BIM object has. The LOI can be boards, specifications or parametric information.

LOMD (Level of Model Definition): According to the British Convention, the model definition scale level. LOMD = LOD + LOI.

M

Measurement extraction: Measurement collection of a model.

MEP (Mechanical, electrical and plumbing): By extension, acronym referring building installations.

MET (Model Element Table): Board used to identify the responsible section that administrates and generates BIM models, and the level of development. MET, normally includes a list of model components in the vertical axe and the project milestones (or the project life cycle phases) in the horizontal axe.

Model categories: Category that relates to real objects of the building model that take part in its geometry, for instance: walls, coverings, soils, doors or windows.

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Model/prototype: Each of the specific objects that may form part of a BIM model.

MVD (Model View Definition): A standard that specifies methodology for the Exchange of data, content or IFC files, between the different programs and agents during the construction life cycle. In process by the Building Smart.

N

Native format: Working files original format from a certain computer application that normally is not useful as a direct way to exchange information with different applications.

O

Object category: Sorting and grouping objects inside a BIM model according to its constructive typology or purpose.

Open BIM: Exchanging of BIM Data by using open formats.

Operating phase: Is the last stage of a building life cycle. It includes all construction subsequent activities and the creation of the building.

P

Parameter: A variable that allows the control of object properties or dimensions.

Parametric model: A term concerning 3D models where objects/elements can be manipulated using explicit parameters, rules or restrictions.

PAS 1192 (Publicly Available Specifications): Specification published by the CIC (Construction Industry Council) whose main function is to be the frame that supports BIM objectives in the United Kingdom. It specifies the requirements to meet BIM standards and it establishes the bases to collaborate in enabled BIM projects, including available reporting rules and data exchange processes.

Passivhaus: Energy-efficient construction standards with a high interior comfort and affordability. It is promoted by the Passivhaus Institute from Germany, which is an international institution.

PIM (Product Information Management): Data management used to centralise, organise, classify, synchronize and enrich information related to products according to business rules, marketing strategies and sales. It centralises information related to products in order to feed multiple sales channels accurately and consistently and with the most current information.

PMI (Project Management Institute): Global organisation whose main objective is to establish Project Management standards, to organize educative programmes, and to administrate globally professionals' certification process.

Point clouds: The result of a data collection of a building or object by laser scanner, consisting in a set of points in the space that reflect its surface.

Procedure: Documented set of tasks developed in a certain order and shape, likely to be repeated multiple times to obtain similar results.

Project: Temporary planned effort that takes place to create a product, service or unique result. In the case of the construction industry, the result will be a building, an infrastructure facility, etc.

Project Management: The application of knowledge, skills, tools and techniques to realise activities necessary to comply with project requirements.

Q

Quality: Compliance measure of the requirements demanded to a product, according to the measurable and verifiable standards.

QA, Quality Assurance: A set of measures and actions applied to a process in order to verify the reliability and correction results.

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QC, Quality control: Operative techniques and activities used to comply with the quality requirements.

R

Reference category: Category that relates to objects that are not a real part of the building but that serve to define it, such as heights, levels, axes or areas.

Restriction: On a BIM model, limitation and blocking over an object, normally over its dimensions or its position relative to another object.

Reverse Engineering: Discipline that obtain information of a physical construction in order to define requirements for a new project.

Rework: Additional effort necessary to correct disagreement on a product.

RFI (Request for Information): The process by which someone participating on the Project (for instance, a contractor) sends a communication to another participant to verify the interpretation of what has been documented or to clarify what has been specified on a model.

ROI (Return on investment): Financial ratio that compares the profit or the profit obtained in relation to the investment made. In relation to BIM, it is used to analyse the financial benefits of implementing the BIM methodology in an organization.

S

SaaS (Software as a Service): Licensing model and software delivery where a software tool is not installed on the computer of each user, but centrally accommodated (on cloud) and it is provided to users by subscription.

Scope: The definition of a desired outcome, product or service related to the project. In BIM, range definition will dictate the model degree of development.

Scrum: Referential frame that defines a set of practices and roles, and that can be accepted as a starting point to define the development process that will be executed during a project. It is characterized by using a strategy of incremental development, instead of the planning and complete execution of the product, base the quality result on people's knowledge in self-organized teams and overlapping of the different development phases, instead of making one after the other on a sequential cycle or cascade.

Simulation: The process of designing a virtual model's object or real system and complete experiences with it in order to understand and predict the system or object's behaviour, or evaluate new strategies – inside the limits imposed by a certain or set criteria – for its functioning

Smart City: Technologic vision/solution inside an urban environment to connect multiple information and communication systems to manage constructed assets in a city. A Smart City vision/solution depends on data collect through motion sensors and monitor systems and is aimed at improving life quality of residents through the integration of different types of services and assets.

Social BIM: Term used to describe organization methods, project teams or the whole market, where multidisciplinary BIM models are generated, or where BIM models are exchanged in a collaborative way between participants on the project.

Soft skills: A collective name for personal qualities, social skills, communication skills, consensus skills, personal habits and friendship that give color to the relationships with others.

Space: Opened or closed area or volume, delimited by any element.

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Specification: A document specifying in a comprehensive, precise and verifiable manner the requirements, design, behavior and other details of a system, component, product, result or service. Procedures are often determining if these dispositions have been fulfilled.

Stakeholder: Person, group of people or entities that intervene or have interests in any part of a process.

Standard: A document established by common consent and approved by a recognized entity that provides common and recurring rules, directives or characteristics for activities or their results, aimed to achieve an optimal level in the context given.

T

Take-off: See extraction

Taxonomy: Multilevel classification (hierarchy, tree, etc.) introduced to organize and name concepts according to a clear structure, for example the objects of a BIM model.

Total cost of ownership: Estimation of all costs of a building/construction during the building life cycle.

Type of object: Subset of objects in a BIM model belonging to the same family and sharing parameters.

Type parameter: A variable that acts over all the objects of the same type existing in the model.

U

uBIM: Initiative promoted by the BuildingSMART in Spain in order to elaborate some guides to facilitate the implementation and use of BIM in Spain.

V

Value stream mapping: Visual tool that allows to identify all activities in planning and manufacture of a product, in order to find improvement opportunities that have an impact on the whole chain and not in isolated processes.

VBE (Virtual Building Environment): Consist on creating integrated shapes to represent the physical world in a digital format in order to develop a virtual world that reflects enough the real world creating the Smart Cities base in a constructed and natural environment, to ease the efficient design of infrastructures and programmed maintenance, and to create a new base for the economic growth and social welfare through the analysis based on evidences. Building and facilities BIM models will be part of this virtual entourage or they would increasingly be incorporated to it.

VDC (Virtual Design and Construction): Multidisciplinary integrated management models for the execution of construction projects, including the BIM model asset, work processes and the organization of the design, construction and operation team in order to meet with the project objectives.

W

WBS (Work Breakdown Structure): Hierarchical structure normally used as a tree that is broken down in works to be done to fulfil the objectives of a Project and to create the deliverables required aimed at organizing and defining the full-scope of it. Inside the construction industry it specifies the activities and tasks necessary to design or construct a new Project that results from this task.

Workflow: A study of the workflow operational aspects: how tasks are structured, how they are realized, what is its correlative order, how they are synchronized, how information supporting task flows and how completion of tasks are tracked. A workflow application automates the sequence of actions, activities or tasks used to execute the process, including the track of the state of each of its parts and the contribution of new tools to manage it. An essential concept to create BIM models, as well as essential to increase interoperability between the different tools that work in BIM environments.

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0.3 Advantages and value of using BIM for different uses

The move from 2D drawings to 3D models is well underway and gaining steam in the architectural, engineering, and construction industries, thanks to tangible bottom-line returns from streamlined workflows.

The model-based approach increases efficiency within individual organizations and truly shines during coordinated project delivery. Building Information Modelling (BIM) offers the advantage of time and budget savings for building and infrastructure projects.

Here are the top 11 benefits of BIM:

1. **Capture Reality**: the wealth of information that's easily accessible about project sites has expanded greatly with better mapping tools and images of Earth. Today, project starts including aerial imagery and digital elevation, along with laser scans of existing infrastructure, accurately capturing reality and greatly streamlining project preparations. With BIM, designers benefit from all of that input compiled and shared in a model—in a way that paper isn't able to capture.
2. **Waste Not, Want Not**: With a shared model, there's less need for rework and duplication of drawings for the different requirements of building disciplines. The model contains more information than a drawing set, allowing each discipline to annotate and connect its intelligence to the project. BIM drawing tools have the advantage of being faster than 2D drawing tools, and each object is connected to a database. The database aids such steps as the number and size of windows for quantity take-offs that are updated automatically as the model evolves. The quick, computerized counting of components alone has been a significant labour and money saver.
3. **Maintain Control**: the digital-model-based workflow involves aids such as autosave and connections to project history so that users can be certain they've captured their time spent working on the model. The connection to the version history of the model's evolution can help you avoid disastrous disappearances or corruption of files that can make blood boil and impinge productivity.
4. **Improve Collaboration:** sharing and collaborating with models is easier than with drawing sets, as there are a lot of functions that are possible only through a digital workflow. Much of this added projectmanagement functionality is now being delivered in the cloud, such as Autodesk's BIM 360 solutions. Here, there are tools for different disciplines to share their complex project models and to coordinate integration with their peers. Review and mark-up steps ensure that everyone has had input on the evolution of the design and that they are all ready to execute when the concept is finalized and moves forward in construction.
5. **Simulate and Visualize: a**nother of the advantages of BIM is the increasing number of simulation tools that allow designers to visualize such things as the sunlight during different seasons or to quantify the calculation of building energy performance. The intelligence of the software to apply rules that are based on physics and best practices provides a complement for engineers and other project team members. The software can do much more of the analysis and modelling to achieve peak performance, condensing knowledge and rules into a service that can run with the click of a button.
6. **Resolve Conflict:** the BIM toolset helps automate clash detection of elements such as electrical conduit or ductwork that run into a beam. By modeling all of these things first, clashes are discovered early, and costly

on site clashes can be reduced. The model also ensures a perfect fit of elements that are manufactured off site, allowing these components to be easily bolted into place rather than created on site.

7. **Sequence Your Steps:** with a model and an accurate set of sub-models for each phase during construction, the next step is a coordinated sequencing of steps, materials, and crews for a more efficient construction process. Complete with animations, the model facilitates coordination of steps and processes, delivering a predictable path to the expected outcome.
8. **Dive into Detail**: the model is a great end point for a lot of knowledge transfer, but there's also a need to share a traditional plan, section, and elevation, as well as other reports with your project team. Using automation and customization features, these added sheets can save valuable drafting time.
9. **Present Perfectly**: with all of the design completed on a capture and alteration of existing reality, the model is the ultimate communication tool to convey the project scope, steps, and outcome. The fact that the design is fully 3D also means that there are fewer steps to render impressive views and fly-through that can be used to sell commercial space or to gain necessary regulatory approvals.
10. **Take it with You**: having a model that's tied to a database is an added benefit of BIM, granting you a great deal of intelligence at your fingertips. Combining this capability with a cloud, there are, means that you have access to the model and project details from anywhere, on any device.
11. **Reduce Fragmentation**: in the days before BIM, getting a truly global view of a project proved difficult—with thousands of unconnected documents in play, sometimes it took years for design teams to see the forest for the trees. By pulling all of a project's documents into a single view, BIM enables teams to collaborate and communicate more effectively.

Nevertheless, the rush to standardize every process and deliverable has evidently taken precedence over the efforts to simplify the collaboration process and minimize project complexity. Model Uses offer a structured language for translating project goals into project outcomes, and thus brings clarity to services' procurement and performance improvement.

According to the defined glossary, Model Uses are the "intended or expected project deliverables from generating, collaborating-on and linking 3D models to external databases". Each Model Use represents a set of defined requirements, specialised activities and specific project outcomes, grouped together under a single heading so they can be more easily specified, measured and learned.

The main drivers for generating - and publicly sharing - a comprehensive Model Uses List are to contribute towards the reduction of project complexity by:

- Identify project deliverables: After project goals has been identified, Model Uses provide a structured language for populating Requests For Proposals (RFP)s, Pre-Qualification Questionnaires (PQQ), Employer's Information Requirements (EIR)s and similar documents;
- Define learning objectives: Model Uses allow the collation of specialised competencies to be acquired by individuals, organizations and teams;
- Assess capability/maturity: Model Uses act as performance targets to be used for measuring or pre-qualifying the abilities of project stakeholders;
- Allow assignment of responsibilities: Model Uses allow Project Team and Work Team capabilities to be matched to particular Model Uses and the assignment of responsibilities;
- Bridge the semantic gaps between project-based industries: Model Uses represent the deliverables of multiple information systems – BIM, GIS, PLM and ERP [3] - and help bridge the semantic gap between interdependent industries (e.g. Geospatial, Construction, and Manufacturing).

According to buildingSMART, an "IFC View Definition, or Model View Definition, MVD, defines a subset of the IFC schema, that is needed to satisfy one or many Exchange Requirements of the AEC industry." Also, according to NBIMS, the "aim of the Information Delivery Manual (IDM) (buildingSMART Processes) and Model View Definition (MVD) is to specify exactly which information is to be exchanged in each exchange scenario and how to relate it to the IFC model." To date, only a few Model Views are defined via official MVDs, and even less MVDs have been implemented by BIM Software Tools. Irrespective of the number of MVDs currently available, will be defined in the future, or will be implemented by willing software developers, there is a prior and separate need for a comprehensive list of Model Uses. This is because:

- On the one hand, Model View Definitions are clearly intended to standardise computer-to-computer exchanges based on common use cases;
- On the other hand, Model Uses are intended to simplify human-to-human interactions, and human-to-computer interactions (HCI). Model Uses' main purpose and benefits - as discussed in Section 1 - are not to improve software tools, but to facilitate communication between project stakeholders and link Client/Employer's, requirements to project outcomes and team competencies.

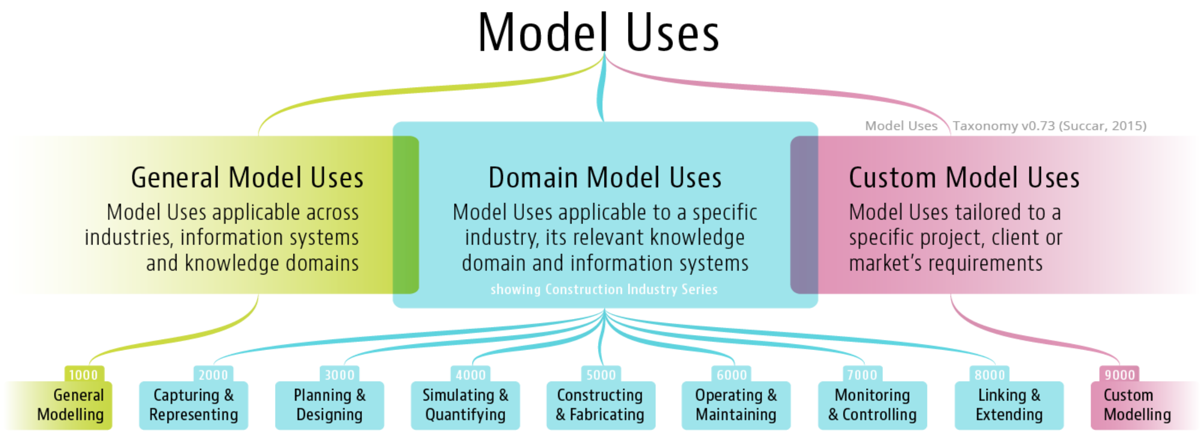
It is possible to define tens or even hundreds of Model Uses (MU)s to represent modelled or model-able information. However, it is important to define the minimum workable number (no more, no less) that allows two seemingly contradictory objectives: accuracy of representation and flexibility of use.

With respect to accuracy of representation, if the number of Model Uses is too small, then their definitions would be wide, less precise and sub-divisible into sub-uses. However, if the number of Model Uses is too large, then their definitions would be narrow, include overlapping activities/responsibilities and thus cause confusion. What we need is a Model Use breakdown which is 'just right' for effective communication and application.

With respect to flexibility of use, and to allow the application of Model Uses across varied contexts, Model Use definitions must exclude unnecessary qualifications that vary from user to user, and from one market to another. To this end, Model Uses are defined independently from their user, industry, market, phase, priority, and inherent activities:

- ✓ Model Uses are defined independently from Project Lifecycle Phases and thus can apply, depending on stakeholder's BIM Capability, at any/all phases of a project;
- ✓ Model Uses are defined independently from how they will be applied: this allows their consistent use in project procurement, capability development, organizational implementation, project assessment and personal learning;
- ✓ Model Uses are defined without a built-in priority: this allows each MU's priority to be set by stakeholders on each project; and
- ✓ Model Uses are not pre-assigned to disciplinary roles: this allows the assignment of responsibility for Model Uses based on project participants' experience and measured capability.

By combining the two objectives - accuracy and flexibility – and after identifying the point of balance between them, the below Model Uses List has been developed:



0.4 Open BIM tools and standard format

One of the basic assumptions of Building Information Modelling is the easy and secure exchange of data between the different figures involved at distinct levels in the project (principle of interoperability). An "open BIM strategy" supports a transparent, open workflow, allowing project members to participate regardless of the software tools they use and creating a common language for widely referenced processes, allowing industry and government to procure projects with transparent commercial engagement, comparable service evaluation and assured data quality.

Open BIM provides enduring project data for use throughout the asset life-cycle, avoiding multiple input of the same data and consequential errors. Small and large (platform) software vendors can participate and compete on system independent, 'best of breed' solutions. Open BIM energizes the online product supply side with more exact user demand searches and delivers the product data directly into the BIM.

As a matter of fact, the specialized software developed for the management and processing of data within specific sectors - such as Engineering & Construction - lacked the ability to integrate each other; the transversely of the BIM approach necessarily requires maximum accessibility of such project and process information to all those.

The solution through which it is possible to guarantee access to data to all operators is called IFC. Acronym of "Industry Foundation Classes", IFC is the open international standard developed by buildingSMART and used by the most popular design software. On one hand, the IFC format allows the designer to continue working with familiar tools; on the other hand, it allows the use and re-use of all the data contained in the project by relating them to other software platforms used by other stakeholders dedicated to other aspects (structural, management, construction, etc.) of the work. IFC is continuously integrated with new items to take into account the AEC needs. In the last years, for instance, IFC for infrastructure is under development and experts of many countries are defining new IFC for rail, highways bridges and tunnels. It is very important to get support of the main stakeholders so that the software applications will meet their needs.

Standardization activity born from the need to address problems of industrial-technical nature and benefits of standardization include:

- ✓ Benefits for business: ensure that business operations are as efficient as possible, increase productivity and help companies access new markets;
- ✓ Cost savings for suppliers and customers: optimize operations, simplifies and reduces project time and reducing wastes;
- ✓ Enhanced customer satisfaction: help improve quality, enhance customer satisfaction to assure customers that products/services are of the appropriate degree of quality, safety and respect for the environment;
- ✓ Protection of consumers and the interests of the community: sharing of best practices leads to the development of better products and services;
- ✓ Access to new markets: help prevent trade barriers and open up global markets;
- ✓ Increased market share: help increase productivity and competitive advantage (helping to create new business and maintaining existing);
- ✓ Increase market transparency: leads to common understanding and solutions;
- ✓ Environmental benefits: help reduce negative impacts on the environment.

There are three main levels of organizations for standardization: national, regional and international.

At European level there is a complete standardization framework on energy calculation methods under the EPDB:

EN 15217:2012 - Energy performance of buildings – Methods for expressing energy performance and for the energy certification of buildings:

- specifies overall indicators to express the energy performance of whole buildings, including heating, ventilation, air conditioning, domestic hot water and lighting systems. This includes different possible indicators;
- specifies ways to express energy requirements for the design of new buildings or renovation of existing buildings;
- specifies procedures to define reference values;
- can be applied to a group of buildings, if they are on the same lot, if they are serviced by the same technical building systems and if no more than one of them has a conditioned area of more than 1000 [m2].

EN ISO 52000-1:2017 - Energy performance of buildings (EN 15603):

- introduces calculation procedures and an indicative list of indicators for the evaluation of the energy efficiency: final energy needs (constructive quality of the envelope), total use of primary energy, total non-renewable primary energy use, and total use of non-renewable primary energy considering the impact of the exported energy.

EN 15316-1:2017 - Energy performance of buildings. Method for calculation of system energy requirements and system efficiencies - Part 4-1: Space heating and DHW generation systems, combustion systems (boilers, biomass):

- specifies methods for the calculation of thermal losses from the heating and the domestic hot water generation system, recoverable thermal losses for space heating from the heating and the domestic hot water generation system, auxiliary energy of the heating and the domestic hot water generation systems;
- specifies the energy performance calculation of water based heat generation sub-systems including control based on combustion of fuels ("boilers"), operating with conventional fossil fuels as well as renewable fuels;
- applicable to heat generators for heating or for combined service as domestic hot water, ventilation, cooling and heating.

EN 15316-2:2017 - Energy performance of buildings - Method for calculation of system energy requirements and system efficiencies. Space emission systems (heating and cooling):

- covers energy performance calculation of heating systems and water based cooling space emission sub-systems.

EN 15316-3:2017 - Energy performance of buildings - Method for calculation of system energy requirements and system efficiencies - Space distribution systems (DHW, heating and cooling):

- covers energy performance calculation of water based distribution systems for space heating, space cooling and domestic hot water;
- deals with the heat flux from the distributed water to the space and the auxiliary energy of the related pumps.

EN 15316-4:2017 - Energy performance of buildings - Method for calculation of system energy requirements and system efficiencies - Part 4-3: Heat generation systems, thermal solar and photovoltaic systems:

Within this standard, 6 methods are specified each method has its own range of applicability:

- Method 1, is applicable for solar domestic hot water systems characterized by the EN 12976 series (factory made) or EN 12977-2 (custom built). The main output of the method is the solar heat and back up heat contribution to the requested heat use;
- Method 2, is applicable for systems for domestic hot water and / or space heating with components characterized by EN ISO 9806 and EN 12977-3 or EN 12977-4 with a monthly calculation time step. The main output of the method is the solar heat and back up heat contribution to the requested heat use;
- Method 3, is applicable for systems for domestic hot water and / or space heating with components characterized by EN ISO 9806 with an hourly calculation time step. The main output of the method is collector loop heat supplied to the heat storage;
- Method 4, is applicable for photovoltaic systems with components characterized by standards and with an annual calculation time step. The output of the method is the produced electricity;
- Method 5, is applicable for photovoltaic systems with components characterized by standards and with a monthly calculation time step. The output of the method is the produced electricity;
- Method 6, is applicable for photovoltaic systems with components characterized by standards and with a calculation time step. The output of the method is the produced electricity.

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EN 15241:2008 - Ventilation for buildings - Calculation methods for energy losses due to ventilation and infiltration in buildings:

- Describes the method to calculate the energy impact of ventilation systems (including airing) in buildings to be used for applications such as energy calculations, heat and cooling load calculation;
- Defines how to calculate the characteristics (temperature, humidity) of the air entering the building, and the corresponding energies required for its treatment and the auxiliaries electrical energy required.

EN 15193:2008 - Energy performance of buildings - Energy requirements for lighting:

- Specifies the calculation methodology for the evaluation of the amount of energy used for indoor lighting inside the building and provides a numeric indicator for lighting energy requirements used for certification purposes;
- Can be used for existing buildings and for the design of new or renovated buildings.

EN ISO 13790:2011 - Energy performance of buildings - Calculation of energy use for space heating and cooling (ISO 13790:2008):

- Provides calculation methods for assessment of the annual energy use for space heating and cooling of a residential or a non-residential building already existing or at the design stage;
- Developed for buildings that are, or are assumed to be, heated and/or cooled for the thermal comfort of people, but can be used for other types of building or other types of use (e.g. industrial, agricultural, swimming pool), as long as appropriate input data are chosen and the impact of special physical conditions on the accuracy is taken into consideration;
- Includes the calculation of the heat transfer by transmission and ventilation of the building zone when heated or cooled to constant internal temperature, the contribution of internal and solar heat gains to the building heat balance, the annual energy needs for heating and cooling to maintain the specified setpoint temperatures in the building.

EN ISO 13789:2017 - Thermal performance of buildings - Transmission and ventilation heat transfer coefficients - Calculation method (ISO 13789:2017):

- Specifies a method and provides conventions for the calculation of the steady-state transmission and ventilation heat transfer coefficients of whole buildings and parts of buildings;
- Applicable both to heat loss (internal temperature higher than external temperature) and to heat gain (internal temperature lower than external temperature).

EN 13465:2004 - Ventilation for buildings - Calculation methods for the determination of air flow rates in dwellings:

- Specifies methods to calculate basic whole house air flow rates for single family houses and individual apartments up to the size of approximately 1000 m[3];
- May be used for applications such as energy loss calculations, heat load calculations and indoor air quality evaluations.

EN 15242:2007 - Ventilation for buildings - Calculation methods for the determination of air flow rates in buildings including infiltration (PNE-EN 16798-7):

- Describes the method to calculate the ventilation air flow rates for buildings to be used for applications such as energy calculations, heat and cooling load calculation, summer comfort and indoor air quality evaluation;

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- The method contained in the standard is meant to be applied to mechanically ventilated building, passive ducts, hybrid system switching between mechanical and natural modes, windows opening by manual operation for airing or summer comfort issues;
- Not directly applicable for buildings higher than 100 m and rooms where vertical air temperature difference is higher than 15K.

EN 15251:2008 - Indoor environmental input parameters for design and assessment of energy performance of buildings addressing indoor air quality, thermal environment, lighting and acoustics (PNE-prEN 16798-1):

- Specifies the indoor environmental parameters which have an impact on the energy performance of buildings and how to establish these for building system design and energy performance calculations;
- Specifies methods for long term evaluation of the indoor environment obtained as a result of calculations or measurements;
- Applicable mainly in non-industrial buildings where the criteria for indoor environment are set by human occupancy and where the production or process does not have a major impact on indoor environment.

EN ISO 15927-5:2006/1M:2012 - Hygrothermal performance of buildings - Calculation and presentation of climatic data - Part 5: Data for design heat load for space heating - Amendment 1 (ISO 15927-5:2004/Amd 1:2011):

- Specifies the definition, method of calculation and method of presentation of the climatic data to be used in determining the design heat load for space heating in buildings. These include the winter external design air temperatures and the relevant wind speed and direction, where appropriate.

EN ISO 52022-1:2017 – Energy performance of buildings - Thermal, solar and daylight properties of building components and elements:

- Specifies a simplified method based on thermal, solar and light characteristics of the glazing and solar and light characteristics of the solar protection device, to estimate the total solar energy transmittance, direct energy transmittance and the light transmittance of a solar protection device combined to a glazing;
- Applicable to all types of solar protection devices parallel to the glazing.

It is widely known that the construction sector is a key sector for achieving sustainable development. Because of that, systems for description, quantification, assessment and certification of sustainable buildings have been developed at international level and in Europe. CEN/TC350 "Sustainability of Construction Works" has the task to establish the European set of rules for sustainability of construction works:

EN 15643-1: 2012 – General Framework:

- Provides the general principles, requirements and guidelines for the sustainability assessment of buildings;
- The assessment will quantify the contribution of the assessed construction works to sustainable construction and sustainable development;
- Applies to all types of buildings (new and existing buildings).

EN 15643-2:2012 - Framework for the assessment of environmental performance:

- Provides specific principles and requirements for the assessment of environmental performance of buildings;
- Assessment is on life cycle assessment;
- Environmental information expressed through quantified indicators (for example: acidification of land and water resources, use of freshwater resources; non-hazardous waste to disposal);
- Applies to all types of buildings (new and existing buildings).

EN 15643-3:2012 - Framework for the assessment of social performance:

- Provides specific principles and requirements for the assessment of social performance of buildings;
- Focus on the assessment of aspects and impacts of a building expressed with quantifiable indicators;
- The indicators are integrated in the following categories: accessibility, adaptability, health and comfort, impacts on the neighborhood, maintenance, safety/security, sourcing of materials and services and stakeholders involvement;
- Applies to all types of buildings (new and existing buildings).

EN 15643-4:2012 - Framework for the assessment of economic performance:

- Provides specific principles and requirements for the assessment of economic performance of buildings;
- Addresses the life cycle costs and other economic aspects, all expressed through quantitative indicators;
- Includes economic aspects of a building related to the built environment within the area of the building site;
- Applies to all types of buildings (new and existing buildings).

EN 15643-5: 2018 Framework on specific principles and requirement for civil engineering works

EN 15978:2012 - Assessment of environmental performance of buildings - Calculation method:

- Assess the environmental performance of a building, and gives the means for the reporting and communication of the outcome of the assessment;
- The assessment covers all stages of the building life cycle and is based on data obtained from Environmental Product Declarations (EPD), and other information necessary and relevant for carrying out the assessment;
- Includes all building related construction products, processes and services, used over the life cycle of the building;
- Applies to all types of buildings (new and existing buildings).

EN 16309: 2015 – Assessment of Social Performance - Calculation methodology:

- Provides specific methods and requirements for the assessment of social performance of buildings;
- In this first version the social dimension of sustainability concentrates on the assessment of aspects and impacts for the use stage of a building expressed using the following categories: accessibility, adaptability, health and comfort, impacts on the neighborhood, maintenance and safety/security;
- Applies to all types of buildings (new and existing buildings).

EN 15804: 2012 +A1:2014- Environmental Product Declaration:

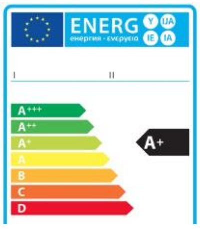
- Provides the Product Category Rules (PCR) for developing Environmental Product Declaration (EPD);
- Apply to any construction products and construction service;
- EPD is expressed in information modules, which allow easy organization and expression of data packages throughout the life cycle of the product;
- There are three types of EPD with respect to life cycle stages covered: “cradle to gate”, “cradle to gate with options” and “cradle to grave”.

EN 15942: 2013 – Environmental product declarations — Communication format business-to-business:

- Specifies and describes the communication format for the information defined in EN 15804: 2012, to ensure a common understanding through consistent communication of information
- Aimed the business to business communication (B2B);
- Is applicable to all construction products and services related to buildings and construction works.

CEN/TR 15941: 2011 - Environmental product declarations - Methodology for selection and use of generic data:

- This technical report supports the development of Environmental Product Declarations (EPD);
- Provides guidance for the selection and use of different types of generic data available for practitioners and verifiers involved in the preparation of EPD;
- Aimed to improve consistency and comparability.



EN 16627:2016 Sustainability of construction works - Assessment of economic performance of buildings - Calculation methods.

Environmental labels provide precise and useful information to clients and consumers about the environmental performance of products or services. A very simple sentence, a graphic, or a combination of both can be used in environmental labels. There are mandatory labels, like the EU energy label or the energy certificate of a building. There are voluntary labels, like the EU ecolabel or environmental product declarations. Mandatory environmental labels are defined in laws and regulations. Usually the objectives are to provide important environmental information to clients and consumers and to promote the products and services with the best performance related to some environmental aspects.

The EU energy label for energy-related products is an example of a mandatory environmental label. It is a label with information regarding energy consumption and other performance characteristics of any goods having an impact on energy consumption during use. There are EU energy labels for lamps, luminaires, air conditioners, televisions, tumble driers, washing machines, dishwashers, refrigerating appliances, vacuum cleaners, space heaters and water heaters, among other products.

The energy certification of buldings is mandatory in all EU countries. The building energy class can be used as a label in advertising providing information on the energy performance of the buiding for buyers or tenants.

Download example of EU label for vacuum cleaner

Download example of EU label for air conditioners

Download example of energy certification of buildings in Spain

There are mainly three types of voluntary environmental labels:

- self-declared environmental claims: are made by producers that wish to inform consumers that their product is better than others in what concerns a particular environmental aspect. In order to become credible among consumers, these claims should follow the requirements established in the international standard ISO 14021.
- environmental labelling programmes: award a product or service with a mark or a logo based on the fulfilment of a set of criteria defined by the programme operator. In order to become credible among consumers, these programmes should follow the requirements established in the international standard ISO 14024.
- environmental product declarations: provide clients with a set of life cycle data describing the environmental aspects of a product or service. In order to become credible among consumers, these declarations should follow the requirements established in the international standard ISO 14025.

According to ISO standards, claims that are vague and non-specific shall not be used, because they are misleading.

The **EU ecolabel** is an example of a voluntary environmental label. The EU ecolabel identify products and services that have a reduced environmental impact throughout their life cycle, from the extraction of raw material through to production, use and disposal. The EU ecolabel awards products and services that fulfill a set of environmental criteria defined for the respective product category.

0.5 The CDE (Common Data Environment)

The CDE - Common Data Environment - can be defined as an application, generally available in Cloud, usable by any device (Computer, Tablet or Smartphone) from which it is possible to manage unambiguously and structured information for project management. The CDE allows distributing information and creating value for the whole chain of operators involved in the process facilitating collaboration among them.

The main areas covered by a CDE are: Document Management, Task Management and Asset Management; all these activities, if properly integrated into a BIM process, are able to offer greater efficiency and control in any process.

To obtain the best results it is also essential that the strategic choices for the correct management of a work are anticipated and shared as early as possible. Moreover, all the choices and the consequent planned activities must be shared in real time in order to allow a high level of collaboration among all the operators; also, in this case the use of a CDE ensures greater efficiency in the exchange of information and a greater collaboration level between all the operators involved in the decision-making process.

The adoption of a CDE finally allows to overcome geographical barriers and allow, for example, to create extended work teams, also belonging to different countries or continents; the possibility offered by the CDE to collaborate remotely using a shared technology platform offers the opportunity to create new business opportunities by lowering management costs

The six key points for building a successful Common Data Environment are:

1. **Choose the right team:** choose team members of the project with necessary skills for performing required activities, motivated to work together to achieve project objectives. A motivated and prepared team is the key to success.
2. **Define roles and responsibilities:** team members who participate in the project and access the Common Data Environment must operate according to the activities assigned to them and their competences with different roles and levels of responsibility; make sure that each of them is assigned the right profile to access the Common Data Environment. A proper setting of the common data environment allows all members of the team to optimizing their needs. Do not skimp on the time it takes to set up the Common Data Environment correctly.
3. **Define workflows:** clearly decide who can do what, for example who can access a certain type of information or documents, define what rules must be approved for documents and activities.

4. **Common language and data availability:** Define a common language, such as which file formats to use, keep in mind that practically all international and national standards require the use of non-proprietary and open formats. The information to be available always and from anywhere must also be accessible from mobile choose a solution that guarantees this fundamental prerogative.
5. **Data security first of all:** the Common Data Environment to guarantee access levels to the H24 data needs to operate in Cloud, which means that data protection must be guaranteed with security levels close to 100% (nobody can guarantee 100%). To ensure an adequate level of security the data must be encrypted and the encrypted communications. Define diversified access with at least three levels of access.
6. **The BIM qualifying factor:** the use of a tool such as the Common Data Environment, combined with the use of BIM, allows to obtain strong cost savings, reliable construction times and a more efficient management of buildings during the entire life cycle of the building. In the Common Data Environment, access to information and the display of federated BIM models must also be guaranteed.

0.6 The BEP (BIM Execution Plan)

Publicly Available Specifications (PAS) are fast-track standards, specifications, codes of practice or guidelines developed by sponsoring organisations to meet an immediate market need following guidelines set out by BSI (British Standards Institution). Within 2 years they are reviewed to assess whether they should be revised, withdrawn, or become formal British Standards or international standards.

PA**S 1192-2:2013** is the Specification for information management for the capital/delivery phase of construction projects using building information modelling. It is sponsored by the Construction Industry Council (CIC) and published by The British Standards Institution. It came into effect on 28 February 2013. It specifies the requirements for achieving building information modelling (BIM) Level 2. Level 2 involves developing building information in a collaborative 3D environment with data attached, but created in separate discipline models.

PAS 1192-2:2013 proposes the creation of a BIM Execution Plan (BEP sometimes abbreviated as BxP) for managing delivery of the project:

1. A pre-contract BEP is prepared by prospective suppliers, setting out their proposed approach, capability, capacity and competence to meet the Employer's Information Requirements (EIR).
   PAS 1192-2:2013, proposes that the pre-contract BIM Execution Plan is a direct response to the **Employer's Information Requirements** (EIR). The EIR is a crucial document which sets out the information required by the employer aligned to key decision points or project stages. It may be considered to sit alongside the project brief. Whilst the project brief defines the nature of the built asset that the employer wishes to procure, the Employer's Information Requirements defines information about the built asset that the employer wishes to procure to ensure that the design is developed in accordance with their needs and that they are able to operate the completed development effectively and efficiently.
   The pre-contract BIM Execution Plan may include:
   - A Project Implementation Plan (PIP) setting out the capability, competence and experience of potential suppliers bidding for a project, along with quality documentation;
   - Goals for collaboration and information modelling;
   - Project milestones in line with the project programme;
   - Deliverable strategy.

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2. A <u>post-contract BEP</u>: once the contract has been awarded, the successful supplier then submits a further BIM Execution Plan confirming the supply chain's capabilities and providing a **Master Information Delivery Plan** (MIDP). The MIDP is the primary plan setting out when project information is to be prepared, by whom, using what protocols and procedures, it is based on a series of individual Task Information Delivery Plans setting out responsibility for specific information tasks.
   The post contract-award BIM Execution Plan sets out how the information required in the Employer's Information Requirements will be provided:
   - Management:
     - Roles, responsibilities and authorities;
     - Project milestones in line with the project programme;
     - Deliverable strategy;
     - Survey strategy;
     - Existing legacy data use;
     - Approval of information;
     - Authorisation process.
   - Planning and documentation:
     - Revised project implementation plan (PIP) confirming the capability of the supply chain;
     - Agreed processes for collaboration and modelling;
     - Agreed matrix of responsibilities;
     - Task Information Delivery Plan (TIDP) setting out responsibility for delivery of each supplier's information;
     - Master Information Delivery Plan (MIDP) setting out when project information is to be prepared, by whom and using what protocols and procedures.
   - Standard method and procedure:
     - Volume strategy;
     - Origin and orientation;
     - File naming convention;
     - Layer naming convention;
     - Construction tolerances;
     - Drawing sheet templates;
     - Annotation, dimensions, abbreviations and symbols;
     - Attribute data.
   - IT solutions:
     - Software versions;
     - Exchange formats;
     - Process and data management systems.

[Download free template of **post-contract** BEP produce by CPIC (Construction Project Information Committee).]

1. Module 1 – Diffuse BIM

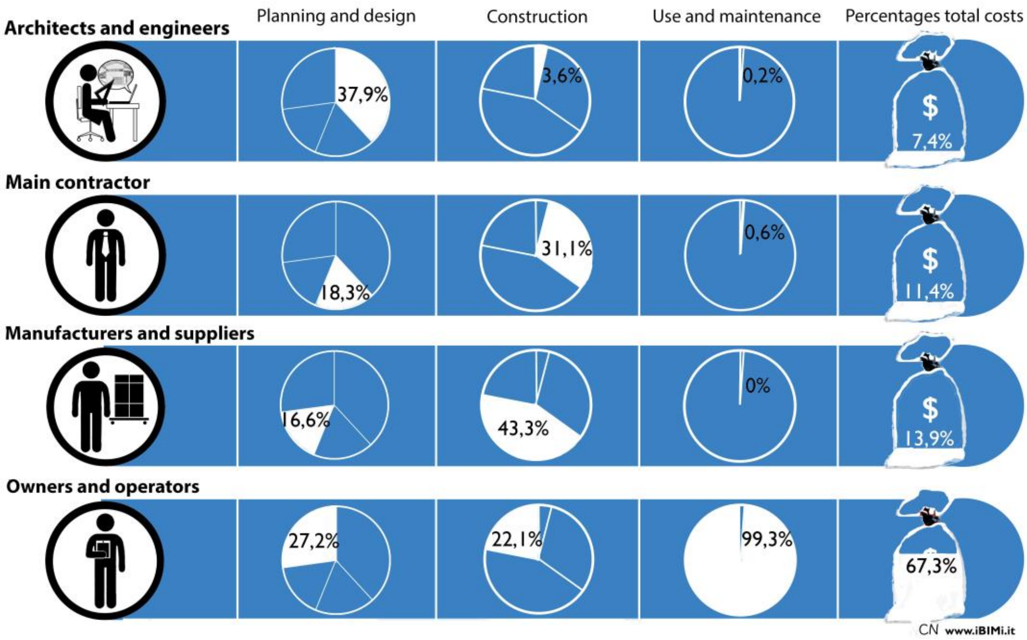
1.1 Return on investments

The following paragraphs report a study made by Autodesk. Similar conclusions can be detected also by professionals using other software. The economic value of BIM technology is often weighed by measuring the ratio of return on investment, or ROI. Companies wishing to adopt BIM technology have always sought reliable factors for understanding how the technology and software transition will impact their company. After more than a decade of experience with BIM, the design and construction industry is now realizing BIM's value and financial impact. Calculating ROI has become a necessary evaluation step prior to many capital or labor-intensive business investments, such as BIM adoption. However, while some firms calculate a return-on-investment ratio to assess the economic benefits associated with process change, others find making this calculation too difficult or cumbersome.

The problem is that ROI analysis is often unable to represent intangible factors that are important to a project or a firm, such as avoided costs or improved safety. In addition, the systems and staffing required to measure and track ROI can be time-consuming and costly. Currently, no industry-standard method for BIM ROI calculation exists and many firms have not adopted any consistent measurement practices, although there is interest in doing so and belief in the potential value of ROI for BIM investment decision-making.

In a study performed by NIST in USA, which involved all the supply chain industry, the cost of non-interoperability was evaluated bringing to very interesting results. The main cost, in fact, burden on proprietary and less on the designers. This is one of the main reasons why it is important to "educate" public administration, as owner of buildings.

The following info graphic shows how the cost of non-interoperability are divided among the supply chian and among the different building life cycle.



In this context we will only analyze the RoI for professionals involved in the design and construction.

Defining the economic impact of BIM for the building design and construction industry is a challenge that has attracted significant academic research interest. This interest covers a breadth of inquiry into BIM ROI that spans the entire project lifecycle, examines various building types and considers varying levels of BIM experience while also looking at a range of calculation methods. There are three types of BIM investments:

1. Startup costs to ensure technology implementation is successful: although technology investment particularly in the startup phase is deemed a significant expense by over 50% of the survey respondents, it is considered unavoidable in the industry if the idea is to stay competitive and up to date. “BIM work requires more computing power and more networking power than traditional CAD work, and that power comes with a cost.” Respondents cited direct labor expenses as the largest component of any project, whether it is a BIM or a traditional CAD project. “When we originally looked into BIM, we knew it was going to be a huge investment to train the staff, how to use it, and how to use it efficiently. There was going to be the whole ramp-up time, in which everyone would be slower than they were in AutoCAD Architecture.”

   The costs of professional development, including initial training in the use of BIM products and further instruction in new work methods, must also be considered in the investment calculation.
2. Costs for tailoring BIM to a specific project: as BIM use on projects proliferates, 32% of survey respondents reported that additional labor investments are needed to tailor BIM to the processes of the firm, such as by adding a BIM manager or more IT support. One electrical contractor stated, “If there is one thing that as an industry we need to be aware of and attempt to change, then that is keeping the level of expertise proportional to the advances that are being made in the technology”.
3. Longer-term outlays for strategic business changes, such as investing in standards development or customization: are part of the calculation, however, such costs can be difficult to quantify. Changes to internal processes – for instance, integrating data and information in the model earlier in the design development process or incorporating modeling during preconstruction – also have to be considered to build a complete investment calculation.

   During adoption and early implementation, companies also find it challenging to measure costs such as workflow disruptions and inefficiencies.

   Virtually all Autodesk customers interviewed about ROI agreed that BIM represents an improvement in the way buildings are designed and promises a host of benefits to project contributors and to the owner over the project’s lifetime. “It wasn’t really a financial decision… this is where everything is going. If we’re going to keep up and remain competitive, we’re going to have to go there.” “For owners, it’s all about getting the building built sooner. The sooner the hospital is operating, the sooner the revenue starts. Nobody builds a building just for fun.”

   Of course, calculating BIM ROI goes beyond these three types of investment. A nuanced view of return on investment for BIM considers three dimensions:

   - ORGANIZATION DIMENSION are benefits measured at the project level or the firm level?
   - STAKEHOLDER DIMENSION what specific role does the company occupy in the project ecosystem?
   - MATURITY DIMENSION how much depth of BIM experience does the team and the company have?

By considering BIM adoption and ROI assessment across these three dimensions, firms may be better able to understand how measurement and technology innovation can be combined strategically to inform progress toward future levels of BIM maturity. “BIM has allowed us to remain where we want to be in the marketplace, and as other firms embrace BIM, we want to make sure that we remain a player. I think that we have strengthened our position in terms of market share and simply being ready to do the kinds of projects we know how to do.”

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At the higher level of BIM maturity it will be possible not only to exchange and share information among different software applications but also to store them for all the lifecycle of the building. This means that the information needs to “survive” to a specific software application and version. This is the basis for the “open BIM” and BuildingSMART international is the not for profit organization, which is developing these standards together not only with the software houses but also with the main players both private and public.

1.1.1 Organization dimension of BIM ROI

When companies make the decision to move to BIM, the drivers for adoption establish important objectives that impact the way returns are pursued and achieved. In some cases, customers interviewed about BIM ROI stated that adoption was driven by a client requirement on a project. In this case, a firm is likely to seek returns resulting from the success and profitability of that completed BIM-enabled project.

The first step for any organization, wishing to implement BIM, is to analyze internal processes as well as processes external to the company with clients and suppliers. From this analysis the company can understand the benefit of a smooth exchange of information without misunderstanding, delay, errors, dispute, etc.. This would be the zero maturity level. From this first analysis the need for digitalization of both graphic and non-graphic information will start to be evident. In the beginning the professionals could even continue to use CAD 2D as far as all the information are linked to this model thorough a database using international standards to ensure the possibility to exchange the data within and outside the company at any time.

Level 1 BIM consists of managed CAD, with the increasing introduction of spatial coordination, standardized structures and formats as it moves towards Level 2 BIM. This may include 2D information and 3D information such as visualizations or concept development models. At this level of maturity there are separate sources of information that covers a range of asset information in semi-structured electronic documents. ‘File based’ collaboration is achieved through the use of a Common Data Environment (CDE). This is essentially a digital place in which all project in formation comes together (not simply drawings and models but also schedules and specifications). Therefore any enterprise can start implementing BIM simply by digitalizing information and sharing them within the supply chain. At this point is possible to evaluate the RoI for using more performing hardware/software systems and for training the employees.

Autodesk customers reported that BIM provided tangible, quantifiable benefits at the project level – such as fewer RFIs (Request for Information) – along with intangible benefits, which are more difficult to quantify. These present an opportunity to efficiently pursue and analyze additional design options and increase project value through parametric design improvements:

- ✓ **Reduction in waste and risk** (for examples significant savings stemming from the design, construction, and erection of structural steel packages designed using BIM);
- ✓ Improved design quality;
- ✓ **Reduction in errors**, being able to contain labor costs more and complete projects faster with fewer errors. As the profession matures, BIM adoption will set us up for working on integrated project delivery projects because the company will absorb the software learning curve as well as the mental learning curve of working on a different risk model. The long-term benefit is that it sets us up to do the kind of work that company want to do economically;
- ✓ **Increased client, design, and construction team understanding and communication** due to a simple showing of an animation generated straight out of the software;
- ✓ Accelerated regulatory approval and permitting, and reduction of risk for the owner;

- ✓ Improved project delivery through efficient use of resources, improved safety and accurate timelines, with a consequent reduction of litigation and claims.

As firms expand their application of BIM to multiple projects or widen use of BIM as a business strategy, the notion of ROI must expand to incorporate benefits at a firm level, such as opportunities for work with new clients. Other benefits included staffing competency and retention. Opportunities for business model expansion or new services, such as quality assurance or model development, are also benefits at the firm level.

Data-rich models provide opportunities for companies to offer ongoing services to clients as data is more seamlessly integrated into facility operations and maintenance.

It can be challenging to attribute returns at the firm level solely to BIM adoption. If companies continue to track business health in terms of traditional metrics such as profitability, risk factors, volume of claims/litigation, projects won or lost, or repeat business with key clients, the actual impact of BIM on these measures can be difficult to separate from other factors.

1.1.2 Stakeholder dimension of BIM ROI

Interview respondents revealed that they assess the returns of BIM differently depending on their role in a project – whether one employs BIM as a tool in design, construction, or operations affects perspective. For example, owners tend to recognize multiparty communication and improved project process and outcomes as top benefits. Contractors list productivity and lower project cost as their top BIM benefits. Owners appear to be much more interested in ROI calculations and, like owners, designers are interested in ROI as a means to gain deeper insights into opportunities. Many design firms were early to adopt BIM based on the perception that their firms would be better positioned to work with public entities which adopted BIM mandates.

	Professional	Technician	Owner
BIM adoption	Widespread	Emerging, and increasingly appreciated	Many specify BIM, but few actively use or completely understand it
Key benefits	Improved collaboration with project contributors Less rework, fewer change orders	Minimizes/eliminates a significant number of changes Improves construction management Great for quantitatives and materials estimating	Can shorten time to completion of project overall Enables more effective management, operations and upgrades
Associated costs	Requires more time to fully populate the model Designers can eat up more time exploring design alternatives	Requires a change in business process and accompanying technology investment to fully realize	Uncertain at present, other than investment in the software
Interest in ROI	Not particularly helpful if tied to a decision to use BIM or not Interested in understanding hidden costs as well as possible revenue opportunities	Not directly relevant as the BIM decision is typically not theirs to make	Interested and in need of education on getting the most benefit out of BIM-designed assets
Outlook on BIM	Here to stay. Makes work more complex but represents the “right thing to do.”	Welcome improvement that should be applied to all projects	Significant potential and increasingly a standard requirement imposed upon project contributors

1.1.3 Maturity dimension of BIM ROI

When moving from 2D to initial BIM implementation, firms calculate ROI to determine whether the technology investment will be worthwhile. However, once firms have moved past the initial stage of BIM adoption, ROI calculation shifts to a more nuanced tool to assess specific initiatives linked to firm strategy. Recent research notes a correlation between different levels of BIM experience and ROI. High ROI is reported by a majority of high maturity BIM users, yet only by 20% of the low maturity BIM users. “The huge cost shifter with BIM is the way we use it to put great tools in the hands of experienced designers. Once trained, these very experienced people can do more in the same amount of time.”

Many customers with significant BIM experience report having internal practices to measure experience, assess company competency, and provide incentive to employees to develop necessary skills. In regions where governments have enacted policies to encourage BIM adoption, such as in the United Kingdom, experience or maturity levels are often officially defined to provide clarity and to drive practitioners to increasing levels of sophistication.

There remains a strong interest in applying ROI to assess specific BIM advances once firms have achieved the first level of maturity. Interestingly, 7% of the firms mentioned moving beyond the need to calculate ROI for BIM after evolving to a higher level of BIM maturity, echoing the observation that technology becomes invisible once it becomes ubiquitous. The practice of targeting benefits, tracking investments over time, and measuring returns helps companies to select from a portfolio of technology/process initiatives, and to plan for strategic business change. In addition, companies agree that ROI can be a strategic tool for internal stakeholders in advocating for process change or to demonstrate the potential value of a new method to internal teams, managers, or employee groups.

Who benefits? Companies with extensive BIM experience observe that a nuanced and sophisticated application of ROI is becoming a factor in working successfully with building owners as that influential group becomes increasingly aware of BIM, realizes the benefits of BIM-enabled project delivery, and grasps the potential for process change in building operations and maintenance. Service providers understand that strategic applications of ROI can serve to demonstrate competency to clients, to increase value through data-driven decision making, and to provide competitive differentiation. Firm leaders can create their own roadmap for process change by developing a strategic BIM ROI practice – a commitment to measurement, benchmarking, retaining information in accessible formats for comparison purposes, and conducting ongoing evaluations of key performance indicators. As opposed to merely being a mechanism for go/no-go decisions, a strategic ROI discipline can support the prioritization and internal socialization of process change initiatives and improved business performance.

By employing ROI to assess BIM initiatives aimed at improving the performance of individuals and teams, companies can prioritize investments for organizational effectiveness to support sustained business improvement or implement models to assess BIM maturity and increase competency levels. Establishing the firm's orientation within the three dimensions of BIM, ROI suggests a set of promising measures for initial implementation and a potential road map for future development. Important strategic factors for firms include:

- the competency of employees
- collaborative culture,
- capability of teams.

1.2 Strategies for a BIM diffusion

When discussing BIM diffusion within an organization (micro) or across a whole market (macro), two terms typically pop-up: top-down and bottom up:

- **Top-Down diffusion** is a push by an authority to mandate the adoption of a specific solution it perceives as favourable. A good example of a macro top-down BIM dynamic is UK's BIM Level 2. At the micro level, top-down diffusion occurs when senior management within an organization (irrespective of its size and location within the supply chain) mandates specific solutions to adopt. Through these, sometimes coercive, pressures, solutions start diffusing down the authority chain and, if coupled with education and incentives, are adopted.
- **Bottom-Up diffusion** refers to the grass-root adoption of technologies, processes or policies without a coercive mandate. At the macro level, this occurs when small organizations those near the bottom end of the authority/supply chain adopt an innovative solution or concept; the solution slowly becomes a common practice; and gradually diffuses up the supply/authority chain (as is the case in Australia). Similarly, at the micro level, bottom-up diffusion occurs when employees near the bottom end of the authority chain introduce an innovative solution and – over time – this solution is acknowledged and then adopted by middle and senior management.

Although these two dynamics are easily noticeable, a third dynamic lies hiding in plain sight: the MIDDLE-OUT diffusion pattern:

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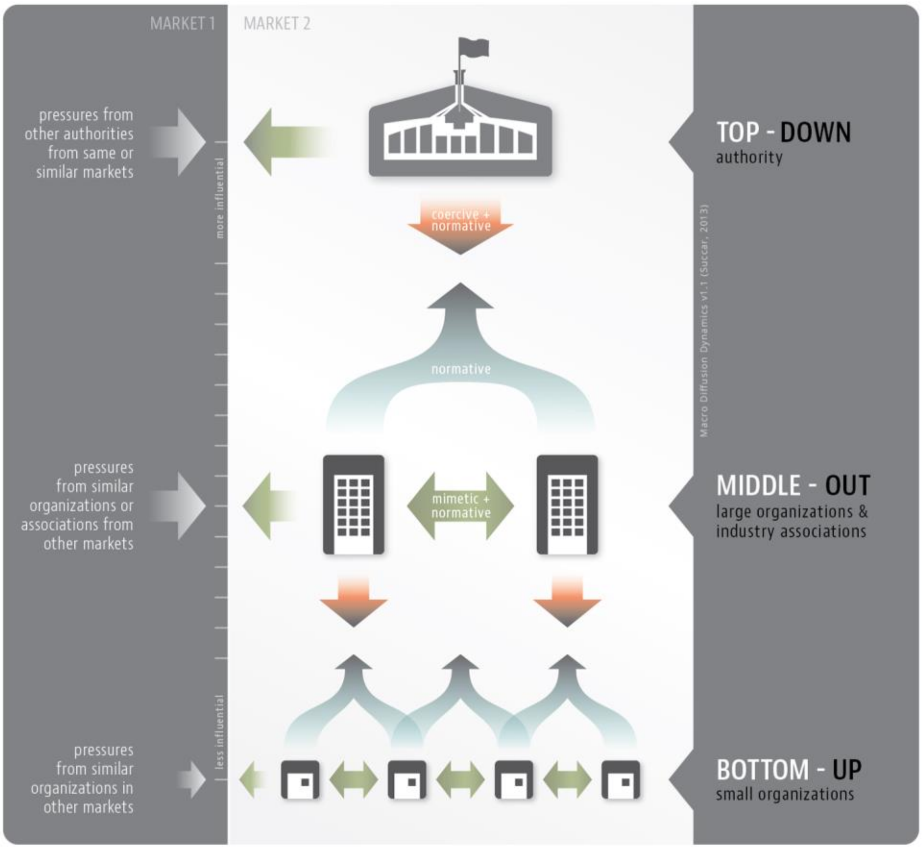
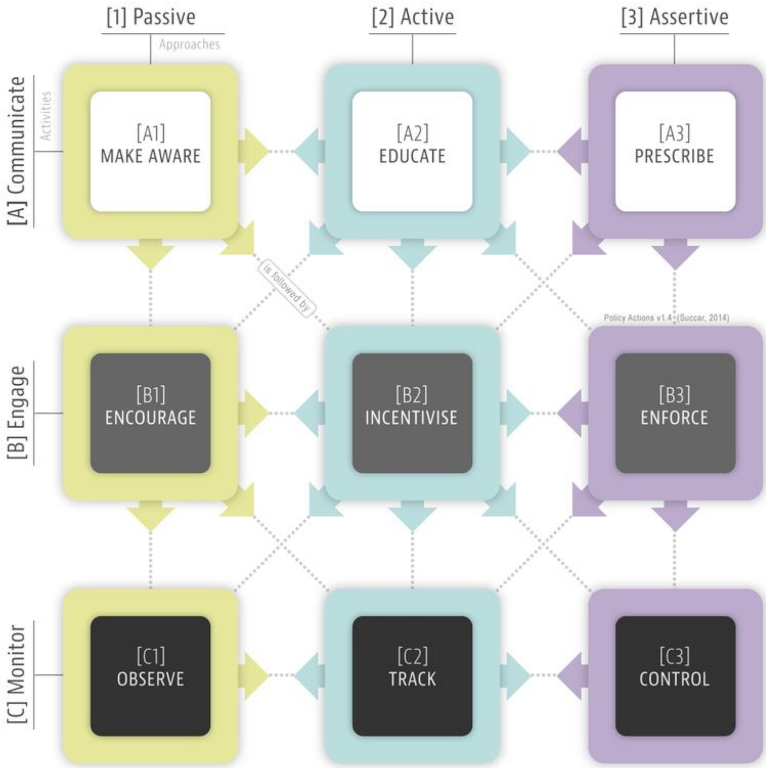
- or **Middle-out diffusion** applies to all those organizations and individuals occupying the median space separating the ‘bottom’ from the ‘top’. At the micro organizational level, team managers, department heads and line managers push what they’ve personally adopted up and down the authority chain. At the macro market level, middle-out dynamic applies when mid-sized organizations (relative to the market – e.g. large contractors in the US) influence the adoption of smaller organizations down the supply chain. They also influence or actively encourage larger organizations, associations and authorities up the supply/authority chain to adopt and eventually standardize their solution



Different organizations and markets display one dynamic more than the other due to a variety of market-driven and social variables. However, top-down, bottom-up and middle-out diffusion dynamics are complementary and even mutually inclusive. It is a misconception that one dynamic can be better than the others. While there is some evidence that a top-down dynamic encourages faster adoption rates across an organization or a market, there’s no that it leads to sustained infusion5 of BIM workflows and deliverables.

One of diffusion models is the **Policy Actions Model,** which identifies three implementation activities (communicate, engage, monitor) mapped against three implementation approaches (passive, active and assertive) to generate nine policy actions:



The three activities are consistently witnessed in markets where there's an intentional top-down push to diffuse BIM tools and workflows. What varies is the intensity these activities are conducted and the mix of player types (e.g. government, industry associations and communities of practice) undertaking the policy development effort[ii]. That is, each of the three activities (communicate, engage and monitor) can be approached at three levels of intensity (passive, active, and assertive) accounting for the differences in cultural attitudes and power dynamics across different markets. Practitioners in one country (e.g. an SE Asian nation) may call upon their government to take an assertive approach, practitioners in another country (e.g. US or Australia) may prefer an active or even a more passive approach.

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	Passive [1]	Active [2]	Assertive [3]
Communicate [A]	**Awareness**: the policy player informs stakeholders of the importance, benefits and challenges of a system/process through formal and informal communications	**Educate**: the policy player generates informative guides to educate stakeholders of the specific deliverables, requirements and workflows of the system/process	**Prescribe**: the policy player details the exact system/process to be adopted by stakeholders
Engage [B]	**Encourage**: the policy player conducts workshops and networking events to encourage stakeholders to adopt the system/process	**Incentivize**: the policy player provides rewards, financial incentives and preferential treatment to stakeholders adopting the system/process	**Enforce**: the policy player includes (favours) or excludes (penalises) stakeholders based on their respective adoption of the system/process
Monitor [C]	**Observe**: the policy player observes as (or if) stakeholders have adopted the system/process	**Track**: the policy player surveys, tracks and scrutinizes how/if the system/process is adopted by stakeholders	**Control**: the policy player establishes financial triggers, compliance gates and mandatory standards for the prescribed system/process

As depicted in the table, the three policy approaches signify an intensification of policy maker's involvement in facilitating BIM adoption: from a passive observer to a more assertive controller. These policy actions are discussed here at low detail. Needless to say, each of the nine actions can be further divided into smaller policy tasks. For example, the incentivise action [B2] can be subdivided into multiple incentivise tasks: e.g. [B2.1] make tax regime favourable for BIM adoption, [B2.2] develop a BIM procurement policy, and [B2.3] introduce a BIM-focused innovation fund.

The Policy Actions Model reflect a variety of actions that policy makers take (or can take) in each market to facilitate BIM adoption. It is important to understand that all approaches are equally valid. However, it is critical for policy makers to select the combination of policy actions which best fulfill the unique requirements of their market.

The Policy Action Patterns sample chart provides a quick comparison of diffusion actions undertaken by policy makers in different markets. Each pattern represents the policy actions taken (or can be taken) by policy players. For example, the top-left pattern represents a wholly passive approach (Make Aware + Encourage + Observe), while the bottom-right pattern represents a mixture of assertive and active approaches (Prescribe + Incentivise + Track).

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2. Module 2 – Apply information management

2.1 Principle of data management in the CDE (Common Data Environment)

The common data environment (CDE) is a central repository where construction project information is housed. The contents of the CDE are not limited to assets created in a 'BIM environment' and it will therefore include documentation, graphical model and non-graphical assets. In using a single source of information collaboration between project members should be enhanced, mistakes reduced and duplication avoided. (Situation in England: Central to level 1 maturity is the establishment of a CDE. This is the collaboration tool that BS-1192 describes as a repository, which will allow information to be shared between all members of the project team.)

The ultimate aim is to improve the creation, sharing and issuing of information that underpins the delivery of a project. The idea of collaboration to drive improved results and efficiencies is at the heart of implementing a Building Information Modelling (BIM) approach on construction projects.

Construction draws on the skills of a wide range of disciplines and the CDE brings together the information from all who work as part of the wider project team.

When implementing BIM, therefore, the CDE plays an important role to share the information among different disciplines and within the supply chain. In order to manage the information some important steps need to be followed:

Project "standard methods and procedure" should be developed agreed and committed to by all the relevant parties involved in the project at the pre-construction contract stage.

Key activities are:

- Roles and responsibilities agreed
- Naming conventions agreed and adopted
- Create and maintain the project specific codes project and spatial co-ordination
- A "Common Data Environment" (CDE) approach should be adopted to allow information to be shared between all members of the project team , for example a project extranet or electronic document management system.
- A suitable information hierarchy should be agreed that supports the concept of the CDE
- A single common project identifier should be defined at the initiation of the project; independent and recognisably distinct from any individual organization's internal job number.
- A unique identifier for each organization should be defined on joining the project.

A quality policy should be developed to ensure that models are maintained over their lifetimes.

Data exchange processes should be established

- Agree as early as possible which data should be exchanged, when, and in what format;
- Agree the version of format to be used for data exchange;
- Establish procedures to test, monitor and report the accuracy of data transfer, and conduct initial data transfer trials;

- Agree a method of recording each issue and receipt of digital data, and what constitutes an acceptable transfer.

Design Management:

- Complete checklist for management responsibilities
- Create an Employers Information Requirement (EIR) as part of the initial brief
- Define classification system to be utilised

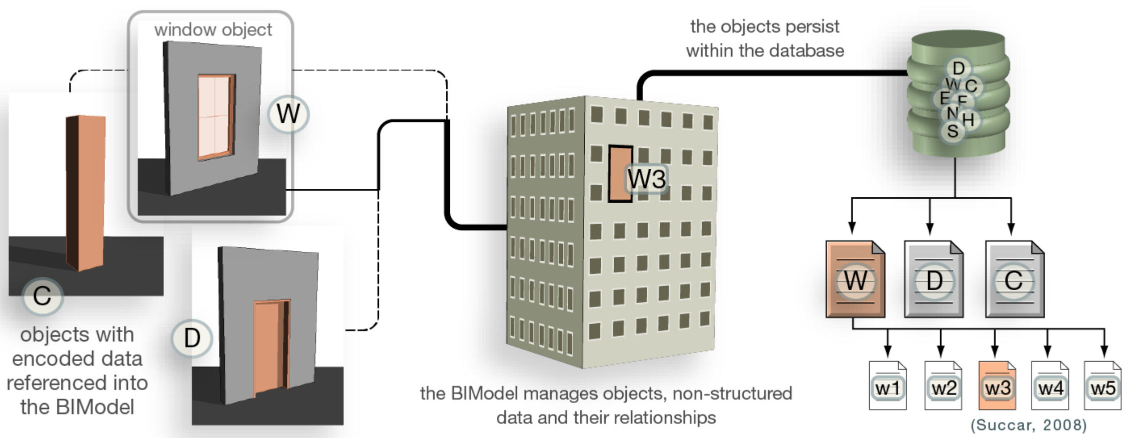
As a single source of information there's no arguments about which version of information should be being referenced. The CDE should serve as the ultimate source of 'truth' and bring a number of advantages for all involved:

- Shared information should result in coordinated data which will, in turn, reduce both time and cost on your project.
- Project team members can all use the CDE to generate the documents/ views they need using different combinations of the central assets, confident that they are using the latest assets (as are others).
- Spatial co-ordination is inherent in the idea of using a centralized model.
- Production information should be right first time assuming that contributors adhere to processes for sharing information.

However, not all models or modelers qualify as BIM. Although there are neither clear definitions nor umbrella agreements of what constitutes a Building Information Modeler, researchers and software developers alike allude to a lowest common denominator.

This non-declared denominator is a set of technological and procedural attributes of BIM Models (Building Information Models), which:

- Must be three dimensional;
- Need to be built from Objects (solid modelling - object oriented technology);
- Need to have encoded and embedded discipline-specific information (more than a mere database);
- Need to have interwoven relationships & hierarchies between their objects (rules and/or constraints: similar to a relationship between a wall and a door where a door creates an opening in a wall);
- Describes a Building of some sort.

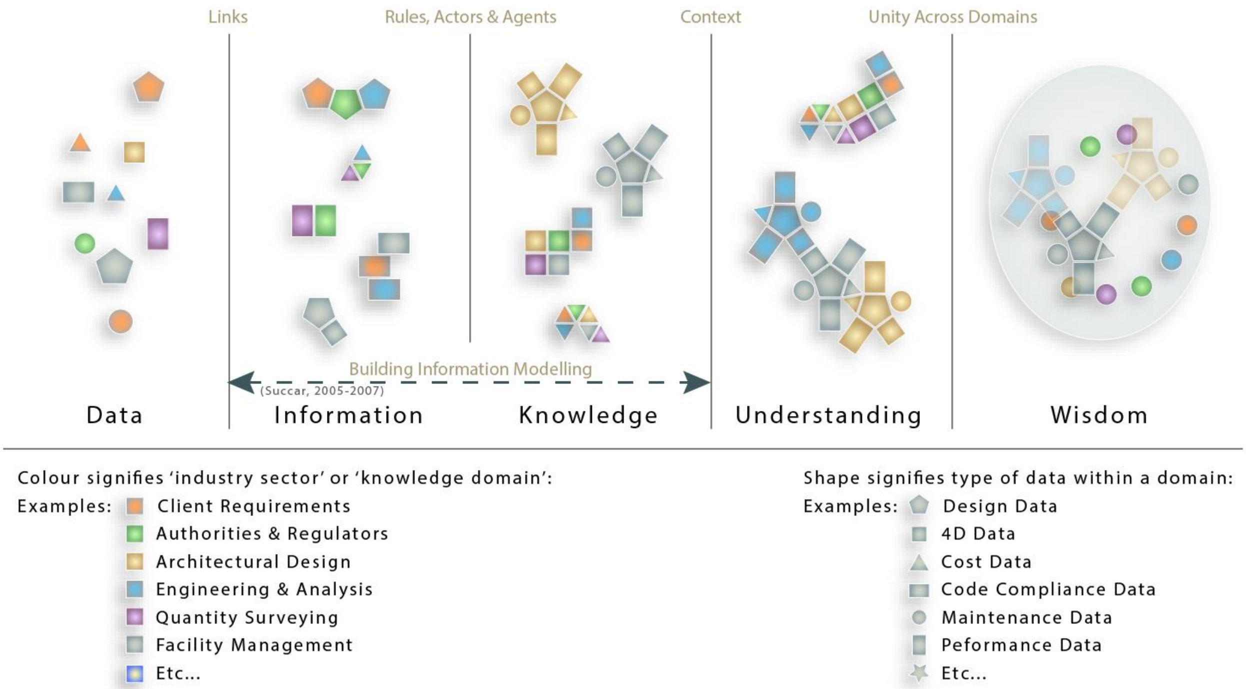


(Succar, 2008)

BIM Modellers do not depict nor encode the full scope of industry knowledge even within individual sectors (Architecture, Engineering or Construction). To express the matter differently, we first need to decipher what is really meant by “information” within Building Information Modelling. There are five levels of meaning that must be understood:

- Data are the basic observations and collectibles. Data are what you can see and collect;
- Information represents connected data whether to other data or to a context. Information is what you can see and say (collect then express);
- Knowledge sets a goal for the information. Knowledge is the expression of regularity. Knowledge is what you see, say and able to do;
- Understanding is the transmission and explanations of a phenomenon within a context. Understanding is what you can see, say, do and able to teach;
- Wisdom is the action based on understanding phenomena across heterogeneous domains. Wisdom is seeing, saying, doing and teaching across disciplines and contexts.

Building Information Modelling deals with Data and Information only although some vendors would like to promote BIM Modellers as Knowledge-Based. As per the definitions above and if we assume Goals to be synonymous to encoded Rules, BIM Models can include Knowledge-Based Models and Models based on Systems Thinking.



BIM Modellers can share little or much information available across desperate industry domains. The optimal BIM Modeller would have the ability to display, calculate and share all data necessary between disciplines without loss or workflow conflicts. This ability, or lack of, is a function of the technology used, the process deployed and the parties (knowledge workers) involved.

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Assuming each domain (industry sector: Architect, Engineer or Constructor) is using a different BIM Modeller, data sharing methodologies, amongst these modelers, can take many forms:

1. **Data Exchange**: Each BIM Modeller keeps its integrity but exports out some of its 'sharable' data in a format that other BIM Modellers can import and calculate (think XML, CSV or DGN for example). This method is arguably the primordial data sharing method and suffers from the highest unintentional data loss rates. Data loss here signifies the amount of data that can't be shared as compared to overall data available in BIM Models. However, not all data must or need to be shared between BIM Modellers all the time. Partial Data Exchange (as compared to unintentional data loss) can be an intentional and efficient method of data sharing.
2. **Data Interoperability**: Interoperability can be in many forms; the one discussed here is merely an example. Assuming file-based data interoperability (not server-based interoperability) one of the demonstrated scenarios for this data sharing methodology is as follows: $BIModeller_1$ produces an IModel (Interoperable Model) that gets imported into $BIModeller_2$ where its worked-on then exported into IModel v.2 (version 2) that gets imported into $BIModeller_3$ where its worked on then exported into IModel v.3 that gets imported into… The amount of data lost/gained between modellers, models and model versions depend on modellers' import/export abilities and the interoperability schema itself (think IFC for example). One major shortcoming of this file-based interoperability is workflow linearity; the inability to allow simultaneous interdisciplinary changes to the shared.
3. **Data Federation**. File linking is a good example of data federation: data in one BIM Model is linked to data in another BIM Model. The files are neither imported nor exported but BIM Modellers (software applications) can read and calculate the data embedded within the linked files. The amount of data loss depends on the amount of data readable or calculable. Referential Models (RModels) are another example of BIM Data Federation. RModels are single or federated models that host links to outside data repositories; much like a hyperlinks on a webpage.
   An example of this would be a virtual building with a referential window object: detailed information (values) beyond the basic parameters are not saved within the BIM Model but are accessed from an external repository whenever the need arises [3] (ex: real-time window cost, availability, installation manual, maintenance schedule).
4. **Data Integration**: The term integration may be understood in many ways including the lower-grade ability to exchange data between software solutions. In a BIM context, an integrated database signifies the ability to share information between different industry sectors using a common model [4]. The sharable data within the BIM Model may be architectural, analytical (engineering) or managerial as well as design, cost or code information. What is important about an Integrated BIM Model is that it co-locates interdisciplinary information allowing them to interact with each other within a single computational framework.
5. **Data Sharing Hybrid**: A combination of any of the data sharing forms discussed above. Most BIM Modellers, whether proprietary or not, coordinate the multi-disciplinary information generated by AEC sectors through hybrid of information sharing methodologies.

A list of documents shared in the CDE is shown below:

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Client brief and technical requirements	Test certificates
Appointments and contracts	Product safety information / emergency procedures
Bonds and insurances (including final building insurance valuation)	Product spare parts, tools and resources
Project stage reports	Product maintenance/ cleaning procedures/ manual
Technical reports (planning, design, environmental, impact assessments, etc.)	Product installation guide
Analysis, assessments and calculations	Product batch/ trace details
Sustainability certification, assessment, application, certificate	Technical data
Surveys (topographical survey, condition survey, etc.)	Environmental Product Declaration (EPD)
Meeting minutes	Product Declaration of Performance (DoP) and CE Marking
Project file notes	European Technical Assessments (ETA)
Request for Information (RFI's)	Agreement certificates (NSAI, BRE, etc)
Method statements	Product specification
Correspondence	Snag lists and quality control procedures
Media (photographs, images, presentations, video, etc)	Inspection plans and inspection records
Regulatory application/submission certificates (planning, building control, fire safety, disability access)	Schedules of certifiers, benchmarks, design changes, non-compliance
Non-statutory applications / submissions / certificates (LEED, BREEAM, etc.)	Compliance specification / certificates / opinions on compliance
Models (3D models, 2D models, federated models, Analytical models)	Design requirements (Tests, certificates, samples, etc.)
Design drawings, specifications, schedules and data sheets	Design responsibility matrix
Cost plans and bills of quantities	Health and safety risk assessments and safety plans
Payment certificates	As-built drawings, specifications, schedules and data sheets
Contracts final accounts	Construction / fabrication drawings, specifications, schedules and data sheets
Project plans and programmes	Technical submittals and approvals
Inspection record	Commissioning certificate
Equipment default "settings" (set points)	Suppliers warranty (parts)
Suppliers warranty (labour)	Supplier contact details

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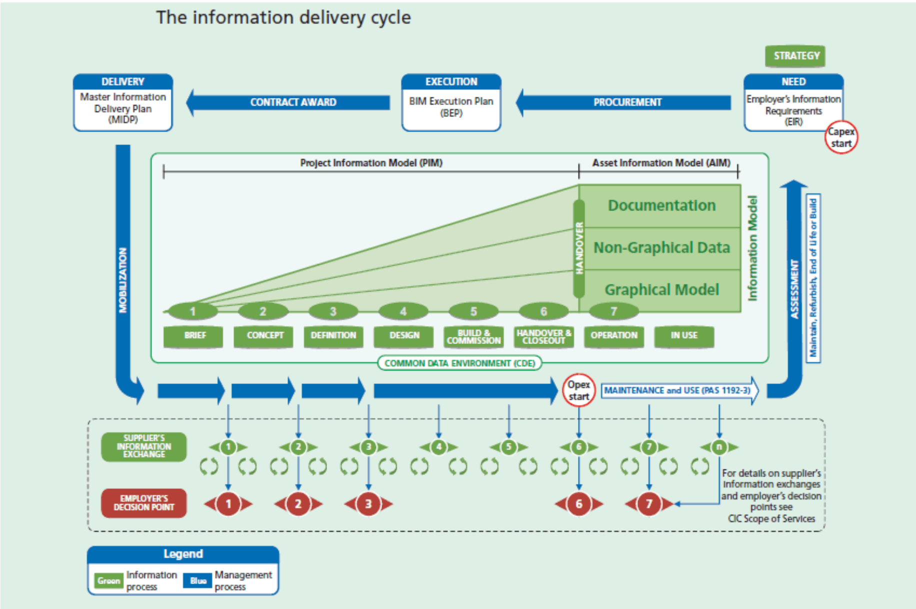
2.2 3D Model of graphic and non-graphic information

BIM is the means of creating, managing and sharing (digital) information in the life cycle of a structure.. One of the aim of BIM is to promote cooperation between parties and to achieve a reduction of errors in the construction process and the associated failure costs.

The flow of digitized building information, through the use of building information modelling (BIM), machine learning, smart infrastructure etc., is leading to a greater integration across practices and scales that were once considered separately. It changes the interactions between and across the multiplicity of related public and private-sector organizations and has implications for policy.



The Information built in a BIM Model can be:

- Documentation – Drawings and PDFs from manufacturers, such as safety Data Sheets, etc. that are usually handed over to clients and their facilities management teams via Operation and Maintenance Manuals
- Non-Graphical Data – For BIM Level 2 that is in line with the British Standard BS1192-4 which utilises the Data exchange format COBie.
- Geometry, Graphical Models – 3D models of the building and the systems and components within it.

The system for working with BIM has a number of functionalities that are continuing to increase:

- Designing a 3D model;
- Generating 2D drawings from the 3D model;
- Visualization and animation;
- Exchange models internally and with the construction partners;
- Clash detection;
- Determine quantities (including parts lists);
- Simulation options (including escape route simulation, smart grid solutions, calculation of an energetic model);

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- Link with planning (4D);
- Link with costs (5D);
- Process control.

With a good implementation of BIM, each party has insight into the same project information from the data model. This is only possible in a traditional process. In addition to the data model, there are also agreements about quality, organization, communication and information provision in the construction process.

Different parties are faced with a BIM. These are architects, (installation) consultants, constructors, installers, contractors, manufacturers and maintenance companies. These parties therefore form the target group for working with a BIM.

Points of attention of a BIM

The use of a BIM has the following focal points:

- Expectation management towards clients, buyers and local residents;
- Better insight into each other's disciplines;
- Communication and cooperation with partners and suppliers;
- Fewer errors or delivery points, less failure costs, higher quality;
- Shorter lead time of design and execution;
- More efficient processes;
- Preconditions in relation to the warning obligation for tenders are more transparent;
- Quantitatively difficult quantitative financial benefit for the customer;
- Existing organizations must be adjusted;
- Relatively much management of the data model;
- Labor intensive in the preparatory phases.

The BIM can in particular contribute to reducing failure costs. Current estimates of failure costs with current construction methods range from 10% to 35% of project turnover. In a downturn, such as those between 2009 and 2013, margins at construction companies come under considerable pressure. This greatly increases the importance of reducing failure costs. To reduce failure costs, efficiency measures such as LEAN system, vertical integration and a BIM are being sought. Working with a BIM also provides opportunities for innovations and maintenance-friendly construction. A prerequisite for this is that working with a BIM is seen as a model for collaboration.

Within construction projects there can be many unforeseen costs and failure. This is a recognition of the downside of poor construction of a feasibility study and lack of attention to detail.

Typical reasons for failure includes:

- Inefficient running of a building project;
- Failure to monitor progress against targets;
- Failure to meet the quality and time schedules;
- Needless repair and replacement due to poor planning or management

The cost of failure is needlessly expensive and can increase costs in indirect ways. Contractors can see that unnecessary expense will be made and of course allow for them by including them in their contract price. Parties that can reduce and control these potential failure costs, because of the use of BIM, have a major advantage compared to their competition.

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Digital building information is no longer collected, analysed and made available through a large organization's single mainframe computer, but in a highly distributed manner. Data collection occurs automatically within the internet of things through embedded sensors and small consumer devices such as the smartphone. Storage of these 'big data' is distributed in the cloud across multiple virtual data stores. Analysis algorithms work 24 hours a day on an unlimited number of central processing units. Yet, new challenges arise as the volume of digital data is doubling in size every two years, with 4.4 ZB (= 10^{21} bytes) of information stored globally in 2013.

A project realized with BIM approach generates a building model composed of hundreds or thousands of BIM objects that can be monitored during the life of the building in which they are inserted. The digitized objects make up the BIM libraries of the manufacturing companies from which the designers can draw for each project.

Making a BIM library correctly requires a deep knowledge of the brand, of the characteristics of the product (forms, performance, application, etc.) and how it relates / associates with another object / product that makes up the constructed work. It is these relationships that define the level of geometric and non-geometric complexity of the object and its modes of representation, in addition to the type of three-dimensional tools and templates to be used.

In addition to the knowledge of the sector and the actors who will use the libraries, those who make BIM objects must also have skills in BIM Authoring and classical modeling software. It will have to discern what is useful to represent and thus avoid an overabundance of geometries, which would unnecessarily burden the models and could jeopardize the know-how of the manufacturing companies, unconsciously spreading important technical and production information.

Given the importance of a BIM library (for designers, builders and manufacturers), it is useful to understand how the BIM objects in libraries are created in practice.

The level of complexity of the production of a BIM object is defined both by its relational geometrical composition (for example if the object consists of several components combined with each other or if it is a specific autonomous entity) and the amount of metadata contained in its internal (textual data and mathematical formulas).

A BIM object / product can contain various product types within it, and each of these is associated with different alphanumeric data. These attributes can refer to the geometric model or belong to the material, non-geometric element, of which the product is composed, and which is assigned to the 'architectural model'. The attributes recorded, selected and inserted, must respect the level of development necessary to meet the objectives required by the phases of the design, construction or maintenance process.

Following the creation of a BIM library, digitized objects are published and distributed on the web to ensure maximum dissemination and use in BIM projects by designers and builders. BIM objects can be published both on the websites of companies and in specialized databases in the publication and dissemination of BIM libraries.

The technicians who take care of the creation of BIM Libraries, inside companies or belonging to external companies, must be experienced people who will take care of the whole process, from the analysis of company needs to the executive production of files, according to qualitative and quantitative standards , in order to meet the regulatory requirements and needs of the end user (designer and manufacturer) and to promote the use and purchase of the product. For example, the BIM Design Team should be composed of specialized professionals, who make BIM libraries offering the most congenial solutions to ensure a valid use of BIM objects in all stages of the supply chain (from the extrapolation of information on product sheets to development geometric and the selection of metadata to be inserted in reference to the regulations) up to the realization of the BIM objects. The designer can download any BIM file free of sites or through the use of plug-ins installed in the software: in this way a network of contacts between manufacturers and designers is created. Moreover, on some sites it is possible to find BIM files with the "Certified" recognizable badge which ensures the validity of the models with regard to the minimum requirements (geometric and non-geometric), considered necessary for their use in a BIM project. oriented.

The architectural BIM model could be created using modeling software. In the model, all elements represented as walls, floors, ceilings, roof, doors, windows, and handrails, were created by adapting existing 3D parametric objects in the software library. The components of decorative character and equipment, such as sofas, chairs, toilets, tables were used directly, merely taking into account the scale factor during their inclusion in the model. The table below presents an example of the orderly steps in the creation of architectural BIM model:

Order	Procedure
1st step	Defining sill elevations of the flooring
2nd step	Importing dwg files
3rd step	Defining the construction platform
4th step	Modifying the contour lines
5th step	Creating, editing and inserting the walls
6th step	Creating, editing and inserting the doors and windows
7th step	Creating, editing and inserting the pavements and the false ceilings
8th step	Creating, editing and inserting the roof
9th step	Creating, editing and inserting the staircase
10th step	Creating, editing and inserting the guardrails
11th step	Inserting the components

Some drawings and projections can be obtained from the established model. The figure below shows a plan and a cut and illustrates the main facade, a general perspective of the model and one view shot of the interior:

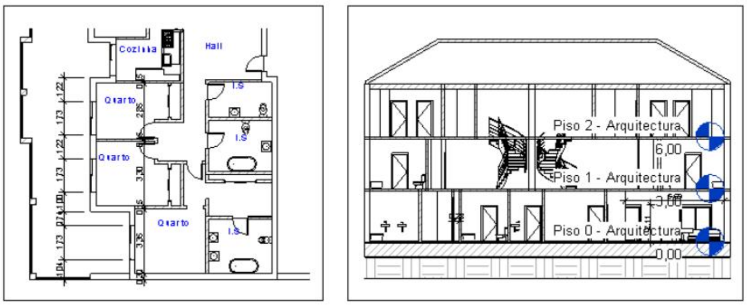

Figure 2.1 – Ground floor plan and vertical cut.

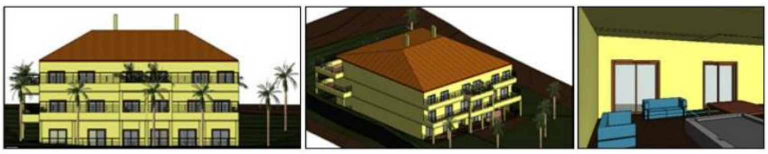

Figure 2.2 – Main façade, general perspective of the model and interior projection of the 3D model.

UK PAS 1192-2 Annex A provides an example of dividing graphical and non graphical information. This standard defines term, definitions and abbreviations for BIM documentation.

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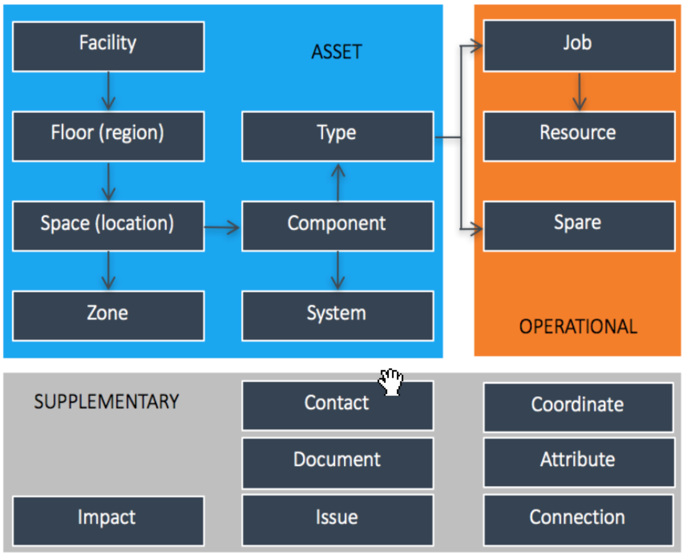

2.3 The maintenance plan in EPC (Energy Performance Contracting)

The EPC (Energy performance contracting) is a contractual arrangement between a building owner or occupier (including public authorities) and an Energy Service Company (ESCO) to improve the energy efficiency of a building. The investment costs are typically covered by the ESCO or a third party such as a bank, so no financial outlay is required by the public authority. The ESCO receives a fee, usually linked to the guaranteed energy savings. After the specified contracting period, the savings from energy efficiency improvements to the building will revert to the public authority. Energy performance contracting is often undertaken in respect of groups of buildings, in order to make the contracts more attractive to potential investors.

Building maintenance is the responsibility of its owner which must use, whenever appropriate, a technician to perform the inspection. A good maintenance depends on the analysis of the anomalies detected during the inspection of the site.

In the EPC the maintenance for the duration of the contract is up to the ESCO proposing the refurbishment. It has been demonstrated that even a NZEB design can bring to higher costs than foreseen for two main reasons: the first is that during the construction some changes occurs that worsen the energy performance, the second reason is that inhabitants do not know how to use the technology and have higher management costs. In both cases the use of BIM will mitigate if not solve those problems. If BIM is correctly implemented, together with the physical building a twin virtual building will be realized and will be enriched with all the information needed for the maintenance. Besides, a remote control of the building functionalities such as a building automation system, will allow the building manager to intervene any time some misuse is identified.

You can also download the Eurostat guide "ENERGY PERFORMANCE CONTRACTS IN GOVERNMENT ACCOUNTS"

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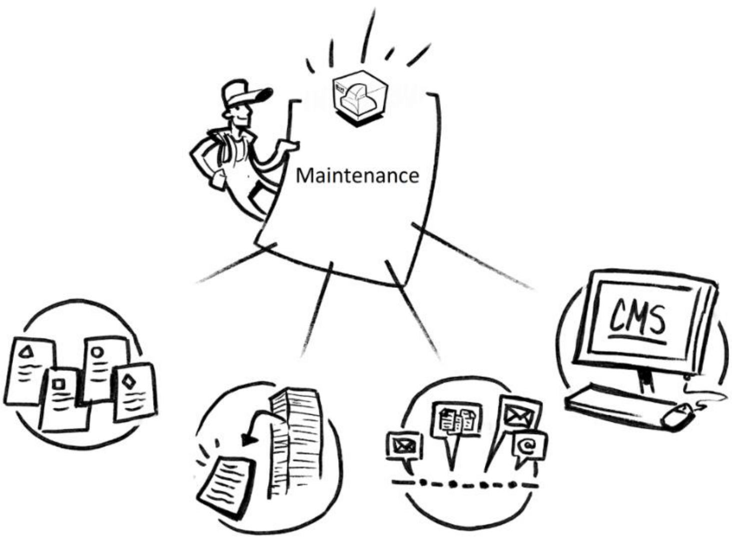
It is very important to define the requirements for the management and maintenance of the assets since the beginning, in the EIR, so that the designers can introduce the BIM objects with the level of details needed for the management and maintenance plan required by ESCOs and/or owners.

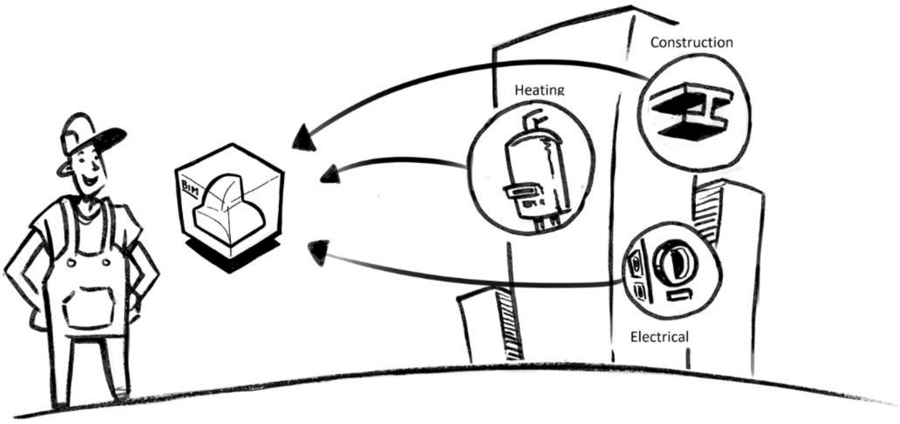
Good digital tools are inevitable for effective management, maintenance and/or asset management. The requirements are dependent on the size of the building, the complexity of the assets and requirements of demonstrability and traceability of activities. In general, a database-oriented solution is necessary where data is included on the business assets that are important of the building function. For a simple building an excel file is probably sufficient. If for example it's something more complex, if there are more projects to be managed, if there are activities planned which should be checked and also if activities should be traceable; specially developed FMIS-packages or specific maintenance and management software packages should be used. These packages are usually modular. The following is a list of common modules and/or functionalities.

- Module for planning periodic maintenance;
- Asset management;
- Contract management;
- Work order management;
- Cost registration;
- Invoicing;
- Hourly accountability;
- People management;
- Inventory management;
- Multi-year maintenance planning (MJOP);
- Condition measurements.

Maintenance management information



Certain information for management and maintenance, in particular information about individual assets, can still be obtained from a BIM model. In the exploitation phase, many other functionalities are often required that can certainly not be filled in with a 3D model. This is also not possible with the software that is used during the construction process in the new building phase. The 3D software that is used during the new BIM process has a too specific goal aimed at building.

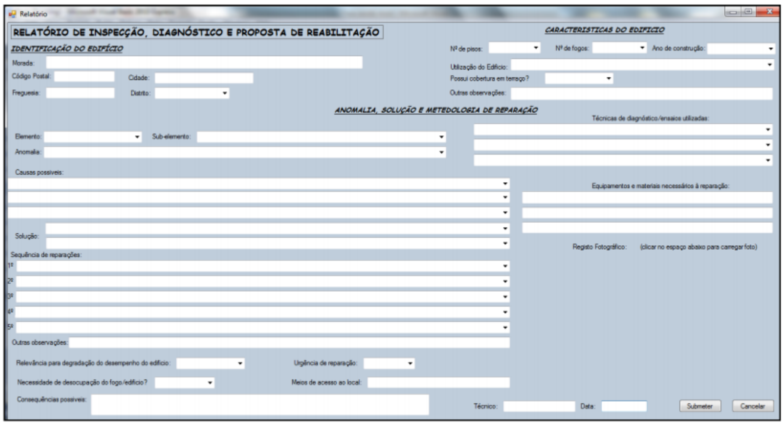


Necessary information with respect to management

The conclusion is that in the maintenance and management phase, software is still required that has been specifically developed for that phase. That is why it is all the more important that parties choose standards to facilitate a good exchange between software packages and database solutions. The most common and obvious classification standards are the NL-sfB and the Cobie standards. Within BuildingSMART international there is a specific activity to develop more standard needed by the market. The “product room” is the environment where these standards are developed.

BIM models have revealed themselves as an excellent tool when it comes to supporting maintenance actions, due to their ability to store enough information in one place and by allowing the user to obtain realistic perspectives and exact drawings. During an inspection operation for maintenance purposes, the developed application, containing a rigorous database, allows the user to identify each anomaly present in building components, directly onto the BIM model, automatically associating them with probable causes, repair methods and a photograph of the anomaly uploaded at the site. Therefore, gains in productivity and a decrease in the error probability can be achieved. The inspection data, converted to the PDF format, is stored in the BIM model, making it suitable for consultation when planning maintenance. Additionally, it was case study the interoperability between BIM modeling and visualizing software, regarding the preservation of information, especially in the IFC format.

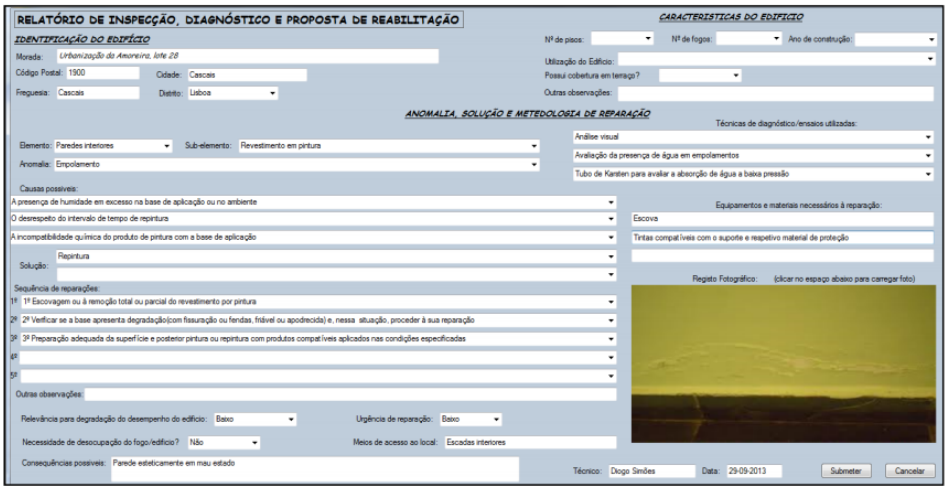
The interactive inspection operations sheet, created using a particular integrated software, has as main objective to support the implementation of an inspection. In its development the database that was used consisted in the compilation of information from other dissertations also developed for maintenance purposes. The information provided in this work relates to anomalies, causes, solutions and repair methodology concerning constructive components: exterior walls, interior walls, pitched roofs. Therefore, during an inspection, the maintenance technician, when observing an anomaly, can consult the database support to fill out the inspection sheets and select the identified anomaly on the site. Subsequently, the completed inspection sheet is then converted to the PDF format and inserted into the BIM model. This model should be constantly updated, in order to accurately support the facility with repair and maintenance plans. The developed computer application has its interface illustrated in the figure below:



An inspection sheet must include some initial information such as identification of the technician, the date of the inspection and the identity and characteristics of the building (address, city, number of floors, year of construction, etc...). A sheet of the inspection must include some initial information such as identification of the technician, the date of the inspection and the identity and characteristics of the building (address, city, number of floors, year of construction, etc...). Most of this information is selected from ComboBox elements, so your registration is carried in a fast way. A ComboBox element is defined with a combination of a text box and a list box, allowing the filling of the text box with one of the options provided in the list that appears as a descending menu.

The application also allows you to include a photograph of the anomaly taken at the site and convert the information presented in the sheet of inspection to a document in PDF format. Such possibilities are essential for an inspection sheet, because the addition of a photograph allows the user to recognize the anomaly, its severity and location, and conversion to PDF format enables the user to save the inspection form in a universal format.

In some software, the application also allows you to include a photograph of the anomaly taken at the site and convert the information presented in the sheet of inspection to a document in PDF format. Such possibilities are essential for an inspection sheet, because the addition of a photograph allows the user to recognize the anomaly, its severity and location, and conversion to PDF format enables the user to save the inspection form in an universal format.



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Practical tips

In determining which assets will be kept in an asset management system, the following tips and selection criteria can be used:

- In the asset management list, only include matters that can actually break down;
- As a criterion, take all components with a power supply or signal cable. In any case, include this in the asset database;
- For large projects, specify replacement types for common products. For example, let a manufacturer participate to maintain an up-to-date translation table (old → new);
- Ensure the use of a generally accepted and accepted (classification) structure. Check whether this structure is suitable for the intended maintenance and management package;
- Choose consciously for a level of detail of the assets that are expected to be maintained in practice in the field;
- Look carefully at the cost-benefit ratio when it comes to the question of whether certain information should / should not be maintained for maintenance and management purposes;
- Choose a maintenance and management package that works easily and is accessible in a low-threshold way. Think of the people who have to work with it;
- Provide expert guidance in setting up the data structure of an asset management system. This set-up must be organized on the basis of the actual information requirement and frequently occurring matters must be easily accessible;
- Long-term maintenance planning needs special attention. In an early stage (before a possible assessment), consider what kind of information is needed for this, what classification is used (Dutch NL-sfB code) and what level of detail this requires (is a detailed 3D model necessary?).

2.4 The "as built" BIM Model for improving the energy performance of buildings.

We can define the "as built" model as the editable copy that represents the final state of the building with the modifications that it has undergone throughout the construction process and that will serve to carry out future constructive interventions in the real estate asset.

These potential interventions cannot be unaware of the energy behaviour of the building and, to this day, these actions involve all types of construction and all geographical areas; the integration of silicon photovoltaic panels in a skyscraper is as important as the improvement of insulation under the Arabic tile roofs of a historic complex of a small town. If one's own initiative is not enough, incentive policies, via grants, may act as a catalyst.

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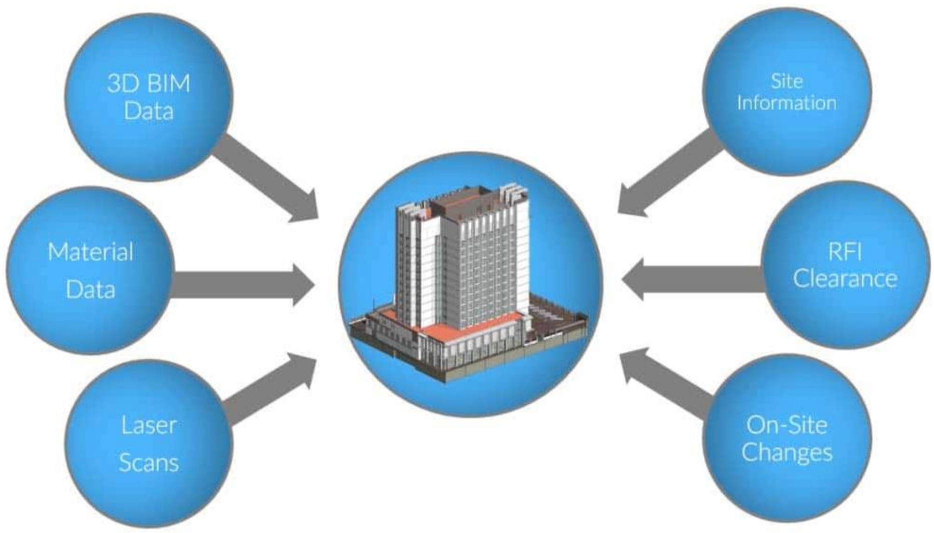
Therefore the original Model is not viable for the operations and maintenance stage till it is efficiently converted into an as-built model. An as-built model has various requirements: first of all it should be geometrically commensurate to actual site construction and secondly it should be having relevant basic information about all the building components which can be later enhanced at the 6D Levels. Nowadays it is common to say that the designers have to build two identical buildings, one is the real structure and the second is the virtual model that contains the level of details established since the beginning of the project..

There are a number of methods in which an existing structure can be produced accurately and as close to the raw survey data as possible. Essential BIM are experts at producing As-built BIM Ready models from all raw survey data types.

1. **BIM ready model from 3D Laser Scanned point cloud data**: it is now common practice for Architectural surveying companies to laser scan structures/buildings. This technique produces a point cloud consisting of billions of points representing real world coordinates that build up the environment from everything the scanner sees. These clouds have been used for years to produce accurate 2D CAD drawings which were then used to model 3D As-Built conditions. Essential BIM have worked with these methods since they have been available and have developed best practices to efficiently produce extremely accurate models.

- **3D laser scanners** capture everything that the scan position can see, by overlapping many scan positions (or



by using recently available mobile scanners) it is possible to get close to 100% scan coverage of the environment. due to this it is possible to model to any level of detail without further visit to site to collect more data, a client can request a basic level of detail initially and specify greater levels of details in areas as required without further disruption of the site, this was impossible with previous traditional methods of surveying.

2. **BIM ready model from 2D CAD drawings**: it is extremely likely that 2D drawings have already been completed for a building from previous years. It may be extremely cost effective to produce a 3D BIM ready model from this already worked up and finished data. This is generally the fastest way to produce a model as the majority of the analysis of the data has already been done. If these drawings have already been completed, then it is generally more cost effective than conducting another survey (assuming nothing has

changed since they were drawn). The 3D BIM ready model is of course limited in detail to what is produced in the 2D CAD drawings

3. **BIM ready model from traditionally measured raw survey data**: as laser scanners are extremely expensive the majority of architectural surveying companies use traditional techniques to capture their data. this could involve creating CAD drawings on site using hand held PCs linked to laser measurers. All of which can be used to create a 3D BIM Ready Model. Essential BIM have produced many models from such data with great success allowing for companies with a smaller budget for equipment to still compete with the larger Market leaders.
4. **BIM ready model from Architectural/structural Plans**: as most Buildings/structures are generally built from plans it is fairly likely that these may be available to produce a BIM ready As-Built (assuming that the building was built closely to the plans). These plans can be easily converted to a BIM ready Model. This can be a perfect solution for Facility Management (FM) as a BIM model can be used for the life time of a building for space planning, costing for materials, scheduling of elements etc. even for handing over to future Architects to use to design a proposed extension from.

For existing building, especially if historical, the relief of existing plants is essential to avoid problems during the refurbishment. In the picture typical tools for the reconstruction of the HAVC plants. In the order: thermo camera, endoscope, sclerometer, magnetometer, cover meter, geophone and georadar

If a building hasn't yet been built then a BIM ready Model can be created from such plans to create photo realistic visualizations or animations to help sell or market the property. The model can be used for early FM and even passed to interior designers, space planners, landscape designers etc. to develop the finished quality of the building, helping the end user visualize their space much easier than they could from 2D plans. The Contractor can even use the model to get a better idea of what needs to be built, the construction and structural details can even be modelled/embedded to aid the contractor with the build work.

Moreover energy performance certificates for buildings must necessarily incorporate so-called recommendations for improving energy performance. Compliance with this simple standard requires a simulation process that must produce results that detail not only the actions to be carried out and the tabulated efficiency improvement, but also the detailed study of the economic analysis of savings measures under real conditions based on historical consumption data of the building.

The BIM work methodology has no competence in simulation processes; actually, it could be said that the BIM model "was born for simulation". A BIM model that incorporates information on the thermal characteristics of the enclosure, as well as 5D information based on the cost of the elements, will make it possible to obtain efficiency and cost reports practically immediately. The incorporation and/or substitution of alternative elements (which can be integrated into a single model) will suffice to obtain the efficiency/cost comparison of potential actions to be carried out on the model. These actions, which can be carried out almost immediately in the BIM model, would require tedious trial and error processes using more traditional methodologies (based on spread sheets, databases and non-integrated models).

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The example proposed for thermal envelope studies is analogous to that of any installation serving efficiency improvement; if the BIM model integrates the necessary systems, the simulation can be carried out without any limitation other than the information integrated in the model.

The versatility of the BIM model derives from its ability to collect modifications and forecast future scenarios. This versatility will allow its adaptation to the different phases of the life-cycle of the project, from its design to its demolition, and the energy side takes on special relevance in this life-cycle.

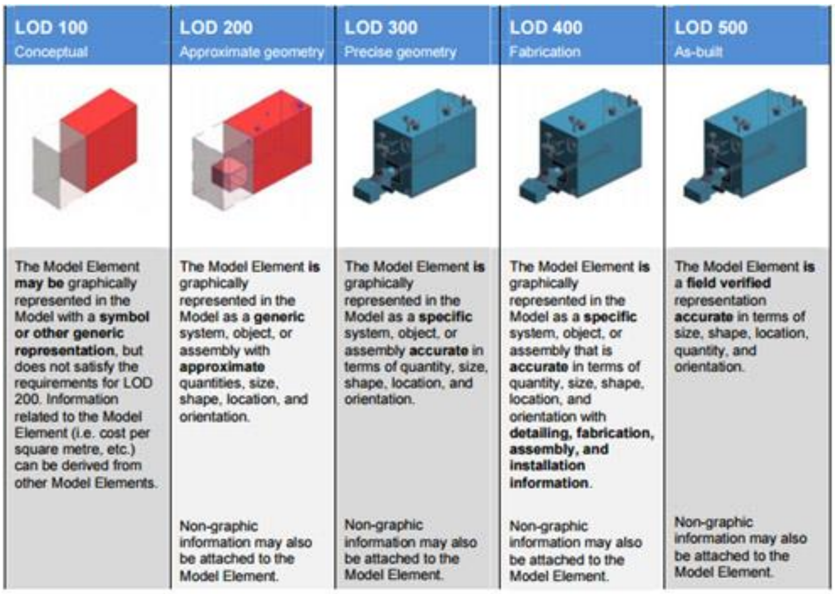
The BIM model "as built" will result in AIM (Asset Information Model); a single source of validated and approved information that relates to the built asset. This replica of the real model, much more manageable and in which mechanisms of augmented reality can operate, will serve to take conscience and knowledge of the asset, that is to say, of the own building or construction. Any potential improvement in the energy efficiency of the asset can be easily tested, simulated and verified in the model.

Level of Detail / Development (LoD)

Designing is done from coarse to fine. Because not all data has to be available at the beginning of a design, a rough design is usually chosen. The further a design is developed, the more detailed it will be. The construction and installation sector has various project phases with their own details. Within a project with a BIM, different project phases are also allowed.

Level of Detail means the necessary amount of information in a data model for exchange with other construction partners. Level of Detail shows the level of detail, while Level of Development emphasizes the progress of a BIM. A frequently used milestone classification has five detail levels: LoD 100, LoD 200, LoD 300, LoD 400, LoD 500 where the figures show the level of detail. The reason for the use of hundreds is to allow users to define intermediate levels of detail. Use can be made here of names such as LoD 250.

The NATSPEC National BIM Guide (developed in Australia) is a suite of documents that can be used to implement BIM on a project and gives a graphical explanation on the LOD definition. In many other countries similar classification have been developed.



LOD 100 Conceptual	LOD 200 Approximate geometry	LOD 300 Precise geometry	LOD 400 Fabrication	LOD 500 As-built
The Model Element **may be** graphically represented in the Model with a **symbol or other generic representation**, but does not satisfy the requirements for LOD 200. Information related to the Model Element (i.e. cost per square metre, etc.) can be derived from other Model Elements.	The Model Element **is** graphically represented in the Model as a **generic** system, object, or assembly with **approximate** quantities, size, shape, location, and orientation.	The Model Element **is** graphically represented in the Model as a **specific** system, object, or assembly **accurate** in terms of quantity, size, shape, location, and orientation.	The Model Element **is** graphically represented in the Model as a **specific** system, object, or assembly that is **accurate** in terms of quantity, size, shape, location, and orientation with **detailing, fabrication, assembly, and installation information**.	The Model Element **is a field verified** representation **accurate** in terms of size, shape, location, quantity, and orientation.
	Non-graphic information may also be attached to the Model Element.	Non-graphic information may also be attached to the Model Element.	Non-graphic information may also be attached to the Model Element.	Non-graphic information may also be attached to the Model Element.

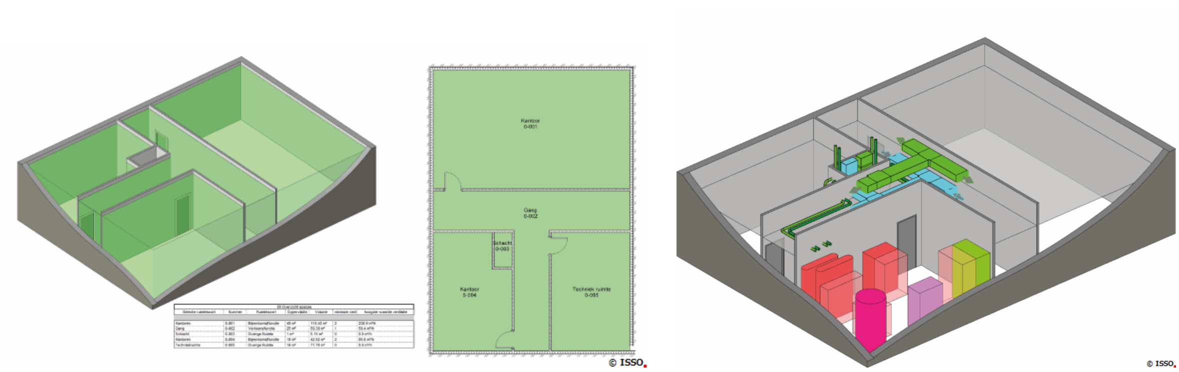
LOD table: Different detail levels in the construction sector in different countries

Dutch (traditional)	RIBA	Denmark	USA (AIA)	CityGML	NEN 2699	NEN 2574
Program of requirements	Phase 1	Level 0	-	LoD 0 / 1	Level 1, 2, 3	Phase 1, 2 en 3 (initiation, feasibility studies and project definition)
Sketch design / structural design	Phase 2	Level 1	LoD 100	LoD 2	Level 3,4	Phase 4 (structural design)
Preliminary desing	Phase 3	Level 2	LoD 200	LoD 3	Level 4, 5	Phase 5 (Preliminary design)
Final design	Phase 4	Level 3	LoD 250 / 300	LoD 4	Level 4,5	Phase 6 (Final design)
Contract	Phase 4	Level 4	LoD 350 / 400	LoD 4 (evt. met ADE)	Level 5, 6	Phase 7 (Contract)
Work preperation	Phase 5	Level 5	LoD 400 / 450	-	-	Phase 9 (Work preparation)
Realisation	Phase 5	Level 6	LoD 400 / 450	-	Level 5, 6	Phase 10 (Realisation)
						Phase 11 (Project delivery)
As built	Phase 6	-	LoD 500	-	-	-
Exploitation	Phase 7	-	-	-	-	-
Demollition	-	-	-	-	-	-

The use of milestones in certain construction phases is discussed in advance by the construction team and recorded in a project cooperation plan. Furthermore, not every discipline needs to work at the same level of detail at a given time. This depends on the agreements made between partners. It must of course be clear for every member of the BIM team that delivers a discipline at a certain time.

It is also possible to use the milestones themselves as phasing in a BIM project. The current building and installation market does not (yet) use this phasing at detail level. A detailed technical installation example is included in figure

Example of level of detail/development



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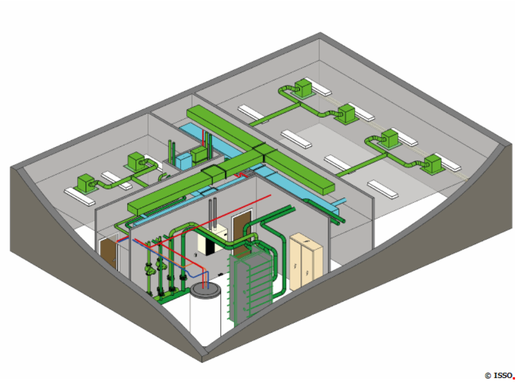
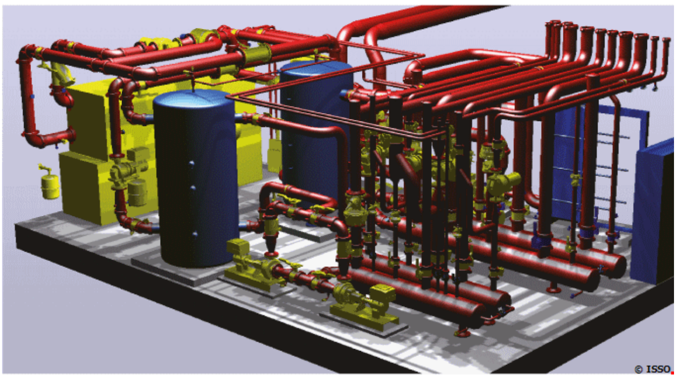
Afb. A.1 Example LoD 100 [15]

Afb. A.2 Example LoD 200 [15]



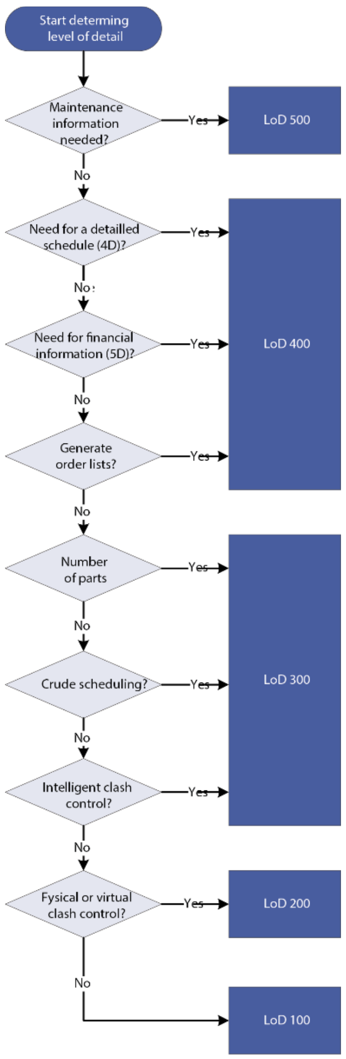
Afb. A.3 Example LoD 300 [15]



Afb. A.4 Example LoD 400 [16]

A client or other BIM partners may need a certain output. This can be a management and maintenance data model or order lists for material to be ordered from a supplier. It can also be a planning or the clarity of the budget. To this end, the data model must have a minimum level of detail. To achieve the desired level of detail, a flow chart is shown in Following figure. The consultant or installer thus has a tool to determine the desired output and the corresponding level of detail together with customers or other parties.

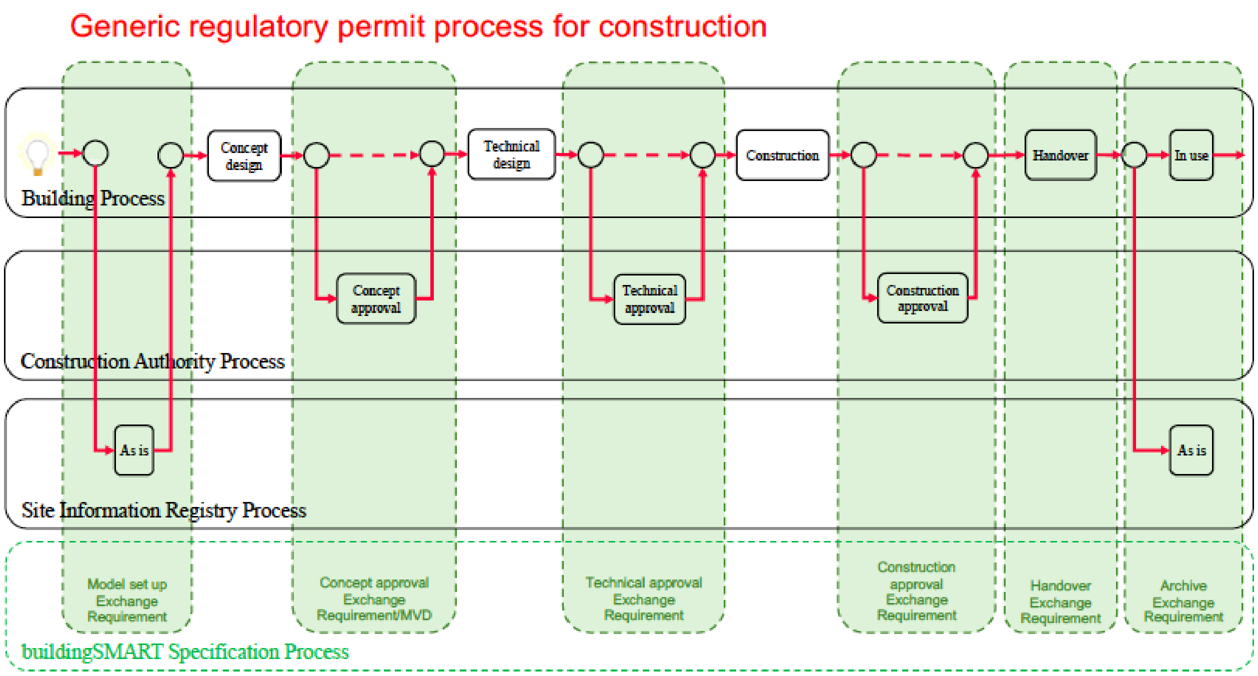
The following flow chart gives an explanation on how to choose the correct level of detail:


Start determing level of detail
Maintenance information needed?
Yes
LoD 500
No
Need for a detailled schedule (4D)?
Yes
No
Need for financial information (5D)?
Yes
LoD 400
No
Generate order lists?
Yes
No
Number of parts
Yes
No
Crude scheduling?
Yes
LoD 300
No
Intelligent clash control?
Yes
No
Fysical or virtual clash control?
Yes
LoD 200
No
LoD 100

3. Module 3 – Apply procurement management

3.1 Quality tender and contracts, guarantees and Change Management

The requirement on the use of BIM in the tender will ensure high quality and will guarantee the results in energy performance both for new and existing buildings. Compared to traditional building process, BIM introduces different controls that are useful to maintain the control for the achievements of the energy performance objectives. It is important for both the clients and customers to understand that the main advantage of the BIM process is the possibility to collaborate among all the parties to find the best common solution while in the "virtual world". The different checks during the building design and, consequently, in construction phases, will keep the process on track without misunderstandings, major changes and possible claims.



Following the above schema during the preliminary phase it will be important to define the best solutions based on the site information. The climatic zone, the presence of other buildings, which could influence the insulation or could introduce shadows on photovoltaic or solar panels, should be carefully evaluated to find the best solution. The conceptual design control will ensure that the main requirements of the national and local legislation are met. The use of the BIM model will facilitate the analysis by not expert people and different solutions could be investigated before defining the technical agreed solution.

Before the construction phase starts, a control on time and costs could be evaluated through BIM 4D, BIM 5D and BIM 6D tools to ensure that the planned work will be delivered in time at the foreseen costs and with the planned energy performance.

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During the construction phase the controller should ensure that the BIM model is the exact twin of the real model, which will be used for the management of the building once delivered to the customers.

In order to achieve the foreseen objectives the tender has to be managed in the correct way. In the following some general principles are defined.

All parties involved in a tender will behave in accordance with the following standards at all times:

- ✓ Honesty and fairness: parties will conduct all procurement and business relationships with honesty and fairness and avoid any practice which gives one party an improper advantage over another;
- ✓ Accountability and transparency: the process for awarding contracts will be open, clear and defensible and all parties must not engage in collusion, hidden commissions and other anti-competitive behavior.
- ✓ No conflict of interest: a party with a conflict of interest will declare and address that interest as soon as the conflict is known to that party.
- ✓ Rule of law: parties will comply with all legal obligations.
- ✓ No anti-competitive practices: parties shall not engage in practices that are anti-competitive.
- ✓ Intention to proceed: parties should not seek or submit tenders without a firm intention and capacity to proceed with a contract.
- ✓ Co-operation: parties will maintain business relationships based on open and effective communication, respect and trust, and adopt a non-adversarial approach to dispute resolution.

Download free best practice guide for tendering and contract management

In international construction projects, it is standard practice for the Employer to request guarantees to secure the performance of the Contractor. The most frequent guarantees are:

- The **Bid Bond** is granted in favor of the Employer to secure that the Contractor/tendered duly complies with its obligations either during the tender phase or afterwards. In particular the Bid Bond guarantees that (i) the Contractor does not withdraw from his tender before the end of the bid acceptance period set by the Employer or (ii) the Contractor fulfills the obligation to sign the contract -if awarded to him- or (iii) the Contractor does not fail to issue the bonds provided in the contract itself after the award of the contract (for instance, to provide the performance bond).
- The **Advance Payment Bond** is issued to secure that any sum paid in advance to the Contractor before the start of the works will be duly paid back to the Employer by the end of the works. The Employer, usually, pays to the Contractor (after the signature of the contract) an amount normally at around 10% of the contract price. The advance payment is used by the Contractor to start the procurement and/or the mobilization process.
  Usually, the mechanism is that the advance payment is repaid back to the Employer during the execution of the project by way of deductions on each interim payment made by the Employer. If the advance payment is not paid back (for instance because the contract is terminated in advance), then the Employer will obtain the repayment of the advance payment not yet repaid back by calling the advance payment bond.

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- The **Performance Bond** is the guarantee which secures the Employer in case the Contractor will not complete (or not duly and/or timely complete) the scope of works under the contract. If the Contractor breaches any specific obligations, the Employer will be entitled to call the performance bond (in full or partially depending on various circumstances) if the breach is not remedied or is not capable of being remedied.
- The **Warranty Bond** secures the Employer from the failure of the Contractor to remedy any defects in the works which could occur during the warranty period of the works as provided under the contract.
  If the Contractor will not repair any defects during the warranty period or will not comply with its warranty obligations in a timely manner, then the Employer will be entitled to call the Warranty Bond.

There are mainly two major categories of bonds in construction contracts. They are (A) the default guarantee and (B) the on-demand guarantee. As the names imply, they operate quite differently:

- **default guarantee**: it is also known as the "conditional guarantee" and, very broadly, will be paid when the Employer has proven the actual Contractor's breach under the terms and conditions of the contract. The guarantor, in turn, may raise any objection that the Contractor could raise against the Employer on the basis of the construction contract;
- **on-demand bond**: on the other hand, the on-demand bond can be called on simple demand by the Employer who does not have to prove the default of the Contractor. Neither the Guarantor nor the contractor can raise any objection (on the basis of the underlying contract) to prevent the payment of the on-demand bond (despite there are certain cases in which the bond cannot be paid, for instance in the case of fraudulent calling from the Employer).

One of the tests you can run to understand if the requested guarantee is in the form of an on-demand bond is to analyze carefully the relation between the bond and the underlying contract. In all those circumstances where the bond is substantially independent of the contract, then likely you are requested to issue an on-demand bond.

The bid documents and the construction contract provide, generally, the type and amount of the bonds that the Contractor has to provide.

The wording used is crucial and it is strongly advisable that at least the contract provides details on the bonds, such as for instance in which circumstances and at which conditions each of the bonds can be called by the Employer. This can, in fact, avoid the majority of the disputes that usually occur in relation to the calling of the bonds by the Employer.

It is normally stated in the bond itself and it happens that the law governing the bond might be different from the law governing the construction contract. This happens especially in the case where the bond is provided by an international bank or surety company.

If there is no express reference to the law governing the bond, usually the guarantee is governed by the law of the country where the guarantor which has issued the guarantee has its location. It is, however, advisable to ascertain that the governing law is expressly indicated in the bond and to take advice from a local counsel.

3.2 Green Procurement

Designers and constructors, who wish to improve the energy performance of a building, need to look at all the lifecycle of any item used in the building. For instance wood will have a minor impact than concrete especially if the wood comes from the local forests. Zero Km products should be preferred to products coming from long distance and

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so on. The green procurement oblige the public administration to take into account the use of green products for the public tender. This is the reason why professionals should know the green procurement directive and should design keeping in mind the whole impact of the products and not only to evaluate the energy consumption during the use of the building. BIM allows using BIM object that could contain also information on environmental impact in order to facilitate the choice of the product do be used in any circumstances. These, in fact could change from one place to another due to the need to prefer local products. Nowadays, especially for insulations, local products such as wool, secondary products of agricultural production, etc. have been developed and promoted in each country. Designers and constructors should choose carefully which product to use.

Green Public Procurement (GPP) is an important tool to achieve environmental policy goals relating to climate change, resource use and sustainable consumption and production – especially given the importance of public sector spending on goods and services in Europe. Minimum energy performance standards apply to public buildings, these are set at national level based on a common EU methodology. From 1 January 2019, all new buildings occupied and owned by public authorities must be “nearly zero-energy buildings” (Directive 2010/31/EU on the energy performance of buildings, recast). The Energy Efficiency Directive also sets mandatory requirements regarding renovation of public buildings and purchase or new rental agreements meeting minimum energy-efficiency standards.

Green procurement steams from pollution prevention principles and activities. Also known as green or environmental purchasing, green procurement compares price, technology, quality and the environmental impact of the product, service or contract. Green procurement policies are applicable to all organizations, regardless of size. Green procurement programs may be as simple as purchasing renewable energy or recycled office paper or more involved such as setting environmental requirements for suppliers and contractors.

"Green" products or services utilize fewer resources, are designed to last longer and minimize their impact on the environment from cradle to grave. In addition, "green" products and services have less of an impact on human health and may have higher safety standards. Whilst some "green" products or services may have a greater upfront expense, they save money over the life of the product or service.

Before a green procurement program can be implemented, current purchasing practices and policies must be reviewed and assessed. A life cycle assessment of the environmental impacts of products or services is required and a set of environmental criteria against which purchase and contract decisions are made has to be developed. The outcome is a regularly reviewed green purchasing policy that is integrated into other organizational plans, programs, policies. A green purchasing policy includes date-stamped priorities and targets, the assignment of responsibilities and accountability and a communication and promotion plan.

Green procurement policies and programs can reduce expenditure and waste; increase resource efficiency; and influence production, markets, prices, available services and organizational behavior. They can also assist countries in meeting multi-lateral requirements such as the Kyoto Protocol and Rotterdam Convention. International Standards Organization and other bodies have established guidelines for green procurement programs.

The use of BIM 5D with appropriate LOD will reduce the waste because any product used in the construction is correctly evaluated.

It is possible to download the “handbook on green procurement”, published by the European Commission in2916 at this link.

Obstacles to implementing a green procurement program include: lack of readily available environmental friendly products; expensive or zero environmental alternatives; inaccurate studies; lack of organizational support; and inaccurate or unsupported environmental claims by manufacturers and suppliers.

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The use of BIM library with "certified products" will make the data more reliable. The use of voluntary green product certificate could promote the dissemination of real green products.

Legislation, organizational policies, directives, environmental management systems or multi-lateral agreements often require organizations to implement a green procurement program.

Standards have a major role in influencing the design of products and processes, and many standards include environmental characteristics such as material use, durability or consumption of energy or water. References to technical standards including such environmental characteristics can be made directly in your specification, helping you to define the subject matter in a clear way. The procurement directives refer to European, international or national standards and various other technical reference systems as one of the means by which specifications can be defined.

When reference to a standard is used, it must be accompanied by the words 'or equivalent.' This means that evidence of compliance with an equivalent standard must be accepted. Such evidence may be in the form of a test report or certificate from a conformity assessment body. A tenderer may also seek to rely upon a manufacturer's technical dossier if it is not able to obtain third-party evidence within the relevant time limits for reasons which are not attributable to it. The contracting authority must then determine whether this establishes compliance.

Given the environmental, economic and social importance of the sector, many public authorities are committed to moving towards more sustainable construction. The most significant environmental impacts relate to the use of buildings, and in particular energy consumption. Other important factors to consider are the materials used in construction, the quality of the air inside the building, water consumption, impacts on traffic or land use, and waste generation during the construction works.

The World Health Organization (WHO) has stated that:

The air we breathe can be contaminated by emissions from motor vehicles, industry, heating and commercial sources (outdoor), as well as tobacco smoke and household fuels (indoor).

- In the WHO European Region alone, exposure to particulate matter (PM) decreases the life expectancy of every person by an average of almost 1 year, mostly due to increased risk of cardiovascular and respiratory diseases, and lung cancer.
- Furthermore, a recent study using data from 25 cities in the European Union has estimated that life expectancy could be increased by up to approximately 22 months in the most polluted cities if the long-term PM2.5 concentration was reduced to the WHO guideline annual level.
- Data from the WHO Environment and Health Information System (ENHIS), covering 357 European cities in 33 countries, show that in 2009 almost 83% of the population in these cities was exposed to PM10 levels exceeding the WHO guidelines. While this proportion was still high, it represents an improvement compared to previous years, as average PM10 levels slowly decreased in most countries in the last decade.
- Some 40 million people in the 115 largest cities in the European Union (EU) are exposed to air exceeding WHO air quality guideline values for at least one pollutant. Children living near roads with heavy-duty vehicle traffic have twice the risk of respiratory problems as those living near less congested streets.
- Indirect effects of air pollution, such as climate change, are becoming increasingly evident. Transport is the fastest growing source of fossil-fuel emissions of carbon dioxide (CO_2), the largest contributor to climate change.
- Ozone pollution causes breathing difficulties, triggers asthma symptoms, causes lung and heart diseases, and according to statistics is associated with about 21 000 premature deaths per year in the Region.

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- Indoor air pollution from biological agents in indoor air related to damp and mould increases the risk of respiratory disease in children and adults by 50%.
- Second-hand smoke causes severe respiratory health problems in children such as asthma and reduced lung function. It also causes lung disease, cardiovascular diseases, cancer and premature death in adults.

Buildings are highly complex systems, consisting of numerous component parts, which all influence the overall performance of the structure as well as the indoor pollution. GPP approaches typically aim to address both the overall impact of a building, and the environmental characteristics of individual components. To gain an integrated view, the use of a dedicated environmental assessment tool can be very useful.

The EU GPP criteria relate specifically to office buildings (additional criteria are available for building components such as fittings) and cover the following aspects:

- ✓ Include selection criteria for project managers, architects and engineers on experience in sustainable building design, and for contractors in implementing improved designs and specifications;
- ✓ Specify minimum energy performance standards above EPBD requirements;
- ✓ Include measures to enhance and ensure high performance at each stage of the procurement process. Consider providing additional points during the award of contracts for performance beyond the minimum;
- ✓ When specifying materials, include criteria to reduce their embodied environmental impacts and resource use (these may be based on a life-cycle assessment);
- ✓ Give preference to designs which incorporate high efficiency or renewable energy systems;
- ✓ Give importance to indoor air quality, natural light, comfortable working temperatures and adequate ventilation;
- ✓ Require the use of water-saving fittings (separate GPP criteria are available for sanitary tap ware and toilets and urinals);
- ✓ Install physical and electronic systems to support the ongoing minimization of energy use, water use and waste by facility managers and occupiers;
- ✓ Include contract clauses related to the installation and commissioning of energy systems, waste and materials management and the monitoring of indoor air quality;
- ✓ Give contractors responsibility within the contract for training users of the building on sustainable energy use and, where they have ongoing responsibilities, for monitoring and managing energy performance for several years after construction.

3.3 Selection of materials and products with BIM

Material and product selection is a delicate process, typically hinged on a number of factors, which can be either cost or environmental related. This process becomes more complicated when designers are faced with several material options of building elements and different suppliers, whose selection criteria may affect the budgetary and environmental requirements of the project, can supply each option.

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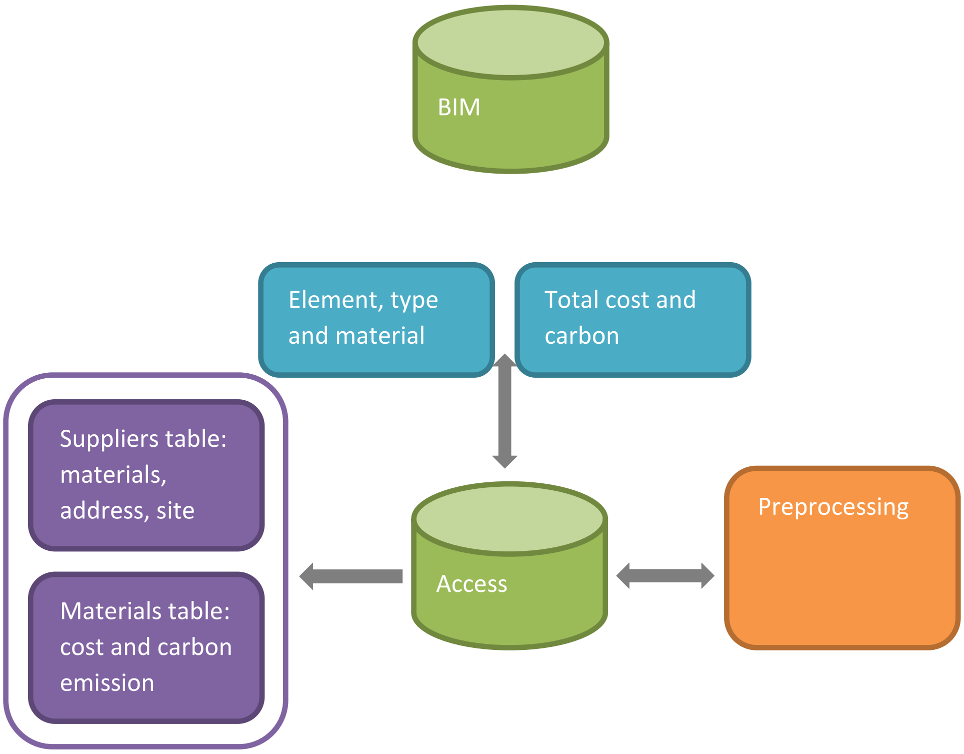


Over the years, there has been an increasing realization of the need to design buildings that are both cost and environmentally friendly. The environmental implications of such designs include reduction in carbon dioxide emission to the environment, embodied energy in buildings and improvement of indoor air quality. In order to meet design objectives, designers are usually faced with the challenge of selecting the most suitable material and product from different options or alternatives.

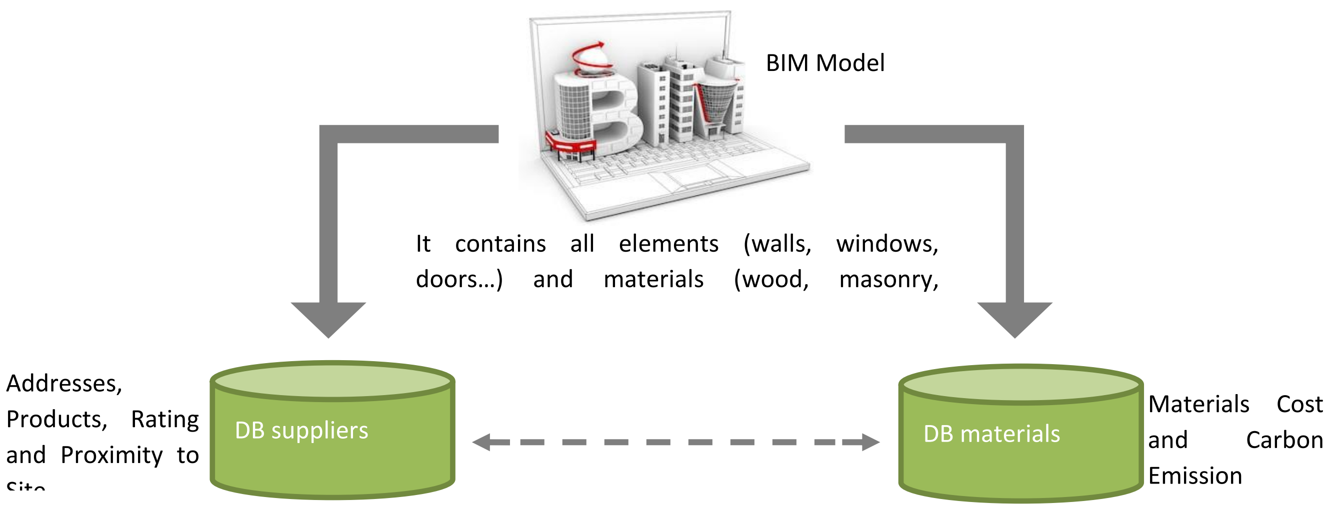
This decision becomes more complicated when different suppliers can supply each option. Additionally, each supplier's ratings may have different contributions towards the budgetary and environmental requirements of the project in terms of measures or criteria such as price, quality of material and service. Building materials have been known to account for about 50% of the total construction cost. Studies have also shown that this cost is highly influenced by supplier selection criteria. This is analogous to green construction projects, which are also characterized by criteria such as proximity to site and sustainable materials. However, little has been done to understand how the weight of these criteria can affect decision making in material selection. Furthermore, studies have shown that without supplier involvement, decision-making might be far from optimal.

Research on supplier selection has evolved from a cost only criterion to a multi-criteria problem. Depending on the level of importance of each criterion to the designer, the budgetary and environmental impacts of a project could be affected. For example, if the quality of a material is of more importance to the designer, the cost of the material and the project will be higher, and if the supplier is selected for low cost, other criteria such as material quality, distance and environmental considerations may be dissatisfying. The later may result in an increase in the projects total carbon emission and transportation costs.

Contracting firms keep a database of suppliers' performance evaluations over a period of time. The most suitable supplier will typically be selected based on an evaluation of criteria or factors, whose individual weights may affect the cost and environmental considerations of each option.

When choosing the products the cost for the end of life should also be considered. The information about re-use or recycling should be carefully stored in the database of the BIM model so that the owner can use that information when dismissing equipment/materials.

The overview of the information flow among the various applications in the proposed framework is shown in the figure below:

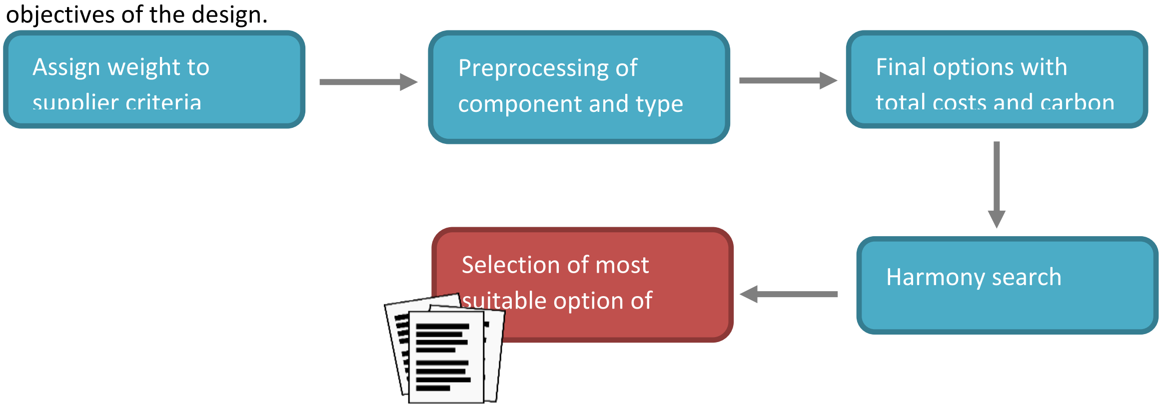


The steps of the model and role of the applications are explained below:

1. **Step 1 - BIM Module, definition of Building Elements and Properties:** The building elements are defined at this stage and the type of each element is determined based on the materials. Other properties defined at this stage include the alternatives of each material, the elements to be included in the simulation and the elements to be considered for analysis. Any BIM tool can enable definition of element and material within design models. In some architectures, when building elements are defined, materials can also be defined as part of the element properties. However, since the designer may be interested in understanding the total cost and carbon emission of multiple materials, the material alternatives can be embedded in the element properties as separate parameters. The use of local and recycled building materials has been argued to offer the advantage of reducing carbon emissions, producing healthier buildings, in addition to strengthening the local economy. Normally, more credits have been implemented for each material option by the suppliers in 500 miles range around the project's location.
2. **Step 2 - BIM-Microsoft Access Database:** the list of materials and their cost, carbon emissions and the supplier information are contained in two separate tables within a Microsoft access database, other solutions could be used as well. Contractors typically keep records of supplier information such as addresses, materials they supply and performance ratings. Alongside this information, the supplier information table will also contain the proximity of each supplier to the construction site. The proximity is obtained by computing the driving distance between each supplier's address and the construction site using web location mapping systems such as Google Maps. The second table contains a list of building materials, their cost and carbon emission. The later can be obtained from published inventories such as the inventory of carbon and energy.

The contents of the database and the inputs defined in stage 1 will be the inputs to the harmony search optimization. It is important to filter and arrange these inputs in such a way that the harmony search algorithm can utilize it. This can be done using plugins. Most BIM software have software development kits that enable developers integrate BIM tools with external applications. Plugins can be developed to extract the inputs defined in stage 1 and the database. The plugin provides quotes of windows and doors from online resources. In relation to this research, a plugin was developed within BIM that enables extraction of supplier data from the supplier database. If a material is to be considered in the analysis, it is checked within the properties. In order to determine the most suitable supplier (from the supplier table) of each material alternative, it is important to evaluate and rate the suppliers. To do this, a set of criterions were established to compare the suppliers.

3. **Step 3 - Harmony Search Optimization:** with the use of harmonization criteria.
4. **Step 4 - BIM Module, Selecting Most Suitable Option:** the objective of this BIM module is to present to the top designer, different designs options and the values of their cost and carbon emissions. Each design will have different combinations of materials. The designer can visualize the different options of total cost and carbon emissions. The selected option is typically the preferred design. However, in order to enable the designer understand the effect of different contributing weights on the supplier criteria, five scenarios were developed. Each scenario represents different weight criterions assigned to each of the supplier selection criteria. In this stage, the lead designer can vary the weights assigned to each criterion depending on the objectives of the design.



After the harmony search optimization, the designer can select from multiple options of total cost and carbon emissions.

Download a proposal of harmony search model for material and product selection

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3.4 Training on Energy Efficiency

A lot of the time, when architecture and engineering firms talk about BIM training, they're thinking about training their experts—people who use BIM programs day in and day out, who need to keep their skills sharp and stay on the cutting edge of technological developments. Engineers, architects, and project managers need BIM skills, too, to be able to communicate effectively with the rest of the design team and to step up to help meet deadlines in a crunch. However, because of you can't expect the same training for BIM specialists and the casual user, here are eight BIM training tips for designing a program to get everybody in your office up to speed.

- Set well-defined goals. Any successful program has to have well-defined goals: total expertise or only a basic understanding (so the designers can hold their own in client meetings) or moderate proficiency (so your designers can comfortably navigate a model and do basic modeling and annotation).
- Choose your topics wisely. One of the hardest challenges to deal with is that there is a lot of ground to cover and company have not much time to spend topics especially relevant for project managers such as contracts, deliverables, and BIM-execution plans. The company needs to decide which are the critical topics and which can be covered in passing, with an invitation to learn more in follow-up sessions.
- Plan your schedule: it is necessary to decide when to hold training sessions, for how long and of which type (courses, e-learning courses, workshop, meeting with round table...).
- Remember that an entire series of straight-up lectures probably won't have the wanted effect (people need more involvement to do their best learning). Therefore, it is advised to mix lectures, discussions and hands-on sessions and labs to give to designers practical experience with BIM programs.
- Get Everyone Involved: Invite Class Participation. Inviting your class to provide input on curriculum content, engaging individuals during group discussions, and encouraging everyone to ask questions will give them a sense of ownership of the training and increase its effectiveness. It also helps to remind people why they're here.
- Plan for some participants to have prior knowledge. It's likely that there will be people in training sessions coming from a variety of starting points. It could be best to divide up experts and non-experts so the first one isn't bored. If it needs to train everybody together, it's possible to tailor the agenda to accommodate them, but it will probably need to acknowledge to your power users that some topics may be review for them. It is possible to use power users as assistants, to help other people with less experience.
- Make the program on-demand. Putting together a BIM training program involves a lot of up-front work, but fortunately that effort quickly pays off: once you have a material set up, repeating it is easy. For larger offices, it will likely make sense to split up into groups to keep the size of the classes manageable and even if it is necessary only one group, at least one person will have a standing meeting that conflicts with training sessions. By making BIM training a continuing effort, it is possible to maximize the opportunity for all designers to attend.
- Promote continuing education because without constant exposure, skills can atrophy. The same goes for BIM (like for a foreign language): if you don't speak it for a while, you start to lose your vocabulary and fluency.
- After the formal BIM training is over, keep even casual users engaged by encouraging them to attend in-house user-group meetings. Keep the agenda well-balanced between basic and advanced topics and make it worth their while to be there. If there's a local user group in the area, encourage them to attend those events as well.

Providing BIM training for designers and project managers isn't a trivial undertaking, but with planning and effort, you can help your entire office understand the benefits of BIM.

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3.5 The identification and collaboration among stakeholders

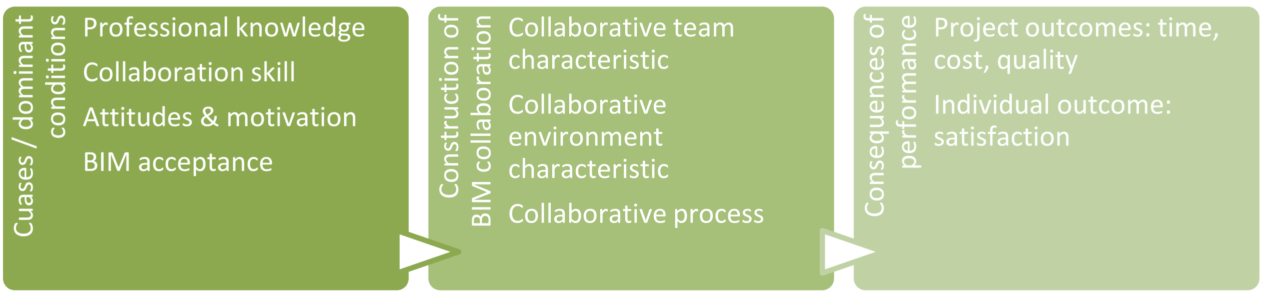
BIM is a collaborative approach to construction that involves integrating the various disciplines to build a structure in a virtual and visual environment. The essence of BIM implementation is collaborative working process in construction work. Therefore, project participants could generate the maximum benefit of collaborative arrangements increasing efficiency and effectiveness. The process allows project team to work effectively, particularly when identifying potential problems before they start to build on site. Maintenance service companies could be involved to review the design and verify the respect of maintenance requirements (accessibility to the HVAC plants, for instance).

The BIM serves as a collaborative platform for all stakeholders to share their knowledge resource and information. Sufficient information increases communication effectiveness. Effective communication allows stakeholders to exchange accurate, update and clarified information for decision makers to form a reliable decision. Being that, BIM is a shared digital representation founded on open standards for interoperability it demands collaboration in order to unleash the utility of BIM implementation and maximize stakeholders' return on investment. It is important to know that BIM project requires a specific process of activities, which involves high level of transactions on data, information and knowledge. A successful BIM project highly relies on effective collaboration among project participants including owners and maintenance services companies.

BIM becomes one way to cope with the cooperation, integration and coordination challenges faced in construction. Many study recommend construction industry to move toward Integrated Project Delivery (IPD), but few identify that IPD as the ultimate objective of construction project delivery method strongly demands closer collaboration and more effective communication. BIM has been proved that enhance collaboration and information sharing comparing those traditional construction processes. BIM is linked to higher level of efficiency in terms of communication and collaboration and a multi-disciplinary collaboration can be achieved through optimal use of BIM, but changing roles of key parties, new contractual relationships and re-engineered processes challenges need to be overcome.

Further, studies identify that coordination defects are the second largest negative impact to project performance after software issue in 35 construction BIM enabled projects. Collaboration issue cannot be demonstrated by any single contract theory or economic theory. Few studies expose the complexities of collaboration in BIM implementation. All the project participants need to be aligned with self-interest, mother company's requirement and project objective. So, this is not an issue of individual collaboration in a team or an organizational collaboration issue in a joint venture. Collaborative process is one of the key factors for BIM to be successful. The full potential of BIM can be realized by considering knowledge, technology and relationship. Many researches focus on the discussion of BIM technology. Few research address the importance of collaborative process of BIM implementation.

Based collaboration framework, the model below suggests that each of the determinants of BIM collaboration has sub-categorized factors.



First, four preconditions of collaborative team characteristics are identified, they are professional knowledge, collaboration skill, attitudes and motivation and BIM acceptance. The most important features of professional knowledge in BIM project appear to be their professional experience and the understanding knowledge of BIM (BIM acceptance). Organizations change their approach to collaboration according their experiences with past partners. Complementarity of professional knowledge contribution across disciplines assures the proceeding of construction project and inter-organizational collaboration. Their BIM acceptance is the perception how they contribute to the utilization of BIM and motivate to collaborate with other professionals within BIM context. Collaboration skill refers to experience of collaboration with others and individual social skills with other team members in a project organization. When project adopts innovative technology such as BIM and use this technology, adoption triggers new challenges of organization including structures and power relations. BIM acceptance is important that participants have mutual perception of BIM implementation in a project. To what extend participant's BIM acceptance can influence the effectiveness of BIM collaboration. Attitudes and motivation appear to be individual intestate in learning BIM and incentive of using BIM. Regarding attitudes, trust is found to be the most important determinants paired with mutual respect and common understanding that determine the appropriate team members. Little attention given to cultural issues, cultural differences do exist but it doesn't impact the formation of collaborative project organization. Because Hong Kong, as an international city, has a well-developed history and achieves certain norm among professionals no matter they are foreigners or new comers in construction industry. They all can find their role and interact with other team members in a brief period. In other words, the appropriate person, due to highly competitive and open market, can automatically fill the vacancy. So, professionals in construction industry work together as a temporary organization to deliver construction projects, they have enough experience to break the cultural barriers and build up a common agreement with each other. However, cultural issue may become important when dealing with other collaboration parties and industries. Second, actions of individuals may impact cooperative inter-organizational relationships.

Environmental conditions also influence the success of inter-organizational collaboration. Few scholars identify the importance of collaboration environment characteristics, despite a collaborative context is more likely to success. In a framework of inter-organizational collaboration, organizations create macro-environmental forces and organizational forces impact the extent of collaboration achieved. The degree of institutional support that individuals receive from their home institutions can determine their willingness to contribute with their time and resources to the project.

In BIM enabled projects, BIM maturity varies from projects and organizations. Sometimes, BIM maturity is also constrained by technology itself. Contract strategy is an important moderating variable in BIM collaboration. This will directly lead the success of BIM implementation as a whole. Practically, we find people adopt BIM under traditional procurement strategy such as design-bid-build which eliminate BIM as a visualization tool at earlier tendering stage. Some other cases we encountered that adversarial contract bind the motivation of individuals to collaborate with other company representatives due to economic consideration and provide minimum contribution according contract responsibility. However, the situation changes significantly in a relational contract environment. Professionals work together as a team and more willing to communicate and solve problem together and creatively. Therefore, we investigated specific contract strategy as a contextual characteristic for our research. Last, an operational platform with appropriate technology is likely to facilitate professionals to communicate and collaborate.

Another process model of collaboration: problem setting, direction setting and structuring. In this model, specific goals are set, clear roles and tasks are assigned to participants. Collaboration can be enhanced in this sustainable long-term activity, identifying the importance of process development in an inter-organizational collaboration. Furthermore, this process is dynamic and evolving over time. BIM collaboration is mainly utilized through its process. These results high demand of software interoperability and clear role and responsibility for each party. Although it is difficult, inter-organizational collaboration depends on specific input and effort contributed by individual members to have a mutual understanding of roles and responsibilities in different organizations. There is a link between communication and collaborative working and, based on these two sub-conditions, process could be fluently developed through a well communication context.

Both formal and informal communications are crucial to the success of project delivery, demonstrating a framework of collaboration model: collaborative decision making involve both formal structured judgment and informal alternative exploration. Decision-making strongly relies on collaborative process and experience of participants and it can increase the individual satisfaction and commitment. Being that uncertainty and conflicts emerge in construction process, decision-making in collaborative process is important. When project has prominent levels of collaborative relationship and participants are willing to share information and communicate, conflict decreases.

BIM execution plan (BEP) is reported as a priority before BIM implementation; a well-defined BEP can assure the compliance of project objectives and requests, can reduce the uncertainty and clarify the role and responsibility in most of BIM enabled projects. Further, BEP is identified as the key to the information management because it sets out protocols for interoperability, project delivery milestones, dimensional accuracy and other details. BEP specifies roles and responsibilities for team members and makes BIM collaboration successful. It is clear that there are correlated relationships between BEP and BIM collaboration success. In terms of consequence of collaboration there is a relationship among overall project performance, inter-organizational teamwork and participants' job satisfaction.

Many researchers measure time, cost and quality as the measurements of project performance and they test different degrees of collaborative working relative to project performance and identify that higher level of collaborative working is more likely to produce higher levels of project performance. Other researchers also address that working relationships have positive impact on project performance in terms of project time cost and quality. This research conceptualizes the formalization of how to collaboration in BIM enabled projects. If participants are able to collaborate through construction project, they can perform more productively and project is more successful. In certain way, company will transmit those benefits to individual benefit such as incentives and more investments in technology and training. This demonstrates us how it can align individual satisfaction to the project success.

4. Module 4 – Use BIM technology

4.1 Sustainable construction sector

Construction activities and buildings have negative impacts on the environment because of the land use, the consumption of raw materials, water, the production of energy and waste and the consequent air emissions. Globally buildings are responsible for:

- X 40 % of annual energy consumption;
- X Extracted materials and minerals quarries 30 %;
- X 30 % - 40 % of CO2 emissions. Households and services are the first emitter of CO2 emissions in EU-15 if the electricity is included in final sectors.;
- X 12% of consumption of water;
- X RC& D: 40 % total waste produced (92% demolition and 8% construction);
- X 42% energy consumption - heating and lighting of buildings accounts for the largest single share of energy use (which 70% is for heating);
- X 22% construction and demolition waste (by weight);
- X 35% greenhouse gas emissions;
- X 50% extracted materials (by weight);
- X Buildings occupy 10% of the space.

Currently 80% of the European population live in urban areas and people spend more of 90% of their lives within the built environment (considering the home, workplace, school and leisure time). This environment, therefore construction activities, largely affects the wellbeing and comfort of the people and buildings also have impacts in human health.

The Sustainable Development is operated during the whole life cycle of the building and should:

- ✓ Reduce consumption of resources (save water and energy);
- ✓ Reuse of resources during the refurbishment or disposal of existing buildings or use of recyclable resources of new buildings. The wrong environmental management of the site encourages the generation of waste that could have been avoided;
- ✓ Eliminate toxics and ensure the healthiness of buildings, applying nature protection (climate change mitigation, biodiversity, ecosystem services);
- ✓ Put emphasis on the quality of the buildings, maximising the durability because, in general, it is more sustainable renovate existing buildings than to demolish and build new;
- ✓ Use eco-efficient materials (without processing) and local materials;
- ✓ Increase the comfort of life (increase the quality of outdoor areas and indoor air).

It is widely known that the construction sector is a key sector for achieving sustainable development. Because of that, systems for description, quantification, assessment and certification of sustainable buildings have been developed at international level and in Europe. CEN/TC350 “Sustainability of Construction Works” – has the task to establish the European set of rules for sustainability of construction works.

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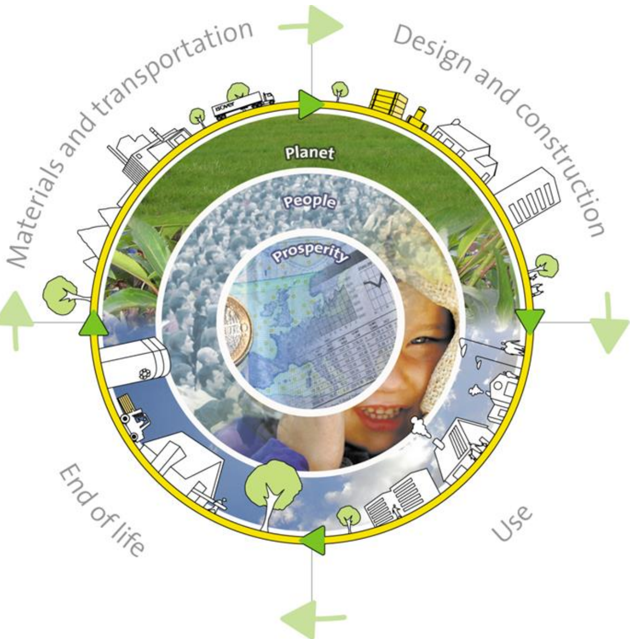
The choice of a building technique, component and construction material is generally based on criteria such as functionality, technical performance, architectural esthetics, economic costs, durability and maintenance. Nevertheless, this choice doesn't have into account the impacts of environment and human healthy. Build sustainably ensure that the social, economic and environmental aspects were taken into account throughout a building's life-cycle: from extraction of raw materials to design, construction, use, maintenance, renovation and demolition.



Refurbishment a housing inevitably leads to the generation of waste due to the demolition work and the construction itself; however, three major guidelines should be used to limit the quantity of waste taken to the landfill or incinerated:

- Prevention - limiting construction waste insofar as possible during the works and with regard to the future transformation or demolition of the building;
- Promoting recycling and reuse of demolition waste by sorting the waste on the construction site;
- When recycling is not possible, eliminating in two means: incineration with recovery of energy and taking the waste to the landfill.

Actions to be taken to limit the impacts on the environment and human health during construction and demolition waste are listed below:

- ✓ Prefer work with standard dimensions and prefabricated components in the construction process;
- ✓ Prefer mechanical fastening systems (using screws and nails) easy to disassemble and sort, and with a high rate of recycling – avoid fastening systems using glue, cement, welding, and other adhesives;
- ✓ Exclude materials or products from construction generating dangerous waste;
- ✓ Consider the re-use of certain in situ materials, without preliminary treatment;
- ✓ Carefully assess the quantity of waste produced on the construction site (construction and disassembly) per type of materials used, and the quantity of waste produced for the duration of the construction site.

The people who are most exposed to substances and emissions of these substances are:

- Workers producing the construction materials
- Workers using the construction materials
- Users of the building
- Workers doing demolition

The primary emissions from materials are high immediately after manufacture, they drop by 60 to 70% in the first six months and by and large disappear entirely one year after they have been incorporated or used (like biocides, fungicides, certain solvents, volatile organic compounds and certain additives). The secondary emissions can persist and even increase over time.

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For an efficient use of the building it needs to build new nZEBs and refurbish existing buildings as “**passive houses**” improving thermal insulation, minimizing thermal bridges, improving airtightness, using excellent quality windows, ventilating with efficient heat recovery and efficient heat generation and using of renewable energy sources. The integration of sustainable development concept into housing and architecture in general is called **Sustainable Construction**.

The professional should have a transversal knowledge of all the techniques to improve energy performance of a building in order to find the best solution when involved in refurbishment works.

4.2 Automatic model checking

The "BIM oriented" design guarantees the interoperability of the models related to the various disciplines allowing simultaneous control with different purposes: controls of the convergence of the models of the single disciplines, checks the elements coexistence of the different disciplines and checks regulatory on the multidisciplinary model.

In general, the validation of the BIM model consists in the requirements and functionality verification carried out in a conceptually (not dissimilar) way from what is normally required in a traditional design approach. Operatively (and synthetically) this is carried out through the verification of adherence to the design and regulatory requirements (Code Checking) and the verification of the coherent design of what is expected (Clash Detection).

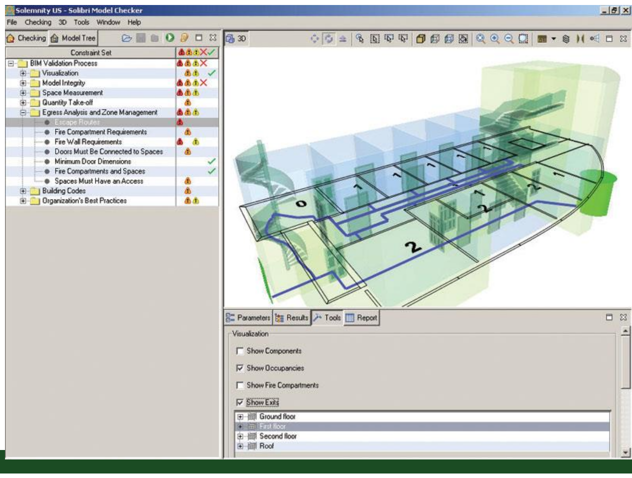
4.2.1 Code checking

Regarding the above-mentioned control, in specific Model Review tools, when the 3D IFC Model of the various design disciplines have been loaded, it is possible to verify compliance with specific needs and reference standards, which can be customized through the parameters of the verification rules. At the same time, the quality of the models of the individual disciplines is guaranteed without loss of information, as happens in the transfers of the same models through 2D formats to 3D formats. Thanks to the IFC file format, the correct transfer of geometry and attributes related to 3D models is guaranteed.

About a subsequent phase of regulatory checks and compliance checks, specific rules are available for the so-called Code Checking, for different reference standards that automatically highlight the differences between the models and the standard, classifying them according to the severity of the discrepancy. The ranges of values that identify problems of low, medium and high differences can be customized by the user, thus managing any limit situations.

Among the main controls (but not exhaustive list of all those available as standard), it is possible to highlight:

- Verification of compliance with hygiene regulations (minimum heights, volumes, services, etc.)
- Verification of the minimum areas of the premises and of the dwellings in relation to their function
- Verification of the air-illuminating relations of the premises
- Verification of the minimum dimensions of stairs and accesses



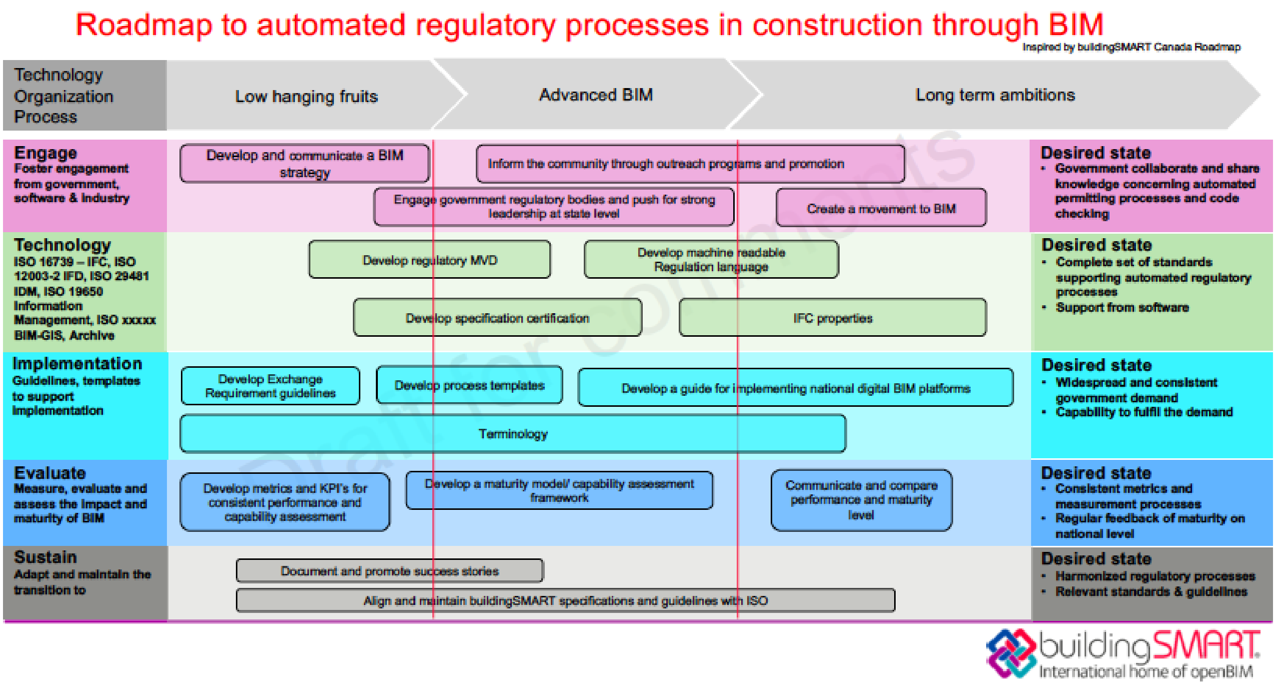
- Verification of accessibility to the premises (corridors, toilets, etc.) and the presence of architectural barriers
- Fire prevention checks (fire resistance of elements and compartments, escape routes, etc.)
- Control of the presence of fire prevention devices inside the premises or corridors
- Verification of free spaces around a specific element (fire extinguisher, hose reel, etc.)

in the case of energy performance there are three level of normative that need to be accomplished:

- European legislation
- National legislation
- Local (municipality) legislation

It is important that the technical office where the building project has to be approved is equipped with hardware and software allowing the code checking, as far as possible in an automatic way. At BuildingSMART International (bSI) the "regulatory room" international ifc parameters to be used in any country are under development. This work will ensure that the software development is consistent with the need of any country.

In the following figure is represented the roadmap for achieving this important result, which will ensure not only the respect of the requirements but will also improve the quality of the design and the energy performance.



The work of the regulatory room starts with the engagement of regulatory bodies, which need to identify a "simple language" that can be used in code-checking software applications. The final aim is to have the Government to collaborate and share knowledge concerning automated permitting processes and code checking.

In order to achieve the e-permit is important to complete the set of standards supporting automated regulatory processes. One of the main outputs will be the development of MVD – Model View definition, that is an agreed subset or filter of the IFC schema that is needed to support Exchange Requirement for e-permit.

To reach international consensus and widespread the e-permit, the development of guidelines and templates to support implementation are required. The final aim is to widespread the best practices and respond to the government demand in a consistent way and reply the to demand of digital permit.

In the transition phase it is important to measure, evaluate and assess the impact and maturity of BIM at local, regional and national level. The next step will be to harmonize the regulatory processes producing the relevant standards & guidelines.

All the differences from the regulations are automatically inserted into slides, which explain the discrepancy through an image accompanied by some technical notes both generic and specific in relation to the codes of the components that generate the problem.

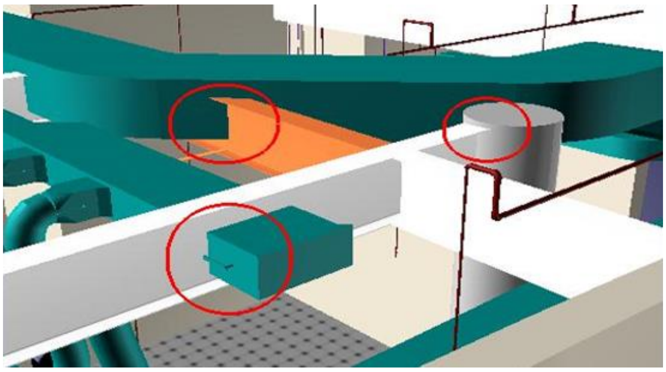
Through reports included in the software, it is then possible to communicate the differences to the various designers and request their correction in the authoring software that generated the controlled model. These reports can be exported either as a table or text file (excel file or rtf, pdf).

However, in addition, they can be generated as three-dimensional reports: the BIM Collaboration Format allows, in the authoring software, through a suitable plugin, to read the notes related to the highlighted criticality, orientate the 3D model and automatically highlight the elements that generate the problem to be corrected making it easier to identify them. The latter method of export is more effective for communication and then the identification of the problem within all the software participating in the BIM process, effectively completing the interoperability between the different disciplines.

4.2.2 Clash detection

One of the key benefits of BIM is the ability to spot “clashes” at an early stage in your project where they should be much easier, cheaper and less time consuming to rectify. In design terms a clash occurs when components that make up a built asset are not spatially coordinated and, therefore, they conflict. In a BIM process these clashes can be spotted more easily during the design phase of a project ahead of work starting on site.

A range of disciplines comes together to work on various aspects of construction projects. Using the architect's model as a starting point, a structural engineer, environmental engineer, mechanical and electrical engineer (and potentially many others) will produce their own model. Each 'model' will consist of a range of model files, documents and structured data files containing non-geometric information about what it will be built. All these assets come together as a digital replica. This will, at first, show what has been designed and will eventually show what has been built and installed. In a Level 2 BIM process the federated models produced by individual teams are integrated (at pre-determined intervals) into a master model that sits inside of the Common Data Environment (CDE). With data from a multitude of models coming together to form a master model it is inevitable that there will be clashes that need to be resolved.



When we imagine clashes we commonly think of two components occupying the same space. These are often referred to as a “**hard clash**” - a column running through a wall or pipework through a steel beam, for example. These kinds of clashes can be time consuming and costly to put right if only discovered onsite. A “**soft clash**” occurs when an element isn't given the spatial or geometric tolerances it requires, or its buffer zone is breached. For example, an air conditioning unit may require certain clearances to allow for maintenance, access or safety that a steel beam would negate. Given sufficient object data, software can even be used to check adherence to relevant regulations and standards. Other kinds of clash might involve the scheduling of contractors, the delivery of equipment and materials, and general timeline conflicts. These are often referred to as "**Workflow or 4D clashes**".

Clash avoidance is a key part of the design and construction process. Documenting a set of standard procedures in a BIM Execution Plan (BEP) and setting out procedures for co-ordination in Employer's Information Requirements (EIR) as part of a project's contract documentation are crucial. So too are the BIM Execution Plans authored by suppliers. During the design and construction process, design team interface managers should assess design decisions and clashes to see if they can resolve them internally, and where this cannot be done, separate models may be combined for review by a design lead.

The traditional design process would see specialists working on separate drawings with tracing papers produced during co-ordination checkpoints to check for compatibility. It wasn't that unusual for clashes to only be spotted on the construction site with the potential of huge costs and delays. In a Level 2 BIM process a range of federated models are produced and coordinated data drops used to inform a master model. BIM modelling software and BIM integration tools allow designers to check for clashes in their own models and when models are combined.

Clash detection software is becoming increasingly sophisticated, allowing the user to check for clashes within specific subsets (structural elements against walls, for example) and for these to be flagged on screen (often in vibrant colours).

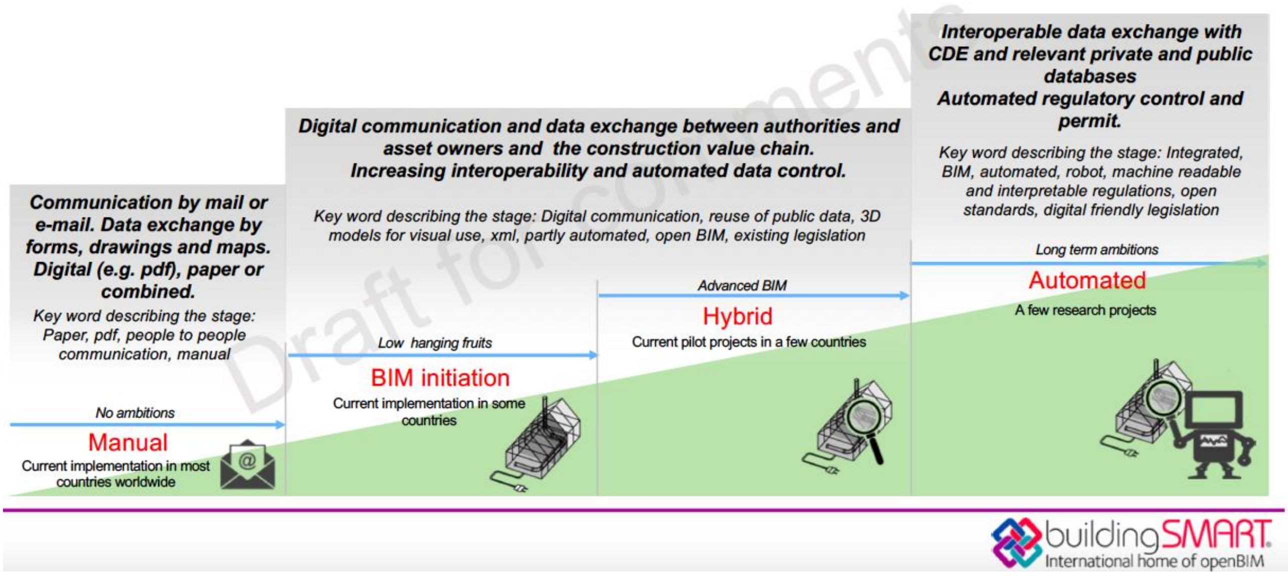
Some geometric clashes will always be perfectly acceptable (think: recessed ceiling lights, pipes embedded within walls) and software rules that draw on embedded object data can stop these kinds of clashes being flagged. As you can imagine the level of detail in BIM modelling is, therefore, crucial when it comes to clash detection.

Running a clash detection scan or report will typically bring up many duplicate instances of the same issue. If a single run of pipework clashes with five beams, it will show as five clashes though, in reality, resolving one issue (the placement of the pipework) will solve all clashes. Reviewing and cancelling these clashes in the design is a key part of the BIM process. As with any automated process these kinds of scans should not be relied upon in isolation and should form part of wider design co-ordination processes.

Software tools are likely to continue to become increasingly sophisticated as ever-richer data in standard formats are combined into models. The greatest potential for improvement however comes with Level 3 BIM. Working on one collaborative, coordinated building model (rather than the numerous federated models brought together to form a single complete model at key stages) should mean that the number of project clashes are dramatically reduced.

4.3 Information maturity index

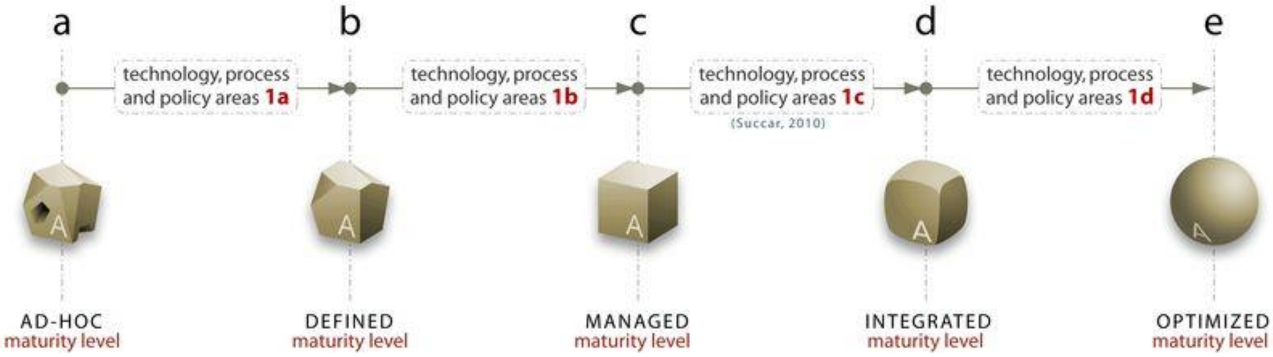
The BIM maturity level has entered in the normal language among BIM experts. The same nomenclature has been used in several fields. What is important to understand is that the "maturity" will be defined on the bases of the weaker "ring" of the supply chain. If the e-permit is not yet widely used among the municipalities, the risk is that very good project designed in BIM will be evaluated as any traditional design and will jeopardize the possibility to really implement BIM at large scale. In the next image the maturity level is referred to the authorization process. The actual situation, in the majority of cases, is based on paper in some cases the permit offices have started to accept documents through digital devices (certified e-mails). In a few situations, especially in the northern countries, the e-permit is in part automated. This ensures that the digitalization of the authorization process is already possible with existing technology. It is therefore important to work on the bSI regulatory room to reach a common understanding on how this process should be organized and digitalized. If an agreement is reached than software houses will develop applications able to automate the authorization process.



The term 'BIM Maturity' refers to the quality, repeatability and degrees of excellence of BIM services. In other words, BIM Maturity is the more advanced ability to excel in performing a task or delivering a BIM service/ product. To address this issue, the BIM Maturity Index (BIMMI) has been developed by investigating and then integrating several maturity models from different industries. BIMMI has five distinct Maturity Levels: initial/ ad-hoc, defined, managed, integrated and optimized. In general, the progression from lower to higher levels of BIM Maturity indicates:

- ✓ better control through minimizing variations between targets and actual results;
- ✓ better predictability and forecasting by lowering variability in competency, performance and costs
- ✓ greater effectiveness in reaching defined goals and setting new more ambitious ones.

The figure below visually summarizes the five Maturity Levels or "evolutionary plateaux" followed by a brief description of each level:



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Maturity Level a (initial or ad-hoc): BIM implementation is characterized by the absence of an overall strategy and a significant shortage of defined processes and policies. BIM software tools are deployed in a non-systematic fashion and without adequate prior investigations and preparations. BIM adoption is partially achieved through the 'heroic' efforts of individual champions – a process that lacks the active and consistent support of middle and senior management. Collaboration capabilities (if achieved) are typically incompatible with those of project partners and occur with little or no pre-defined process guides, standards or interchange protocols. There is no formal resolution of stakeholders' roles and responsibilities.

Maturity Level b (defined): BIM implementation is driven by senior managers' overall vision. Most processes and policies are well documented, process innovations are recognized and business opportunities arising from BIM are identified but not yet exploited. BIM heroism starts to fade in importance as competency increases; staff productivity is still unpredictable. Basic BIM guidelines are available including training manuals, workflow guides and BIM delivery standards. Training requirements are well-defined and are typically provided only when needed. Collaboration with project partners shows signs of mutual trust/respect among project participants and follows predefined process guides, standards and interchange protocols. Responsibilities are distributed and risks are mitigated through contractual means.

Maturity Level c (managed): The vision to implement BIM is communicated and understood by most staff. BIM implementation strategy is coupled with detailed action plans and a monitoring regime. BIM is acknowledged as a series of technology, process and policy changes which need to be managed without hampering innovation. Business opportunities arising from BIM are acknowledged and used in marketing efforts. BIM roles are institutionalized and performance targets are achieved more consistently. Product/service specifications similar to AIA's Model Progression Specifications or BIPS' information levels are adopted. Modelling, 2D representation, quantification, specifications and analytical properties of 3D models are managed through detailed standards and quality plans. Collaboration responsibilities, risks and rewards are clear within temporary project alliances or longer-term partnerships.

Maturity Level d (integrated): BIM implementation, its requirements and process/ product innovation are integrated into organizational, strategic, managerial and communicative channels. Business opportunities arising from BIM are part of team, organization or project-team's competitive advantage and are used to attract and keep clients. Software selection and deployment follows strategic objectives, not just operational requirements. Modelling deliverables are well synchronized across projects and tightly integrated with business processes. Knowledge is integrated into organizational systems; stored knowledge is made accessible and easily retrievable. BIM roles and competency targets are imbedded within the organization. Productivity is now consistent and predictable. BIM standards and performance benchmarks are incorporated into quality management and performance improvement systems. Collaboration includes downstream players and is characterized by the involvement of key participants during projects' early lifecycle phases.

Maturity Level e (optimized): Organizational and project stakeholders have internalized the BIM vision and are actively achieving it. BIM implementation strategy and its effects on organizational models are continuously revisited and realigned with other strategies. If alterations to processes or policies are needed, they are proactively implemented. Innovative product/process solutions and business opportunities are sought-after and followed-through relentlessly. Selection/use of software tools is continuously revisited to enhance productivity and align with strategic objectives. Modelling deliverables are cyclically revised/ optimized to benefit from new software functionalities and available extensions. Optimization of integrated data, process and communication channels is relentless. Collaborative responsibilities, risks and rewards are continuously revisited and realigned. Contractual models are modified to achieve best practices and highest value for all stakeholders. Benchmarks are repetitively revisited to insure highest possible quality in processes, products and services.

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4.4 4D and 5D BIM technologies

BIM models are the result of the superposition of multiple layers of information, from simple geometry to information related to maintenance or asset management. Each of these "information layers" are usually known as the "BIM dimensions", so we can find references to BIM 4D, 5D, 6D, etc. models. In the particular case of BIM 4D models, the "protagonist" information layer in the model is related to planning and time management, i.e., the data that allows us to temporarily locate a certain construction element during its commissioning.

4.4.1 4D Phase Planning

Gantt charts have long been a staple of project planning, but they leave something to be desired when it comes to visualizing a project schedule. Most builders invested in their first project planning system more than a decade ago and they've become a vital tool for project management services. BIM solutions on the other hand are relatively new. Rich with information, building information models provide architects a wealth of design-centric tasks, energy analysis, sun studies, and specification management, to name a few. Given the success of BIM in the design realm, building firms are now turning to building information models for their own uses, constructability analysis, trade coordination, quantification, cost estimating, and so on. One of the most obvious building applications for BIM is where design and construction first come together: construction planning.

4D Construction planning is an ongoing effort to manage the progress of a construction project and react accordingly – dynamically adjusting to the "situation on the ground." Of course, a building's design is at the core of its project plan, and by adding schedule data to a 3D building information model (i.e., the building design) you can create a 4D building information model, where time is the 4th dimension. 4D models include planning data such as the start and end date of a component and their criticality or slack.

Therefore, a 4D BIM model can be defined as the result of the integration of two layers of information, geometry of constructive elements and list of tasks or activities (with their corresponding durations and links), through the use of a software tool that allows to interrelate them. The result is an integrated model that, from the point of view of sustainability (understood as a reduction in the environmental impact of construction, very in line with the concepts that consider certifications such as BREEAM, LEED or GREEN) can be used in two main areas: the planning of the construction process of the project and the planning of the site itself and the impact on its immediate environment.

Focusing on the first of these, the construction sequence of the project, the use of tools and methodologies based on BIM 4D models provides a holistic view of the building to the technicians in charge of managing and planning the execution process of each and every one of the elements of the project. Access to all this information and, above all, the ability to simulate different construction scenarios, make BIM 4D planning an integral tool for improving construction times, reducing interference between construction systems and optimizing the purchase, delivery and commissioning of different materials, especially those that, due to their particular impact on the energy performance of buildings, it is critical to control and verify their correct execution.

As a result, a 4D building information model provides an intuitive interface for project team and other stakeholders to easily visualize the assembling of a building over time. It enables 4D construction simulation, a key planning tool during preconstruction to evaluate various options. 4D storyboards and animations make BIM a powerful communication tool – giving architects, builders, and their clients a shared understanding of project status, milestones, responsibilities, and construction plans. Teams usually start out developing 4D models by manually mapping the schedule dates from the project plan to the model components. That effort helps them improve the plan and improve how they communicate the plan to the whole team. Later, as they advance their skills, they programmatically link the schedule to the model, to save time and increase their ability to evaluate various construction sequence options.

As a complement to this detailed planning of the construction sequence, we find the planning of the immediate surroundings of the work, where simulation and control tools based on BIM 4D models allow us to precisely control and simulate three key aspects in the environmental impact of our building: the stockpiles and work zones, safety and health on the work site (routes, risk zones, etc.) and construction waste management (studying quantities, types, locations and, above all, their evolution throughout the construction process).

It is possible to use several approaches for linking a building information model to a project plan, exporting from BIM software to Project Management software in a specialized 3D/4D visualization environment linked to a project plan.

In summary, the use of BIM 4D models allows us to understand and visualize planning beyond the Gantt diagram, showing constructive sequences, relationships between elements, alternatives and anticipating interferences and conflicts during commissioning; in short, it is a question of better planning to build in a more efficient and sustainable manner.

4.4.2 5D Cost Estimation

Cost estimating is yet another aspect of the building process that can benefit from computable building information. Designing a building is the responsibility of architects, whereas assessing the cost to build it is the domain of estimators. In general, the architect's scope of work doesn't extend to material takeoffs or cost information. That's left to the estimator.

When preparing their cost estimates, estimators typically begin by digitizing the architect's paper drawings, or importing their CAD drawings into a cost estimating package or doing manual takeoffs from their drawings. All of these methods introduce the potential for human error and propagate any inaccuracies there may be in the original drawings.

5D is that dimension of the application of the BIM methodology that explicitly corresponds to the estimation of costs. In the three-dimensional model, the economic variable is introduced for the valuation of the costs of the project in order to control them and estimate expenses (assigning the price to the different objects or modelled elements as the value of a parameter).

By using a building information model instead of drawings, the takeoffs, counts, and measurements can be generated directly from the underlying model. Therefore, the information is always consistent with the design. And when a change is made in the design – a smaller window size, for example – the change automatically ripples to all related construction documentation and schedules, as well as all the takeoffs, counts, and measurements that are used by the estimator.

The time spent by the estimator on quantification varies by project, but perhaps 50-80% of the time needed to create a cost estimate is spent just on quantification. Given those numbers, one can instantly appreciate the huge advantage of using a building information model for cost estimating. When you do not require manual takeoffs, you can save time, cost, and reduce the potential for human error. In fact, a common complaint from estimating firms is how much they hate paying estimators to simply count or quantify when they bring so much more expertise and experience to the table.

By automating the tedious task of quantifying, BIM allows estimators to use that time instead to focus on higher value project-specific factors - identifying construction assemblies, generating pricing, factoring risks, and so forth - that are essential for high-quality estimates. For example, consider a commercial project slated for construction in northern

Minnesota in the winter. The estimator will realize that winter heating and dewatering will be needed for a portion of the concrete substructure. This is the sort of specialized knowledge only professional estimators can factor in to the cost estimate accurately. This construction wisdom, not "counting," is the real value professional estimators bring to the cost estimating process.

If thanks to BIM modeling tools applied to the design and virtual modeling of a building, it is possible to increase the efficiency of the construction process from its conception and throughout its entire life cycle, by managing the cost that BIM 5D allows, it will be possible to estimate these costs from a very early stage, which will allow, at the same time as analyzing the different design proposals and exploring and simulating the different alternatives in terms of efficiency (by means of conceptual analysis of energy flows, evaluations of thermal performance, analysis of solar control, evaluations of energy efficiency, analysis of lighting, etc.) to evaluate and study the economic impact of each of the proposed solutions. The changes in the design reflected in the BIM model will have a quick response in the budget generated from it, being able to be updated immediately.

There are a variety of ways of getting quantities and material definitions out of a building information model into a cost estimating system. Broad categories of integration approaches include:

- **Application Programming Interface (API)** to commercially available estimating programs from vendors with a direct link between the costing system and BIM Modelling software. From the BIM-strategy software a user exports the building model using the costing program’s data format and sends it to the estimator, who then opens it with the costing solution to begin the costing process.
- **ODBC connection (Open Data Base Connectivity)** to estimating programs, useful for integrating data-centric applications like specification management and cost estimating with building information modeling. This approach typically uses the ODBC database to access the attribute information in the building model, and then uses exported 2D or 3D CAD files to access the dimensional data. Part of the integration includes a reconstitution of the building data within the costing solution linking cost geometry, attributes, and pricing.
- **Output to Excel**. In comparison to the approaches outlined above, quantity takeoffs done and output to a Microsoft® Excel® program may seem lackluster, but the simplicity and control is perfectly suited to some costing workflows. For instance, many firms just create material takeoffs, output the data to a spreadsheet, and then hand it off to the cost estimator.

There are no right or wrong approaches – each integration strategy is based on the estimating workflow used by a specific firm, the costing solutions they have in place, the pricing databases they use, and so on.

We must not forget that, although the energy efficiency of buildings pursues as its ultimate goal the saving of natural resources, the reduction of the carbon footprint and, ultimately, the preservation of the global balance of our planet, the truth is that the decisions to be taken in the constructive process, as business action that is (at least, in most cases) must also respond to criteria of business efficiency, i.e. reduction or, at least, compensation of costs. The BIM methodology in general, and the BIM 5D in particular, offers us the tools so that these decisions can be taken on the basis of reliable data that, in addition, can be obtained, as we said before, practically immediately. The reduction of uncertainties is one of the greatest achievements of the BIM methodology; this allows the best possible decisions to be taken at the most appropriate moments of the construction process.

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4.5 Laser scanning technology

The application of laser scanning technology has been popular in the geospatial and survey industries for many years. However, recent advances in hardware technology and building information modeling (BIM) are helping to usher in a new level of scanning utilization for the building construction industry. Scanning for building construction is being applied most often to existing structures but is also seeing an advent of applications relating to new construction work. Scanning technology is becoming a critical function necessary to complete the integrated BIM cycle and provides a clear value-add for the integrated BIM workflow.

Renovation: Information using reverse engineering

If there is an existing building, no digital model is available in most cases. The information must then be obtained and recorded on the basis of the existing physical situation: reverse engineering.

For this, two solutions are described here: Reverse engineering d.m.v. manual recording and using point clouds.

Both contain two parts on the main line:

- Defining the spatial situation of:
  - The installations with regard to the constructional matters;
  - The structural situation such as recesses, edge beams, mushrooms, etc.
- Recording the specifications of the installed installation components.

For both methods, it must be considered in advance which information will be used. If possible, this should be done more selectively than in the case of creating a BIM model for new buildings.

Manual recording

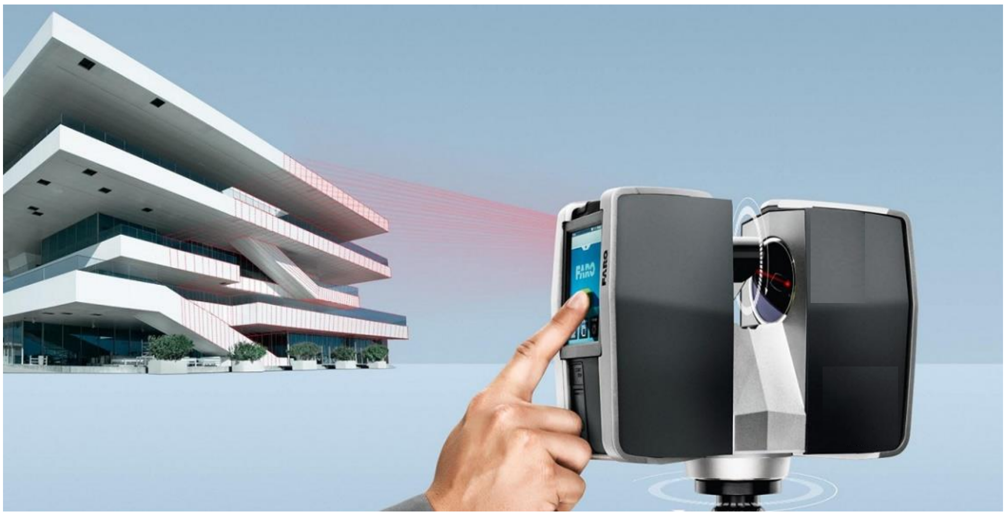
With this method the following steps are followed, assuming that no information is available yet:

- Choosing which information should be recorded;
- Collecting floor plan drawings;
- Collecting current room numbering;
- Create fill-in lists for laptop or tablet on which all relevant and chosen information can be entered;
- Tour of the building and the on-site recording of the information of installations;
- Note on the floor plans, for example regarding positions and distances between installations and with respect to structural elements and the structural elements themselves;
- In many cases, ceilings must be opened in order to inspect concealed installation parts;
- Separated from this admission, a condition measurement must often be made with which the state of maintenance is recorded.

It is clear that this is a labour-intensive process in which good preparation and making pre-choices are essential in order to prevent many unnecessary human hours.

Digital recording with point clouds

In many cases, especially in older buildings, there is little reliable or insightful spatial information available from building and installation engineering. Particularly in the case of partial renovations or modifications, in which parts of installation therefore remain, this is often a serious handicap. This leads to long construction times and often a lot of time loss i.v. mismatched components and small recesses. It also happens that the engineer has projected a new pipeline at a location where existing matters remain structurally or technically technical. The engineer then has no overview from his engineering place and therefore overlooks things. In such a case, the use of so-called point clouds can offer a solution.



To understand how scanning technology can be applied to the integrated BIM workflow we must first take a moment to understand what laser scanning is and what basic functions it intends to serve. At the highest level, scanners are used to send out a high density of laser beams for the purpose of positional measurement. Laser beams project outward from the scanning hardware and are measured in time of flight or phase shifts as they return to the source. The hardware measures the return time of the laser and can tell how far away a physical element is. Current scanning technology has the ability to send out thousands of beams per second, resulting in a “point cloud” of data. Scanners can also identify the R,G,B color value for a more intuitive display of point cloud information. Resulting point clouds can include millions, even billions, of data that reflect the physical environment being scanned.

What is a point cloud?

A point cloud is a method of determining the spatial situation in an existing building with the help of a laser instrument that can scan and measure a building from the inside or the outside.

The instrument scans the distance to a surface from a specific own tripod position relative to the building with a laser and then records the distance in that direction. The laser rotates and does those measurements all around in a hemisphere.

In this way, by means of the measured distance and the direction of the laser a point in the space is determined where something / a surface is. All these points can then be displayed together in a spatial model in a point cloud or point cloud. Now, by moving the laser to another position in the room, a line can also be seen 'behind' for example. From that new position, a new point cloud is then created.

By combining different point clouds with smart software into one combined point cloud, a tube or a recess with points can also be displayed in many cases.

A technical room can be converted into a point cloud within a day, whereby almost all spatial information can be recorded with the accuracy of a few millimetres.

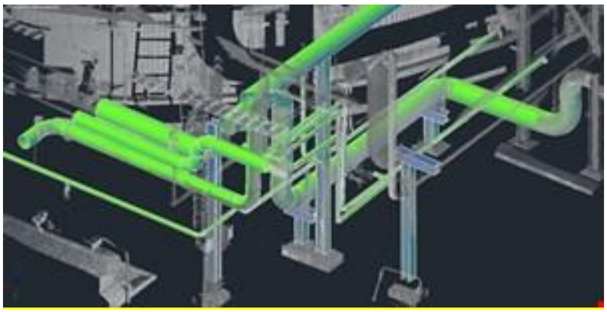
It is important that the sight lines are as open as possible; suspended ceilings etc. must be removed.

Properties of a point cloud:

- A point cloud is often many gigabytes in size because so many points are recorded in a relatively 'stupid' way;
- The model contains no intelligence. A pipe is not an object but a collection of loose dots without cohesion;
- Only the outside is visible, you can not look behind or through pipe insulation;
- By transcribing building components you can make the model much lighter. This makes it easier to remove items that are disassembled from the model. Afterwards, it can be digitally assessed whether the new installations fit into it;
- Within such a model, virtual measurements can be made to determine distances and dimensions. This can be done at the office.

Ideally, an almost photorealistic 3D model is available with a point cloud, which saves a lot of time, especially in more complex renovations, during the engineering phase and time loss can be prevented in the execution phase. Even when supplying prefab components, this method is very suitable for avoiding non-fitting parts.

Spatial information is thus effectively and accurately recorded, but for the determination of the specifications of the installed installation components and building materials, manual work based on local recordings also remains necessary.



Example of point cloud

Point clouds resulting from scan data are immensely powerful for analysis on their own; however, the point clouds need to be converted to object-based BIM models. Converting scan data into BIM models is traditionally a three-step process:

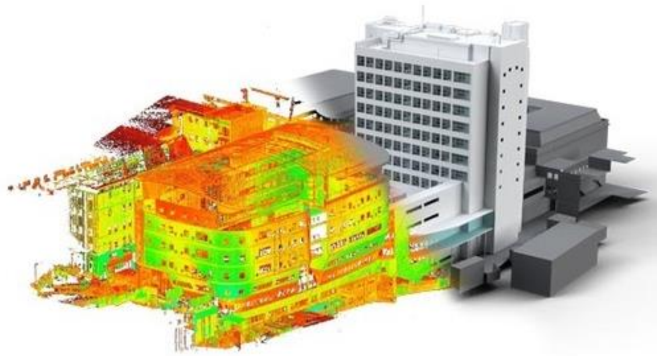
1. First, multiple scans are captured from different scanning stations.
2. Second, data from multiple scanning stations is stitched together in what is commonly known as the post processing or registration stage.
3. Next, CAD or BIM software can be used to author object models while referencing the point cloud.

Some registration software has the capability to create content from within the point cloud by running algorithms across the data points and recognizing surfaces from it. Creating objects within the registration software offers the benefit of rapid creation but has some limitations surrounding the accuracy and metadata acceptance of modeled objects. Creation of object models using external authoring applications is slower and more manual but has the benefit of detailed object representation and increased metadata acceptance.

Scanning can be a time-consuming endeavor, resulting in very large and/or complex datasets, so it is recommended that any team wanting to apply scanning technology plan their effort very carefully. First, the desired outcome of the scanning application should be clearly identified. In many cases the desired outcome is to identify precise locational (X, Y, Z coordinate information) about physical work in place. Next, a team must consider what they will do with the knowledge that comes from the work in place information. For example, 3D information is often used in design validation. Further, element information can be leveraged to extract 4D time information and 5D cost information. Last but certainly not least, objects can be further populated with 7D facility management information.

A scan plan should be made after the project objectives have been clarified. A scan plan is a set of information that outlines the scope and approach that will be taken to capture the data on-site. Often, a scan plan starts with detailed analysis of precisely which elements need to be captured. If using scanning for new work most scanners will capture the position of each element that will be geo-referenced. In the case of renovation work, scanners will often have the specific objective to gather more information. Identifying the exact scope of elements to be scanned helps the on-site team to prioritize their efforts and mitigate time spent capturing unnecessary elements. With a clear scope in mind a document can be created that identifies the optimum equipment location necessary to capture the desired information.

At the same time, knowing which elements to capture, scanners can be set to gather the precise level of detail at which the information is needed. Many projects will recognize that there is only a significant need to capture elements of a certain size, such as 2° and above. Attempting to capture smaller elements is often impractical and unnecessary. With these tolerances in mind the scanning hardware can be dialed in to precise operational settings to regulate the fidelity of the laser beams, which is known as the resolution and quality settings.



The resolution of a scanner can reach half millimeter, which, for geometrical values, has a much higher resolution than any traditional metering system.

During the scanning process a series of targets will be used to assist in the post processing effort. Targets for scanning can be paper-based hatching patterns that are placed onto a flat surface or spherical objects that can be set onto a surface. The intent of targets is to provide a minimum of three common points of reference across scanning locations so that each reference can be joined with its previous scan presence. Increasing the number of common targets increases the accuracy of the final registered scan. Failing to have enough targets can greatly hinder the post processing effort and will result in a low-quality registration. Further, failing to have enough targets may require additional site visits and cost. Proper target placement is fundamental for successful scanning!

In order to know the dimension of a wall, for instance, the scanning will be performed both inside and outside the building. Each point will have precise Cartesian coordinates and merging the internal and external scanning the dimension of the wall will be defined within one millimeter.

Once on-site scanning is complete, and the multiple scans have been registered together, the object model creation process begins. Again, object creation can occur in the registration software or in external modeling applications. The choice of which tool to be used for modeling should depend upon the desired scope outcome. For detailed scopes, such as complex structures, specific authoring applications (less detailed scopes can be very quickly represented using simple authoring applications). Using external authoring applications requires a methodical approach to model creation whereby elements are created systematically and in order of importance pertaining to the scope. Attempting to recreate every single element in a single area can lead to loss of focus and failure to meet the broader objective. In many projects the structures are modeled first; while architectural features are modeled second, and finally mechanical systems. In the case of renovation work, modelers will be well advised to include some kind of “existing to remain” delineation so that those model elements can be viewed separately throughout the BIM use cycle.

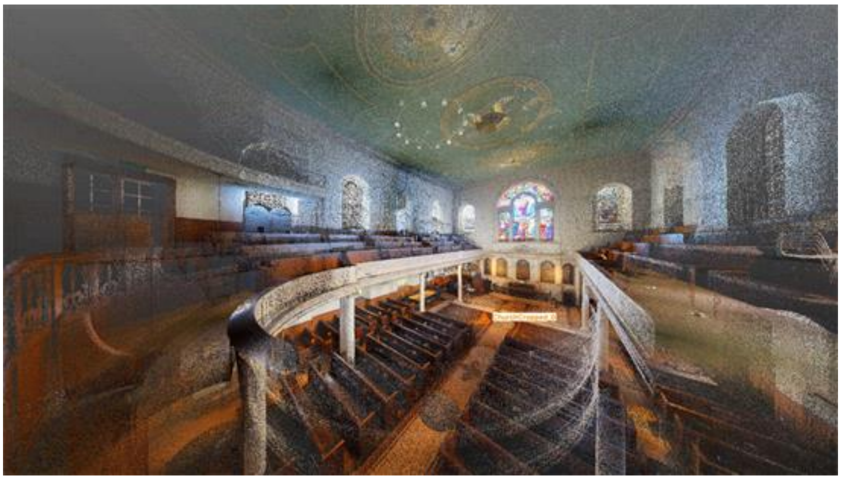
Of special importance for design validation efforts is the support of the coordination process. Oftentimes renovation projects include a mixture of existing to remain elements with newly placed elements. The scan and model data is capable of providing detailed information about points of connection that may exist between these two work scopes. Having exact points of connection between the two work scopes allows for a more accurate coordination process.

Stemming from accurate coordination is the ability to prefabricate. Many project subcontractors are very sophisticated in their ability to create physical work assemblies in off-site locations and then bring them on-site in large clusters for rapid installation. Prefabrication offers many benefits, including safer working conditions, controlled environments, and automated machine usage. However, prefabrication can only be successful when used in conjunction with accurate information about the destination of the final installation, which laser scanning provides.

Having an accurate 3D representation of elements from scanned data allows for further use of the data when considering the 4D time aspect associated with each construction element. Specifically, the quantity and position of each element can be leveraged to create detailed location-based schedules. Location-based schedules have a significant advantage over traditional schedules in that in they use detailed quantity and position information to represent the true work volume and position to take place during construction. Location-based scheduling is a concept that further extends into the ability to perform production control on-site and make teams proactive when managing a project schedule. The combined pro-activeness of scanning information and production control is a key component to mitigating schedule delays on renovation projects.

Additional variances in schedule activities may be recognized when considering tasks such as connecting newly designed pipe systems to existing pipes. In the case of these tie-ins, it may be necessary to isolate, shut down, drain, and make safe the existing pipe system before a new connection can be made. Because pipe systems often stem from a central location or plant, the shutdown of a system for a new connection in one location can have a dramatic impact on downstream functionality of the pipe system. An additional challenge could exist when making these sorts of tie-in connections is the discovered that the existing to remain pipes are not of suitable quality and have to be replaced. Therefore, scanning and scheduling renovation work prior to commencement should offer the opportunity to put schedule buffers surrounding tasks that integrate new works with existing works.

The combination of scanning and scheduling has already demonstrated significant benefit in specific cases of phased renovations of occupied spaces, including renovations of healthcare and manufacturing facilities. Scanning of work allows for a macro view of the mechanical systems than is often not available when “poking around” in an occupied space before construction. The macro perspective of the system allows for a more insightful schedule plan, again because the system uptime and performance can be viewed as a whole and then accurately delineated into the individual work spaces using the location-based methodology of scheduling. Using integrated software for these purposes also allows the planner the ability to produce schedule simulations. Schedule simulations are a great way of communicating to owners how construction work will impact their facility. This offers significant value to building operators who must accommodate for shut downs by maintaining new paths of travel across the facility, or new locations for production equipment uptime.



Scanning of work before construction has also proven to be a value-add as the quantifiable information coming from 3D elements allows for more detailed cost planning, or 5D as it is called. Scanning of work produces the 3D models and allows for the accurate delineation of cost assemblies associated with new and existing work. Cost components relating to the two different phases of construction may include different unit rates, different crews and different cost buffers in order to arrive at a more accurate project estimate. Similar to the duct example above, different work activities will be performed on new vs. existing to remain scopes and so will have different unit rates tied to the quantity of work. A unique line item for the cleaning of duct would be necessary for existing to remain elements, yet there need not be a cost line item for the placement of hangers and sealing of such duct work. It could also be recognized that the production rate, which is ultimately multiplied by the unit cost, for insulating new vs. existing duct may be different because existing ducts can be more challenging to access and so will have lower productivity.

Savvy contractors have also found a way to be more precise when applying cost buffers to renovation work after scanning. All contractors recognize that there are many unknowns when doing renovation work and so put a buffer on the project cost to account for the unknown. Scanning and modeling the work before execution allows for the cost buffers to be tied to the actual quantity of work which is existing and/or new, and so may have a less dramatic impact on the overall estimate. Accurate vs. broad cost buffers tied to an estimate can be the difference between being awarded a project and losing a project.

A clear benefit to laser scanning can be identified when considering the final deliverables that will go to the owner at the end of a project. Owners are responsible for operating the facility throughout its lifecycle and so are very interested in having as much detail as possible about the as-built condition of the building. Laser scanning can be applied at various stages of work commencement to measure the final position of work installed. Final element position can then be cross-checked with the BIM to ensure that the handover model truly reflects the installed position. Understanding the installed position of elements from the model allows facilities operators to be much more calculated when addressing problems because investigation can be performed from within the facilities office, rather than up a ladder in an occupied space.

Scanning at the end of work phases may sometimes require multiple scans due to the limitations of site that occur as systems become layered atop one another. This can present some unique challenges to the team managing the data and creating the BIM, however cases such as this present the optimum need for data capture and handover to the facilities team. Consider that if multiple scans are needed to capture and reflect element positions there is likely to be a scenario where facilities managers would be required to get “up into a space” to investigate problematic equipment that is located above other elements. This can be very unsafe, as there is rarely proper support up inside mechanical

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spaces for a human to navigate and rest upon when performing maintenance. Using a BIM model to investigate the space beforehand allows the maintenance personnel to be more tactful when planning their approach to the physical space and problem correction.

Several sophisticated owners have also opted to use laser scanning for the purpose of creating a facilities BIM model even when construction operations are not ongoing. This is because the sophistication of facility management software allows for a more proactive building management plan instead of the traditional reactive approach. Being proactive when managing the building offsets the cost of scanning because maintenance is done in a pragmatic manner beforehand and is significantly more cost efficient than emergency responses that include downtime.

Similarly, scanning may be performed on buildings that are not under construction for the purpose of capturing and maintaining historically significant features. It may be the case that a facility does not immediately have the funding to repair decaying features but can capture their condition before things get any worse. In this case, the scans can be retained and provided to the repairing contractor when funds are available for fixes, and the contractor has the ability to reference the scan data prior to fixes being made.

The implementation of laser scanning brings an entirely new realm of possibilities to an already powerful integrated BIM workflow. The ability to capture detailed information about elements in their physical space allows for more precise use of data. Whether capturing 3D information for coordination and prefabrication, or leveraging the quantity information for estimating and scheduling, laser scanning is surely a necessary endeavor to increase the accuracy of project information. Decreasing hardware costs and increased software capabilities have made scanning a competitive advantage for contractors willing to invest the time and effort into this fully integrated BIM workflow.

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5. Module 5 – Analyse the BIM Model

5.1 BIM for quality management

Most managers in existing buildings need to manage the influences of daily activities as they oversee the maintenance and operations of these facilities. Typically, their top concern is managing thermal comfort. Managers also must manage the quality of the indoor environment — humidity, lighting, sound, etc. — as well as the quality of services provided, building operating costs, energy use, water use, recycling, and waste reduction. With the rise of reporting mandates, measuring building performance is more important than ever.

Most managers already work with several technologies as they manage facilities. A building automation system (BAS) or building management system (BMS) most often handles the operating of building mechanical and lighting systems. An energy management system, which might be part of the BAS or BMS, handles the energy. In many facilities, integrated work management systems (IWMS) or computerized maintenance management systems (CMMS) support facility management – maintenance activities, work orders, space management, capital planning, personnel, etc.

All of these systems are data-intensive. Anyone who has been involved in implementing them in an existing facility knows that to be truly valuable, they take careful planning, understanding of expected outcomes, detailed data collection, testing, vetting, and training.

While the need for planning and training will never go away, BIM technology and the standards developed around it might offer a way to knit these various systems together. In the standard way of operating, managers have many documents that provide information about facilities: generations of drawings, specification books, operations and maintenance manuals, warranties, system test reports, and other project records.

Seldom these information sources are linked electronically. In many cases the management of data is incomplete. Seldom are maintained as master drawings for each building, as well as each of the major systems within those buildings. Depending on the activities in a given month, the data management becomes a part-time to full-time job. Accessing the information is another matter because it is not always up to date or easy to extract.

Managers certainly understand the need for consistent, accurate, and easily updatable information to help manage facilities, but the technology hasn't always been available to support it in an easy fashion. The use of BIM in a consistent way can ensure the exchange and the storage of the correct information that can be used by the building manager in the right moment. In order to achieve this important objective, since the beginning the building manager has to establish the requirements for the information delivery management (IDM) and keep it under control. During the construction phase, in fact, the information of any plant and any installed equipment needs to be documented and instructions on the use and maintenance have to be provided as well.

During the management phase any maintenance has to be accurately uploaded in the model to keep each information updated. The building manager will have to ensure that the maintenance services provide this information.

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5.2 Simulation techniques and energy and lighting analysis

It is very important to define the requirements for energy performances since the design phase for both new and existing buildings and identify the data need for the correct simulation of the energy performance.

For any building the use for the different "zones" need to be identified to establish the foreseen temperature, the number of air exchange, etc. besides the thermal transmittance of each wall, ceiling, pavement, window, door, etc. need to be known. The more these data are reliable the better will be the simulation. Especially in the case of existing building, it is very important to know the habit of the tenants so that the simulation can be performed in the correct way.

In order to have an accurate energy analysis of the building, a 3D geometric model created is converted into an analytical model. First, it is needed to convert all the spaces into rooms. In the BIM tool, rooms are considered to be the equivalent of zones that need to be defined. A thermal zone is a completely enclosed space bounded by its floors, walls and roof and is the basic unit for which the heat loads are calculated. The extent of a "room" is defined by its bounding elements such as walls, floors and roofs. Once a "room" is defined for the purpose of analyzing the building's energy, these bounding elements are converted to 2D surfaces representing their actual geometry. However, overhangs and balconies, which do not have a room, are considered as shading surfaces. In order to determine whether a room is an interior or an exterior one it is important to define its adjacent in the analytical model. By using the developed plug-in that is loaded in the BIM tool, designers will directly transfer the created model of the building to the energy simulation and analysis tool using both the gbXML and IFC formats.

In order to test what type of data was included in each of those file formats, a careful comparison will be necessary. The created case building model is tested for building materials, thickness, geometry (area and volume), building services, location, and building type. All the input variables are kept constant in the base case while the testing is done with one alteration at a time.

The platform provides a suitable environment to establish a Decision Support System (DSS) to help the design team decide on the selection of the best type of sustainable building components and families for proposed projects based on defined criteria (i.e. Energy consumption, Environmental impacts and Economic properties) in an attempt to identify the influence of the design variations on the sustainable performance of the whole building. The final design will be influenced by the results of the energy and lighting analysis, the LCA and Environmental Impact and embodied energy results, and the sustainability evaluation of every building component based on the LEED rating system, as well as the initial costs of these components. The LEED (Leadership in Energy and Environmental Design) is one of the most popular green building certification programs used worldwide. Developed by the non-profit U.S. Green Building Council (USGBC) it includes a set of rating systems for the design, construction, operation, and maintenance of green buildings, homes, and neighborhoods that aims to help building owners and operators be environmentally responsible and use resources efficiently.

- **Energy Models**: These building information modelling models deal with all the big questions. You'll often use an energy model at the earliest stages of your analysis. The energy model helps you to interpret the basic information. You'll figure out what you need to know about your structure's form and orientation at this stage. Often, you'll only use basic geometry to build your models. More realistic and defined specifications come with later energy models.
- **Lighting Models**: These are all about the presentation because the lighting model handles the visual aspect. They tend to contain much more detail than energy models. You'll touch up your geometry and use this

model to define the properties of your materials. This is the model that helps you to figure out exactly what you need, as well as how everything should fit together. Generally, your finished lighting model is similar to the one you'll present to clients.

When imported into the energy simulation tool, the model would assume the default values for the location given when creating the digital model. In order to discern that the information related to the selected material used in the model has been completely transmitted over to the energy simulation and analysis tools, a new material could be assigned to the 3D model of the building.

The basic requirements for lighting analysis and design are highlighted in the box below:

- Spatial geometry;
- Surface reflectance;
- Luminaire photometry and associated factors;
- Luminaire position and aiming.

The newest feature is the ability to calculate light levels in a space from the sunlight and skylight at a given day and time. All-Weather Sky method, uses historical weather data to better approximate the sky conditions for the selected day and time.

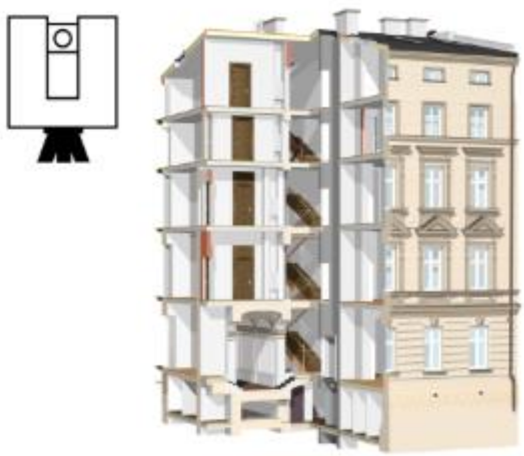
5.3 Technical supervision of construction works

The digitalization of the building sector implies the construction of twin buildings, one being the real one and the other being the virtual model, which has to be the exact copy of the real one. To achieve this objective, during the construction, the professional in charge of the supervision of the construction works need to ensure that any change made during the construction is correctly reported in the model. Besides, the technical schema of each installed equipment needs to be linked to the object for future maintenance. All the information of the real materials and equipment used during the construction will populate the model in IFC format so that can be view, in future by any software application. For bigger construction software for the building management can be used as well. The owner of the model will finally ensure that their customers will receive a model that can read and bring all the information requested, since the beginning through the EIR (Employer Information Requirements).

Throughout the duration of the construction the checking and documentation of the current state of works is needed, and any change has to be introduced in the BIM model of the building. In this way, after completion of construction, the investor receives the BIM model being precise replica of the existing building. This model can be the basis for facility management, as well as the further modernization works:

- BIM Model for mobile devices: BIM model and all current technical documentation are within reach, thanks to applications for mobile devices. Quick access to the documentation because of the frequent changes in the project is essential to the realization of investment in fixed timetable.
  Typically, supervision is carried out once a week or once every two weeks. Some architects use IFC browsers, which greatly improves communication with teams carrying out work on the site. Supervision may be carried out in the planned time frame and on the investor's request. It is usually connected to the inventory of the current state of the construction work.

- Exchange of information with the construction site: Good cooperation between the designer and the contractor of the investment is crucial. A continuous exchange of information from the construction into a BIM model is essential. The collection of information from the building is done in several ways, making very accurate measurements, creating an inventory of photographs and text reports.
  Throughout the duration of the construction professional team keeps checking, measure and document the current state of construction. In this way, the investor has an insight into the progress of the construction work, which allows to control the compliance of the facts with the executive project and schedules. Additionally, the so-called "As built" model is established, which is consistent with reality. The individual elements of the model have the status that determines whether they are existing parts, for demolition, or designed. During supervision elements are added, their status is updated or are removed. Also, changes made during realization are applied to the model, thereby generating a post-completion project in real time. In this way, after completion, the investor receives the BIM model being precise replica of the existing building, which could be the basis for facility management, as well as the further modernization works. The model is supplied in both several file formats, and in IFC open format, supported by the organization buildingSMART. The cost of the development model is calculated based on the duration of the construction and the complexity of the object.



- Update of BIM model with data from construction site: Changes in the BIM model are introduced immediately after the revision on the site, which allows designers for adjustments of the project and the selection of appropriate technical solutions. Correct and fast update of the model is essential to make changes that are important for the contractor.

Contractors will conduct the self-inspection first when a major working procedure is completed. Then supervisors from a contracted supervision company will confirm the inspection result on behalf of the society before the next procedure can be continued. Managers from a developer such as a real estate company may inquire the inspection state and result whenever they want. All the relevant inspection items, inspection methods and required quantity of inspection points are described in the standards.

The users of the system include the relevant inspectors such as contractors, supervisors and managers.

The key functional requirements of quality supervision system based on BIM are listed below:

Number	Function name	Function description
1	Import, browse and operate 3D model	Import IFC data, view model and components hierarchically, operate model with zoom, translation and rotation to help inspector quickly get the inspection target.
2	Automatically generate inspection lots, items and points	Establish an algorithm to generate inspection lots, items and points automatically which can help inspectors establish inspection plan before construction and carry it out orderly and normally at the construction site.
3	Fill out customized forms C	Complete supervision successively by filling out the customized forms with smart tips
4	Automatically generate standard documents	The form completed at the construction site can be automatically converted into standard document without second input.
5	View the state and results of supervision process	View and monitor the supervision data transmitted from the construction site and count up the status and result of the whole supervision process.

5.4 BIM for handover and maintenance

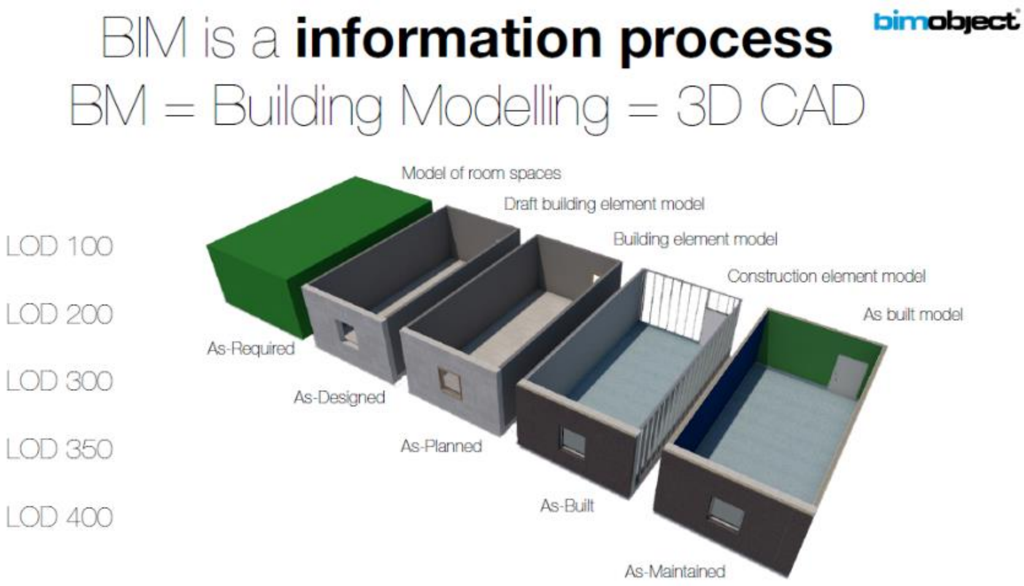
Design and construction teams are typically contracted to deliver a structured information handover package to support a client's asset operations and maintenance at a project's end. However, not often this handover information is checked for completeness, accuracy and appropriateness at the point of receipt. This goes some way to explaining why asset owners and facilities managers can often struggle to ensure an asset delivers against its expectations (cost or scope) in the early years. So, there's a case to be made that facilities managers can be more upfront to clarify all preferences and expectations of the information they need on day one. BIM and a collaborative approach to building design, construction and handover can play a crucial role in taking us even further along the path towards better executed built assets and less headaches for all.

When they are handed the keys at the end of a construction project, what a facilities manager (FM) will be typically given is a box, be it virtual or physical, filled with information and data. That box should contain explanations on building maintenance, equipment warranties, security operating instructions and asset lists among other things. This information may be in all kinds of formats, including paper and digital media like CDs and USB keys.

To complicate matters further, vital building-related information risks being lost during the handover of that box. When the facilities manager notices that there is information missing, they will need to spend unwanted time tracking down historical project information. This is a waste of efforts, not least because of the labour involved. The information that is resurrected after the ordeal often might be inaccurate or incomplete. In the worst-case scenario, that data can't be recovered and the FM then must undertake a fresh survey of the building or part to capture its as-built condition. The result of this is a cost paid twice over by the building owner for a survey (and for the maintenance contractor) which should only have to happen once.

A diffuse use of the so-called "BIM object" will facilitate the handover. A BIM object is an element of the building both belonging to the structure and to the Heating, Ventilation and Air Conditioning (HVAC) plants and can even include piece of furniture and domestic appliances. The BIM object can contain any information like geometry, connection to the plants, instruction for maintenance, warranties, etc. Many producers are now converting their traditional catalogues into BIM objects catalogues so that designers can just take the object and insert into the model. The "plug and play" can be done with different "Level Of Definition" (LOD) in the different phases of the life cycle of the building.

During the preliminary design phase, for instance, only the geometry is needed while for the technical design all the information about connections to central plants would be provided and finally, during the handover and close out, any other information will be provided. In the picture an example of different LOD for the same object.



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On the other hand, assume that every piece of data handed-over was proper, complete and future friendly. Not only that, but it was relevant with all immaterial information either filtered out already or organized so that it could be easily sorted and made usable for the next twenty years. Then, the information could contribute to the improved ongoing operation of the building, not just now, but for years after the handover.

What's all of this got to do with building information modelling (BIM)? BIM allows information flow seamlessly from the start of a construction project all the way through to facilities management. It articulates to the client everything from floor plans and layouts to materials used, asset shelf-life and required maintenance schedules – essentially, it depicts what products are in the building, where they are, how they work, and how they all fit together. It relates objects in a model and links them to each other for the greater understanding of all parties involved in the design, construction, operations and ongoing upkeep of the structure.

What this means in the long term is enhanced predictability and the opportunity to take early steps towards proactive FM action; they can realize the full value of their asset over its useful life through cost-, sustainability- and time-effective operation and maintenance. With BIM, facility managers can visualize facilities being created, helping them to understand project intent. BIM lets them see into the future – it lets them see the effect individual design features will have in the immediate future, that very evening and in the days following.

BIM can also act as a bridge between different stages of the handover process. Where teams implement Common Data Environments, such as Aconex, workflows can be automated on a shared, neutral platform, whilst providing a comprehensive information resource accessible by interested parties and shared during or after the project. In this way, the risk of losing asset information created earlier on in the project is lessened. Accurate information should have been recorded, verified, and submitted in a timely fashion throughout the process, not just collected at the end.

It is common for FMs to be concerned that they haven't been involved in contributing to the design of the building and that this makes their job harder. What BIM will mean for them is working not harder, but smarter. New working practices encourage, through embracing BIM, a need to involve asset owners and facilities managers to understand the information they require on handover. It will mean bringing people together. Facilities managers do not have to know everything about CAD technology or 3D modelling – but they can still have an important say during design, can impact the result, and can ensure the information handed over by the contractor fits their specific needs.

How do we achieve this collaborative way of working? By encouraging open conversation between all disciplines. The direction of travel in the industry will eventually lead to a point where facilities management experts can help and educate others within the design and construction stages on the long-term benefits of using BIM to aid the asset lifecycle. A specific role comes to the open BIM formats like IFC (Industry Foundation Classes). It's an international data standard for BIM which allows communication between parties during the project, irrespective of the software platforms they use, and makes sure that the data can still be read in ten years and more. It creates rules and foundations for collaboration to ensure that everybody is speaking the same language.

Without sophisticated digital handover tools, contractors are scrambling to retrospectively gather project information at practical completion to deliver to the owner, or risk penalties or late payments. Even then much of this information is inaccurate and/or incomplete. BIM gives owners a multidimensional model of the as-built asset, but more importantly, the opportunity to develop a structured digital information source of the asset so that the design can be modified and approved while testing its constructability. In the future, the facilities manager has the opportunity to influence the quality of the information they receive, including a complete digital representation, and a geospatial view, with all relevant project and handover information detail included.

Education affords many things. In our line of work, it opens doors and windows so that clients are fully conscious of the data they will need to make their lives easier. With more meaningful insights added every day, digital twins will emerge as the digital replica of physical buildings. Harnessing that sort of cutting-edge technology can elevate facilities management to a new space.

After delivery, the client has a digital data model (eg LoD 500). This can be elaborated in a 7D model whereby the maintenance of a structure is made transparent. At the moment there is limited software available that can display such maintenance and management information. For that reason, translating the data model into information for maintenance and management is laborious. In the following flow chart a possible maintenance process.

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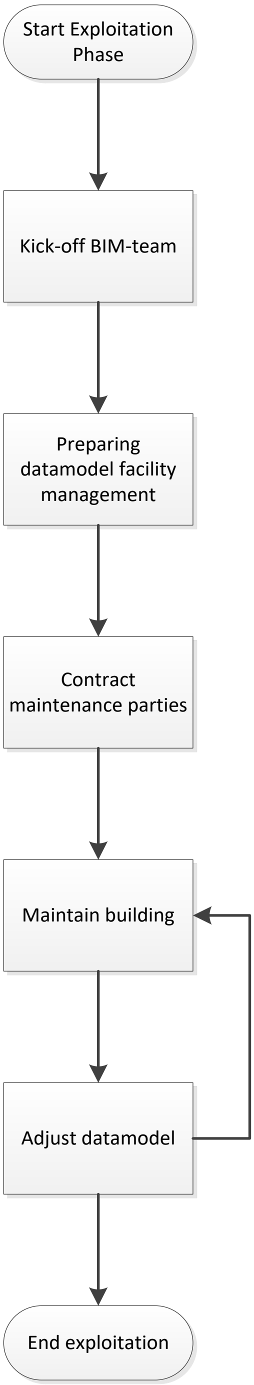

1. Organize kick off with BIM team

First there is a kick-off from a (new) BIM team to discuss the management and use phase in relation to the data model.

2. Work out completed data model

From this model data can be generated for maintenance of a structure. These are, for example, the replacement frequency of filters in air handling units or the square meters of window frames.

3. Contract maintenance parties

On the basis of the detailed data model maintenance parties can be contracted to maintain the building.

4. Perform maintenance

In the operation the building is periodically maintained. Preventive and corrective failures are handled and small modifications are made to the installations.

5. Adjust data model

During the lifecycle of the structure, adjustments in the data model are taken into account by the responsible maintenance party.

Communication

After completion of the building it can be put into use. It is possible that another (for example facility) organization will use and maintain the building. A good transfer of the data model is therefore desirable through one or more consultation sessions. In particular, maintenance departments must be properly instructed on how data from installations can be made transparent via the BIM.

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Appendix I: e-learning courses

In appendix we report the link to the relative e-learning courses developed by the partners of the various countries in the respective languages, within the relative web page are available information on how to register and how to access the course.

Here you can find a guidelines about how to register and to access step by step for the different courses available:

✓ **Guidelines e-learning courses**

The e-learning courses followed somewhat different structure in every partner country but as mentioned before have always included all the learning outcomes and training content defined in respective deliverables. Additionally, each respective partner developed their e-learning courses at different levels of interactivity which then followed their course structure.

Select your national course and start a new lesson:

- Italian course
- Croatian course
- Spanish course
- Estonian course
- Lithuanian course
- Slovakia course
- Netherlands course

Appendix II: Projects stages and BIM Use Case structure

In appendix we report the link to the document developed by Lithuanian partner DiG.Con. Digital Construction about construction projects stages and BIM Use Case structure:

✓ **Construction projects stages and BIM Use Case structure**

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The present deliverable will be update during the project in order to align the outcome to the market needs as well as to other BIM related projects realized within Horizon 2020 program.

The updated version of the deliverable will be only available in the website of the project www.net-ubiep.eu.

Some deliverables could also be translated in partners national languages and could be find in the respective national web pages. Click on the flags to open the correspondence pages:

International web page

Italian web page

Croatian web page

Slovak web page

Spanish web page

Dutch web page

Estonian web page

Lithuanian web page