BIM-based EU -wide Standardized Qualification Framework for achieving Energy Efficiency Training

D2.2 – Benchmark of existing training offers

- Public version / Extended Abstract -

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Abbreviations

ALO	Achieved Learning Outcomes
BEM	Building Energy Model
BIM	Building Information Modelling
CA	Consortium Agreement
DoA	Description of the Action
EE	Energy Efficiency
EPBD	Energy Performance Buildings Directive
EPC	Energy Performance Certificate
EQF	European Qualification Framework
GA	Grant Agreement
HOTS	High Level Thinking Skills
ICT	Information and Communication Technologies
ILO	Intended Learning Outcomes
KSC	Knowledge – Skills – Competencies
LO	Learning Outcomes
LOTS	Low Level Thinking Skills
Mx	Milestone date designating the start of a given task
My	Milestone date designating the end of a given document delivery deadline
PC	Project Coordinator
PSC	Project Steering Committee
QA	Quality Assurance
RIBA	Royal Institute of British Architects
ToC	Table of Content
WP	Work Package
WPL	Work Package Leader

1 Executive Summary

This report involves benchmarking existing EU-wide Building Information Modelling (BIM) training across the building value chain (incl. lifecycle and supply chain). This phase of the project involves highlighting energy efficiency linkages; identifying qualification targets and accreditation mechanisms, whilst highlighting training gaps and enhancement potential.

It highlights the challenges and benefits associated with integrating BIM into energy performance assessment with the aim of streamlining procedures to help ensure delivery of energy efficient buildings which perform more closely to their design intent.

Building on the BIMEET D2.1 deliverable (BIM&EE requirement capture), this report reviews the training offered in the countries represented by the project partners to the supply chain across the construction life cycle. In particular it considers the role of apprenticeships and university courses as a vehicle to develop suitably trained construction professionals in this field. It also assesses the existing BIM training provision and associated certification offered by training organisations to determine whether this can provide the required skills and knowledge.

2 Introduction

In this section we present the current state-of-the art in the field of BIM and associated construction applications with regards to energy efficiency and training.

2.1 BIMEET project

The aim of BIMEET is many-fold: (a) pave the way to a fundamental step change in delivering systematic, measurable and effective energy efficient buildings through BIM training with a view to effectively address European energy and carbon reduction targets; (b) promote a well-trained world leading generation of decision makers, practitioners, and blue collar workers in BIM for energy efficiency; (c) establish a world-leading platform for BIM for energy efficiency training nurtured by an established community of interest. These general aims translate into the following strategic objectives (STO):

- STO1: Screen and synthesize past and ongoing European, as well as national, initiatives and projects with a focus on assembling evidence-based quantitative / measurable scenarios and use cases that demonstrate the role of BIM in achieving energy efficiency in buildings across the whole value chain.

- STO2: Benchmark existing Europe-wide BIM trainings across the building value chain (including lifecycle and supply chain), highlighting energy efficiency linkages, as well as qualification targets, delivery channels, skills, accreditation mechanisms, while highlighting training gaps and enhancement potential.
  - ✓ This will include: (a) better determination of future capability needs; (b) clear routes of entry and clear career progression pathways; (c) clear, standard means of recognising competence; (d) exploring the scope to make apprenticeships more flexible; (e) an industry review of the current skills and capability delivery mechanisms; (f) review of approaches to career planning, training and development with a commitment to rationalise.

- STO3: Harmonize energy related BIM qualification and skills frameworks available across Europe (Objective 1) with a view of reaching a global consensus through our BIM for energy efficiency expert panel.
  - ✓ The focus is on setting up a mutual recognition scheme of qualifications and certifications among different Member States supported by an effective strategy to ensure that qualification and training schemes are sustained after the end of the project.

- STO4: Map identified skills, qualifications, and accreditation into a BIM for energy efficiency overlay with a total lifecycle and supply chain (including blue collar) perspective.
  - ✓ There are country specific delivery and process variations that will be considered to ensure successful take-up of the BIMEET training program at a national level.

- STO5: Adapt the BIM4VET platform (delivered in the context of a related ERASMUS+ ongoing project) to provide a robust computer-based online and open-access environment for BIMEET.
  - ✓ The BIM4VET platform is already providing: (a) BIM stakeholder competence matrix, (b) classification of BIM training curriculums in Europe,

(c) BIM qualification maturity assessment method, and (d) recommender system for BIM training selection.
  - ✓ The resulting BIMEET platform will be available on-line on an open-access mode, nurtured by an established community of interest underpinned by an adapted business model.

- STO6: Establish a governance, policy, and regulatory framework as well as adapted business models to ensure the long-term sustainability of the proposed BIMEET training agenda.
  - ✓ The consortium will be supported by a 200+ members of the BIMEET community of interest and a panel of experts (around 20 members).
  - ✓ The consortium members will adopt an incremental and participative approach engaging effectively all the above stakeholders.

- STO7: Disseminate within and beyond Europe the resulting BIMEET platform and training program.

BIMEET endeavours to enhance the skills, qualifications and capabilities of construction practitioners (from high professionals to blue collar workers), thus increasing market penetration and adoption of key technological development in BIM, given the timeliness of the need for training in combined green and functional performance engineering. There are several areas that are key to the potential growth of BIM for energy efficiency and its impact on the green building marketplace:

- Multi-disciplinary integrative capacity of BIM: BIM provides a unique opportunity to integrate data, information and underpinning processes across lifecycle and supply chains. This will promote informed and energy efficient design interventions.
- Informed sustainability design: BIM contributes to sustainable lifecycle decisions and processes as it leverages on the capability of the complete construction value chain thus optimizing design decisions on complex issues such as energy efficiency.
- Modelling standards: BIM is currently promoting the development and adoption of a wide range of standards and best practice guide as evidenced by BIM adoption dynamics in Europe.
- Increase of BIM use for retrofit: there is an increasing trend for use of BIM in large as well as smaller projects with a sought benefit of maximizing energy efficiency and sustainable outcomes. Recognition of the appropriateness of BIM for small retrofit projects is also critical given the dynamic growth anticipated in the green retrofit market in the existing domestic stock across Europe.
- Using BIM for building performance monitoring: there is an increasing evidence of the value BIM tools during the operations and maintenance phase of a project, with the view of reducing the endemic gap between predicated and actual energy consumption in buildings.
- Training support & communication tool: As BIM embraces building products and processes, it constitutes a useful support for training, and to communicate the best practices for energy efficient and high-quality construction, in particular to on site staff.

This report focuses specifically on objective no. #2.

It builds upon the previous BIMEET output D2.1 *BIM for energy efficiency requirements capture* as well as the findings from the BIMEET expert panel workshop held in Brussels in

February 2018. It therefore focuses on benchmarking existing EU-wide BIM training across the building value chain highlighting:

- Energy efficiency links
- Qualification targets
- Delivery channels
- Training gaps for future potential

2.2 Background

BIMEET output D2.1 provides background on the EU targets to improve the energy performance of buildings, the challenges these pose for the construction industry, the development of BIM and how this can help the industry address the energy challenges.

The digital transformation is revolutionizing our lives as individuals, industries and communities. Consider the handling of our banking and transactions, as well as Electronic Point of Sale (EPOS). Through the use of Big Data, corporations are able to analyse our digital footprints to profile our spending habits and lifestyles.

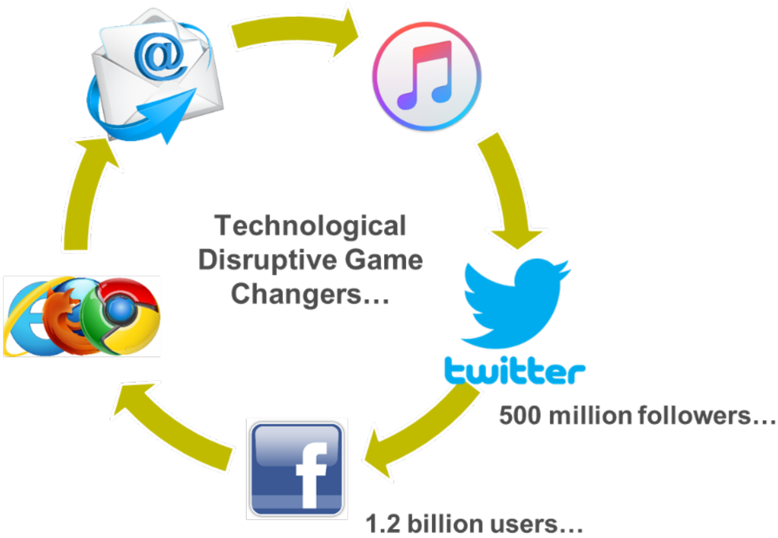


Figure 1: Technological disruptive game changers

All around us an inexhaustible variety of machines, objects and sensors are communicating and sharing data across the Internet of Things (IoT). By 2014, 16 billion devices, twice the global population, were connected to the IoT. This figure is projected to grow to 50 billion by 2020, and 1 trillion by 2040 [1].

It is because of these technological drivers that the construction needs to move towards disruptive processes like Building Information Modelling.

Many consider this a Darwinian moment for the Construction industry. The quote (often mis-attributed to Darwin)[1]: "*It is not the strongest species that survive, nor the most intelligent, but*

[1] https://www.darwinproject.ac.uk/people/about-darwin/six-things-darwin-never-said

the ones most responsive to change", has never been more pertinent to AEC industry than at present. Whilst the First and Second Industrial Revolution were about mass production, the Third Industrial Revolution is about information economy. We are entering the 'Age of Information' where information is traded, consumed and used continuously, forcing industry, businesses and individuals to adapt or be left behind.

New skills to transform Architecture and the Built Environment will need to be considered with these rapid advancements in new technologies. To enable these new technologies and processes we need to perhaps look at new roles and responsibilities for Architecture and Built Environment.

Industry needs to build the case for investment in innovation to drive the necessary changes.

As part of Digital Built Britain, the UK Government's BIM Level 3 strategy, the Digital Built Britain report talks about the Government wanting to sell UK industry's expertise and technologies internationally and seize a share of the $15 trillion global construction market forecast by 2025 [2]. This cannot happen without heavy investment from both government and private sector. The same applies across other EU countries.

The Digital Built Britain Report highlights the need for the following to meet the future needs of industry within the UK:

- A skilled digitally enabled workforce
- A big data supporting new developments & markets
- Sharing technologies across many sectors & markets
- Effective Education & Change Management programme

It is clear from the report that to provide a skilled, digitally enabled workforce, an effective education and change management programme is required. The world economic forum, recognizing the need to skilled future professionals published a list of the most desirable skills for the future (https://www.weforum.org/agenda/2016/01/the-10-skills-you-need-to-thrive-in-the-fourth-industrial-revolution/).

What new roles are we looking at to fill these skills gaps of the future?

Steve Jobs, former CEO and co-founder of Apple, attributed his success to that fact that he was interested in more than one thing. When developing the new Mac Book he attributed his interest in calligraphy as the inspiration for its beautiful topographical design. Like many other successful innovators, he wasn't a narrow specialist. This raises a question at a time when creativity and ideas are critical to business success: Should our professional be a generalist to some degree? [3]

Andy Boynton of Forbes (2011) identifies two types/ shapes of professionals:

- The "I" shaped (think narrow and tight) professional who is highly versed in a specific area of expertise and learns by drilling more deeply in a particular field.
- The "T" shaped professional who has broader skills and knowledge and learns linking up different perspectives from different specialities.

He comments that although both types are essential in any organization, many leaders today feel that "T" people are better at fostering the diverse connections and conversations that bring exceptional ideas to the surface. He also notes that the same leaders bemoan what they see as a shortage of them in today's hyper-specialized environments.

Boynton's observations are very relevant to the AEC industry when we consider the skill-set requirements of the future workforce.

Take the current role in architecture as an example. The Architect/Technologist enters into practice with a core professional competency. Soon other office roles become bolted on such as installing software and general IT support.

Over time the professional gains more experience and develops further competencies and his role begins to diversify. Working within the BIM environment the professional begins to interact with other disciplines in a collaborative manner and starts to better understand their roles.

In addition, Industry is getting to a point where designers are beginning to develop their own apps and analyse data on models through tools such as dynamo or grasshopper. In the future, perhaps in 10 years, these roles might expand to incorporate social sciences and relationship management.

According to World Economic Forum[2], today's education systems simply "cannot keep up with the rapid pace of change. Too many of today's graduates are merely not business-ready for the jobs that now exist. For the rest who may not have the academic credentials and special skills, they face barriers as well, as the non-cognitive skills they might possess are often discounted."

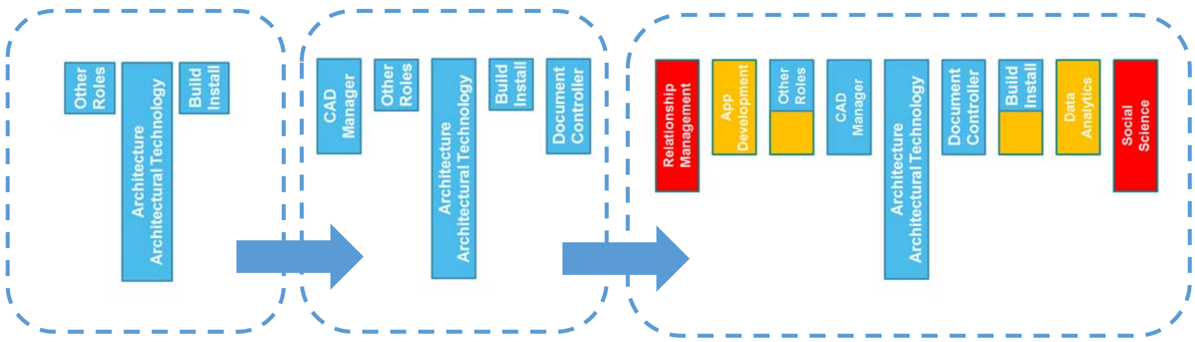


Figure 2: Example of the career progression of a T-Shaped Architectural Professional

In this context, a very relevant initiative is BUILD UP (http://www.buildup.eu/en/skills), the European portal for energy efficiency in buildings, which highlights the need for a qualified building workforce to ensure the higher levels of quality required for moving towards Nearly Zero-Energy Buildings (nZEB) and to accelerate the rate of building renovation in Europe. Training construction workers, both blue and white collar throughout the entire building value chain is crucial to address upcoming challenges. These include new materials and technologies, the integration of renewables and collaboration using BIM.

2 https://www.weforum.org/agenda/2016/02/beyond-jobs-beyond-corporations-the-collaboration-economy

3 BIM standards and energy efficiency

3.1 Standardisation

Before proceeding it is important to appreciate the drive to BIM standardisation and its relevance to energy efficiency.

Building information modelling (BIM), as defined within ISO 29481 is 'use of a shared digital representation of a built object to facilitate design, construction and operation processes to form a reliable basis for decisions'. Put simply, BIM ensures better information to support better decision-making. Historically, the focus has been placed on the decisions made by clients. However, there are a myriad of decisions that need to be made by the project team members.

When discussing the interface between design professionals, a key BIM Standard is ISO 29481, which focuses on Information Delivery Manuals (IDMs). IDMs are 'documentation which captures the business process and gives detailed specifications of the information that a user fulfilling a particular role would need to provide at a particular point within a project'. To establish this documentation there must be:

- **Use Case**, the purpose this process fulfils
- **Initial Information**, the raw data and information needed to complete the process
- **Activities**, the elements of the process that consume this information
- **Result**, the product of the process to fulfil the use case.

While there is no definitive list of 'use cases' there are several sources which include uses relevant to energy efficiency:

- **BIM Think Space**
  BIM Think Space, an independent BIM resource managed by Bilal Succar which includes a schedule of 'model uses' (http://www.bimthinkspace.com/2015/09/episode-24-understanding-model-uses.html). Several of these could be considered use cases such as:

  4050 – Code checking and validation,
  4190 – solar analysis,
  4090 – energy utilisation,
  4220 – sustainability analysis,
  4230 – thermal analysis,
  4120 – lighting analysis,
  4250 – life cycle assessment and
  7030 – performance monitoring

- **ISO 12911**
  ISO 12911, 'Framework for building information modelling (BIM) guidance' (https://www.iso.org/standard/52155.html) supports the development of BIM specifications. Table A.1 in the Standard identifies a series of outcomes (considered equivalent to IDM results) and includes:

  1.2.1.3 – Regulatory Compliance
  1.3.1.1.3 – Thermal analysis and simulation
  1.3.1.1.4 – Light analysis and simulation

1.3.1.3.1 – Energy use analysis and simulation
1.3.1.3.2 – Resource use analysis and simulation

Each of these 'use cases' require 'initial information' to support the process. For example, solar analysis will likely require coordinate and orientation information. Through BIM, the information needed for each use case can be formalized. For example, the IES Revit Plug-in user guide (http://www.iesve.com/content/downloadasset_2862) sets out 'information constraints' in regard to units, coordinates, orientation, modelling, properties. These 'information constraints' ensure that any information received by actors undertaking energy-related use cases are optimized to the relevant software and activities.

Once the initial information has been received, the identified activities can be undertaking. Such activities may include: importing information, running analysis, iterating to provide solutions.

Ultimately this process completes with a result. Typical outputs include reports, information, or graphical models.

To accelerate the market uptake of BIM, standardisation of standards, methods and procedures are important. Within the context of CEN, Technical committee 442 (Building Information Modelling) was created in September 2016. At ISO level, Technical Committee 59 is also dealing with BIM.

CEN TC 442 has a broad work programme covering the following areas (https://standards.cen.eu/dyn/www/f?p=204:29:0::::FSP_ORG_ID,FSP_LANG_ID:1991542,25&cs=1085D2CA41E34A1C2DA860E5234AA5A97#1):

- WG 01 – Terminology
- WG 02 – Exchange Information
- WG 03 – Information Delivery Specification
- WG 04 – Support Data Dictionaries
- WG 05 – Chairperson's Advisory Group

These working groups produce new Standards and documentation. For example, to develop on the short term data structures for providing data from CE marking in BIM compatible formats, CEN within CEN/TC 442/WG 04 has set up a 'Smart CE marking' workshop agreement. With the market uptake of BIM, and assuming information models will be used for EPC calculations, there might be also new tasks for data standardisation in relation to EPBD related standards. BIM offers the possibility to have better modelling of energy processes, a topic which is picked up again below. It is important that the (CEN and ISO) standards reflect such developments.

3.2 BIM and convergence of national EPC calculation procedures

At present, there are still major difference in the national calculation EPC (Energy Performance Certificate) processes. It is expected that, due to the release of International standards such as ISO 52000-1 (https://www.iso.org/standard/65601.html) and the associated energy performance of building European standards and technical reports, that a convergence of procedures would occur. With the majority of these standards and technical reports published within 2017 and 2018, this convergence is likely to occur within the next decade. This convergence will not only allow for a better energy performance comparison of buildings internationally, but will also establish a formalised process which could be automated through the use of digital technologies and collaborative processes such as BIM.

Through the adoption of information management using BIM, there is the possibility output a more accurate physical modelling of the energy performances with little, if no, additional resourcing required. These more accurate digital representations, combined with a standardized process to extract and interpret information presents the possibility of nearly no differences in approaches between member states. This was the subject of the 1st conference *BIM and energy performance of buildings* (http://qualicheck-platform.eu/2018/04/1st-european-conference-bim-and-energy-performance-of-buildings-25-june-2018-brussels-belgium/), organised by INIVE EEIG on behalf of the QUALICHeCK platform, which aims to present the status of BIM and opportunities and challenges regarding BIM use for the regulatory assessment of the energy performance of buildings.

Wouters addressed this in his paper[3] *Overview – Possibilities and challenges of BIM with respect to the assessment of the energy performance of buildings* and which he developed in his presentation at the aforementioned conference.

At present, data collection (surfaces, volumes, product and system data …) to calculate the EPC of a building by entering into a software tool is in most cases an autonomous activity not linked to other design and execution processes. This might fundamentally change when BIM becomes mainstream. All relevant product and system data can then be directly coupled to digital objects (fan, heat pump, etc.).

Wouters proposed the following examples of simplified procedures:

- to treat a dwelling as a single zone,
- to have default values for various systems, and,
- to have simplified procedures to deal with thermal bridges as the BIM model has all the relevant information:

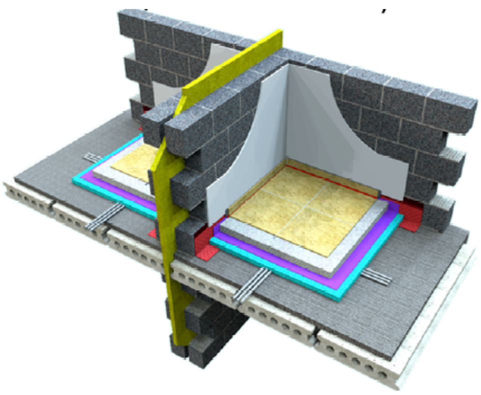


Figure 3: Constructive details in a BIM model

An example of this would be the adoption of the IFC data schema when undertaking energy efficiency related processes. IFC, as defined by ISO 16739, provides a series of default properties and values that can be applied to digital objects (see e.g. in Figure 3) for use within building information modelling. Several of these properties are relevant for energy efficient.

[3] Available at: http://www.buildup.eu/en/news/overview-possibilities-and-challenges-bim-respect-assessment-energy-performance-buildings-0

Materials (ifcMaterial) have a group of properties, known as a 'property set' related to thermal performance. Within 'Pset_MaterialThermal' there are two properties of particular interest:

- SpecificHeatCapacity (J/kg.K)
- ThermalConductivity (W/m²K)

If energy efficiency related processes consistently used these properties, then the automation of these process, as well as the other relevant IFC properties, could be vastly accelerated There still will be a challenge for compliant data, but this will not be any longer a specific challenge for the energy related performance.

Another example of BIM enabling energy efficiency processes is the assessment of overheating risk. In most cases simplified procedures giving only a rough indication of overheating risk and/ or energy consumption for achieving the targeted thermal comfort are used. However, much more refined assessment methods are possible through the use of detailed BIM models without the traditional efforts of colleting input data.

BIM also allows for the more refined assessments around HVAC systems and energy performance. At present most countries use simplified procedures which are not accurate in their output

3.3 BIM and EPC compliance

The use of BIM to substantially reduce the required efforts of obtaining an EPC (Figure 4). There would be no need to collect the EPC calculations as they would already be part of the model. This method would however be dependent on the Level of Development of the information.

Figure 4: BIM to EPC process (credits: Shutterstock, Autodesk)

Moreover, one can expect that the information model will be updated once design or execution modifications are decided and this not driven by the energy concerns but by the need that the information model effectively represents what is constructed.

As a result, it might mean that, once the BIM approach has become mature, there is nearly no need for specific compliance efforts related to EPC compliance.

A specific example of this has been demonstrated in the UK by Rossiter through his BIM-related blog *"There's No BIM Like Home"* (www.bimblog.house). SAP (Standard Assessment Procedure) is the national calculation methodology to demonstrate compliance with the UK's energy performance requirements and to calculate EPCs of dwellings. New dwellings use SAP in its entirety, but to generate EPCs for existing dwellings the Reduced Data SAP (RdSAP) is used to support completing the SAP calculations.

The advantage of RdSAP is that it embodies simplifying assumptions for data inputs that can be used within the SAP calculation. BIM provides an opportunity to complete the values required which is being explored by Rossiter. As part of his series of publications he is using Construction Operating Building information exchange (COBie) (https://www.nationalbimstandard.org/files/NBIMS-US_V3_4.2_COBie.pdf), a subset of IFC, as the initial information to inform his own SAP calculations. To date he has demonstrated the ability to automate the import of a dwelling's geometry (https://bimblog.house/2018/03/26/plq-3-4-frank-sappa/), as well as information relating to specific products within his dwelling. The process Rossiter has implemented uses COBie, IFC and standard naming conventions (https://www.iso.org/standard/26189.html) so that the initial information could be modified to test retrofit options and still seamlessly import this information.

BIMEET report D2.1 also highlighted the above advantages that could stem from integration of BIM and energy efficiency (Figure 5). In addition to simplified, more accurate and more efficient calculation of energy performance that can be updated to better reflect changes in the design phase, it identified the potential to link models to monitoring actual performance during the operation and maintenance phase of a building.

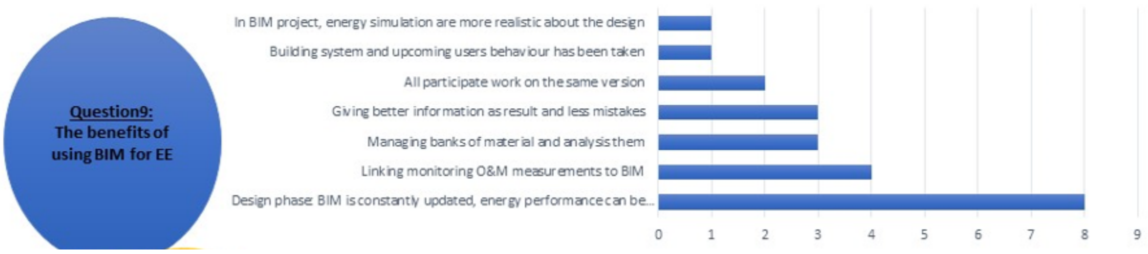


Figure 5: Benefits of BIM for Energy Efficiency highlights in BIMEET D2.1

3.4 BIM and energy efficiency – knowledge and skills gaps

To realise the benefits of integrating BIM and energy efficiency requires practitioners across the supply chain to be aware of them and to develop and/or use the associated tools. One of the activities in BIMEET output D2.1 was to survey BIM and energy efficiency experts about the training and skills agenda in this arena. The questions and responses are summarised in Figure 7 overleaf, but the knowledge and skills gaps can be distilled down to several key challenges:

- Poor understanding of policies and standards
- General lack of awareness of BIM and energy efficiency
- Unable to build effective models
- Limitation of models (e.g. interoperability)
- Unable to use models (extract data from and enter data into)
- How models and processes can help collaborative working (communication, working as teams etc.)

Encouragingly, these gaps were echoed by the BIMEET Expert Panel at a workshop held in Brussels. The findings from this brainstorm session are summarised in Appendix 1 and these were broken down by stakeholder group and RIBA stage:

Figure 6: BIMEET Conceptual approach

- Challenges were highlighted across all stages, but particularly at design and construction
- At the briefing stage clients had limited awareness of the benefits of BIM and energy efficiency
- Architects and engineers were hampered by lack of integrated tools and inexperience in using tools at the design phase. There was also a general lack of leadership and team working
- At construction and maintenance blue collar workers had little experience of BIM and tools. Product manufacturers also need training

Figure 7. BIMEET survey on BIM and energy efficiency training

The Panel's recommendations for training that needs to be developed are summarised in Appendix 2.

A potential consequence of these knowledge and skills gaps is the 'performance gap', i.e. the difference in energy performance of a building between design intent and actual as shown here.

This gap is well-established and has been observed across the EU.

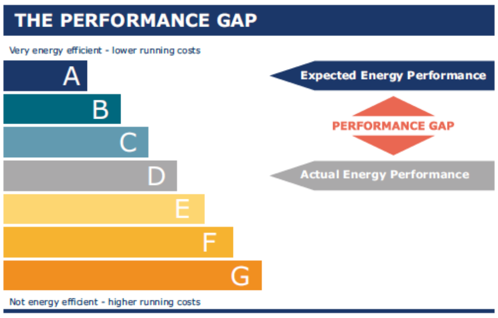


Figure 8: Performance Gap

Its causes are multi-faceted as illustrated in the Figure 8 and Figure 9 overleaf. They represent a summary of the findings from research undertaken by the Zero Carbon Hub (ZCH) in the UK that assessed the causes of the performance gap in new housing (http://www.zerocarbonhub.org/current-projects/performance-gap).

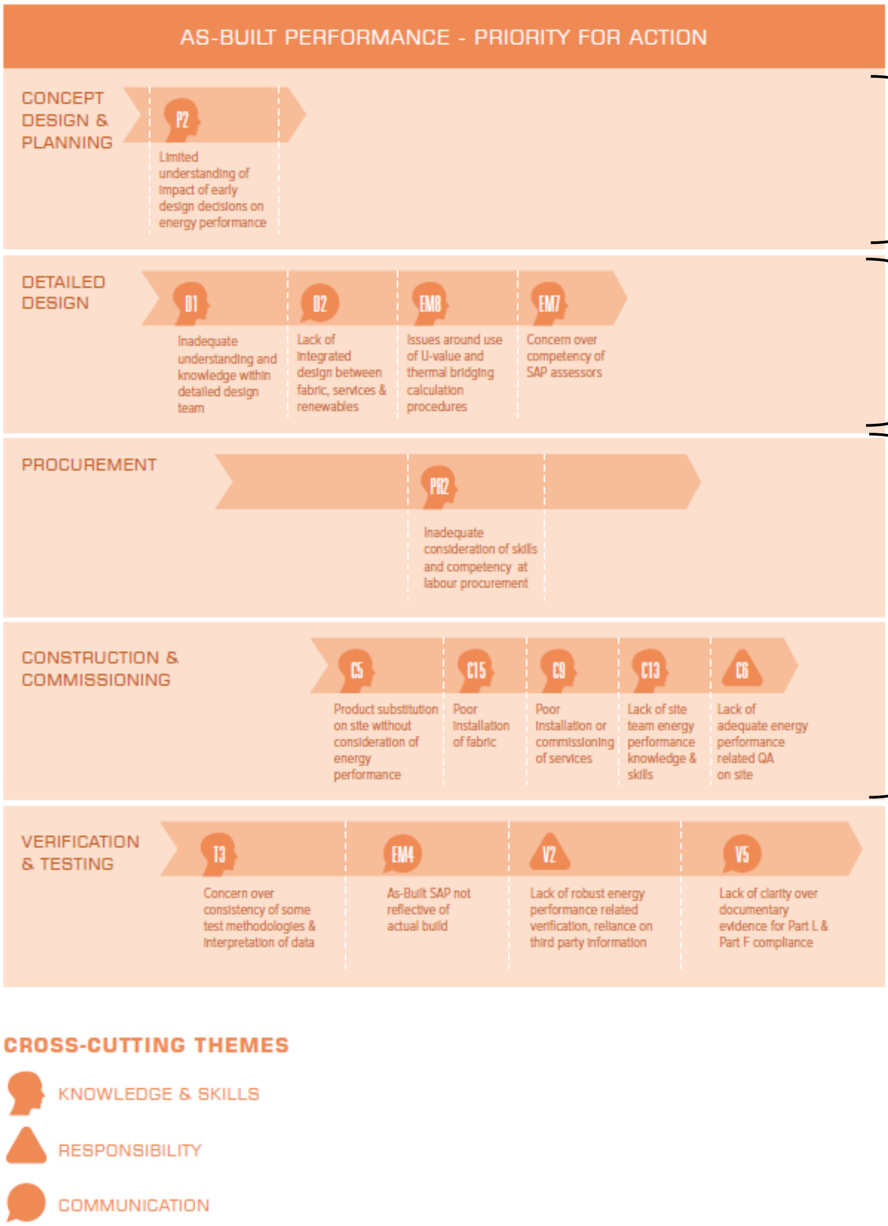
The issues were grouped on the basis of the strength of evidence and size of impact as detailed in the graph here.

Figure 9: Strength of evidence and size of impact

The two figures overleaf are the key areas: 'Priority for research' and 'Priority for action'. They list the causes of the performance gap broken by RIBA stage and categorised by the cross-cutting themes 'Knowledge and skills', 'Responsibility' and 'Communication'.

As mentioned above, the causes are broad, but the figures highlight where the training and skills gaps relating to BIM and energy efficiency (as identified within BIMEET) can contribute towards the performance gap.

A report summarising the role of BIM in reducing the performance gap has also been prepared by the ZCH (http://www.zerocarbonhub.org/sites/default/files/resources/reports/ZCH-DVAB-EndofTermReport-AppendixG_0.pdf).



- Early involvement of actors
- Lack of awareness

- Effective use of models
- Limitation of models

- Application of BIM models
- Poor communication

- Application of BIM models

Figure 10 Causes of the energy performance gap and role of BIM (priority for action)

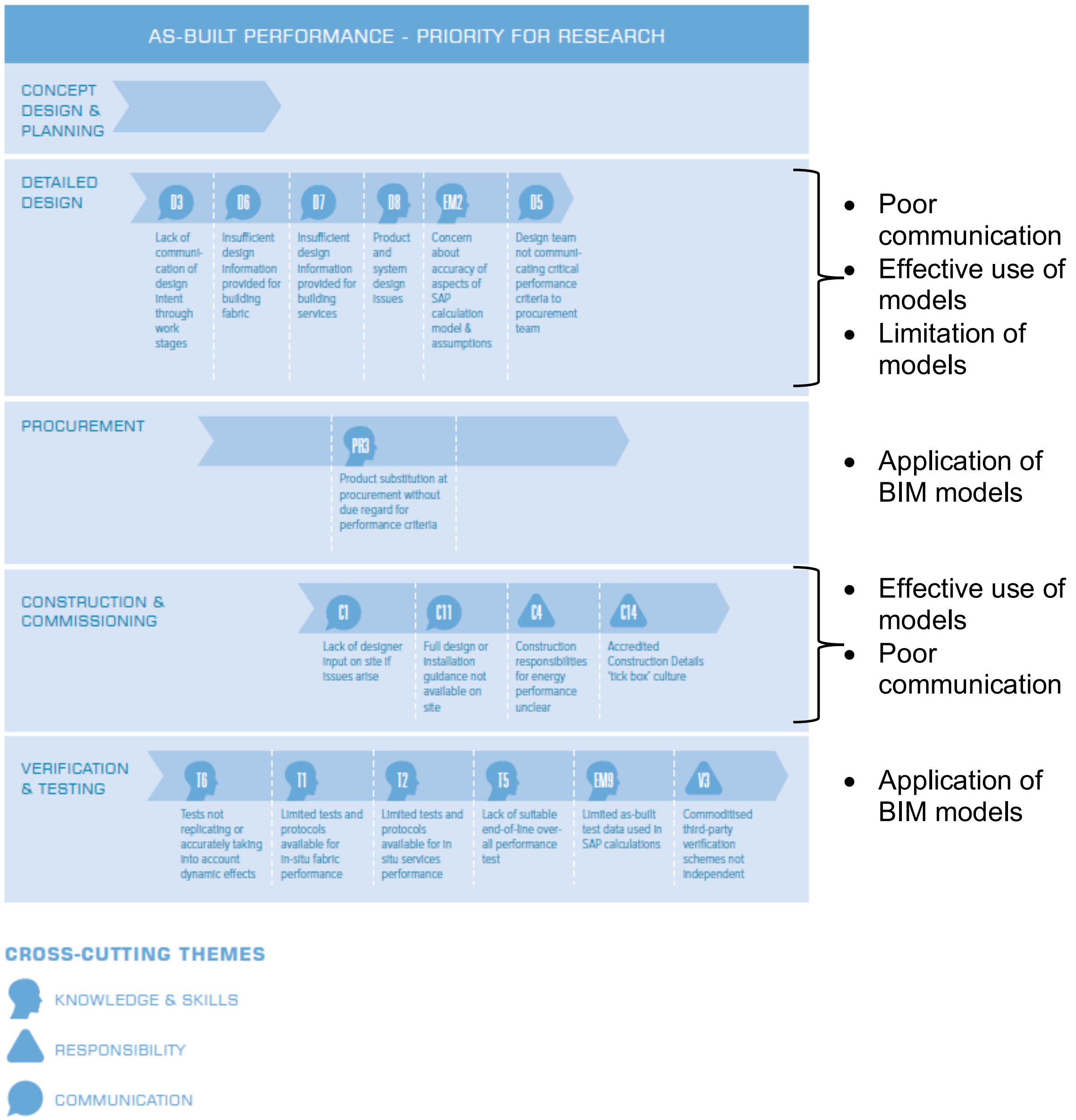


Figure 11. Causes of the energy performance gap and role of BIM (priority for research)

4 Means of recognising competency

4.1 Introduction

A common problem for organizations delivering BIM-enabled services is how to assess the abilities of their staff, improve their performance and recruit new competent ones. This section continues the discussion on BIM Capability/Maturity assessment and focuses on the BIM competency of individuals engaged in managing, facilitating and delivering model-based projects.

The term 'individual' in Individual BIM Competency (IBC) refers to an employee [1] of an organization irrespective of his/her discipline, position or role. That is, an individual can be a senior manager, project leader or junior staff member of any organization involved in the design, construction or operation of facilities. Second, the term 'competency' is used here [2] to represent individuals' combined knowledge, skill, experience and – in some cases – their attitudes and personal traits (friendliness, leadership, ability to work in groups, etc.). Third, the term 'BIM' has already been covered in report D2.1.

Someone can be referred to as competent when they have demonstrated an adequate level of proficiency in performing a particular role, activity or task. In other words, individual competency cannot be generic and must be evaluated against the requirements of a specific position or role. A good Model Manager [3], for example, may be a below-average BIM Trainer [4] and the opposite may also be true. An excellent BIM Manager [5] may be a technical guru but the opposite may not be true. So how do we tell if person A or 10 other candidates are suitable for BIM Role X? More interestingly, how do we prepare a person B to fill a Senior BIM Position Y? What are B's competency challenges that need to be addressed if (s)he is to successfully fulfil the requirements of her new role? The answer is two-fold: Individual BIM Competencies and Competency Mapping.

4.2 Individual BIM Competencies

Individual BIM competencies are the knowledge, skill and personal traits required to generate model-based deliverables [6] which: (a) can be measured against performance standards, and (b) which can be acquired or improved via education, training and/or development [7].

While no definitive list of IBCs is available, sources of IBCs can be identified such as BIM Think Space (http://www.bimthinkspace.com/2012/08/episode-17-individual-bim-competency.html) which groups IBCs under nine headings: Managerial, Functional, Technical, Supportive, Administration, Operation, Implementation, Research & Development and Core competencies.

Table 1 below presents a short description of each together with an example of one sample competency [4]:

Table 1: Competencies items from BIMeXcellence

Competencies	Example
[M] Managerial Competencies: the decision-making abilities which drive the selection/adoption of long-term strategies and initiatives. Managerial competencies include leadership, strategic planning, organizational management, etc.	"The ability to understand the business benefits and business risks of model-based workflows".
[A] Administration Competencies: the day-to-day organizational activities as required to meet and maintain strategic objectives. Administration competencies include bidding and procurement, contract administration, HR and recruiting, etc.	"The ability to identify BIM knowledge and BIM skill requirements for large collaborative projects".
[F] Functional Competencies: the non-technical, overall abilities needed to initiate, manage and deliver projects. Functional competencies include collaboration, facilitation, project management, etc.	"The ability to facilitate a multi-disciplinary BIM meeting".
[O] Operation Competencies: the daily, hands-on individual efforts required to deliver a project or part/aspect of a project. Operational competencies include design, analyse, simulate, quantify, estimate, etc.	"The ability to use models to generate Bill(s) of Quantities".
[T] Technical Competencies: the individual abilities needed to generate project deliverables across disciplines and specialities. Technical competencies include modelling, drafting, model management, etc.	"The ability to use BIM software tools to generate accurate, error-free models".

[I] Implementation Competencies: the activities required to introduce BIM concepts and tools into an organization. Implementation competencies include component development, BIM library management, standardization, etc.	"The ability to develop protocols specific to generating and maintaining a Model Component Library".
[S] Supportive Competencies: Supportive competencies are the abilities needed to maintain information technology and communication systems. Supportive competencies include file and network management, hardware selection and deployment, software troubleshooting, etc.	"The ability to assist others to troubleshoot basic software and hardware issues".
[R] Research and Development Competencies: the abilities needed to evaluate existing processes, investigate new solutions and facilitate their adoption - within the organization or by the larger industry. R&D competencies include change facilitation, knowledge engineering, teaching and coaching, etc.	"The ability to monitor, select and recommend technological solution which may enhance the deliverables of an organization".
[C] Core Competencies: an individual's speciality, overall experience (in terms of months/years), market exposure (in terms of geography), and project experience (in terms of project types, sizes and budgets). Core competencies also include an individual's personal traits like those measured through Myers-Briggs Type Indicator [9] or similar personality assessment systems.	

In delivering a complex activity, an individual will need a mix of competencies. For example, for A to coordinate project deliverables with other consultants, they require technical, functional and managerial competencies. However, for a simpler task (e.g. exporting a 2D drawing from a 3D model), they require only one relevant technical competency.

4.3 BIM4VET – BIM roles and competency matrix

The BIM4VET project (http://www.bim4vet.eu/) was funded by the Erasmus+ programme and has developed a European skills matrix for BIM actors and a method to assess the maturity of skills using a tangible interface. This will enable BIM skills to be assessed collectively and individually for the actors that work together on a digital model project using BIM processes.

Figure 12 shows the methodology that was used to develop a BIM competence matrix[4]:

1. **Problem definition.** The project aims at defining a BIM competence maturity matrix that has analysed, synthesized and evaluated the multitude of BIM related skills and abilities necessary to fulfil tasks within a BIM environment. Secondly, the project aims at defining a process of BIM maturity self-assessment to enable the comparison and gap analysis to provide training advice to BIM learners.
2. **Literature review.** A literature review was undertaken to identify previous research and journal publications, which could contribute to the BIM competence matrix definition.
3. **Scoping exercise.** Two questionnaires were developed to ask internal BIM

[4] BIM4VET IO1 report http://www.bim4vet.eu/en/results/deliverables/

Subject Matter Experts questions about: (i) BIM repository of expertise, and (ii) BIM maturity, constraints, barriers, etc. This exercise indicated that further research was required on the structure of BIM team compositions and profile developments prior to the development of a maturity assessment.

4. **BIM responsibilities and competencies definition.** Four principal BIM roles were introduced along with a set of responsibilities as a proof-of-concept, as well as competencies coming from the BIMe Initiative's repository of competency sets [5] were associated to these roles.
5. **Delphi Survey method.** Two rounds were used to present the results to a BIM expert panel and obtain a consensus on the four BIM profiles.

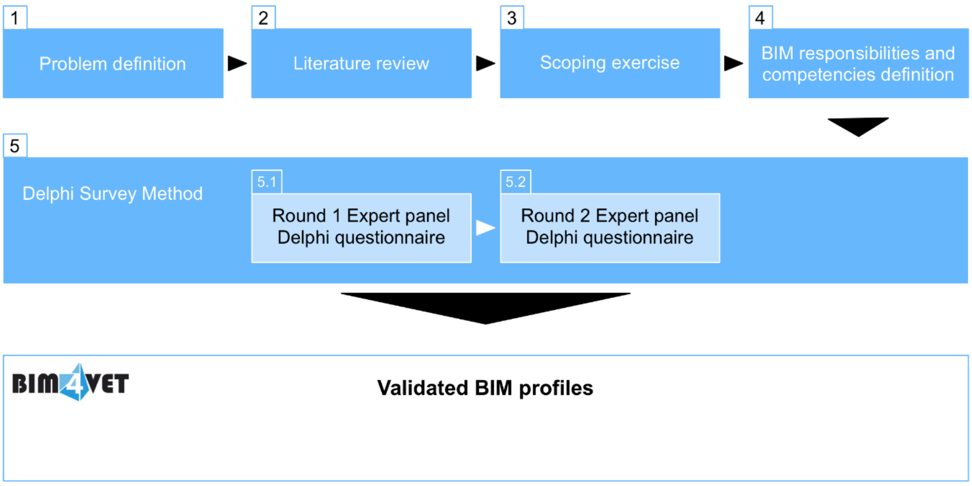


Figure 12. BIM4VET methodology

The resulting four validated BIM profiles are illustrated in Figure 13:

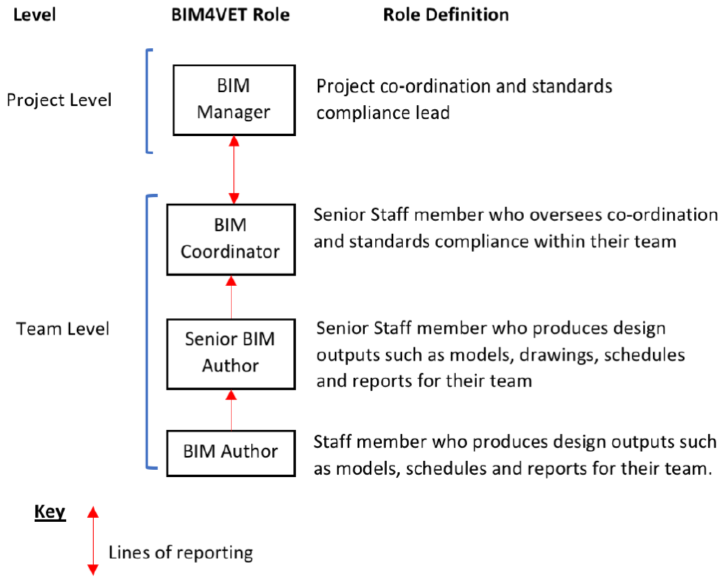


Figure 13. The BIM4VET BIM roles

A comprehensive overview of BIM roles is provided in [6].

The competency sets referred to in Section 4.2 above were assessed by the panel to produce a final BIM competency matrix for the four roles identified. The panel also assigned the roles to an appropriate EQF level (see Box 1).

Box 1. European Qualification Framework (EQF)

The European Qualification Framework joins the qualifications of different EU members together to facilitate mobility by relating different countries' national qualifications issued to a common European reference framework. Since 2012 all new qualifications issued in Europe carry a reference to the EQF Level which are set out below.

		Knowledge	Skill	Competence
Levels	1	Basic general knowledge	Carry out simple tasks	Work under direct supervision in a structured context
	2	Basic factual knowledge	Carry out tasks and solve routine problems	Work under supervision with some autonomy
	3	Knowledge of facts, principles, processes and general concepts	Solve problems by selecting and applying basic methods and tools	Take responsibility for completion of tasks, adapt own behavior to circumstances in solving problems
	4	Factual and theoretical knowledge in broad contexts	Generate solutions to specific problems	Exercise self-management, supervise the routine work of others, taking some responsibility for the evaluation and improvement of activities
	5	Comprehensive, specialized, factual and theoretical knowledge and an awareness of the boundaries of that knowledge	Develop creative solutions to abstract problems	Exercise management and supervision, review and develop performance of self and others
	6	Advanced knowledge involving a critical understanding of theories and principles	Solve complex and unpredictable problems	Manage complex technical or professional activities or projects, taking responsibility for decision-making in unpredictable work, take responsibility for managing professional development of individuals and groups
	7	Highly specialized knowledge, critical awareness of knowledge issues in a field and at the interface between different fields	Develop new knowledge to be integrated from different fields	Manage and transform work or study contexts that are complex, unpredictable and require new strategic approaches, take responsibility for contributing to professional knowledge and practice and/or for reviewing the strategic performance of teams
	8	Knowledge at the most advanced frontier of a field	Solve critical problems, extend and redefine existing knowledge	Demonstrate substantial authority, innovation, autonomy, scholarly and professional integrity and sustained commitment to the development of new ideas or processes at the forefront of work or study contexts including research.

The resulting BIM competence matrix containing the mapping of the BIM competencies to the four defined BIM roles is shown in Figure 14.

BIM4VET

	BIM competence matrix	BIM author (junior)	BIM author (Senior)	BIM coordinator	BIM manager
1	Refer to the work done by other project team members				
2	Develop & maintain Graphical and Non-graphical models against Project Standards				
3	Prepare model for sharing with internal and external stakeholders				
4	Produce project outputs from graphical and non-graphical models				
5	Revise outputs to incorporate clash resolution - Maintain a continuous interface with the BIM Coordinator - Participate in coordination and BIM technology meetings				
6	Reference of other shared models to ensure design coordination and clash avoidance.				
7	Revise Outputs regarding QA/QC protocols				
8	Assist in Maintaining Project Standards				
9	Address immediate software issues and support the upskilling of staff				
10	Remain fully UP TO DATE with Industry good practice around the production and exchange of Information				
11	Help maintain internal CAD standards and workflow by providing feedback to BIM coordinator				
12	Ensure compliance to project standards				
13	Ensure compliance to corporate standards				
14	Ensure compliance to relevant national and international standards				
15	Coordinate the different BIM authors' outputs to ensure the good quality and compliance of the model according to the BIM Project Execution Plan / BIM Protocol / client's requirements				
16	Supervise Clash detection, reporting and resolution				
17	Address immediate software issues and support the upskilling of staff				
18	Ensure implementation of BIM software				
19	Define & maintain project standards				
20	Agree software solutions to be implemented				
21	Define project outputs, according to the clients requirement				
22	Create & maintain a coordination programme for delivery				
23	Ensure the implementation of a system to share project information				
24	Lead BIM activities at project level				
25	Assess project team capabilities to comply with project standards				
	EQF Level:	5	6	6	7

Figure 14. BIM4VET competency matrix

After this exercise, data about BIM training offers in the EU were collected and associated to the BIM responsibilities and maturity level. This allowed the project team to produce the BIM4VET recommendation system (see Figure 15) which allows the user to measure their maturity, and the gap between the current situation and the expected maturity level. Based on this gap, and parameters configured by the user, the BIM4VET application recommends the most appropriate BIM training courses for a team, and supports the related collective decision-making.

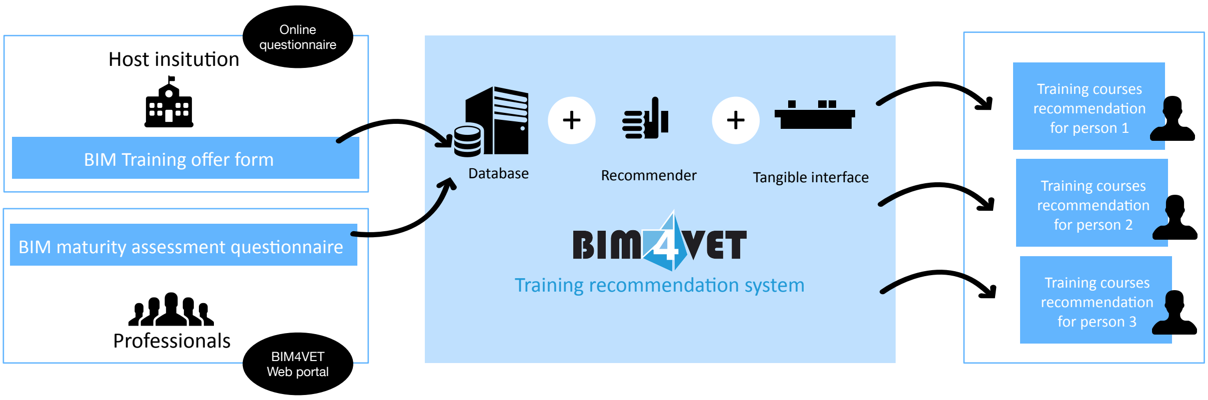


Figure 15. BIM4VET training recommendation system

The system shown in Figure 15 is composed of:

1. **Database.** Centralises all the data related to the user's BIM maturity and BIM training offer data.
2. **Recommender algorithm.** Ranks training courses according to the users' preferences.
3. **Tangible interface.** Helps to visualise the data and support the collective decision about training course selection:

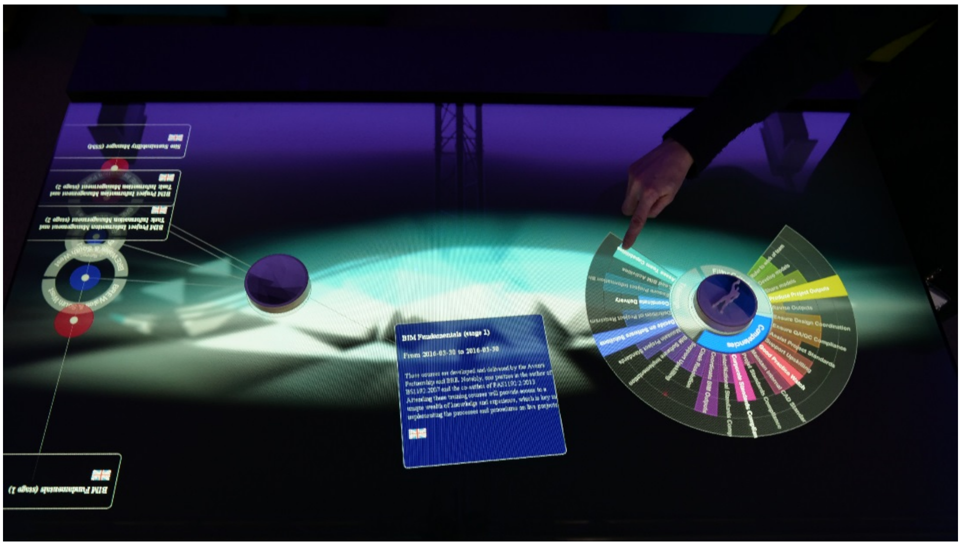


Figure 16: View of the BIM4VET application

Figure 16 shows the application running on a tangible tabletop device.

The expected impacts of BIM4VET are the definition of a European skills matrix for BIM actors, the development of their skills by attending recommended training courses following the skills' assessment as well as the development (or the improvement) of BIM courses for construction sector professionals. In the long-term, the project results, and the uses that will be made of them, should contribute to increasing the recognition and certification of BIM actors, as well as their mobility in Europe.

There is no explicit reference to energy efficiency in the role definitions and the associated competencies, although it is implicit in several competencies, particularly for the BIM author roles (junior and senior), e.g. "Develop & maintain graphical and non-graphical models against Project Standards" and "Produce project outputs from graphical and non-graphical models".

These roles and competencies are returned to in subsequent sections.

5 Conclusions

Figure 17 overleaf is a 'traffic light' matrix that illustrates the level of training offered across each of the RIBA plan of work stages for the key stakeholders in the construction supply chain. For completeness two matrices are presented: one focussing on BIM training, the other showing integrated BIM and energy efficiency training.

The key points to note are:

- Raising awareness of BIM across the supply chain is reasonable, particularly amongst designers, contractors and clients, but *there could be improvements amongst sub-contractors and facility/asset managers*. With regard to BIM/energy efficiency awareness raising, the provision is limited across the supply chain.
- Similarly, designers and contractors are well-served by BIM training across the concept, design, construction and handover phases. This is usually provided by private training organisations. In this they are supported by certification schemes offered by these bodies, such as those in France and the UK, whereby they can demonstrate their knowledge and competence. Such courses *are often focussed on modelling software*, as in Greece for example, which emphasises the planning and design aspects.
- Students also appear to be well-served, at least those taking bespoke BIM degree courses such as a masters (Level 7) in the UK, or the Level 5 and 6 courses offered by universities in Finland. *Bachelor degrees in traditional construction areas such as architecture, civil engineering, surveying, planning and construction management are increasingly integrating BIM*.
- *Conversely, the extent of integrated BIM and energy efficiency training is either poor or limited in these areas*. Some of the Finnish courses do incorporate aspects of energy and use well-established software tools to undertake energy simulations, overheating assessments etc. Similarly, some of the UK masters degrees include treatment on the delivery and performance of low energy/sustainable buildings, but these are in the minority.
- Software providers are helping to fill this void and are providing courses aimed at modellers and designers helping them to integrate BIM and energy performance tools with the intention to streamline the process and avoid duplication. There is *certainly scope to integrate BIM into national calculation methodologies for energy performance certification, thermal bridge assessment* etc.
- Clients, facility managers and sub-contractors do not appear to have sufficient BIM training across many of the plan of works stages, and such training is largely absent for BIM/energy efficiency. The situation is much the same for students outside of the brief, concept and design stages.
- Overall, the position is developing rapidly with the proposed establishment of courses across the project partners, particularly courses in Luxembourg and France, university courses in the UK etc. but there needs to be a focussed effort in those areas where the main gaps have been identified.

Figure 17. Traffic light summary of BIM and energy efficiency training (Top: BIM training, Bottom: BIM and energy efficiency training)

- One of the areas to address is apprenticeships. As noted above, efforts to improve them are being made, including:
    - improving the image of apprenticeships
    - re-structuring apprenticeships to make them more inclusive, improve entry routes and clarify career pathways
    - providing additional guidance and funding
    - engaging with employers
    - improving the quality of apprenticeships and providing transferable skills

But a key point is to introduce energy efficiency as a cross-cutting theme and to improve the integration of BIM into apprenticeships as this will help to fill the training gaps amongst, for example, facility managers, sub-contractors (including blue collar workers and technicians) etc. who are responsible for the design, installation and maintenance of fabric measures, building services etc.

Finland is introducing BIM into its vocational courses and France has already made considerable strides in this direction and is integrating BIM into its *Brevet de technicien supérieur* (BTS) Fluids, Energies, Home Automation (FED).

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BIM-based EU -wide Standardized Qualification Framework for achieving Energy Efficiency Training

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