LAB University of Applied Sciences

Benchmarking research work of development state of BIM in the UK

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Abstract

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Abstract

In the construction industry, Building Information modelling (BIM) is described as the process of creating and managing data during the design, construction, and operation of buildings. The topic is important because BIM research is largely based on data analysis. So, ultimately, the data sources and the way they are used shape the reality of BIM-level on a national and international scale today. Despite existing studies on BIM adoption, gaps remain, especially regarding in-depth empirical examples relating to specific factors that enable its successful implementation.

This research aims to investigate the Maturity level of BIM. Currently, the United Kingdom ranks as one of the leading BIM countries in the world. In this case, BIM is investigated in three sectors: housing, infrastructure, and city modelling. This research is conducted as part of the BIM-ICE project. In order to assess the level of implementation of BIM in the UK, BIM-ICE members have created a questionnaire that has been mailed to individuals involved in BIM. Additionally, the results were analysed along with open sources and existing literature. Using the questionnaire survey results, a comparison was made with an existing survey. Moreover, Public statistics and government reports were primarily used for the data search.

As a result of this study, the reader is given a broad overview of the current level of awareness of Building Information Modelling in the United Kingdom. There is a description of guidelines and standards based on BIM level, as well as the software, tools, and technologies that are available. Transition to International Standards Organisation (ISO) 19650 is also facilitated with various methods, such as UK BIM framework and RIBA Plan of work. Standards such as Cobie and IFC are highly recommended. Therefore, all sectors of the UK construction industry use Uniclass 2015 for common data. Furthermore, the research provides an understanding of how BIM can be applied in the three areas mentioned above and the implications of the United Kingdom government's emphasis on its implementation. In the study, it was observed that BIM is highly used. Moreover, teachers, professionals, students, and other individuals involved in education can benefit from several promising directions and further advancements through BIM.

Keywords

House BIM, Infra BIM, BIM city modelling, Maturity level of BIM, BIM-ICE

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Glossary of terms

Abbreviations

CI/SfB: Construction industry (CI) and the Swedish Samarbetskommitten for Byggnads-fragor (sfB)

BIM standards

BS 1192: An original standard describing the collaborative production of information based on industry standards and best practices

PAS 1192: According to PAS 1192, the model level is the basis for displaying the model information (the non-graphic content), the definition of the model, and the exchange of model information.

ISO 19650: In building information modelling, this standard describes how information is managed over the entire life cycle of a building asset.

BIM Levels

BIM level 0: at this stage the collaboration is low, and it describes unmanaged CAD (Computer Aided Design)

BIM level 1: partial collaboration, manages 2D and 3D CAD, Models cannot be shared between project team members, therefore it is called 'Lonely BIM'.

BIM level 2: Full collaboration, Collaboration and 3D modelling in a collaborative environment with separate discipline models for building information.

BIM level 3: Full integration, Although the details are still being defined, it is expected that a single, collaborative, online project model will include information about construct sequence, cost, and lifecycle management will be available.

BIM level 4: Achieving better social outcomes and wellbeing is the focus of level 4.

Collaborative practices

BIM Protocol: Incorporate provisions for preparing deliverables for 'data drops' at defined stages of the project and specifies BIM specifications at defined levels of detail.

Common data environment (CDE): The central repository where documentation, graphical models, and non-graphic data are collected, managed, and disseminated for the entire team.

Construction Operations Building Information Exchange (COBie): The built asset can be operated and maintained using this information. BIM Level 2 exchange schema for this information is COBIE selected by the UK government.

Digital plan of work: It is a framework that facilitates the provision of reliable information at each stage of a project.

Industry Foundation Classes (IFC): At the heart of openBIM, it organizes and exchanges relevant data between various software applications.

Open BIM: Promotes collaboration among participants throughout the lifecycle of a project and asset, thus promoting interoperability.

RIBA plan of work: Explains each stage's outcomes, core tasks and information exchange requirements at the various stages of briefing, designing, constructing, and operating building projects.

RIBA Plan of work toolbox: In this document, members of the project team are defined along with their responsibilities.

Uniclass 2015: In the construction industry, Uniclass is a voluntary classification system for organizing information throughout all phases of design and construction. Interoperability between systems is facilitated by adopting a standard classification.

Information Requirements

Asset Information Requirements (AIR): Answers the questions raised in Organisation Information Requirements.

BIM Execution Plan (BEP): This document sets out the foundation for successfully deploying advanced design technologies on BIM-enabled projects.

Employer's Information Requirements (EIR): describes what information must be transferred, in what format, and at what level, and how stakeholders can collaborate.

Organizational Information Requirements (OIR): This document describes the information an organization needs to administer its asset management systems and other organizational functions.

Level of details

Level of details (LOD): Model precision is described by this term

1 Introduction

Building information modelling (BIM) is growing at the speed of light. Various parts of Europe are using BIM to some extent. The construction industry is becoming more and more reliant on BIM. At its core, BIM is a collaborative process that enables teamwork and communication among architects, contractors, and clients.

In collaboration with the BIM-ICE project, LAB University of Applied Sciences conducted this thesis report as part of benchmarking research BIM-ICE project (BIM-integration of higher and Continuing Education) co-funded by the European Union

As the United Kingdom currently ranks among the world's leading countries in terms of BIM, the fact raised curiosity about the maturity level of BIM in the country. The implications of the level of BIM in the UK on other countries and the standards in place. Recently, BIM has gained a great deal of popularity and understanding within the construction industry. This is due to the UK having established both national and international standards, guidelines, and different approaches to implementing BIM among construction professionals.

In order to collect data for the thesis, several experts were surveyed. As a result of the questionnaire answers, the database for the thesis has been constructed using the answers to the questionnaire. Analyse existing normative documents and articles related to the report's topics was also gathered. Besides the open resources, existing surveys have also been analysed and compared to the current survey, to obtain additional information beyond the information available in the open resources.

This research is based on benchmarking the use of BIM in the United Kingdom from various aspects such as BIM house, BIM infrastructure, and BIM City modelling. The study mainly focuses on the maturity level of BIM in house sector. Maturity level sometimes referred to as a level of use. It involves the level of collaboration and information sharing between stakeholders involved in a project that results in technological progress in the architecture, engineering, and construction sector (AEC).

2 Background analysis

The 2020 annual BIM Report produced by NBS shows that 73% of respondents are aware of BIM; adoption has reached its highest level. The number of people using BIM had substantially increased from 2011, when only 13% were using it, compared with 1% in 2020, and 43% were completely unaware of its benefits. Increasingly, BIM 2016 adoption was driven by the UK Government's mandate to comply with BIM Level 2, which emphasizes collaboration. Data, documentation, and information about the project and assets must be kept electronically for efficient delivery during design and construction. Although BIM users' boost has stalled a little in the last two years among the 27% not using it, 72% anticipate using it for projects over the next five years. (Blundell 2021.)

Based on United Nations statistics, most people lived in urban areas instead of rural areas in 2008. It is expected that 70% of the world's population will live in cities by 2050. Cities are equally important in the UK, with a third of the country's population living in the ten largest metropolitan areas. A population of 2.5 billion people would live in cities around the world. As a result of this, smart cities have gained significant attention. In other term, "BIM City modelling" initiatives worldwide, resulting in governments' strategic response to this growth. It is widely believed that the UK leads the world in adopting BIM. BIM was used on projects by almost 70% of construction industry professionals in 2019, and most others were aware of it (NBS 2017, 4-5; Hazem 2022).

In 2013 a study made by Kenneth explained the necessity of using BIM for reducing CO2 emissions in the construction sector, especially in housing. This fact has significantly increased the attention of "BIM house." Existing housing stock contributed 27% to CO2 emissions. By refurbishing this housing stock, the UK Government can achieve its target of reducing emissions by 80 percent by 2050. Remodelling a house is difficult due to high initial costs and a lack of knowledge and skills in the construction industry. As a result of BIM's ability to overcome current barriers, it should be utilized to achieve the CO2 reduction target (Kenneth et al. 2013, 765-768). Furthermore, the UK government has mandated the public sector to adopt BIM for construction projects since 2016. As such, the study examines the use of BIM for houses, infrastructure, and city modelling.

3 BIM in the United Kingdom

BIM is considered a leader in the United Kingdom, with the government implementing its Construction Strategy in 2011 for all government projects. The government has been working hard to improve the use of BIM Level 2 because the UK construction sector historically has struggled with productivity and efficiency. (NBS 2017, 4; Hazem 2022.)

A new policy in 2011 required BIM Level 2 for all projects. BIM Level 2 means that design and stringing are done in a shared environment that can be seen by all involved. Consequently, both the public and private sectors have embraced BIM more widely. As announced by the government in March 2016, industry is expected to upgrade from BIM Level 2 to BIM Level 3 by 2020. (NBS 2017, 4-5; Hazem 2022.)

3.1 Public sector

In the public sector, construction was one of the last major sectors to transition to digital following the implementation of Level 2 BIM under the Government Construction Strategy (GCS) program. The UK is now a world leader; it represents an unprecedented international achievement toward the digitalization of the built environment.

Smart cities, services, and grids are accelerated through Level 2 BIM. Asset owners and operators can maximize utilization and minimize energy consumption by tracking real-time efficiency. With Digital Built Britain, the built environment is digitized, meeting the Government's targets of 33% lower costs, 50% fewer emissions, and 50% better exports by 2025. Data and BIM will continue to be crucial to achieving these goals. (NBS 2017, 5.)

3.2 Private sector

Contractors in the private sector and some parties contribute to lowering BIM's supply chain. The reason may be that most investors in the private sector do not necessarily invest in buildings they intend to occupy. Still, rather than in properties, they intend to sell or rent for a profit, so they do not necessarily care about the longevity of the building. (CMS 2017.)

A whole-sector collaborative platform aligned with government requirements is developing through the willingness of private-sector clients to implement BIM requirements. A tangible push for greater adoption is now emerging from the supply side, in addition to a willingness to push boundaries in BIM technology and processes. Corporate BIM strategies are worth learning about from companies that are pursuing them actively. (Blackwell 2012.)

4 Maturity level of BIM

BIM maturity level describes the degree to which stakeholders collaborate and share information in a project that results in technological progress in the construction sector (AEC). It varies from 0-4 as follows BIM Level 0, BIM level 1, BIM Level 2, BIM level 3, BIM Level 4. PAS 1192 and BS 1192 are national BIM standards that support each level (figure 1).

To support the use of BIM maturity level, standards, guidelines, and software have been developed. In this section of the report, the focus is on levels 2 and 3. BIM level 2 is now a standard, and it is mandatory for state projects; on the other hand, there are also a number of large-scale construction projects that use BIM level 3. However, it must be noted that these differences are, in fact, based on the national and international standards used in the country.

4.1 BIM Standards and guidelines

A branch of National Standards has been developed in the United Kingdom. These standards are divided into levels from 1-3 (figure 1). As far as BIM standards are concerned, the first level consists of both national and international standards.

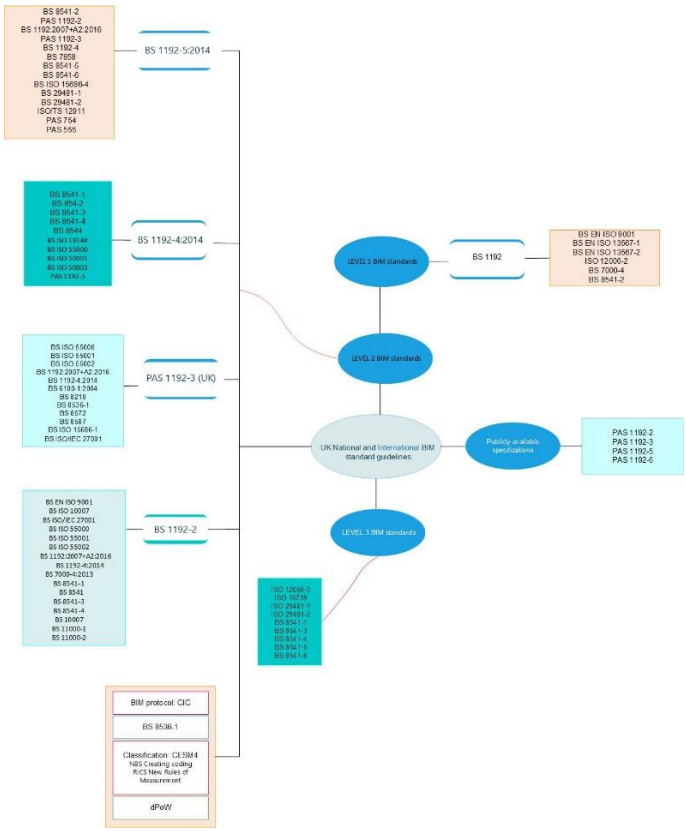

Figure 1. UK National and International BIM Standards

Figure 1 illustrates that BIM level 1 follows British Standard (BS1192), which emphasizes the collaborative production of architectural, engineering, and construction information. Standards for Level 3 still need to be fully defined. (Appendix 3.)

BIM standards at Level 2 consist of eight core standards: PAS 11922-2 specifies how data should be managed in capital and delivered construction projects; PAS 1192-3 specifies the use of BIM for the management of operational data in construction projects. Followed by BS 11922-4, which specifies the development of collaborative information during the operational phase of construction projects. PAS 1192-5: specifies an integrated digital built environment with smart asset management. BIM protocol: Among the BIM protocols are CIC (Construction Industry Council), defined as a service for RIM (Role of Information Management). A code of practice is included in BS 8536-1, which covers building infrastructure. A classification level based on ISO 12006-2:2015, CESM4, RICS New Rules of Measurement - NRM 1, and NBS Create coding is applied. Lastly, the Digital Plan of Work (dPoW). (Ocean 2020.)

By developing standards, guidelines, plans of work, and resources, BIM is essential for the management of information in today's world. The UK BIM Framework provides guidance and support on the fundamental principles of BIM. In order to ensure the overall implementation of the standard, BS EN ISO 19650 Guidance Parts 1 to F are provided. These guidance parts contain specific content for BS EN ISO 19650-2 and BS EN ISO 19650-3. (Figure 2.)

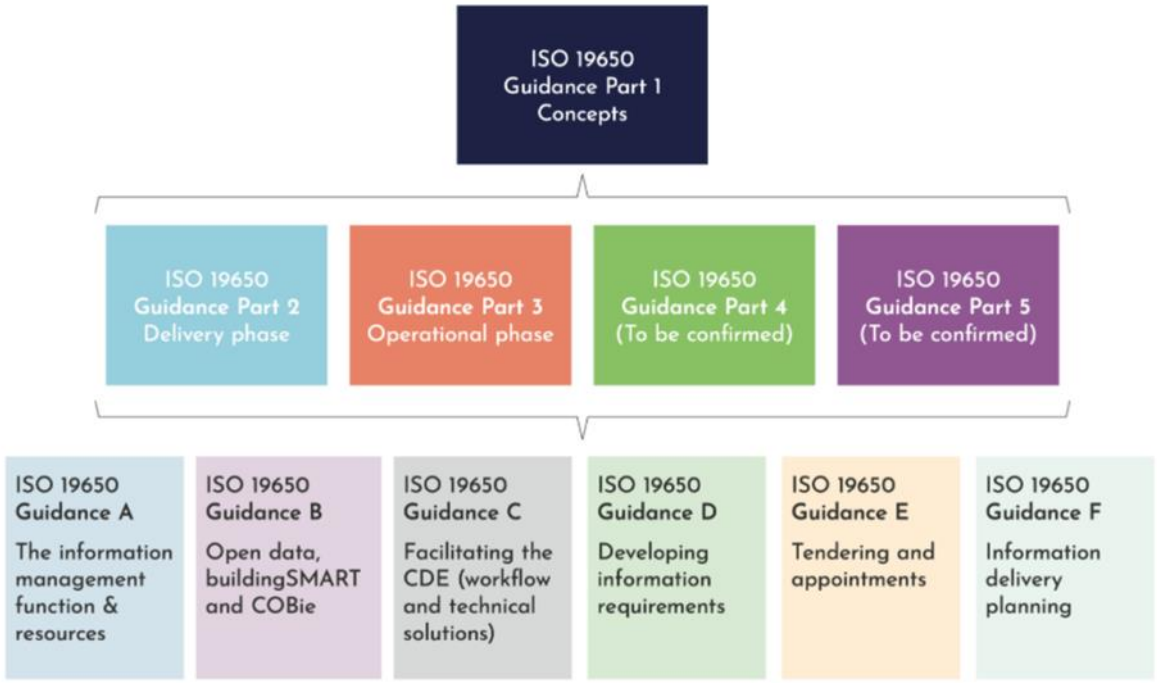

Figure 2. Guidance on the UK BIM Framework (Framework 2017).

As a result of the UK BIM Framework, individuals and organizations in the UK will have a better understanding of how to transit from BIM Level 2 to the UK BIM Framework based on BS EN ISO 19650. Clients will need time to adjust their information requirements and appoint documentation before they can shift to international standards and align documentation with ISO 19650. The framework will assist them in this process. With the proliberation of global construction projects, clients with an international supply chain will benefit from a unified global approach. (Framework 2017.)

BIM is a key issue in architectural and engineering professional appointments. According to the RIBA's Plan of Work described in Appendix 1, new tasks and stages were included, including BIM activities. In its Plan of Work, RIBA refers to stage 7 as "In Use". A common set of standards and technical specifications is considered part of the Project Execution Plan. The project execution plan consists of the agreement of the Design Responsibility Matrix, the exchange of information, and the creation of the Project Execution Plan. Followed by the preparation of the project execution plan includes technology and communication strategies, as well as UK Government Information Exchange tasks. Due to the UK Government's desire to exchange data at various stages and its need to have data-rich information during occupancy, this was added to encourage considerations. COBie, a spreadsheet containing data about the building, will be the primary means of delivering this information. (CMS 2017.)

In the public sector, a series of BIM guidelines was produced jointly by the Construction Industry Council (CIC) and BIM Task Group as part of the United Kingdom government's 2016 goals. In 2013, CIC developed two BIM documents with assistance from the BIM Task Group. BIM requirements must be adhered to for all common contracts in the first BIM Protocol Version 1. In addition, the Best Practice Guide for Professional Indemnity Insurance When Using BIMs v1 outlines the key risks insurers may encounter. BIM standards have also been developed by British Standards Institution (BSI) and AEC-UK Committee. A number of digital life cycle definitions and information exchange standards have been released by the BSI B/555 committee in the construction industry. (BIMVET3 2021.)

BIM Protocol version 2.0 was released by AEC (UK) in 2012, four years after the first BIM Standard was released. Since then, there have been a lot of learnings and experiences that have gone into the updated version. In addition to this generic document, there are software-specific supplements that are provided to enhance the platform-independent protocols. AEC-UK has explored several BIM protocols from Autodesk Revit to Bentley AECOsim Building Designer and Graphisoft ArchiCAD since 2012. (BIMVET3 2021.)

4.2 BIM Level of Requirements

UK BIM requirements vary by level. BIM level refers to the standards required for the project to comply with BIM. The government has set these milestones on a scale of 0 to 3, understanding that incremental efforts are needed to make the construction industry cooperative. (NBS 2017, 4-5; Hazem 2022.)

As a prerequisite for reaching level 2, an organization must: Meet the requirements outlined in Level 1, install CAD software capable of supporting IFC and COBie file formats. In recent years several classification systems were developed to emphasize BIM such as: CI/SFB created by RIBA British Adaptation of the CIB Master list, Uniclass. It is recommended to use Uniclass 2015 for both BIM Level 1 and Level 2. Construction companies use Uniclass 2015 to classify projects. Unlike other construction regulations, it covers all construction sectors, including buildings, landscapes, and Infrastructure. To keep track of what needs to be done, RIBA Plan of Work can be used by clients at the beginning of a project for guidance in setting up their project. Appendix 1. (Hazem 2022.)

4.3 BIM Level 2

In light of the fact that BIM Level 2 has been extensively used in UK procurement as well as other industry documents, a "descriptor" for the overall concepts and principles is still required. A collaborative framework called "UK BIM Framework" has been proposed by the UK BIM Alliance, CDBB, and BSI in order to replace "BIM Level 2". (Framework 2019.)

As an aside, ISO 19650-1 and 2 are based on British Standards 1192:2007+A2:2016 and PAS 1192-2:2013, which represent an evolution of British standards derived from building information modelling for information management. In general, these standards remain the same. ISO 19650 series, however, does not use the notation of "BIM level 2". (Framework 2019.)

To make the most of the "UK BIM Framework", project requirements and proposals must be specified by appointment, not just referenced. As a result of the development of BIM Level 2, there was a practice that was unacceptable. BIM Framework implementation discourages maturity labelling. (Framework 2019.)

4.4 BIM Level 3

By creating a new digital standard for the growing construction sector, the UK government announced its intentions in its 2016 budget policy paper. In 2020, the industry is expected

to upgrade to Level 3 of BIM. BIM Level 3 is mainly concerned with structural changes in communication means, which are crucial to successful project implementation compared to Level 2, which focuses on processes.

To maintain its leadership in the digital construction industry, the UK has developed BIM Level 3 to reduce unnecessary construction costs while maintaining its leading position within the global industry. As an additional measure of support, the government has released a policy paper under the title: In order to support its argument, the National Infrastructure and Projects Authority issued the "Government Construction Strategy 2016-2020." (Hazem 2022.)

As a result, the aim of the government is to describe the steps it intends to take to reach this goal both across its social Infrastructure and economic projects. As part of the BIM Level 3 specification, the concept of Open BIM is introduced, which refers to full collaboration and communication among all project participants during all stages of the project, from conception to demolition. (Hazem 2022.)

As a representative sample of BIM use in the country, these five projects presented in table 1 illustrate the possibilities of BIM at its best, even though there are hundreds of BIM-based projects in the country.

Table 1. UK's top five projects showcase (Hazem 2022).

Project/Client	Contractor(s)	BIM Tools	Description
Slussen Lock, Stockholm/City of Stockholm	Skanska	Autodesk Navisworks, BIMEye, Revit	Old Stockholm's Slussen Lock has been remodeled four times since the 1600s. As part of the current design process, BIM working methods were used, as well as a cloud-based BIM data management platform (BIMEye) that facilitated the process.
22 Bishopsgate, City of London/City of London	Multiplex	Revit, Rhino, Unity	In the financial district of London, the 62-storey tower is expected to be the highest building when completed. During construction, Multiplex, the company's contractor, utilized advanced 4D modeling and VR applications.
Forth Bridge/Bridge over the Forth Road	Scottish School of Simulation and Visualisation and Historic Environment and the Center for Digitalisation Documentation and Visualisation (CDDV).	Laser scanning, specialised 3D dataset, VR	The project requires complex 3D scans, making it challenging and complex.
Orchard Village/Clarion	Hill Bespoke, DMA	Autodesk, 360 Field	An offsite manufacturing scheme was created for this project using BIM. By using BIM, quality was improved while residents were inconvenienced to a reasonable extent.
39 Victoria Street, London/Department of Health	Willmott Dixon Interiors	BIM and Virtual Reality	In this eight-floor project, BIM Level 2 was implemented in the delivery process and it was awarded "Best Overall BIM Project" by the RICS.

BIM level 2 is highly used in the country, as well as technologies such as VR, laser scanning, and specialized 3D datasets. Furthermore, BIM level 3 is also incorporated since a cloud database is used along with 4D and VR. (Table 1.)

4.5 BIM software

Based on the following chart, these are the best BIM softwares used in the United Kingdom in 2022. In the first column, the most frequently used items are listed, while the least frequently used items are listed in the last column.

Table 2. UK's top BIM software ranked by highest usage rates (SourceForge 2022).

1	2	3	4	5
SkyCiv Structural 3D	Vectorworks Architect	StreamBIM	FINFROCK	BEXEL Manager
PMWeb	BIMx	VRcollab	Resolve	LIRA-SAPR
BricsCAD	MTWO	IconSystem	Dimension10	TeamSystem
InEight	ArCADia-ARCHITECTURE	FINE MEP	BuildingWorks	BIMcloud
OpenProject	ArCADia BIM	cmExe	ProKitchen	CellBIM
Edificius	VisiLean	Cubicost TBQ	CTC Software BIM Project Suite	Visoplan
OpenBuildings Designer	LOD Planner	MagiCAD	Plans2BIM	Vertex BD
Catenda	VAM2	Urbest	usBIM	SysQue
ProtaStructure	Builterra	UNIFI	EdiLus CONCRETE	
ARCHLine.XP	Imerso	The Wild	EdiLus STEEL	
Cupix	SpinalTwin Suite	Kahua	CerTus SCAFFOLDING	
AutoCAD Plant 3D	Arcadia-Water Supply Installations	Trimble Quadri	Giraffe	
Asite	eTakeoff Bridge	Civil 3D	UrsaLeo	
EPESI BIM/CRM/ERP	SierraSoft Land	Autodesk AEC Collection	VisualARQ	
HoloBuilder	thinkproject	BIM Collaborate Pro	JOIN	
Archdesk	Infurnia	Tekla Structures	ProtaBIM	
iTWO cx	SmartBIM Platform	Tekla Model Sharing	Revit LT	
IrisVR	SierraSoft Roads	Dynamo Studio	Vectorworks Designer	
Fexillon	Pype	Trimble Field Points	GAMMA AR	
Assemble	BIMobject	BIMPro	BIMcollab Cloud	
Metacom+	Revit	Stabicad	Cintoo Cloud	
Candy	Revizto	Hevacomp	BIM Classify	
Causeway Estimating	Trimble Connect	GT STRUDL	BIM Assure	
ARCHIBUS	Zuuse Pulse	Autodesk PD&M Collection	Ideate BIMLink	
Visual Analysis	Kreo Software	3D Repo	JP Interactive Viewer	

It is evident that the UK has developed and integrated a wide array of BIM software. With 108 software highly used, CAD software that presents 2D dimensions is not on the list. From table 2, a range of 3D software technologies emphasizing the use of BIM in house sector, infrastructure, and city modeling. There is a high rate of BIM level 2 adoption and BIM level 3 is at least being considered.

4.6 Level of Detail (LOD)

This document describes the content of BIM projects at various stages of their development and evolves from an initial concept to a construction model over time. In a BIM model, a LOD consists of two elements, Level of Geometry (LOG) and Level of Information (LOI), a visual representation of a project. (Designing Buildings Wiki 2022.)

Table 3. Level of Detail (Ellis 2020).

UK LOD	US LOD	DESCRIPTION	CONTENT
1		Brief	A model communicating the performance requirements and site constraints. Building models would be block models only
2	LOD 100	Concept	Conceptual or massing model including basic areas and volumes, orientation and cost. In the RIBA Plan of Work, this is equivalent to stage 2
3	LOD 200	Developed design	A design development model, "generalized systems with approximate quantities, size, shape, location and orientation." Equivalent to RIBA stage 3
4	LOD 300	Production	Equivalent to RIBA stage 4. Production, or pre-construction, "design intent" model representing the end of the design stages. Modelled elements are accurate and coordinated, suitable for cost estimation and regulatory compliance checks.
5	LOD 400	Installation	Model suitable for fabrication and assembly, with accurate model of the construction requirements and specific components, including specialist sub-contract geometry and data.
6	LOD 500	As Built	An "as built" model showing the project as it has been constructed. The model and associated data is suitable for maintenance and operations of the facility.
7		In Use	Asset Information Model used for ongoing operations, maintenance and performance monitoring

Similar stages are used in the US, although they are numbered differently. There are seven levels (1-7), each of which combines the Level of Model Detail (LOD) and the Level of Model Information (LOI) in PAS 1192-2 - Specification for Building Information Modelling - Specification for the management of information (now replaced by BS EN ISO 19650). (LOI). (Ellis 2020.)

5 Awareness of BIM in the United Kingdom

A comparison has been made between two surveys carried out by two organizations in 2020 and 2022 in light of the low response rate of the latest survey. It is the purpose of this comparison to determine the current level of awareness of BIM in the industry. The first survey was conducted by the NBS in 2020, while the second was conducted by the BIM-ICE project in 2022.

5.1 Existing survey analysis

BIM was unknown to 43% of respondents in 2011. According to the 2020 BIM adoption survey, BIM adoption has grown substantially. Lately, 73% of businesses use BIM, indicating widespread awareness. It is becoming increasingly common to use the standard documents and tasks outlined in the BIM standards, and many professionals are accustomed to using them. It is not surprising that barriers to BIM adoption still exist due to a lack of client demand and a perceived unsuitability for projects. Because more clients do not require BIM, smaller practices may view it as irrelevant to their projects. It is estimated that 67% of those who adopt BIM are involved in creating or executing a BIM Execution Plan. As a result, people are increasingly following a standard consistent approach. In addition, many professionals use Uniclass 2015 to comply with ISO 19650 when managing their information. It is estimated that 38% of respondents use Uniclass 2015 in their organization. (Bain 2020.)

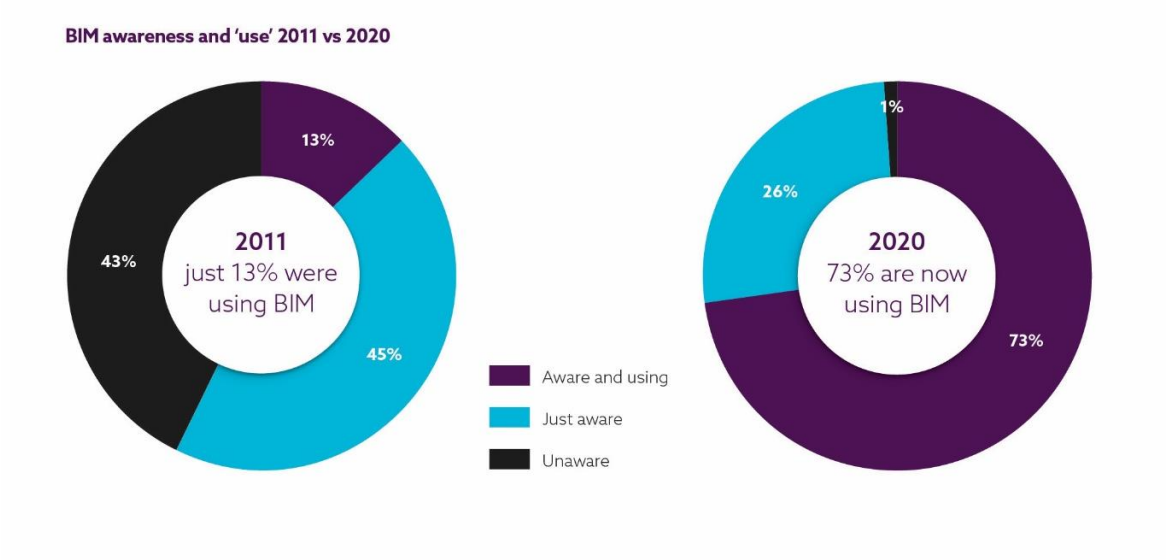

Figure 3. BIM awareness and use in comparison 2011 to 2020 (Bain 2020).

In recent years, UK productivity has declined. Most BIM adopters (71%) and a majority of non-BIM adopters (57%) agree with this statement. Construction consultants, contractors,

their profit margins, and clients are all benefited by increasing productivity. 77% of private companies use BIM, while 62% of public companies use it. As opposed to being driven by government, private sector organizations are adopting BIM. (Bain 2020.)

Small businesses struggle to adopt BIM, overcoming these challenges will be rewarding. 62% of companies with 15 or fewer employees have adopted BIM, compared with 80% of companies with more than 50 employees. Nevertheless, this has increased from 56% in 2019. It is just as likely that small practices that have adopted BIM will see its benefits as large practices that have not. (Bain 2020.)

Digital natives have become a large part of the workforce, and many embrace digital technology and BIM in a big way. The construction industry is set to undergo a revolution thanks to digitalization, according to 80% of those under 35 who have adopted BIM. As the next generation of construction leaders and managers, these digital natives will likely continue to drive digital transformation and BIM adoption. (Bain 2020.)

NBS is used by over 59% of UK respondents due to its many benefits. Among these respondents are some engineers, surveyors, contractors, and project managers, along with many UK architects and architectural technologists. Digital objects continue to grow in popularity, and most people now say they need them. More than any other provider, 71% of survey respondents in the UK use NBS BIM libraries. As a result, 75% of UK architects and 79% of UK architectural technologists believe that CAD is significant. (Bain 2020.)

5.2 Current survey results

In 2022, a BIM questionnaire was developed as part of the BIM-ICE project to identify the extent of BIM implementation in the UK. The questionnaire included BIM for houses, BIM for infrastructure, and BIM for city modelling. The questionnaire was sent to BIM specialist companies in the UK. Thus, few submissions were received, and some questions were unanswered. The attached Appendix 4 encloses the BIM questionnaire survey.

In accordance with the questionnaire survey, Graduates of AEC universities who have specialized in BIM technologies are usually rated by their companies within the field of BIM using a scale of 0 to 5, where 5 is the best score. BIM is used by students and academic staff in AEC Universities in projects, but the transition to BIM is not entirely complete. Additionally, 2D CAD drawings still dominate. Several factors inhibit BIM technologies' study and application in AEC Universities: the university management is less interested in BIM technologies, the academic staff is less interested in BIM technologies, and the academic staff is less knowledgeable about BIM technologies. The situation varies a lot from one AEC university to another. The transition from 2D to BIM in AEC Universities

was achieved by training academic staff, organized by universities, using development projects and Research in BIM, Without any specific action from government or university boards. There are no BIM competitions organized between AEC Universities.

In the BIM house market, only 50% of companies specialize. It is crossly overestimated that 71% of companies use BIM, according to the BIM Survey 2021. Based on the BIM experts experience the right figure might be 30-50%. Autodesk Revit is the most used BIM software for the following designs: architectural, structural, water supply electrical engineering, and HVAC. In comparison, Autodesk Navisworks which is used for construction management.

BIM Infrastructure widespread level of use in projects is rated from 50-70%. It is most often used for the design of pipeline networks for oil, water, gas, heat, and other liquids, planning areas, coordinating design, as well as quality assurance. Based on the results of the survey, it is estimated that 50% of infra models are utilized both in building and industrial construction projects. The other 50% do not use infra models at all.

BIM City information Modelling CIM is widely used in a range of 0-10%, and City Information Modelling is not used in house projects. In addition, the survey says that there is no guideline specified for city information modelling.

5.3 Survey summary

According to the findings of this study, it is evident that the majority of people had at least some knowledge of BIM as of the year 2020. Since the United Kingdom is a leading country in this field, it can be predicted that by the year 2022, the level of awareness will significantly increase. Based on the questionnaire results, graduating students are familiar with software databases and generally prepared to meet the requirements of employers. However, some may require additional training in BIM to meet their needs. AEC Universities have faced several obstacles in developing BIM technologies, including a lack of interest among management in BIM technologies, a lack of interest among academic staff in BIM technologies, and BIM technologies are not well known among academic staff.

6 BIM in the construction industry

BIM applications in housing, infrastructure, and city modelling are discussed in this section of the report. It is now known in the UK that BIM is much more than a technology that helps architects design innovative buildings. As a result of BIM, construction and design processes can be significantly improved, including cost and resource savings, increased efficiency, and shorter project cycles. Additionally, prefabrication and modular construction will be more readily available, as well as higher quality results.

6.1 BIM for housing

In recent years the UK faced a crisis due to issues raised by the case in the house-building industry, which stated that insufficient output prevents the industry from expanding to meet demand due to its structure. The industry suffers from a loss of skills in recessions, while labor and materials shortages result during growth periods. Quality control on site is problematic due to the reliance on subcontractors and low levels of training. Although innovative construction methods are being tested, they have yet to gain widespread acceptance. Such as: Lack of adoption in the absence of BIM and digital technology, quality control on-site is affected, resulting in construction defects, warranty claims, and other issues dissatisfied customers. (Burgess et al. 2018, 9.)

As of 2019, the UK In 2019, UK construction released 13.5 million tons of carbon dioxide. About three percent of the UK's carbon dioxide emissions were reduced from the previous year. Since 1990, 45% increase has been observed in the UK construction industry's carbon dioxide emissions. There is a wide range of construction emissions, with almost half of construction emissions coming from civil engineering. As for buildings and construction work, these emissions account for 17 percent. (Tiseo 2022.)

Existing housing stock in the UK contributed 27% of the UK's carbon dioxide emissions. Providing a renovated home can help the UK Government achieve its target of 80 % by 2050. Nevertheless, remodelling a house is difficult due to high initial costs and a need for more construction knowledge and skills. As a result of BIM's capability to cope with current challenges, it is imperative that CO2 reduction target be achieved (Kenneth et al. 2013, 765-768.)

Housing development expenditures in 2021/22 were approximately 9.6 billion British pounds, primarily derived from local authority housing. During 2009/10, this category reached its peak with 10.95 billion pounds spent. (Clark 2022.)

6.1.1 Barriers to adoption in house building

BIM adoption in the housing sector has to be rethought, it is essential to remove three main barriers need to be removed, namely, "business barriers," "technical barriers," and "human barriers." Building houses using BIM has faced the following challenges: inadequate scale, lack of standardization, difficulty ensuring that the built home conforms exactly to the CAD or BIM model, Lack of a fourth stage, slow BIM objects implementation in domestic projects. (Gemma et al. 2018, 22-23.)

Housing associations and industry experts are encouraged to use BIM by the UK government by supporting associations such as this. BIM for Housing Associations (BIM4HAs) is supported by the National Housing Federation (NHF). Housing associations can digitize development and asset information using free resources made available by BIM4Has. A new Asset Information Model has been added to the Toolkit to help housing associations digitalize their asset information and manage vital building information. In addition to providing a toolkit, BIM4HAs offers a forum for housing associations using the Toolkit to share experiences, ask questions, and receive feedback. The Toolkit is free of use to anyone, and it includes the following: Scopes of services, Asset Information Requirements (AIR), Organisation Information Requirements (OIR), Asset Information Model, Housing Association Data Dictionary, Guidance, and BIM for existing Buildings. (National Housing Federation 2022.)

6.1.2 Construction of public buildings - statistics & facts

The industry has grown in terms of turnover generated since 2010, reaching nearly 119 billion euros in 2016. Approximately 97,000 companies were registered in the building construction sector in 2018, of which 2,780 had revenues exceeding five million pounds. (Statista 2022.)

It is expected that new house buildings raised by 20.9% in 2021, then continue to rise by 9% in 2022. According to the Certified public accountant (CPA), houses outside major cities were likely to remain in demand for at least six to nine months due to shifts in working patterns. Since the initial lockdown, Residential repairs, maintenance, and improvements recovered the fastest, with output nearly 19.3% higher than before the recession, on the basis of data from the Office for National Statistics (ONS). Increasing demand has been observed for outdoor leisure areas and home offices. (British Stainless Steel Association 2022.)

Based on the statistic figure 3, it can be forecast the number of homes completed in the United Kingdom (UK) between 2018 and 2022. It is estimated that approximately 205 thousand houses will be completed in 2022.

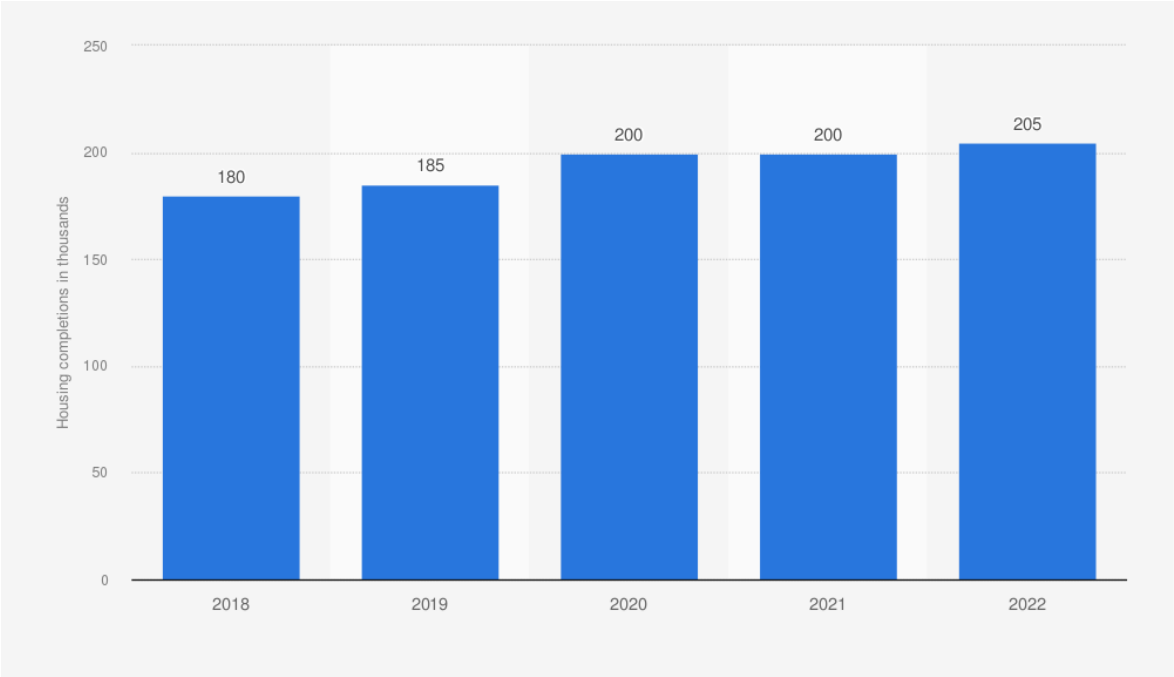

Figure 4. UK housing completions forecast 2018-2022 (Jan 2022).

During the last few years, the UK has built a lot more houses compared to previous years. Since the United Kingdom has a CO2 emission problem, BIM holds the housing sector accountable for reducing CO2. Furthermore, since 2016, BIM level 2 has been mandated by the UK government and financially supports the industry by creating associations dedicated to BIM for houses. As a result of this, it can be concluded that BIM for housing has reached level 2 since both the private and the public sectors have implemented BIM. (Figure 4.)

6.2 BIM for Infrastructure

BIM for Infrastructure is a vague concept. Building Information modelling begins with conceptual design and continues throughout asset lifecycles. A BIM Infrastructure Project should preserve intelligent information throughout its various stages. Therefore, Autodesk has developed a collection of Autodesk Infrastructure Software Applications for planning, construction, and design phases of BIM projects. (Scottish Futures Trust 2022.)

BIM compliance is becoming increasingly important as the UK Government develops the BIM mandate. Private clients and large contractors demand BIM compliance from civil engineering consultants and infrastructure designers. In addition to roads, rails, drainage,

utilities, and GIS, Autodesk Infrastructure Solutions for BIM covers all disciplines within the civil engineering industry. To assess potential infrastructure projects visually, BIM helps infrastructure companies present early-stage design ideas to stakeholders and planners. Autodesk's Infrastructure Tools make it easy to create visualizations, drawings, and documentation from models. BIM simplifies the process of understanding the project and gaining stakeholder approval. (Talbot 2022.)

Digitalization in the construction and infrastructure sector has been accelerated by COVID-19. As national standards have evolved into ISO standards, the focus has shifted from adopting and implementing BIM as the end goal to incorporating BIM and CDE to facilitate a holistic shift towards a model-driven approach to delivering, operating, and maintaining assets. In addition to the industry-standard Infrastructure Tools, Autodesk also offers: Autodesk Infraworks 360, Infraworks badge 150px, Autodesk AutoCAD Civil 3D, civil 3d 2020 badge 150px, Autodesk Navisworks, Navisworks 2020 badge 150px. (Talbot 2022.)

6.2.1 Infrastructural BIM demand

Theo Agelopoulos, Autodesk's infrastructure director, asserts that UK infrastructure asset owners understand BIM best in the world. Despite the fact that UK clients such as Network Rail and Transport for London have adopted BIM standards, asset owners worldwide still have much catching up to do. Moreover, during his remarks, Agelopoulos applauded the UK government's initiative to develop BIM level 2 on all projects that are sponsored by the government. (Horgan 2019.)

As of today, Nordic countries are probably on par with the UK, while France and Germany are lagging. Germany announced a mandatory BIM program in 2020. Also, there is an emerging market that copies Britain's nationalized model. Based on its success, Malaysia, Singapore, and India have all implemented BIM mandates in recent years that are Similar to the UK. (Horgan 2019.)

A comparison of the UK's infrastructure performance against those of other countries provides useful information about the country's infrastructure. According to the World Bank, the UK's infrastructure quality fell behind France (7th), Germany (8th), and the Netherlands (2nd). Investment has long been squeezed, and policy has been erratic, according to the National Infrastructure Commission. Infrastructural growth has not kept pace with modern needs. Providing reliable phone and internet service is especially challenging with the digital infrastructure. (Rhodes 2018, 4; Keep 2021, 6.)

6.2.2 Investment in infrastructure

To support the infrastructure sector in the country, funding infrastructure projects is done in three ways: Public, private, and mixed public/private funding. In the public stage, projects During the public stage, public funding is provided to projects by the government. A public fund will be used to finance High Speed 2. Through customer bills or charges, private companies recoup their investment. Private investment entirely financed Heathrow Terminal 5. Both the public and private sectors contribute to mixed funding. (Keep 2021, 7.)

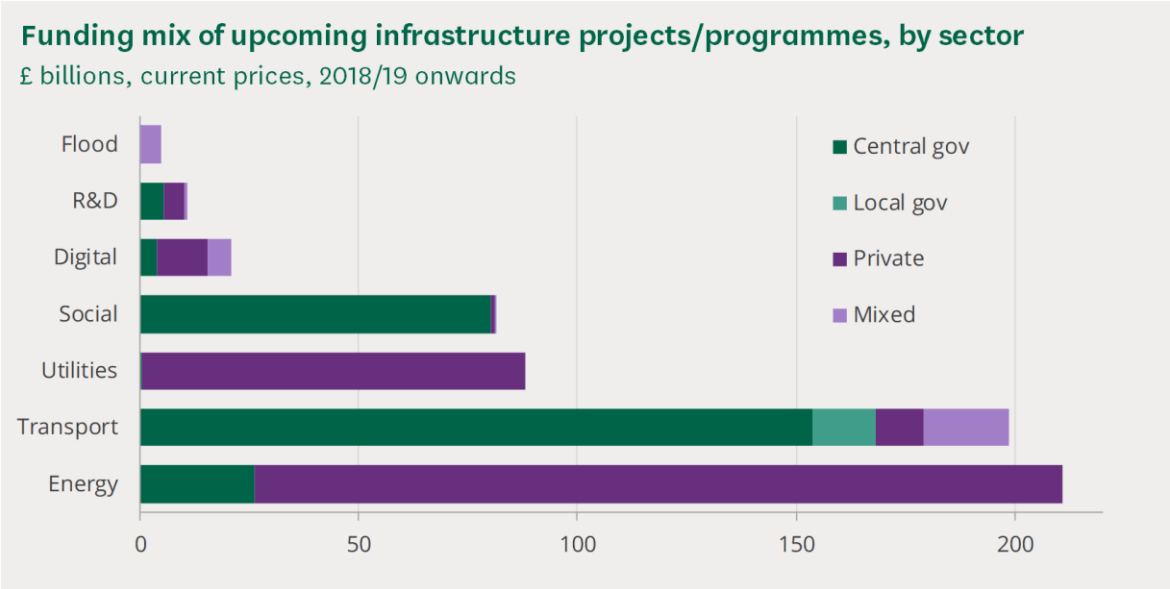

Figure 5. Sectoral funding mix for infrastructure (Keep 2021).

Infrastructure and Construction Pipeline can be used to determine which funding types will be used for upcoming projects. Updates to the Pipeline were last made in autumn 2018. Figure 5 shows a funding mix for each infrastructure sector based on projects scheduled from 2018/19 onwards. In this analysis, funding is taken into account for each individual program or project, and it is grouped by sector. Public funding accounts for 46% of the Pipeline projects, private funding accounts for 49%, and the remaining 5% is a mix of public and private funding. (Keep 2021, 7-8.)

As BIM and digital working continue to grow in the infrastructure sector, the Scottish BIM Delivery Group is committed to sharing best practices. These practices are defined by a Map outlining which encloses all case studies in the application of infrastructure technology within Scotland. The infrastructure BIM Level 2 related case studies. (Scottish Futures Trust 2022.)

6.3 BIM for city modelling

Building Information Modelling and upscaled city Information Modelling are still very much developing in the construction industry to some extent. While BIM has been slow to take off in some quarters, most industry players recognize it will become increasingly important as time goes on.

SimCity was a 1989 video game released by Maxis that allowed players to design the ultimate city. Following the franchise's success, a number of sequels and spin-offs have followed, focusing more on the individual. However, SimCity games also maintained their own appeal. Creating a thriving, high-tech metropolis from an empty plot of land has long been a favorite pastime for many gamers. Essentially, City Information Modeling is a collaborative process between architects, planners, and others involved in city-wide planning, but it is done in a highly sophisticated way. (Trimble Constructible 2022.)

An analysis by Zion Market Research found that BIM market value is expected to reach $10.36 billion by 2022. Government mandates requiring collaborative 3D BIM for all centrally funded projects have contributed to other markets rapidly catching up to the UK. Although BIM uses 3D modeling, it also integrates all aspects of a building project's lifespan, going beyond CAD capabilities. Different aspects of the project can be linked together collaboratively to create potential expansions. Individual BIM files can be plugged into a city-scale platform. Unlike BIM, CIM incorporates Infrastructure, services, and even how people interact with and move around the city beyond the remit of most BIM models. (Trimble Constructible 2022.)

6.3.1 Factors driving smart city adoption

A smart city initiative from Manchester, Hull's Smart City OS, Smarter London Together, Bristol Is Open, and Future City Glasgow are among the UK's most exciting smart city initiatives. Technology innovation and a decline in component costs are driving the development and adoption of smart cities. Investing in these technologies and the infrastructure that supports them is also important. The government has announced investments in 2020 of £5 billion to provide 5G technology demonstration in 2021-22, including gigabit-capable broadband. (Bechkoum 2022.)

Smart city adoption could be impeded by regulatory hurdles, public distrust, and skills shortages. Several technologies have been developed and implemented faster during the COVID-19 pandemic due to increased digitization. According to Nesta, an innovation charity, local authorities are implementing new operating models in response to the pan-

demic, including changing staff roles and digitizing processes. Local authorities' ability to horizon scan and innovate may be reduced by reallocating staff, changing priorities, and additional financial demands caused by the pandemic, even though this focus on digitization may speed up some aspects of smart city implementation. (Rowland 2020.)

This desire has been followed by most UK cities, where data is readily available to the public. For example, Smart Cities Scotland uses in seven Scottish cities (Aberdeen, Dundee, Edinburgh, Glasgow, Inverness, Perth, and Sterling), Smart Cities Scotland uses the Comprehensive Knowledge Archive Network (CKAN). As open data sets can be utilized and ultimately accessed, smart city solutions can be developed. (Rowland 2020.)

6.3.2 Smart cities in 2030

In the United Kingdom Smart city technology is being implemented as a way to educate citizens. According to an analysis carried out by Will Brown, A smart city strategy that is widely used, whether in primary schools, secondary schools, or adult education, is the education of citizens. Children, school leavers, apprenticeships, and adult/community were the categories to which 31 digital education projects were selected. Adolescents are also targeted by other initiatives. Additionally, Manchester and Cardiff have committed to developing the revised curriculum, with an emphasis on key skills like digital literacy 61, 62, and London's Digital Talent Programme 14. (Brown 2020, 11-13.)

In Bristol, smart city innovation is driven by addressing the real-world problems of citizens and the city with the latest technology. People in Bristol are trailing new technologies to help save energy and discover new ways to travel. Some of the most recent projects demonstrate this approach: Smart Homes which are meant to saving energy and reducing carbon footprints. (Brown 2020.)

The project aims to rethink travel choices by using app-connected electric cars and bikes to reduce households' energy consumption and use smart white goods to reduce energy consumption. In recent years, Bristol has experienced a resurgence of the harbourside, including new residences, offices, leisure areas, and entertainment venues. Consequently, resident and visitor safety has been put at higher risk; incidents of falling into the water have a significant impact on emergency services, operational control rooms, and the people involved, and the number of such incidents has increased. City operation centers receive alerts transmitted via trial 5G networks. In this way, incursions can be monitored and controlled in real time while having high bandwidth and low latency connections. In its first trial, this technology saved lives. Bristol's traffic network is managed and monitored by the

facility. Additionally, they provide telecare monitoring, allowing individuals to remain independent at home by using technology tailored to their needs. (Brown 2020.)

Figure 6. Model of Bristol in 3D digital format (AccuCities 2020).

Bristol is represented in a digital 3D model that is structured in tiles aligned to the Ordnance Survey grid. Photogrammetry captures the terrain in stereo 3D and separates it into layers. With an accuracy of up to 15 cm, all Bristol city models are available in a Medium or High Level of Detail. (AccuCities 2020.)

As found in the Bristol case study, there is a connection between infrastructure, houses, and smart cities. These connections can only be achieved by relying on the capabilities of these types of technology, such as BIM, CIM, and the Internet of Things (IoT). Aside from its smart city initiatives, Bristol strives to reduce carbon dioxide emissions by implementing BIM technology. High-tech modelling is needed for smart cities. Consequently, such big-data technologies require BIM level 2 and 3 that can handle them.

7 Conclusions

British national standards were mostly incorporated into ISO standards. Clearly, BIM has a higher level of documentation in the UK than in other countries. Construction in the UK has been greatly impacted by the adoption of BIM. This has led to most countries transitioning to ISO 19650 standards.

BIM awareness is high, as evidenced in this study. BIM level 2 is mostly used in the UK; the fact does not exclude the use of CAD. In addition to that, the UK construction industry claimed to transit to BIM level 3 by 2020. Hence BIM level 3 standard are under development Appendix 3. Also, the research shows that since BIM Level 2 has been mandated in the UK by the government for public sector. The fact has had a great impact on private sector which uses BIM on a larger scale compared to public sector. Although, most private developers do not necessarily invest in buildings they intend to sell or rent commercially, neither in buildings they intend to occupy and use.

Maturity level of BIM is being emphasized by the Government by creating standards, guidelines, frameworks, classifications, toolkits, associations, and other resources. All public sectors are mandated to use BIM level 2. Consequently, this has had a tremendous impact on the private sector, which is now embracing BIM Level 2 in increasing numbers. The fact that BIM level 3 standard is under development, BIM level 2 national standard has a wide range of documentation which sustain its implementation. In addition, consistently recognised benefits include Improved information coordination, Smarter productivity, Reduced risk, Profitable operations.

In addition, BIM is now mandatory in high-rise residential projects in the UK. The construction sector contributes to CO2 emissions. To reduce carbon dioxide, different approaches are being considered, such as Building Information Modelling. Thus, COBie is the preferred document for BIM level 2. As a major component of ISO 19650, RIBA's 2020 plan of work has been highlighted. Nowadays, several types of software are available. As demonstrated in table 1, BIM software is predicted to be mature in the UK based on its most widely used applications.

By developing standards, guidelines, plans of work, and resources, BIM is essential for the management of information in today's world. The UK BIM Framework provides guidance and support on the fundamental principles of BIM. In order to ensure the overall implementation of the standard, BS EN ISO 19650 Guidance Parts 1 to F are provided. These guidance parts contain specific content for BS EN ISO 19650-2 and BS EN ISO 19650-3. ISO 19650 is closely aligned to the national standard UK PAS 1192. (Figure 2.)

A number of BIM tools, such as the digital plan of work, the RIBA plan of work Appendix 3, Uniclass 2015, specifications, and the BIM Toolkit LOD, BIM protocol, highlight the benefits of BIM.

Further research should be conducted to fully understand the level of BIM use in the following areas: house modelling, infrastructure modelling, and city modelling. The UK is transitioning from national to international standards. According to ISO 19650, "UK BIM Framework" refers to BIM maturity levels defined by national UK standards PAS 1192. Hence, standards used in the BIM construction industry determine these appellations. As a result, it can be predicted that BIM maturity levels will be eliminated from UK documentation in the near future, since national standards are transitioning to international standards.

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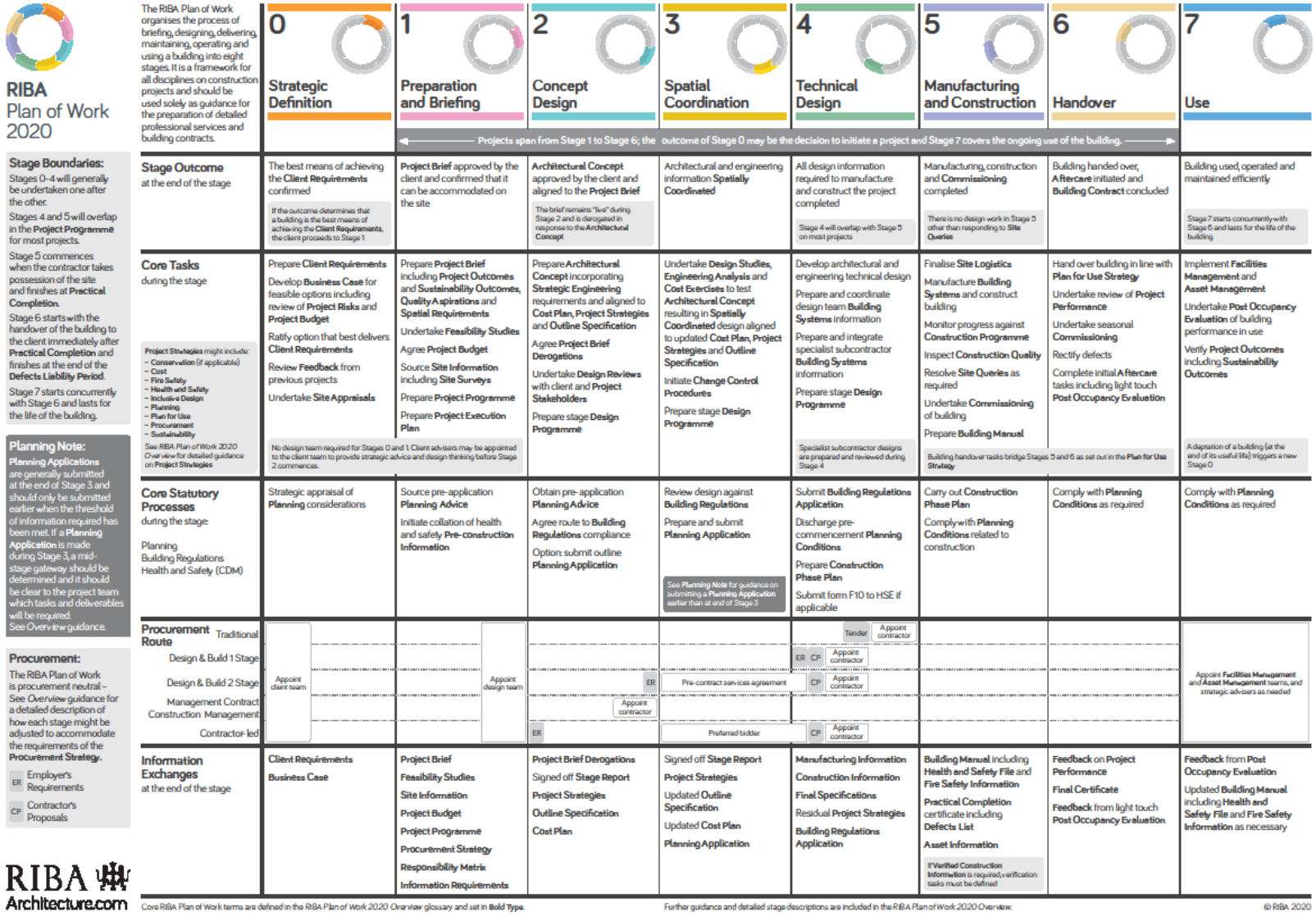
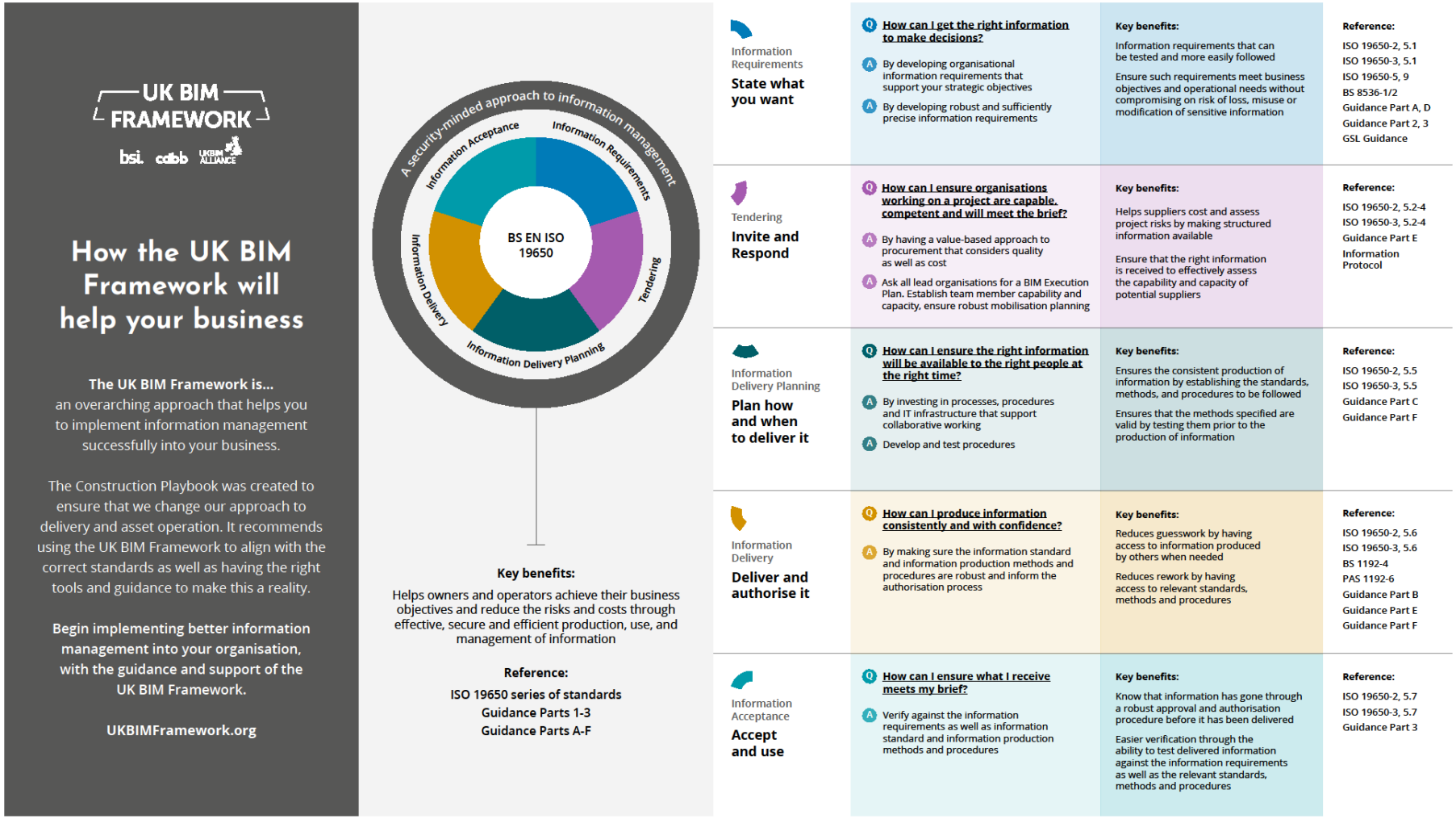
Appendix 1. RIBA Plan of work 2020

The Riba plan of work can be read (RIBA, 2020)

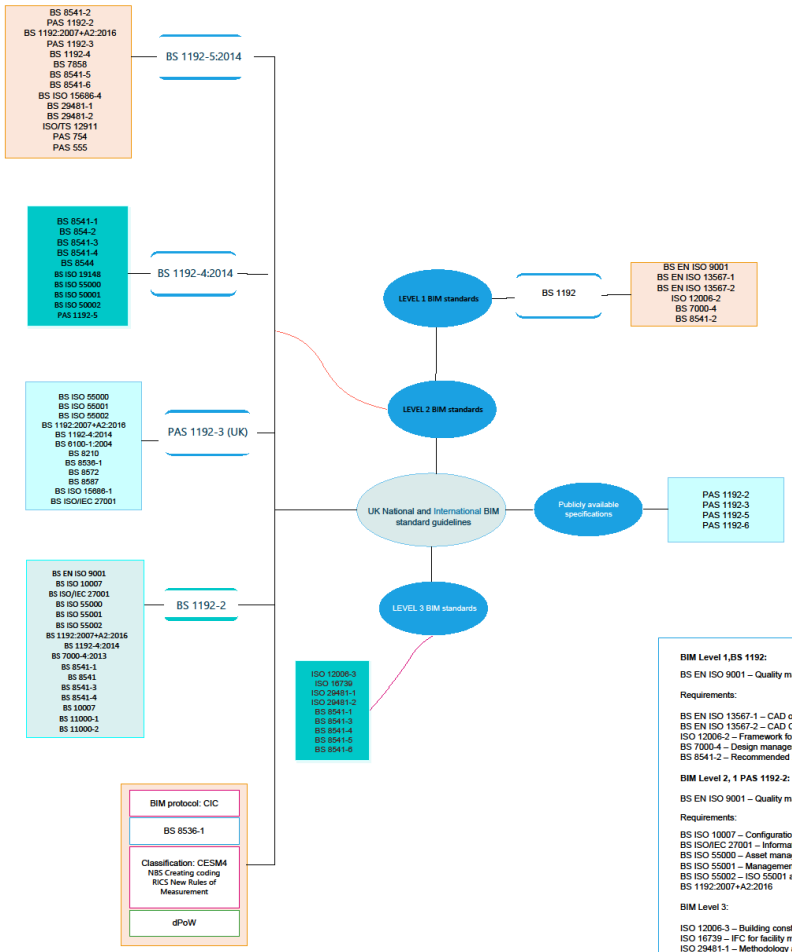


Appendix 2. UK BIM FRAMEWORK

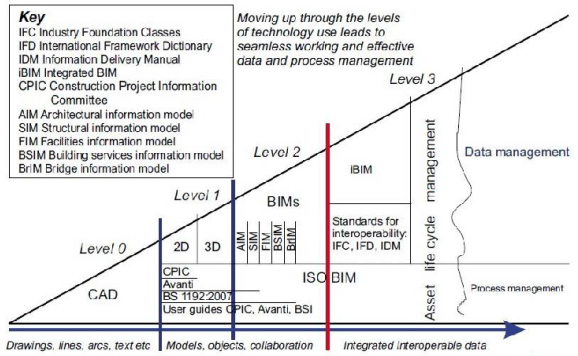
The UK BIM framework can be read (FRAMEWORK, 2022)



Appendix 3. United Kingdom National standard BIM level



This model was originally developed back in 2008 by Mervyn Richards and Mark Bew, and you can find one of the examples of such a model below.



Source: Bew and Richards, 2008

Source: https://www.researchgate.net/figure/The-Wedge-Diagram-showing-BIM-Technology-Maturity-Levels_fig4_320172140

BIM Level 1,BS 1192:

BS EN ISO 9001 – Quality management

Requirements:

BS EN ISO 13567-1 – CAD overview and principles
BS EN ISO 13567-2 – CAD Codes and formats used in construction documentation
ISO 12006-2 – Framework for classification information in construction works
BS 7000-4 – Design management systems
BS 8541-2 – Recommended 2D symbols of building elements for use in BIM

BIM Level 2, 1 PAS 1192-2:

BS EN ISO 9001 – Quality management systems

Requirements:

BS ISO 10007 – Configuration management
BS ISO/IEC 27001 – Information security management systems
BS ISO 55000 – Asset management
BS ISO 55001 – Management systems
BS ISO 55002 – ISO 55001 application
BS 1192:2007+A2:2016

BIM Level 3:

ISO 12006-3 – Building construction – IFD
ISO 16739 – IFC for facility management and construction industries
ISO 29481-1 – Methodology and format of IDM
ISO 29481-2 – Interaction framework of IDM

BS: British Standard
BSI: British Standards Institution
PAS: Publicly Available Specifications
ISO: International Organization for Standardization
CIC (Construction Industry Council)
Digital Plan of Work (dPoW)
RICS New Rules of Measurement – NRM 1

Appendix 4. BIM-ICE questionnaire survey

BIM-Integration in Higher and Continuing Education

BIM-ICE BIM Questionnaire for European countries

Mandatory fields are marked with an asterisk (*) and must be filled in to complete the form.

Dear respondent,

We are interested to learn about the current state of BIM in your country: From varying sources, we have concluded that BIM-competence is at high level in your country and BIM is extensively integrated in the building processes. Your country is one of five European countries selected by the BIM-ICE project for benchmarking.

This questionnaire is mainly focused on the use of BIM in house construction projects but also contains general level questions about infrastructure and city modelling for experts who may have additional information about them. Some questions also collect information about level of education and future prospects of BIM.

In the BIM-ICE project, we are developing BIM-education in the LAB University of Applied Sciences (Finland) and the St. Petersburg State University of Architecture and Civil Engineering (Russia). By benchmarking the current state of BIM with other countries we can identify the main needs of development in our countries.

The BIM-ICE project (BIM-Integration in Higher and Continuing Education, 2020-2022) is financed by the EU, Russia and Finland via South-East Finland - Russia CBC 2014-2020 programme. More information about the project and our team: https://bim-ice.com/

Answering the questionnaire takes about 15-20 minutes. For additional information, please contact our project engineer Jarno Rautiainen, jarno.rautiainen@lab.fi.

1. Which country do you represent? *

- ◯ Norway
- ◯ United Kingdom
- ◯ Netherlands
- ◯ Switzerland
- ◯ Germany

2. Which field(s) of BIM do you specialize in? *

- ☐ House BIM
- ☐ Infra BIM
- ☐ City modelling

BIM IN HOUSE CONSTRUCTION

3. What percentage of construction and design companies in your country operate in BIM?

- ◯ 90 - 100%
- ◯ 70 - 90%
- ◯ 50 - 70%
- ◯ 30 - 50%
- ◯ 10 - 30%
- ◯ 0 - 10%
- ◯ I find it difficult to answer
- ◯ Free answer _____

4. What are the 3 main hindrances for design and construction

companies when they were (are) transferring from 2D to BIM?

- [ ] Organizations work effectively without the use of BIM
- [ ] Regulatory insufficiency
- [ ] Lack of personnel with the necessary competencies at the labour market
- [ ] Resistance to change and the use of innovative solutions among employees
- [ ] High BIM implementation cost
- [ ] Other reasons (fill in) _____

5. When designing houses, what parts of the project are still made generally without BIM?

- [ ] Architectural
- [ ] Structural
- [ ] HVAC
- [ ] Water supply and sewerage
- [ ] Electrical engineering
- [ ] Cost analysis
- [ ] Construction planning design
- [ ] Labour safety
- [ ] Fire safety
- [ ] Other (fill in) _____

6. Are there any typical indicators for using BIM in the projects? (You can choose several options)

- [ ] Projects that are bigger than some m2 limit
- [ ] Projects that cost more than some € limit
- [ ] At the request of the client organization
- [ ] Initiatives and agreements between stakeholders

☐ The use of BIM is mandatory due to government regulations

☐ Other (fill in) _____

7. When the design project is on the running, what file exchange method is used most widely?

◯ Flash drives

◯ E-mails and messages

◯ Model-authoring cloud solutions

◯ Model-authoring and model-checking cloud solutions

◯ Cloud-based common data environment for all project information

8. How is the BIM data generally transferred between stakeholders in construction projects?

◯ Only IFC standard and IFC compliant models

◯ Only native models (BIM software's original file formats)

◯ Both IFC and native models from each software

◯ Combination models (e.g., SMC, TBP, NWD)

◯ All options above are used

◯ Other (fill in) _____

9. How is the use of BIM mainly supported in your country? (You can choose several options)

- [ ] By national BIM guidelines
- [ ] Governmental regulations and related guides
- [ ] By using international standards in process development
- [ ] Companies develop internal guides based on good practices
- [ ] Other (fill in) _____

10. What other fields than house BIM do you recognize being utilized in house projects? (You can choose several options)

- [ ] Geotechnical models
- [ ] City models
- [ ] Infra models
- [ ] Virtual models (and game engines)
- [ ] Machine control infrastructure models
- [ ] Other (fill in) _____

11. How well do you know the following international BIM standards or related concepts? (1: Do not recognize - 5: Know well and utilize in projects)

	1	2	3	4	5
BEP (BIM Execution Plan)	○	○	○	○	○
EIR (Exchange Information Requirements)	○	○	○	○	○
CDE (Common Data Environment)	○	○	○	○	○
MVD (Model View Definition)	○	○	○	○	○
BCF (Building Collaboration Format)	○	○	○	○	○

	1	2	3	4	5
COBIe (Construction Operations Building Information Exchange)	◯	◯	◯	◯	◯
IFC (Industry Foundation Classes)	◯	◯	◯	◯	◯

Software - Please select most popular BIM software for modelling for parts of the project design

12. Architectural design

◯ Autodesk Revit

◯ Graphisoft ArchiCAD

◯ Nemetschek Allplan

◯ Bentley Microstation

◯ Other _____

13. Structural design

◯ Autodesk Revit

◯ Trimble Tekla Structures

◯ Other _____

14. HVAC design

◯ Autodesk Revit

◯ Autodesk Revit + MagiCAD

◯ Autodesk AutoCAD+ MagiCAD

◯ Bentley Building Mechanical Systems

◯ Other _____

15. Water supply design

- ◯ Autodesk Revit
- ◯ Autodesk Revit + MagiCAD
- ◯ Autodesk AutoCAD + MagiCAD
- ◯ Bentley Building Mechanical Systems
- ◯ Other _____

16. Electrical engineering

- ◯ Autodesk Revit
- ◯ Bentley Promis.e
- ◯ Other _____

17. Cost analysis

What is the most popular soft-ware for cost analysis in your coun-try? [ ]

18. Construction management

- ◯ Autodesk Navisworks
- ◯ Elecosoft Powerproject
- ◯ Bentley SYNCHRO Pro
- ◯ RIB iTWO

◯ Other _____

BIM IN INFRASTRUCTURE DESIGN

19. How widespread is the use of infra models in projects? (Percentage of model-based projects)

◯ 90 - 100%

◯ 70 - 90%

◯ 50 - 70%

◯ 30 - 50%

◯ 10 - 30%

◯ 0-10%

◯ I find it difficult to answer

◯ Free answer _____

20. For what are the infra models typically used?

☐ Lane design

☐ Pipeline networks design (water/gas/heat/oil/etc)

☐ Area planning

☐ Creation of greenspaces and sports grounds

☐ Machinery control in infra projects

☐ Design coordination and quality surveillance (combination models)

☐ Quantity take off and cost estimation

☐ Scheduling

☐ Construction management

☐ Maintenance and renovation

☐ Other (fill in) _____

21. What are the most used BIM software for each discipline? (If known, please write examples into text boxes)

Lane design	
Pipeline networks design (water/gas/heat/oil/etc)	
Area planning	
Creation of greenspaces and sports grounds	
Machinery control in infra projects	
Design coordination and quality surveillance (combination models)	
Quantity take off and cost estimation	
Scheduling	
Construction management	
Maintenance and renovation	
Other (discipline, software name)	

22. Are infra models utilized in building construction or industrial construction projects?

- ◯ Yes, for both building construction and industrial construction projects
- ◯ Yes, but only for industrial construction
- ◯ Yes, but only for building construction
- ◯ Infra models are not used in these projects

23. How? Experiences?

24. Have the needs been recognized?

25. How is the information transferred with infraBIM?
Are OpenBIM principles used?

26. Is there a national guideline for infra modelling in your country?

◯ Yes. (please specify name) _____

◯ No.

CITY INFORMATION MODELLING

27. How widespread is the use of City Information Modelling (CIM)? (Percentage of Cities)

◯ 90 - 100%

◯ 70 - 90%

◯ 50 - 70%

◯ 30 - 50%

◯ 10 - 30%

◯ 0-10%

◯ I find it difficult to answer

◯ Free answer _____

28. How are the City Information Models used in general?

_____

_____

_____

_____

_____

29. Are City Information Models utilized in house construction projects?

◯ Yes, City Information Models are (sometimes) used in house projects

◯ City Information Models are not used in house projects

30. How? Experiences?

31. Have the needs been recognized?

32. Are there major differences in use of City Information Modelling between different cities?

33. How is the information transferred with City Information Models? Are OpenBIM principles used?

34. Is there a national guideline for City Information Modelling in your country?

◯ Yes. (please specify name) _____

◯ No.

BIM IN EDUCATION

35. Evaluate the qualifications of AEC universities graduates in the field of BIM on a scale from 0 to 5, where:

- ◯ 0 - I find it difficult to answer
- ◯ 1 - Graduates do not work with BIM, they are not trained in any programs for working with BIM models
- ◯ 2 - Graduates are familiar with the basics of one or more BIM software, but need additional training
- ◯ 3 - Graduates ' qualifications in the field of BIM technologies generally meet the companies' expectations, graduates are able to use the necessary software
- ◯ 4 - Graduates are fully trained to use all the necessary programs and technologies for working in the BIM environment
- ◯ 5 - Proficiency level of graduates in BIM generally exceeds the level of employees in the design and construction companies in the country

36. Do students and academic staff in AEC universities in your country use BIM in their project work?

- ◯ Yes, BIM is 1st choice for every design project work
- ◯ Yes, but the transition to BIM is not completed fully
- ◯ No, 2D CAD drawings are still dominating

37. What do you see as the main obstacle to further development in the study and application of BIM technologies in AEC universities in your country? (multiple choice)

- ☐ Lack of powerful computers and special BIM equipment (VR helmets, laser scanners, drones, etc)
- ☐ High cost of BIM software
- ☐ Lack of interest in BIM technologies among the university management
- ☐ Lack of interest in BIM technologies among the academic staff

- [ ] Lack of knowledge in BIM technologies among the academic staff
- [ ] Lack of interest in BIM technologies among the students
- [ ] Lack of hours for BIM technologies in most educational standards and the inability, in this regard, to devote sufficient time to teaching this discipline
- [ ] Lack of national standards, regulatory documents on BIM in the country
- [ ] Lack of a common terminology in the field of BIM and a common approach to this technology in the professional community
- [ ] No obstacles, development is underway
- [ ] The situation varies a lot from one AEC university to another

38. How was the transition from 2D to BIM in AEC universities achieved? (multiple choice)

- [ ] By trainings of academic staff, organised by universities
- [ ] By mass substitutions in academic staff
- [ ] By stimulating universities' academic staff with different grants
- [ ] Using development projects and research in the field of BIM
- [ ] Without any specific action from government or universities' boards

39. Are BIM competitions for students organized between AEC universities?

- ◯ Yes, like tournaments for individuals
- ◯ Yes, like team tournaments
- ◯ No

OpenBIM and Future

40. What is the situation with the implementation of OpenBIM in your country?

41. How do you see the use of BIM developing in near future? Promising use cases?