LAB University of Applied Sciences

Benchmarking research work of development state of BIM in Norway

LAB University of Applied Sciences
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Abstract

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Title of the thesis

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Abstract

BIM technologies is closely associated with the construction industry. Large international companies use this technology in their work. The public may still think that BIM is a visualization tool, but it is more than just a three-dimensional image.

This research was performed for BIM ICE (BIM-Integration of Higher and Continuing Education) which is co-funded by the European Union and LAB University of Applied Sciences. This paper aims to determine the maturity of the technology, the level of ownership and awareness in Norway. The methods of this research are the analyze of open sources and existing literature, publications, manuals, as well as the analysis of a questionnaire that was sent to persons associated with BIM in country. Determining the level of BIM application is globally important for determining the needs and problems at home. Exchange of experience and knowledge is possible.

The results of the study give the main idea about the development of building information modeling in Norway. This research is also aimed at identifying the problems faced in Norway and which other countries developing BIM may face. The materials that were used during the research are in Appendix 1 and Appendix 2.

Summing up the content of the research, Norway is at a high level and is one of the leading countries in the implementation of BIM in projects. Norway has been actively implementing this technology for more than 10 years and is making good progress. The study showed that BIM has found its application in building modeling and infra modeling, but city modeling has not found its application.

Keywords

Building Information Model, BIM, Infra Modelling, House Modelling, Norway

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List of terms

BCF	BIM Collaboration Format
bSDD	buildingSMART Data Dictionary
bsN	buildingSMART Norway
CityGML	An open standardised data model and exchange format to store digital 3D models of cities and landscapes
IFC	Industry Foundation Classes is an openBIM standard for data exchange, an object-based file format, intended to describe building and construction industry data
IFD	International Framework for Dictionaries
LOD	Level of Development, terms used to describe the precision of a model
mvdXML	Format that define allowable values at attributes of data types

1 Introduction

New technologies are implementing in our life every day. Technologies affects in all areas of our life. The development and extensive use of BIM programs in construction field strongly impact and simplify it. BIM allows to automate changes to a geometry of object model.

The thesis was conducted as a part of the benchmarking research of the project BIM-ICE (BIM-Integration of Higher and Continuing Education) which is co-funded by the European Union and LAB University of Applied Sciences. A questionnaire prepared by BIM-ICE team was used for the survey. The results of this survey gave useful for information writing the final thesis report.

It is necessary to determine the level of implementing BIM in European countries to identify needs in different cases of using BIM. By benchmarking the state of BIM, it is possible to identify the gaps in our countries and eliminate it. It is important to compare it in different indicators, so it requires a comprehensive review.

The research methods for collecting data for the thesis was processing the answers of experts in questionnaire. Analyze an existing normative documents and article on the corresponding topics also used in report. Open resources were considered, and surveys have been conducted. The research took four months.

This thesis supposed to determine the development state of BIM in Norway. At the time of research process Norway is one of the most competent countries in Europe and BIM is extensively integrated in the building processes. That is the reason why research cover this country.

The main discourse of the thesis is about house, infra, city modelling in Norway, what software do they use in different cases, what kind of standards exist, who is responsible for standardization processes.

2 BIM (Building Information Modelling)

There is no universal definition for Building Information Modelling that can be used worldwide. However, there is a lot of different definitions from organizations and specialists from this field. Some of them understand BIM as a final model filled with information, others the process of creating model. But all these approaches are the equal because they describe the same phenomena (technology) in design and construction activity.

Despite the fact that this acronym is familiar to many, there may still be confusion in the definition and understanding of what it is and why it is used, so various studies and publications on this topic are necessary.

2.1 What is BIM?

It is needed to give BIM comprehensive definitions for this technology. Definitions can be found from the articles and literature given below.

BIM (Building Information Modeling) is a process- a methodology- of managing project with an intelligent 3D-digital information model during the entire lifecycle of the building. Specialists from the different disciplines are provided to work together in an open cloud platform for real-time collaboration. (Autodesk, 2022)

BIM is a use of a shared digital representation of a built asset to facilitate design, construction and operation processes to form a reliable basis for decisions. (SFS EN ISO 19650-1:2019, section 3)

BIM (Building Information Model)- it is not just a geometry; it is a new way to display a physics and functional characteristics of object. BIM considers a lot of factors and information about object and its elements, geography, design, impact to the atmosphere. It is a 3D model that is closely connected to an information about elements and the whole object. Changing one item of a building model will automatically bring changes to all systems components of model, visualization, schedule, drawings.

BIM tools can be used during the whole lifecycle of project, from the first concept till the demolition. BIM programs allow to involve in work process all specialists (architectures, design engineers, MEP engineers etc.) and solve emerging problems, collisions. They are working in the same model and interconnection of design solution occurs in shortest possible time. Thus, BIM minimizes mistakes and provide growth controlling expenses and quality of project.

BIM has a lot of adventures in different stages of constructions work and designing of project. BIM is a beneficial tool that becomes widespread in worldwide construction community.

BIM software is used not only for House modeling, but also to create models for infrastructure and cities.

The most common and understandable is *House Modelling*. With the help of BIM software, architectural, structural and MEP models of a building are created. This is a model in three-dimensional space that displays the architecture scale of the project. With the use of this technology, the construction process becomes more manageable and more developed at all stages of construction. Errors and collisions are detected at the early stages of design, communication between the customer and the contractor is simplified.

Infra Modeling is almost as widespread as House Modeling. Infrastructure software helps optimize model design, construction, and maintenance. Infrastructure solutions are used in the field of road, railway construction, tunnel construction, bridges. Using BIM has all the same advantages as in House Modeling.

City Modeling is a digital representation of the terrain and related and located objects on it, such as buildings, trees, vegetation, and some artificial objects belonging to an urban area in three-dimensional space. 3D models of cities are, in fact, a computer or digital model of a city containing a graphical representation of buildings and other objects in 2D or 3D. A city model is created by integrating information from the IFC Standard and the CityGML Standard. As the 3D city model gives the visualization of the real view, it can be used for urban planning, risk management, traffic jam control, energy efficiency and noise level estimation etc. (Surendra Pal Singh, 2013)

2.2 Status of BIM adoption globally

The popularity of BIM can be explained by the large number of advantages that this technology gives, as well as the development of the construction sector and the general introduction of technologies in all areas. BIM allows built environment professionals do their jobs better, with greater collaborative input. It optimizes the work process and communication between AEC professionals.

BIM has found application in all countries of the world. Many countries report that BIM affects their construction industry at various levels. Overall, the reports assume active implementation BIM globally, with Scandinavian countries, United Kingdom and United States of America that are forefront of all (Figure 1).

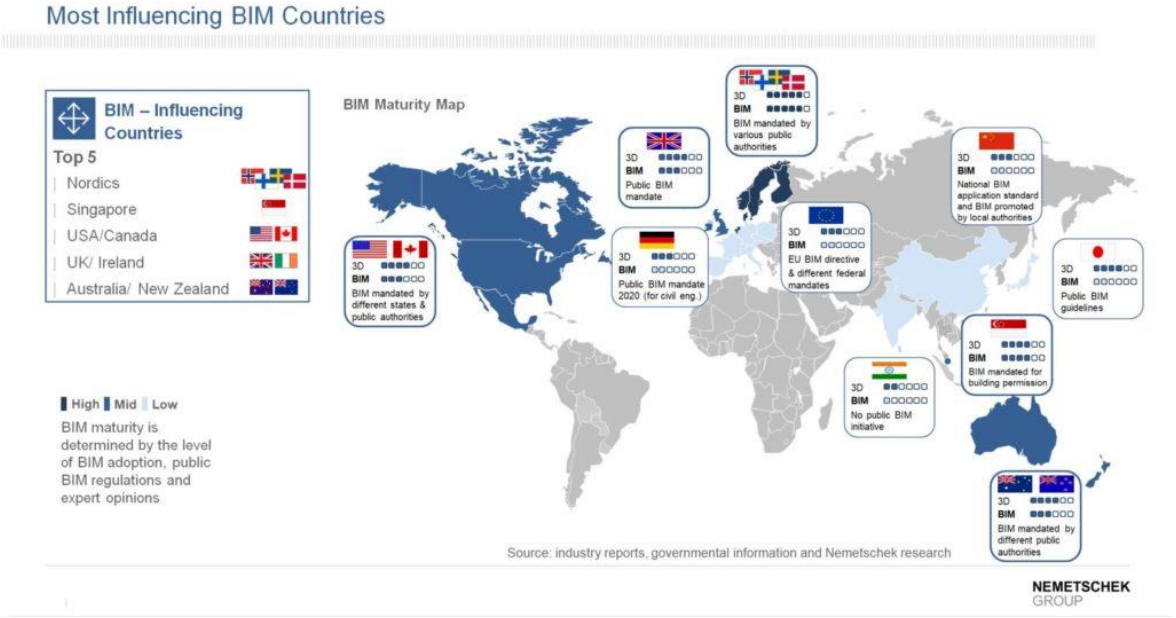

Figure 1. BIM influencing countries (BIM corner, 2020)

The United Kingdom is a leader group among the European countries. Some articles notice that 70% of all construction industry professionals were using BIM on projects. In 2011 it was just 10% - it is an extensive growth appeared after the government's construction strategy. In 2016 the UK announces their expectations to improve BIM level to 3rd level by 2020. Since this time the UK has continued to see rising BIM usage. This rising usage is associated with a significant positive impact on the construction industry, for example, a more accurate determination of the volume of materials, a change in working relations for the you better due to better collaboration. (PlanRadar, 2021)

In 2015, a BIM task group was established in Germany by several organizations to develop a national BIM strategy. The government plays a big role in promoting BIM and became to be mandatory for public infrastructure projects by 2020. Currently almost 80% of German constructions companies use BIM at different levels, it is possible to say that is ready to intercept the UK's leading position in Europe. (PlanRadar, 2021)

The research consists of analysis BIM adoption, government support to the field in 7 European countries that show a different levels of implementation BIM. Overall, the BIM level maturity does not even reach level 2 except for certain projects. Research cover implementation BIM in Germany, UK, France, Poland, Croatia, Austria, and Russia. The number of developers varies from almost 80% to only 12% (Figure 2).

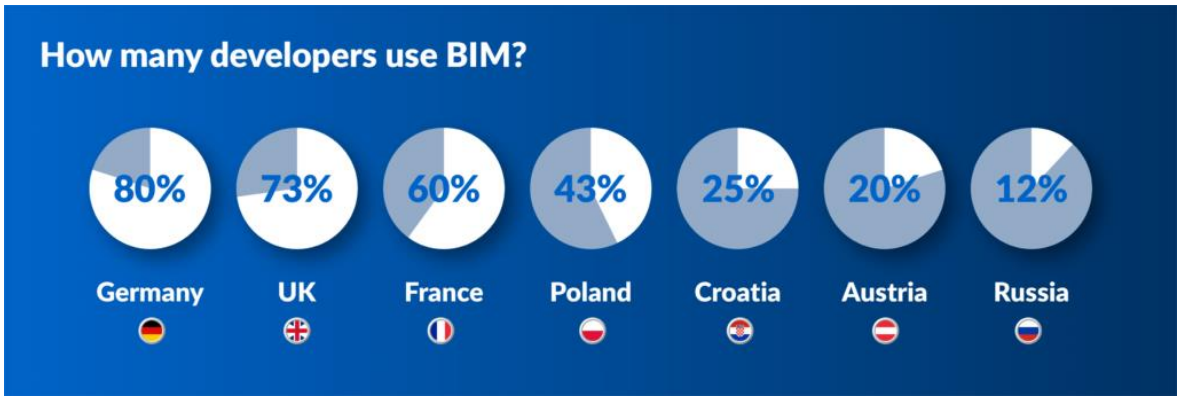

Figure 1. Amount of developers use BIM (PlanRadar, 2021)

Among the countries participating in the study, Germany and the United Kingdom are leaders not only in the number of developers, but also in the level of maturity of BIM in the country. In the UK, level 2 is mandatory for government orders, the country aspires to level 3. In Germany, the maturity level is 2, but in mass use it is still 1 level, 3 are used for certain projects (Figure 3).

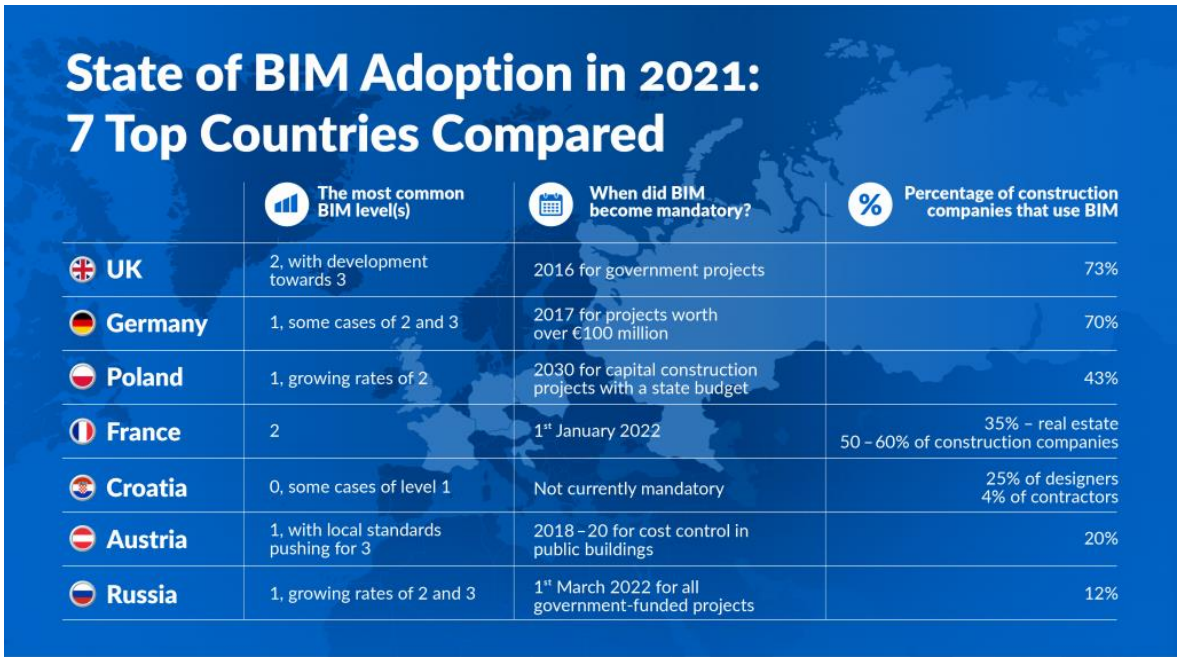

Figure 2. State of BIM adoption (PlanRadar, 2021)

In the UK, it was common practice to describe the maturity of BIM technology using four levels. Therefore, for a general understanding, these levels are used in comparing the level of BIM application in countries, and the result is shown in Figure 3.

Level 0 means the exchange of information between the team in paper or electronic media, the inability to work in a common environment on a project. The project is being developed in 2D CAD drawings.

Level 1 includes a project in 3D and 2D formats. Information is exchanged digitally using a common data environment. 3D is used for conceptual work, everything else is achieved using 2D.

Level 2 means collaborative work of specialists on one model; communication takes place through a common file format. When using this maturity level, it is possible to avoid collisions, the project can be analysed and improved, it is possible to track the schedule and cost of the project.

Level 3 implies the collaboration of all project participants and the full possible filling of the model with data that will be used at lifecycle of the life of the building. It implies the integration of all project data and all stages of the process, compatible with the IFC format.

The desire to reach these levels reflects the depth of understanding by companies and specialists of the full potential of BIM technologies. Training in the use of all opportunities takes a lot of time, the conservatism of workers in the construction environment also causes a slow process of introducing BIM into the industry.

The first idea about implementation BIM was in 1970s years and gradual introduction has started in 1990s in USA. BIM is not mandated across all states per now. The national program "3D-4D-BIM Program" was formulated in 2003, according with it the use of technology has become mandatory for public building projects. (Shimonti Paul, 2018)

Switzerland is slower in adoption BIM compares to other European countries the reason is investments in construction industry, it takes 73% of private investment and architects are still very traditional when it comes to this issue. The buildingSMART Switzerland started its journey in 2016. 70% of organizations that do not yet using BIM would like to implement it within two to three years without a pilot project. (Cristina Popa & Jose Urena, 2020)

The Netherlands also has one of the highest BIM adoption rates in the world. Currently, about 80% of architects use BIM in their projects. The Netherlands is close to making BIM mandatory for government projects. The Government Buildings Agency required all construction projects over 7,000,000 square meters to use BIM in 2011. (Fabio Palumbo, 2021)

The high level of application of BIM technologies in these countries is because not only individual interested companies, research centers and professional associations are engaged in promotion, but also government support. (Knut Sandvik, 2021)

3 Current BIM situation in Norway

Norway was one of the early BIM adopters among the countries. Standards and requirements for public sector are already exist in Norway. The Statsbygg have used BIM since 2007 and mandated it in 2009 for all their projects. Norway's government develop a BIM standard it is called SIMBA which must be used in public sector.

To be the leader in BIM implementation it is necessary to educate new specialists. The universities have noticed that new technologies require a programs and model of teaching and they have adapted their courses. (Knut Sandvik, 2021)

3.1 BIM education

All universities with building and civil engineering degree in Norway provide BIM courses for their students. The Norwegian University of Science and Technology (NTNU) has a master's degree program in digital construction processes also there is a few colleges offered a program in BIM specialization. (NATSPEC, 2022)

The first 13 students who received the title of BIM-technician begun their education in 2008 in Fagskolen (technical school). Currently the school has been realising several groups of graduates.

NTNU in Trondheim, initiated a partnership with Stanford University in 2019 and is now organizing and running its own VDC-certified course together. The course is being organized for the first time on such a scale, and yet the 200-seat limit. The format of this collaboration involved inviting lecturers from Stanford to organize training, or company employees went to courses at Stanford University. (Konrad Naborczyk, 2021)

BuildingSMART Norway (bsN) supports BIM education with annual seminars and act an industry partner for the master thesis each year. (NATSPEC, 2022)

Also, COWI provides the course "Digitalization in practice" which gives students an idea of what the digital everyday work of engineers really looks like. The great interest in the course confirms the interest of a new generation of engineers in digital engineering. The purpose of this course is for participants to gain hands-on experience with Revit and get a little sense of what it means to participate in the project. In the existing Revit model, students had to try out navigation, functions, interfaces with other subjects, as well as extract information from the model before exporting it to IFC and drawings to PDF. (Hilde Statvik Eide)

3.2 Organizations associated with BIM

Boligprodusentenes Forening (The Home Builders' Association) is an organization representing the interests of companies engaged in the production of housing in Norway. The Association has about 800 member companies. In 2011 they have published a Norwegian Home Builders' BIM Manual version 1 in English.

Lean Construction NO was established in 2007. The goal is to spread knowledge about methods inspired by lean construction.

The one of the organization involved in standardization is *Statsbygg*. Statsbygg is a Norwegian government's building commissioner, property manager and developer also advise the government in construction. This organization published the first BIM manual in collaboration with Norwegian Directorate of Public Construction and Property. Statsbygg is an active supporter of the use of open, international standards. In the BIM area, open buildingSMART standards such as IFC, bSDD / IFD, BCF and mvdXML are important. (Statsbygg)

Other organization that plays a big role in BIM implementation and standardization is *buildingSMART*. buildingSMART Norway appeared in 2010. Since then, bSN has held various BIM-related events that aim to have a positive impact on the spread of open BIM. The Statsbygg was an active member in the establishment of bsN. buildingSMART Norway had 131 members from government sector, software vendors, universities, consultants, contractors, standardization organizations. (buildingSMART)

buildingSMART Norway is a member-based organization. bsN develops and maintains standards for digitization of the construction industry in open formats. They have a cooperation agreement with Standard Norway. 10% of buildingSMART Norway members are from the educational sector. The bsN initiative appear a certification program by 2023 that based on ISO 19650. buildingSMART and a several Norway's organization is involved in the development of National and International standards for digitalisation construction industry.

The products of buildingSMART are open standards, including the Industry Foundation Class (IFC), the International Framework for Dictionaries (IFD), the BIM Collaboration Format (BCF) and the Integrated Delivery Manual (IDM). Also, the product of bsN activity is preparing to openBIM training, organization annual conferences and meetings, providing BIM- related information. They have a cooperation agreement with Standard Norway. (Nam Bui et al. 2019)

Standard Norway is responsible for standardization tasks in almost all areas. Standard Norway has the exclusive right to develop and publish the Norwegian Standard and is a

Norwegian member of CEN and ISO. Standards Norway (SN) is a private and independent member organisation. Standards Norway is responsible for standardisation activities and is the national member of International Organization for Standardization (ISO) and the European Committee for Standardization (CEN). (Standard Norge)

3.3 The mandatory level of BIM

The Norwegian state require to use BIM for over a decade now, so all big projects – hospitals, airports, operas, and the like – has been doing BIM to one degree or another. (Knut Sandvik, 2021).

Norway one of the most advanced countries in BIM implementation. Norway is a relatively small country; it means that the construction market is also small. There is a meager number of large construction and design companies. It becomes an adventure when there is a need to introduce new technologies to the field. The entire field should follow the tendency of innovation and adapt quickly to meet the demands of market. One more reason of high- Naborczyk, 2020)

Statsbygg ran a pilot project in 2005, published the first BIM Manual in 2008. Since 2010 the use BIM has become mandatory in public construction projects with governments and has received legislative confirmation in this country. Now all projects should be done with application technology information modelling and meet standard IFC (Industry Foundation Classes), so all who involved in big projects- hospitals, airports, theatres etc. has been doing BIM. Mandatory use of BIM in all large projects helps to avoid major mistakes at the initial stages and in the process of changes in the project. (Knut Sandvik, 2021)

Other countries have also actively started to implement BIM. There are no specific deadlines or methods of implementation in Europe, so the level of technology application varies depending on the country and the prescription of the decision to introduce BIM into the industry. Some countries are already leaders in the use of BIM, others are just starting their way to this technology (Figure 4).

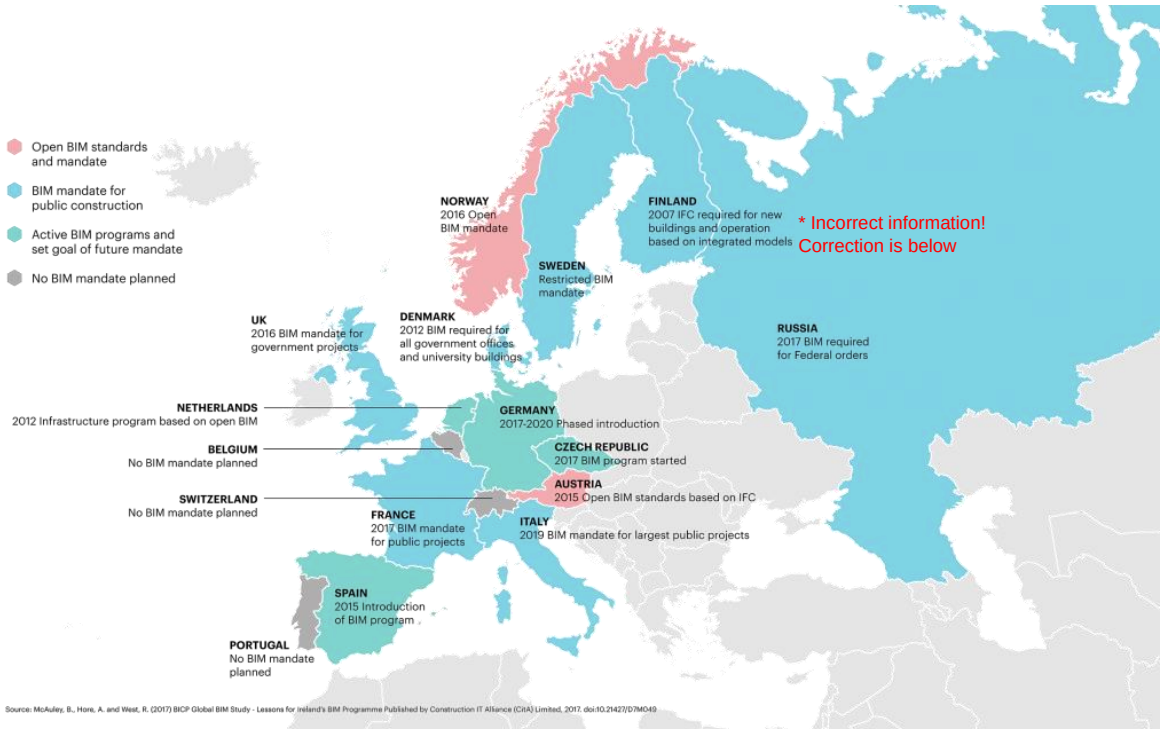

Figure 3. Status of BIM adoption in Europe (MagiCAD, 2020)

Timo Lehtoviita was interviewed about this section and highlighted that the use of IFC has been recommended in national guidelines since 2012 in Finland. (Lehtoviita ,2022)

Specialists from COWI in Norway published an article in 2019, the headline is 3d models of infrastructure will soon become a preliminary requirement for carrying out maintenance work. In Norway, it is expected that resource management with using specifications, drawings and other documents will soon be out of use. This will increase the need for BIM models for the entire infrastructure. Switching to digital maintenance is a problem for new projects, since they were usually developed using models, but for old designs this can become a problem. Railway tunnels became the first digitalization project. The 3D model was created using a combination of laser scanning and video shooting using a 360° camera. (Finn Raun Gottfredsen, 2019)

3.4 Software used in Norway

According to the Ignacy Lozinski (BIMCorner, 2021) Norwegian engineers and architects use an advanced globally known software in their projects, they also produce their own software that fits their needs and standards.

The range of programs used is quite wide. Specialists use not only programs, but also their plug-ins to expand their design capabilities, accelerate the processes of documentation

formation, create simulations of various processes and many other functions that are not available in the program itself.

3.4.1 House modelling

For buildings and constructions Norwegian companies use a *Revit* and its addins. Revit is a most common BIM construction software around the world. Autodesk Revit offer Revit Structures for constructors, Revit Architecture for architects, as well as Revit MEP for sanitary, plumbing, and electrical engineers. Revit offers a 3D modelling environment but with 2D documentation (plans, sections, views etc.). For architects aims Revit allow create a design of structure, generate plans, sections, details. Revit can be used for creating a 3D visualization and get access to created model in virtual reality. For structural engineers this software allows create a reinforcement design using a Revit's addin, create accurate steel and concrete designs with a big database the model will correspond to a real-world objects and materials.

Dynamo is a visual programming addin for Revit war written by designers and construction professionals. Dynamo is built into the Revit program in the form of a module that allows you to work in parallel in these two systems, creating algorithms of actions in Dynamo that are performed immediately in Revit. With Dynamo, you can create scripts to automate repetitive tasks. This addin helps to work with extremely complex geometry. Using the Dynamo provide a simply passing through a lot of design options and find the right option, it will save the time for going through all designs but will take time for programming this code. (Ignacy Lozinski, 2021)

There is a *MagiCAD* is a popular add-in to Revit used for MEP design in Norway. It is a very intuitive tool that allows efficient and accurate modelling MEP systems. MagiCAD offers a set of modelling functions for MEP disciplines, this addin has access to a large library of manufacturer content. (Ignacy Lozinski, 2021)

Naviate is not a plugin for Revit and Civil 3D, it is a set of tools. There is a various tool for architects, structural engineers, MEP designers, landscape architects, road designers. Their product portfolio consists of Naviate for Revit, Naviate for Civil 3D and Naviate Nexus. These tools are programmed features that provide generate a quick result, save time, avoid errors in project. (Ignacy Lozinski, 2021)

Another software used in structural modelling in Norway is *Tekla Structures.* It is a well-known software around the world. This software has automated process of creating working drawings. Tekla structures was released by Trimble, and it has a multilingual interface. Modeling in Tekla Structures includes structural steel, construction steel, concrete and

reinforced concrete monolithic structures, reinforcement frames. Tekla Structures users can exchange design information and drawings with users of other CAD systems for architectural design and modeling of engineering networks. The ArchiCAD, Revit Architecture and other software for architects that fully comply with the IFC standard, as well as Tekla Structures. Other formats such as DGN and DWG. (Ignacy Lozinski, 2021)

Archicad is a software used for architecture design, was created by the Hungarian firm Graphisoft. Designed for the design of architectural and building structures and solutions, as well as landscape elements, furniture, etc. This program makes it possible to create a model, make visualization using Archicad architectural visualization tools, documentation tools and publications help simplify this process. (Ignacy Lozinski, 2021)

Rhinoceros is a universal program that gives full control over the project. This is an ideal tool used to solve architectural ideas and design tasks in a wide variety of industries. This software will help to create geometry, print a modeling object, can simulate various phenomena (wind, gravity). (Ignacy Lozinski, 2021)

Grasshopper is a visual programming language for Rhino. Grasshopper has become a full-fledged component of Rhino, which has been built into the program since version 6. This plugin makes it possible to simulate the distribution of flows of people, wind direction, natural lighting. Designed to do automatically what is manually done for a very long time or not done at all. (Ignacy Lozinski, 2021)

3.4.2 Infrastructure modelling

Trimble Novapoint used for various type of infrastructure projects (creating 3D models of roads, tunnels, bridges, railways). There are different products for different disciplines: Novapoint Bridge, Novapoint Railway, Novapoint Tunnel, Novapoint Road etc. These Trimble products include geometric function, drawings producing, tools for structural calculations and annotations for drawings, creation of terrain surface, standardized templates. This software offered by Trimble is advanced and have a wide range of features. (Ignacy Lozinski, 2021)

Autodesk Civil 3D is a software used for specialists in the field of land management, geodesy, general plan design and infrastructure facilities. AutoCAD Civil 3D allows you to create a single digital model of the surface, you can import data from any geodetic equipment, and then process them, the ability to create 3D visualization of projected objects, communication with Google Earth. AutoCAD Civil 3D significantly simplifies the work with drawings and the release of the necessary documentation. (Ignacy Lozinski, 2021)

Focus CAT (Civil Advanced Tools) is a BIM application for Autodesk Civil 3D. Focus CAT Basis contains template files adapted to Norwegian conditions and several tools for handling and calculating terrain models, as well as importing and exporting Norwegian file formats such as SOSI or KOF. (Ignacy Lozinski, 2021)

Gemini Terrain is a Norwegian-developed tool used by most of the construction professionals in Norway. Software used for designing models for tunnels, roads, construction pits. Automatic calculation and visualization of all terrain interventions provides a complete overview of the situation before and after. (Ignacy Lozinski, 2021)

Autodesk Infraworks widely used in Norwegian companies that use Autodesk programs. Infraworks offers a conceptual design capability, analysis and simulation, visualization, context modelling. Infraworks works seamlessly with Civil 3D and Navisworks which give designers more flexibility in their design process. (Ignacy Lozinski, 2021)

3.4.3 Validation software

dRofus is a a cloud-based solution made in Norway. The software is used to plan and manage data at all stages of a project for all types of buildings, including some of the largest, most complex, and iconic buildings in the world. dRofus has strong ArchiCAD, Revit and IFC integration with bi-directional data sync capabilities, unique numbering of all rooms, import design models in IFC format, visualize and view the actual location of the rooms. (Ignacy Lozinski, 2021)

Here, a dynamically changing information model of the object is formed, which contains structured up-to-date information. dRofus fully supports Open BIM, which allows you to combine and include all participants in the creation of an object in a single process. The system has a visualization module. (Ignacy Lozinski, 2021)

Simple BIM allows validate, clean up, standardize, enrich IFC models, this tool used in Norwegian government organization Statsbygg. Simplebim is an Open BIM application. The software can be used in merging and splitting, calculating quantities and much more features for validation process. (Ignacy Lozinski, 2021)

4 Norwegian BIM regulations

Along with other Scandinavian countries, Norway has been working on various aspects of BIM technologies for a long time. This work is actively taking place in the field of building construction and in the field of highway management.

For the accelerated adaptation of technologies in the field of construction, the Norwegian government organization authorized for construction publishes a practical guide. Statsbygg and Norwegian Homebuilders are two organizations that are responsible for the construction, management, and development of all public and government facilities. They have been using BIM for their projects since 2007 and have required FIM compliance since 2010 (buildingSMART Australasia 2012).

Together with government organizations, companies create their own manuals for information modeling and apply it to their projects, but there are also manuals that are available to the public.

4.1 Statsbygg BIM Manual 1.2.1

This manual was released in 2013 on Statsbygg's official web page. This document is available in Norwegian and English languages. The purpose of BIM Manual 1.2.1 is to describe Statsbygg's requirements to Building Information Models in IFC format. The manual based on previous version 1.0, 1.1, 1.2 of manual that are available only in Norwegian. This BIM guidance is used as a mandatory requirement for all projects above €5 mill. It is therefore important to be aware that only parts of the requirements can be checked automatically. (Eilif Hjelseth,2017)

Chapter A of the document presents the objectives and references to the normative documents based on which the manual was created, definitions and abbreviations used in the text.

Chapter B of the document presents the basic requirements for the design process in the BIM methodology. Specifies in which formats the models should be presented, how they should be named. The BIM must be presented to the client in the IFC 2x3 and ifc XML format, in addition to the IFC (which is the main result), the original modeling format (e.g. **.rvt** files from Revit or **.pla** from Archicad).

Chapter C provides the basic requirements for information models at different stages of the project. It includes default modelling requirements to architecture, landscape architecture, structural, mechanical engineering, fire safety modelling etc. The review on default requirements for architectural and structural below.

An architectural model usually includes parts of other areas, for example, electrical and mechanical equipment of a building and structural foundations of a building. The architectural model should contain supporting structures - columns, ceilings, slabs, internal and external walls. All stairs, ramps, elevators, and escalators must be modeled.

Section C contains, in fact, for different level of development in different stages (Outline conceptual design, Full Conceptual Design, Coordinated design, procurement and full financial authority), as well as for different sections of the project.

Structural modeling includes all load-bearing structures, considering data on the type, material, geometry, location, connection, and dimensions of the structure. All types of connections shall be modelled. The LOD should depend on the contract and should be agreed with all participants of the project.

Chapter D presents the requirements for the analysis of the design solution. Autodesk Navisworks and Solibri Model Checker (SMC) act as a program for visual IFC verification files. The architectural and structural models are checked for the correctness of the structure of the building and the floor and the correctness of the relationships between the building objects, the “legal” dimensions for certain types of objects, the placement of components (objects should not hang in the air), checking for collisions or waddling objects and other tests including collision analysis, energy conservation, accessibility analysis etc.

Chapter E presents additional report results that may be required. Certain stages may require DXF, DWF, DGN, P (plotter file) etc. drawing formats, model export to other formats, open BCF format may be required.

In general, this document will be useful only at the design stage of buildings.

4.2 Statsbygg BIM Manual 1.3

The SIMBA 1.3. requirements are based on Statsbygg’s BIM Manual 1.2.1 (SBM1.2.1) from 2013. SIMBA 1.3.1 consists of three main parts: machine readable requirements, non-machine-readable requirements, guidance to requirements.

Statsbygg introduces a new methodology for specification of requirements and verification of BIM results to improve the quality of results. The machine-readable requirements of SIMBA 1.3.1 are based on the requirements of SBM 1.2.1

General requirement all object classes must be exported to IFC with all properties.

Additions to the requirements described in SBM 1.2.1 are formulated in Part 3 of the document. The new requirements relate to the delivery of the model to the archive, machine validation, and other requirements that relate to machine readable requirements.

The document is a formalization of the current requirements for the interdisciplinary TFM tag system; commissioning of the coding of the process state - the "Model Maturity Index" (MMI), which format it should have, in the form of a single line and/or separate elements of the TFM line; the requirement to deliver the model to the archive at the end of each stage.

4.3 SIMBA - Statsbygg's BIM Requirements 2.0

The SIMBA 2.0 requirements are developed SIMBA 1.3, so it is based on Statsbygg's BIM Manual 1.3. The set of requirements describes new requirements for the landscape subject and for the premise subject fire safety and acoustics. Applies to all new projects from 1 July 2021. SIMBA 2.0 sets requirements for exchange and delivery on IFC4. This document also available in English. A new version SIMBA 2.1 will be published in summer 2022 with some changes that will cover interior architecture, water supply, and sanitation and other parts that's in processing.

4.4 HB V770 Modellgrunnlag. Krav til grunnlagsdata og modeler

HB 770 model base. Requirements for basic data and modeler is an English version of the document name. This guide is a requirement for basic data and models in the road construction industry for which BIM technologies are used. The manual consists of 22 chapters. The entire document can be divided into an introduction to BIM, requirements for initial data for design, requirements for information models, as well as the functions and responsibilities of the parties to the contract.

The purpose of HB 770 is: to ensure uniform requirements the quality of the source data, the widespread introduction of 3D design, standardization of the description of object models, the use of open standardized formats, the use of information models when performing work at the construction stage, standardization of the presentation of final documentation at various stages of the project.

The document is quite convenient and detailed, with a lot of references to standards In Norway, unfortunately only the Norwegian version is available.

4.5 Norwegian Home Builders' Association. BIM used manual

Chapters 1-5 of this manual are a theoretical basis, there are no requirements, in chapter 6 there are checklists with the help of which the work is monitored. In this section there are tables that indicate the evaluation parameters at each phase of the project for all disciplines involved in building modelling.

4.6 International standards

The digital construction and BIM process requires the creation of standards that provide a framework for the management and exchange of information in projects where BIM is used. Many international standards are relevant and are references for the Norwegian manual. Standard Norge has a web page about digital process and BIM regulations.

NS-EN *ISO 19650* is an international standard for information management throughout the life cycle of a building using BIM. This document describes information management using BIM and terminology. The standard applies to the entire life cycle of buildings, including strategic planning, design, development, execution, usage (operation), maintenance, reconstruction, and disposal.

NS 8360 currently consists of two parts. NS 8360-1 defines digital model construction methods, design description, automatic quantity calculation, investment cost calculation, CO2 emissions calculation, Life Cycle Cost Calculation (LCC), sustainability calculations, production management, progress planning and sizing. This document is not widely used but it exists.

There are two standards promote increasing efficiency of processes and more reliable exchange of information. It is *ISO 23386* and *ISO 23387*. ISO 23386 allows you to unify the exchange of information between data dictionaries. ISO 23387 describes the principles and structure of computer templates used to describe the properties of construction objects.

Knut Sandvik notes that the European BIM standard, CEN/TC 442, is beginning to be required for projects in Norway as well. CEN/TC442 will define methodologies for the digital definition, description, exchange, monitoring, recording and secure processing of asset data, other external data which other TCs will then adopt.

NS 3420 is used to prepare descriptions and quantitative lists. The standard is also used in several contexts during the operation and maintenance phase, as well as during the restoration and reconstruction of buildings and structures. (Standard Norge)

5 Results of questionnaire

Of the 44 contact persons from different BIM-related companies to whom the survey was sent, only 3 responded by the closing date. One of these responds answered most of the questions. It is important to note that some questions in the questionnaire were skipped and not answered. Appendix 1 provides a questionnaire that was conducted as part of the research.

The questions in the questionnaire are divided into blocks related to House, Infra, City modeling and the origin and scope of respondents. It was asked for what purposes BIM is used in the country, how data is exchanged, what software is used, etc. The questions on the structure were with the options of one answer, a question with several answers, as well as a free answer where it was possible to express the answer in writing.

All respondents were associated with Infra Modelling, and only one of the persons participating in the survey specialized in Infra and House Modeling.

5.1 House modelling

Based on the answers of the questionnaires, it can be concluded that BIM in the country is used mainly for structural and architectural design and for construction planning. Water supply and sanitation, electrical engineering, cost analysis and others are developed without the participation of BIM. BIM is not used in all projects, but only if the customer requires or the cost of the project exceeds a certain amount and exceeds a certain area. Graphisoft ArchiCAD is used for architectural design in Norway, and for structural Trimble Tekla Structures. Autodesk Revit + MagiCAD is used in the design of HVAC rooms, water supply and sewerage, and Autodesk Revit is used for electrical engineering.

These questions were answered by only one respondent, so it is impossible to be sure of the universality of the use of this software throughout the country. But based on these answers, it can be understood that there are specialists in Norway who can work with different programs for different disciplines.

5.2 Infra modelling

2 out of 3 respondents noted the high prevalence of infra model in projects, one found it difficult to answer this question. These answers are confirmed by a large number of infra projects using BIM, which can be found on open sources. Two respondents noted that infra models used area planning, design coordination and quality control, quantitative selection and cost estimation, construction management. Only one respondent noted that for lane

design, pipe networks, equipment management in infrastructure projects, schedule. According to the survey results, it can be concluded that the infra model is more actively used for different disciplines compared to the house model. 50% on figure means 1 answer, 100% means 2 answers (Figure 5).

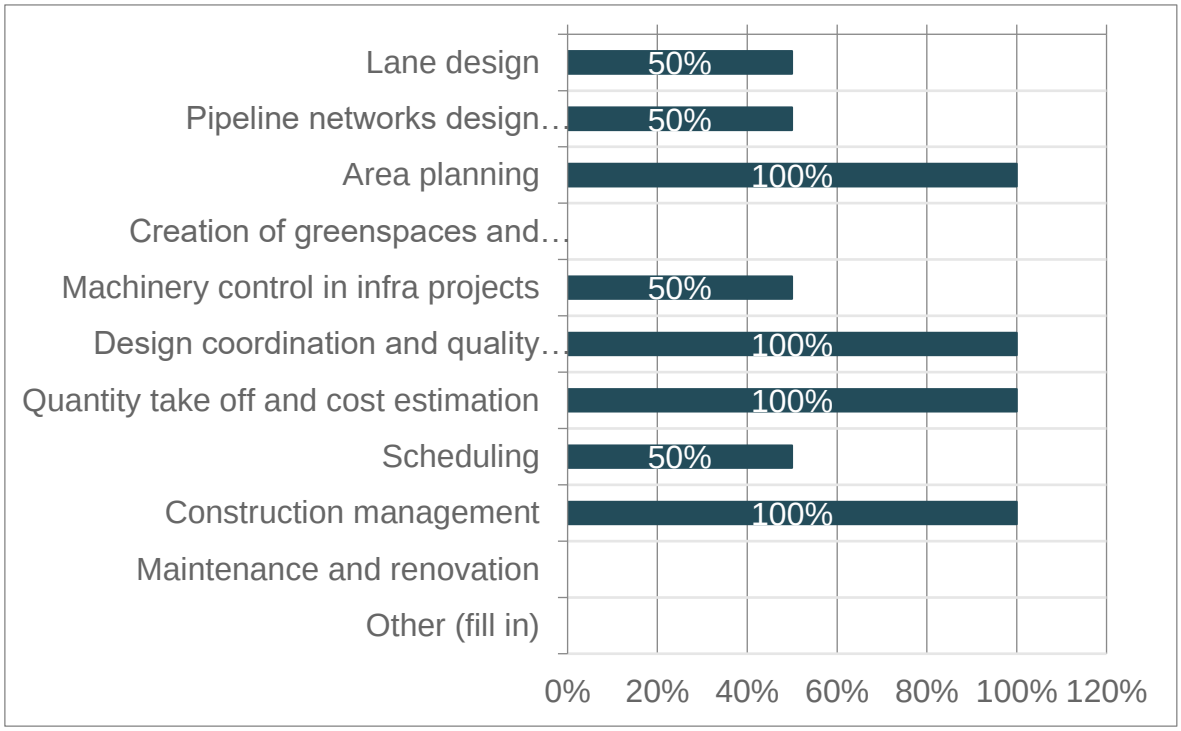

Figure 4. Typical use of infra model

One of the questions in the questionnaire was a question about software that is used in different disciplines in Infra Modeling. Respondents did not mark the entire list of software that was described in the Ignacy Lozinski article in 2021. Based on this, the software from questionnaire is more extensively used (Figure 6).

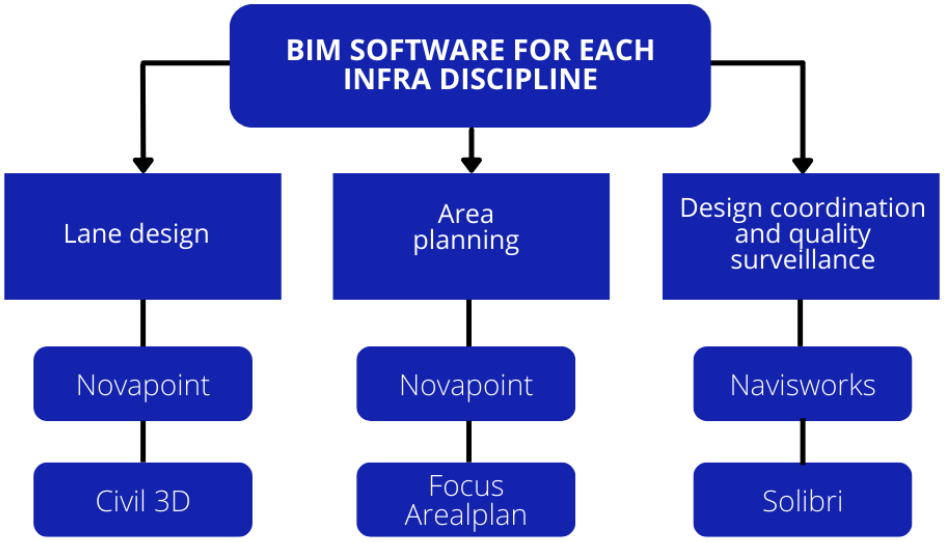

Figure 5. BIM software for Infra Modelling

In the question on the use of infra models in the construction of buildings or industrial construction projects, the opposite answers were received from two respondents. One of the respondents notes that infra models are used for large projects and in this case face difficulties in the form of lack of standardization and life cycle orientation in information requirements. another is that infra models are not used in such projects.

Proprietary formats are widely used for collaboration now. But there are changes towards open BIM, and it is expected that within a year or two it will be mostly openBIM.

5.3 Summary

More information has been collected about infra modeling than about house modeling. It is strange that experts answered polar answers to one question, the reason for this may be different levels of involvement in large projects. House modeling is used for a narrow range of disciplines, the use of BIM in infra modeling covers more disciplines in Norway.

According to the results of the questionnaire, graduates are familiar with software databases and mostly fit the requirements of the employer, sometimes additional trainings are required to increase the level of skills in using BIM.

The respondents had a question about the reasons for the problematic development of the use of BIM technology in the industry in the country, they noted that little interest and lack of knowledge in most plays a key role, the program is also problematic in some universities, where there is an insufficient number of hours on BIM technology, as well as a lack of national standards and regulatory documents.

It is important to understand that the results of the questionnaires are very restricted, so the conclusions and graphs cannot accurately reflect the real place of BIM in Norway.

All the questions that were provided by the respondents are given in Appendix 1. The list of questions is important for understanding what information we expected to receive during the research. Also, a cover letter can be found in Appendix 2, which was sent to all respondents. It explains the essence and objectives of the study, as well as a link to the questionnaire.

6 Conclusions

Based on the research, it can be concluded that the level of BIM application in Norway is quite high, large companies actively use the software in their projects. This success in the application of technology is due to the active participation of the state in the regulation of the industry and the direct influence of the buildingSMART organization.

Statsbygg actively supports the use of open international standards. In the field of BIM, buildingSMART open standards such as PC, bsd/ID, BCG and mvdXML are of great importance. GS1 open standards, such as GTIN and GLN and OGC standards on GML, are equally important for their applications.

International companies COWI, buildingSMART in collaboration with NTU University conduct courses for students who want to get a practical overview of BIM software.

Norway uses world-famous programs and promotes its developments in the field of software. Government organizations associated with infrastructure or buildings create guidelines and requirements for projects, which specify the requirements for models, drawings and documents.

One of the main indicators of determining the level of BIM application in Norway was a questionnaire. As the questionnaire and research of open sources of the network showed, urban modeling has not found support from government organizations and is not developing in the country. Other areas of construction are actively using technology in their projects.

Several professors from the Norwegian University appear at international presentations and speeches. Not many BIM specialists from this country are in the international arena and talk about the BIM experience in their country and publish their articles on open resources.

Norway is a small country where large international companies set the trend and everyone else must listen and implement technologies in their work. International companies participate in BIM competitions and receive awards for their projects, adopt the experience of other countries and optimize their work. The company's specialists also receive awards for their projects in competitions at the international level. So, Hilde Stokvik Eide received an award for the project by Stavanger Hospital, which was named the best digital construction project in the world by Autodesk at the international conference. Marius Sekse and Knut Hallgeir Wik received their award for their contribution to standardization from Digital Landscape Architecture 2018 in Freising.

Due to government support and the companies' own initiative, the level of BIM application in Norway is at a high level. The country started its BIM journey more than 10 years ago and is now a leader in BIM technologies.

Despite the fact that open sources write about the high level of BIM application in the construction industry, the survey showed that there are a number of problems in the country due to which the development of technology is slowing down. Based on a small analysis of the questionnaire, it is impossible to draw unambiguous conclusions that the real situation is very different from the situation described in open sources. The questionnaire was aimed at identifying the problems that specialists face in real life. The results of the survey, where some problems were identified and the ignorance of graduates about BIM technology does not negate the fact that Norway is at a high level in the use of BIM.

The survey confirmed that the requirements for BIM are set depending on the customer and depending on the size of the project. But respondents also said that there is lack of regulation of the industry in infra modeling. Since Norway is still in the development stage, it is possible to predict the correction of these regulatory holes soon, since the first steps have already been taken by the state organization Statsbygg and other organizations that have prepared guidelines for the use of BIM.

Respondents expressed their hopes for the future wider use of technology. The hope was expressed by respondents to ISO 19650 specialists, but the Norwegian industry does not accept it yet, there is also an assumption that BIM will be used not only to build a model, but also for cost estimation, planning, coordination, maintenance, and operation. So, Norway is on the way to expand BIM dimensions and start using the potential to a greater extent than it is now.

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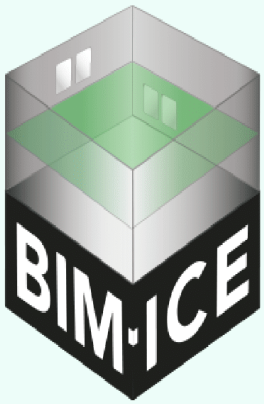
Appendices

Appendix 1. Survey questions



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?

Appendix 2. Survey contact letter

Dear [person's name],

My name is Anastasiia Kuzmina I am a double degree student in LAB University of Applied Sciences in Finland.

I am writing my bachelor thesis about the BIM-use in Norway for the BIM-ICE project, which is currently benchmarking the BIM-use in five European countries. We have understood that the BIM-competence is at a high level in your country and BIM is extensively integrated in the building processes. Thus, we would be willing to learn more about these issues in your country.

In the BIM-ICE project we are developing BIM-education in the LAB University of Applied Sciences. Benchmarking the status of BIM-use with other countries will help us to identify the development needs.

We have created an online survey to collect insights about the BIM-use in the construction sector. The survey is targeted to BIM-experts in five countries selected for benchmarking. The answering is anonymous and will take 15-20 minutes at maximum.

Please feel free to send this link to also your colleagues who might be competent and give answers to the survey?

Link for the questionnaire will close on 21st of May. Please find the survey here: https://link.webropolsurveys.com/S/DFB7D37B9C3D464E

The BIM-ICE project (BIM-Integration in Higher and Continuing Education, 2020-2022) is financed by the EU. More information about the project: https://bim-ice.com/

BR
Anastasiia