Centre for Digital Built Britain Mini-projects Programme 2017-18

International experiences: Future Cities and BIM

Final Report

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DR. FRANZISKA SIELKER & PROF. PHIL ALLMENDINGER

Department of Land Economy

17-21 Silver Street, Cambridge

UNIVERSITY OF CAMBRIDGE

Executive Summary

At the same time as the digitalisation of the construction industry rose in the form of Building Information Modelling (BIM), global urbanisation has developed apace, with more than half of the population world-wide living in cities. These developments coincide with increasing calls for low carbon societies and energy efficient buildings. BIM solutions are widely claimed to allow improvements in energy and cost-efficient building allowing cities to develop more sustainable. The use of information modelling in BIM can therefore be of particular interest to city development. It is worth noting that BIM is not a uniquely UK phenomenon and work is underway in different countries to develop and deliver the advantages of digitalization in the built environment. On the contrary: in a worldwide comparison the UK is a relatively late-starter, with now, however, a substantial commitment. Against this background the goals of this research project are

- *to review cities engagement with BIM,*
- *to provide a comparative analysis of international experiences with BIM,*
- *to inform policy making through a set of recommendations and identify further research needs.*

Our initial research findings revealed that cities play a much smaller role than expected given the push for smart city development. In coherence with the CDBB Mini-project on Urban Planning and BIM, we instead found that contemporary BIM strategies are largely driven by national governments: local planners and stakeholders are not yet aware of BIM and far from having a vision of a BIM supported city development. Despite a general awareness of BIM in cities with dedicated smart city strategies, as a rule, cities have no BIM strategies, representatives or in most of the cases awareness for the potential use of BIM for their city development.

In order to identify how cities' engagement with BIM can be supported, the questions this research addresses are twofold:

1. Cities and BIM: (I) How are cities adapting to BIM? What awareness is there of BIM in future city thinking and strategies particularly around Smart Cities? (II) What are the drivers of BIM? What issues are being addressed through BIM? What are the barriers to BIM in future city thinking? (III) What are the experiences of BIM and what research, evaluation and policy exist?
2. International experiences and BIM: (IV) Which countries commit to BIM, and why? In what ways do national strategies target city development? (V) What tools and policies are being used in different countries to take forward BIM and how do countries aim to foster sustainable city development through BIM? (VI) What are the success factors for some countries? What makes a successful BIM strategy? Why are some countries more advanced than others?

We commence the review of international and European experiences by summarising world-wide activities and describe the European policy framework. Methodologically, we address this research through desk research, including academic literature, blogs, company websites, governmental publications and policy documents as well as through semi-structured interviews. Given the relatively recent development of digitalisation of the construction industry it is not surprising that the broad set of policies is still under development, or in many countries just at the stage of experimentation.
We analyse six case studies by presenting national governmental strategies and their policy framework and by presenting illustrative examples of BIM implementation. The case studies include European and international forerunners in BIM: USA, United Kingdom Denmark, Germany, The Netherlands and Singapore.

The analysis of different countries' strategies to foster the use of BIM in the construction industry shows a significant diversity in the mix of regulatory, financial and other elements. In short, strategies include the public sector taking the lead, standardisation, incentives for BIM adopters and requirements on calls, removal of impediments, capacity building and best practice examples. Common elements in BIM strategies are the definition of standards and support of BIM through requirements in tenders on governmental projects, in particular for infrastructure projects. Few countries have developed a particular financial incentive through dedicated BIM funds and through education measures. In general, the research suggests that a provision of a governmental framework and the amendment of the legal systems plus the definition of standards are somewhat the basis for BIM development.

BIM can give a new momentum to rethink the future city development. We conclude that in order to better make use of BIM for city development, the momentum of smart cities strategies can be better exploited. The opportunity to link data from BIM modelled construction sites for the wider city development is captured under the concept of City Information modelling (CIM). BIM and CIM can be understood as enablers for smart city development. City Information Modelling can lift smart city development up to the next level, and integrate the information provided by BIM for city planning and development. The recognition of the urban level would however be needed to be recognised in national strategies, e.g. through the planning provisions, support of e-planning or education. Further research is needed to explore how planning and national strategies can support the lower levels to integrate BIM and collaborate with the construction industry.

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"So what is BIM Level 3? That's like asking back in the early 1990s, what will today's internet look like? We now know the internet can be anything; its open source approach and classification of data has made it part of everyday life. BIM Level 3 will invoke disruptive change in the same way." (Terry Stocks 2016)

1. Introduction

This decade has seen the rise of Building Information Modelling (BIM) – the digitalisation of the building industry and construction sector. Nevertheless, BIM seems to still be somewhat misunderstood and lacking in visibility. This report contributes to demystifying BIM through a comparative analysis of international BIM approaches and some illustrative examples.

New technologies have historically been a feature of building design. Early forms of 3D-modelling and data sharing have been used for architectural design for over two decades. Yet it was not until the early 2000s when a more integrated approach to Building Information Modelling became possible through new technologies, improved availability of data and the increasing use of cloud-based common data environments. At the same time global urbanisation has developed apace, with more than half of the population world-wide living in cities. These developments coincide with increasing calls for low carbon societies and energy efficient buildings. BIM solutions are widely claimed to allow improvements in energy and cost-efficient building allowing cities to develop more sustainable. The use of information modelling in BIM can therefore be of particular interest to city development. In order to realise the full extent of the economic opportunities DBB's scope was extended in February 2016 beyond construction efficiency to include information to support the growth of our cities, emphasising the strong link between the success of cities and economic growth as well as wider social and environmental benefits of DBB to the built environment. Cities are a key enabler to productivity and economic development. However, they are currently acting as a brake on economic growth. Traffic congestion cost the UK economy £31bn in 2016 and the NHS spends £600m per year treating illnesses caused by living in poor housing conditions. The increase in the UK population and changing demographics (in particular an aging population), will place significant strain on the existing built environment and the services it provides further limiting economic growth. In addition to attempting to realise the full economic benefits of DBB by focusing on cities as well as buildings there are also social and environmental benefits that can flow from coordinating and integrating BIM at different spatial scales. For example, more accurate material ordering leading to less waste to landfill and optimised simulation of energy analysis leading to lower energy demands from the built environment and help lower greenhouse gas emissions. Social impacts can arise from engaging with the public and communities in the assessment of future needs in the built environment, helping better coordinate planned infrastructure investment, building design and location.

Cities are at the forefront of many of the societal challenges that BIM seeks to help address, e.g., housing affordability, the impacts of climate change, ageing infrastructure, traffic growth and congestion. Yet the relationship between city development and BIM is largely unknown. Across the World countries and cities constitute a 'policy laboratory', approaching the integration of common BIM principles in different ways that reflect unique challenges and distinctive political, administrative and legal cultures, ways that could provide valuable lessons and experiences on the roll out of BIM.

It is worth noting that BIM is not a uniquely UK phenomenon and work is underway in different countries to develop and deliver the advantages of digitalization in the built environment. On the contrary: in a worldwide comparison the UK is a relatively late-starter, with now, however, a substantial commitment.

The questions that this research seeks to address are:

I. *How are cities adapting to BIM? What awareness is there of BIM in future city thinking and strategies particularly around Smart Cities?*
II. *What are the drivers of BIM? What issues are being addressed through BIM? What are the barriers to BIM in future city thinking?*
III. *What are the experiences of BIM and what research, evaluation and policy exists?*

In our initial research we immediately identified that the urban level has largely not taken up BIM as a development opportunity. Cities play a much smaller role than expected given the push for smart city development. In coherence with the CDBB Miniproject on Urban Planning and BIM, we instead found that contemporary BIM strategies are largely driven by national governments. We further elaborate on this initial finding in the next question. These initial findings led us to enlarged the scope of our research and ask why it is that some countries are more advanced BIM than others:

IV. *Which countries commit to BIM, and why? In what ways do national strategies target city development?*
V. *What tools and policies are being used in different countries to take forward BIM and how do countries aim to foster sustainable city development through BIM?*
VI. *What are the success factors for some countries? What makes a successful BIM strategy? What makes countries world leaders in BIM?*

Table 1 Research Methodology.

Aim	***Method***
a – Review of cities engagement with BIM: experiences, adaption to and awareness of BIM.	*Desk and internet research, literature review and exploratory interviews: identification of local constituencies and government sectors involved in BIM, analysis of practices and smart city strategies and local plans based on an initial selection of cases known from our own research on smart and resilient cities and the work by Future Cities Catapult. Review of existing literature and research on planning and BIM.*
b – Review and comparative analysis of international experiences with BIM: issues, strategies, drivers and barriers	*Desk and internet research, literature review, case-study identification and semi-structured interviews: identification of leading BIM nations, analysis of six case studies in which national BIM strategies have been developed, examination of exemplary implementation projects, interviews with BIM experts on the experiences and national strategies needed ranging from key persons in government to the European BIM Task Group and the UK BIM Task Group. Comparative analysis of strategies to gauge BIM and assessment of success-factor based on interviewees reflections, analysis of current implementation practices of BIM.*
c – Inform policy and policy makers and make recommendations for change.	*Report for the Centre for Digital Britain Website setting out findings and making recommendations; identifying areas for further research.*

The report is structured as follows. First, we expand on our initial research findings of cities adopting to BIM and their awareness. We position the urban level between the political multi-level governance system and the project level implementing construction projects. We, second, summarise the global landscape of BIM implementation at the national level as well as the European policy framework. Third, we present six case studies of international BIM strategies. These case studies highlight the approaches, thematic focus and challenges to the further roll-out of BIM at the city level. Fourth, we provide a comparative analysis to identify success factors for BIM implementation, and the role of different governmental level including the urban level, before we conclude the report with a number of recommendations on going forward and recommendations on further research needs. Throughout the report we present illustrative examples of BIM practices.

2. Initial research findings – Cities and BIM

This research has been exploratory in nature. Initially we started off with the proposition to compare practices of BIM strategies in cities across Europe. Soon it became clear that BIM remains a goal set by many countries, often being delivered through limited individual projects. Some countries and cities set benchmarks in BIM implementation. One well-known example is Singapore, which as city state has the potential to link national guidelines and regulations with urban developments.

Many cities and public agencies use BIM to some extent, or at least a form of "pseudo"-BIM, by making use of CAD software for planning purposes. These planning documents are then shared with other stakeholders, such as architects, developers or engineers.

BIM can be used for a set of different activities in the lifecycle of construction:

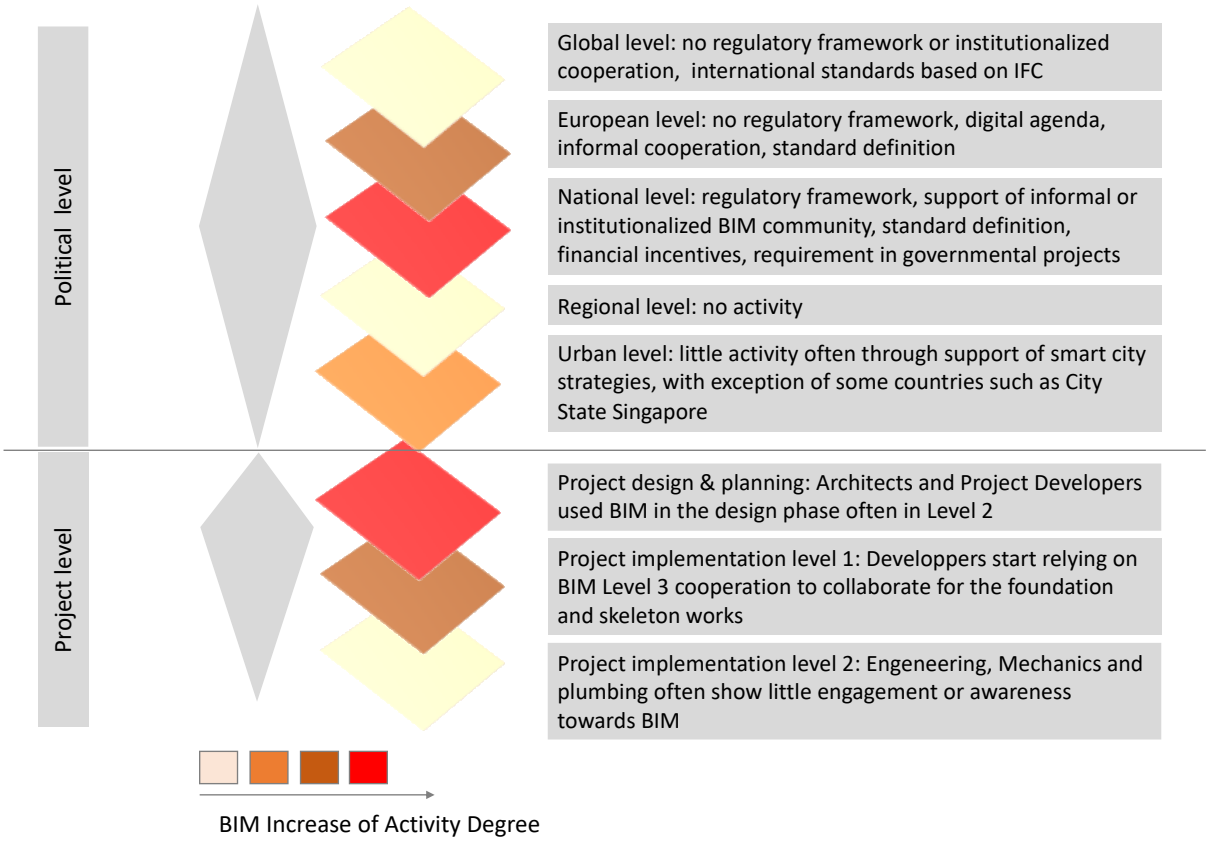
- *Project planning (standards, data inclusion, finances and property, etc.)*
- *Project design (construction materials, geophysical conditions, etc.)*
- *Project implementation (safety regulations, contracting, quality management, scheduling, etc.)*
- *Asset management (supervision, ownership documentation of repairs, life-data analysis, etc.)*

When it comes to city development it is somewhat surprising that despite the strong push towards smart city development (see excursus below) few cities worldwide are actively engaging in BIM. Exploratory conversations revealed that there is an above average awareness of BIM in cities with smart city strategies. Nevertheless, as a rule, cities have no BIM strategies, representatives or in most of the cases awareness for the potential use of BIM for their city development. These international experiences coincide with the results of CDBB twin-project on Urban Planning and BIM: local planners and stakeholders are not yet aware of BIM and far from having a vision of a BIM supported city development. The reasons are manifold. One reason is that BIM is largely seen to be useful for collaboration between architects, engineers and construction processes. The opportunities for BIM in planning and for planning taking forward BIM is rarely exploited. One reason might be the lack of skills and the lack of awareness. A set of exploratory telephone conversations confirmed that a key point in the delivery of BIM for cities is a consistent national framework, which offers guidance, standards, regulations and financial incentives. A reason is that a city planner would not want to interact on different data platforms for different projects. The national policy framework is considered as a key framework which enables cities to make use of the proposed advantages of BIM and provides the backdrop against which cities can make use of BIM to address societal challenges.

Given the relatively recent development of digitalisation of the construction industry it is not surprising that the broad set of policies is still under development, or in many countries just at the stage of experimentation.

Table 2 illustrates and summarises the different activity degrees of BIM activity in the political multi-level governance systems. While the global and European level support BIM delivery through standardisation of formats and files, the main activity level is currently at the national level, which in many cases currently develops national strategies, sets a regulatory framework alongside the provision of legal accountabilities and importantly experiments itself through requirements by government-led projects. These are often infrastructure projects and buildings of public institutions such as hospitals. These buildings often provide an example for other urban actors.

Table 2 Initial Finding: Degrees of BIM Activity.



Source: author's analysis.

The high number of infrastructure projects that start their development with BIM strategies indicate the potential for large-scale opportunities. The different type of projects that can be delivered through BIM, and that can provide real-time data for these assets offers a number of opportunities for cities to link to planning and different citizen uses and needs. The opportunity to link data from BIM modelled construction sites for the wider city development is captured under the concept of City Information modelling (CIM). BIM and CIM can be understood as enablers for smart city development.

Excursus: City Information Modelling (CIM) and BIM – a turn in smart city development?

After the establishment of BIM and the engagement of Architecture, Engineering and the Construction Industry, pioneering cities now experimenting with using intelligent modelling for city development. This movement to use digital infrastructure at the broader level of 'human habitation' or the city offers new opportunities to link urban planning and urban design with BIM – CIM is the idea to develop a digital DNA of cities.

There are clear advantages of information exchange between individual buildings and city infrastructure. An individual building is not developed in isolation. It is necessarily integrated in its build environment, such as utilities and infrastructure. The provision of services to buildings, e.g. energy, differs between the use of buildings in a city depending on their use. For many the city of the future is somewhat linked to the use of data flows and new technologies.

The basic idea is to have a city model which contains information about different entities for the cities and allows to link different information. CIM can be used to provide simulation of traffic flows, congestion, energy use and provision, smart grids. Currently CIM is used in the insurance and reinsurance industry to analyse the impact of natural disasters such as floods, earthquakes or storm events.

The digitalisation of cities is known to citizens and planners as "smart cities". Similar to normative goals of a more effective and efficient city development promoted by CIM the smart city concept aims to provide smart planning and connectivity for a liveable city. Smart city initiatives are to be found all over the world, with each concept highlighting different elements. There are by now numerous initiatives and definitions. Commonly definitions describe smart cities to encompass a modern and secure digital infrastructure, delivery of services through user focused offers, offers to inform decision making based on just-in-time data analysis, transparency of service provision and the use of new technologies. The areas in which smart developments are employed are for examples transport systems (e.g. to avoid congested roads or improve parking management), support for citizens and their life (e.g. in the health sector through telecare or in education), smart grids and energy networks, waste and water management), e-government, broadband services and public WiFi. Smart city development is therefore connected to the idea of (1) public services, (2) infrastructure, (3) green building and a low carbon society. Notable examples are San Diego, Singapore, Barcelona or Amsterdam.

In short, the difference between the broad smart city concept and CIM is that smart cities involve much more than technology and focus on the idea of a liveable city for citizens based on policies, politics and governance that may make use of new technologies. City Information Modelling can lift smart city development up to the next level, and integrate the information provided by BIM for city planning and development.

City Information Modelling focusses primarily on the use of digital information for the purpose to assist in planning and analysis of a city. This can include real-time monitoring or simulation in the planning process. There, leading companiesin BIM software have already experimented to develop and expand their software with a CIM portfolio (these are exemplary Autodesk and Bentley). These softwares allow the analysis of 3D City through 360 Degree views. An example is Berlin. Based on a concept by Virtual City Systems a 3D Modell of Berlin has been development, which is free for download (see: http://www.businesslocationcenter.de/berlin3d-downloadportal/)

The potential of CIM in support of planning future cities has recently been recognised in academia. Thompson et al. (2016) highlight for example, that while data modelling and visualisation in urban planning

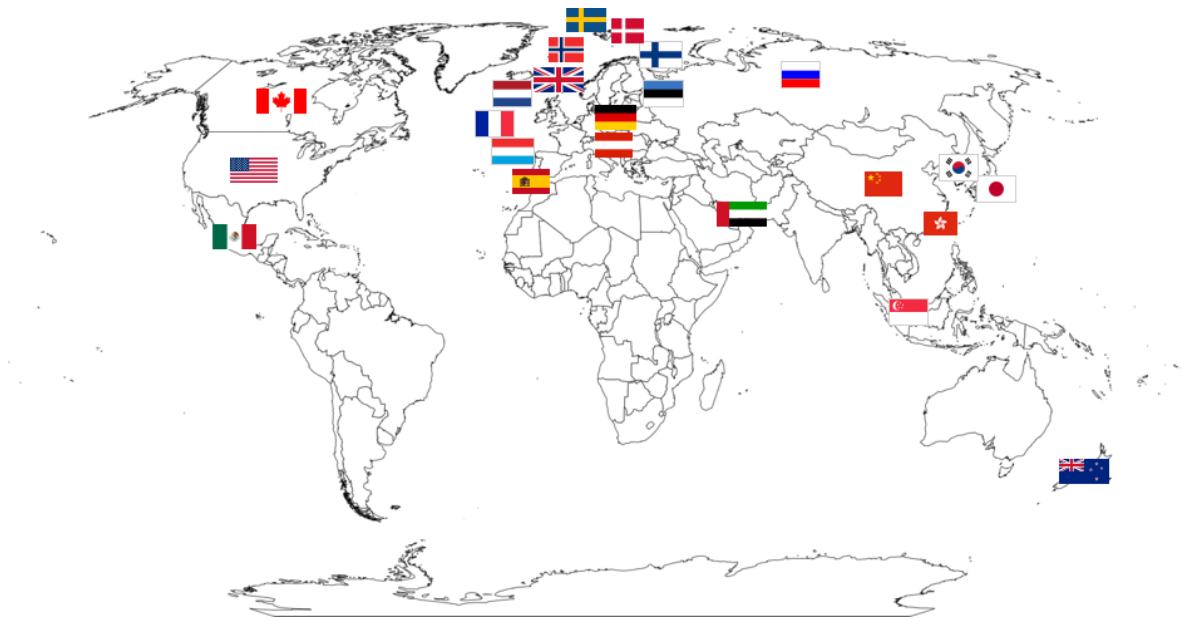
can contribute to better informed decision-making by planners, the accessibility of data, accuracy and consistency of data manageability and integration of data remain challenges in making use of CIM. They reiterate that sustainable urban future can be delivered by making use of this data, interpreting it and ultimately develop policies.

3. Global and European experiences

3.1. The global BIM landscape

We commence the review of international and European experiences by summarising world-wide activities. The implementation is led by a number of pioneering countries such as the USA, Estonia, Germany and the UK, and is followed by new adopter countries such as Korea, New Zealand and Canada. Further countries such as Peru and Chile are starting to think about BIM and look likely to require BIM by the end of the decade. The USA are considered as one of the early promoters of BIM adoption. Finland is the first nation to have adopted BIM building standards. Apart from Northern America, and the generally very active North-western European countries, the Middle East and South East Asian countries are considered to be at the forefront of BIM usage. Dubai, for example, requires BIM in the development of buildings higher then 40 stories, for facilities or buildings that exceed 25.000m² or for all governmental projects such as hospitals, universities or similar.

Table 3 Active BIM countries.



Source: Own elaboration based on desk research, cartographic base downloaded from website lokado

BIM usage is accelerating forcefully prompting more countries to developing a strategic framework. Countries approach the implementation of BIM quite differently. This may encompass the development of national standards, BIM protocols, legal contracts, guidance documents, public pilot project, obligatory government projects, the development of project procurement systems, project databases and libraries, engagement indices, BIM education programmes, BIM funds, BIM awards, BIM network development, BIM

hubs, BIM taskforces and government leadership. Often countries provide some kind of regulatory framework alongside financial incentives.

The approaches of these strategies are extremely diverse and opinions towards what is to be considered as successful BIM implementation vary even more. In the following sections we will zoom-into some very active BIM countries to be able to analyse and compare different strategies. We aim to identify common elements in the strategies. Interviews with country and industry representatives will further allow identification of elements considered as instrumental in delivering BIM.

There is a broad relationship between those countries involved in BIM and an openness towards technological innovations, digital solutions and information and communication technology. Interestingly, all the countries that are leading the BIM development are leading in the ranks of the World Economic Forum's "Networked Readiness Index". This index measures countries readiness to exploit opportunities of information and communication technology. The World Economic Forum Global Information Technology Report identifies Singapore as the number one 'technology-ready' country (see Table 4). The table indicates in light blue countries explored as case studies in this research (see next chapter). All case studies rank in the top 15. Interestingly Estonia ranks as 24^{th,} which considering its size and history after the fall of the Iron Curtain is an astonishing development. Estonia is a world-leading country in the process of developing a digital society.

Table 4 Network Readiness Index.

Rank	Economy
1	Singapore
2	Finland
3	Sweden
4	Norway
5	United States
6	Netherlands
7	Switzerland
8	United Kingdom
9	Luxembourg
10	Japan
11	Denmark
12	Hong Kong SAR
13	Korea, Rep
14	Canada
15	Germany
[…] 24	Estonia

(Source: World Economic Forum 2016)

There are many other rankings and indicators comparing the advancement of information technology (e.g., smartphone use, internet speed, etc.). These rankings are an indication of the general priority given by national governments to support digitalisation processes, which are the basis for making use of BIM. The ways in countries then approach the process of digitalisation of the built environment and its construction differ considerably, with countries such as Singapore and Estonia setting a benchmark.

3.2. The European policy framework

The Juncker Commission has set the Digital Agenda as a priority in 2014, followed by a number of initiatives to make the EU a world leader in information and communication technology. This includes increasing digitalisation in cities and the built environment. The latest example for this strong engagement is the Digital Cities Challenge. 15 cities were selected in 2018 to receive coaching and facilitation from high level experts as they embark on their digital transformation journeys. The process of digitalisation on the city level is so far more targeted to support cities in unlocking their potential to use new technologies for delivering services for their citizens. From 2015 onwards, the European Commission has as well put the roll-out of BIM on the agenda.

In reviewing BIM literature, blogs and company websites authors consistently reiterated that global and national standards are necessary in order to achieve the results and efficiency envisioned by this technology (cf. Smith 2014). The European Union has made an important step in lifting the development of BIM standards up towards an international level.

With the idea to develop a pan-European approach to best practice in BIM, the European Commission awarded a two-year funding (2016-2017) for the EUBIM Task Group. The EUBIM Task Group aims to deliver a European network and bring together the different national efforts with the goal to align European approaches for a digital construction sector. The general vision of the group is to "to encourage the common use of BIM, as 'digital construction', in public works with the common aim of improving value for public money, quality of the public estate and for the sustainable competitiveness of industry" (website EUBIM). The group was co-funded by the European Commission's Directorate General for Internal Market, Industry, Entrepreneurship and SMEs (DG Growth) and the UK's Government's Department for Business, Energy and Industrial Strategy (BEIS). The latter was the lead coordinator of the programme, which involved public sector organisations from 21 countries (cf. EU BIM Task Group 2017).

The main output of the group was a handbook, which serves as a guidance to public authorities. The group concludes that a top-down leadership in BIM is a powerful tool. Governments need to closely collaborate with industry to achieve digital transformation. The group further argues for a coordinated public-sector action across borders. The handbook shall support government by providing a European common strategic framework and a common performance definition of BIM. The latter indicates the criteria that in order to be considered an EUBIM project procurement and delivering construction should be undertaken in a consistent way across Europe. This loose framework was chosen in order to not require any changes to legal frameworks in EU countries.

In October 2016 the EU has in addition adopted the so called buildingSMART international standards (CEN/TC 442: IFD (ISO 12006-3:2007). IFC (ISO 16739:2013) and IDM (ISO 29481-2:2012).

Apart from this Europe-focussed collaboration, a number of initiatives is underway worldwide. According to Adam Matthews, the chair of the EU BIM Taskforce, there is collaboration developing with a number of Asian countries, e.g. Vietnam, as well as an information and best-practice exchange with South American countries. The international BIM community is developing fast with more countries getting involved in BIM.

BIM Examples –The Rail Baltica Project

Rail Baltica is the largest Baltic-region infrastructure project in the last 100 years. The goal is to connect Helsinki, Tallin, Pärnu, Riga, Panevežys, Kaunas, Vilnius and Warsaw. The project includes Lithuania, Latvia, Estonia and Finland. The project integrates the Baltic States in the European rail network and is part of the EU's North Sea Baltic Ten-T Corridor. The investment is estimated to be more than 5billion Euros to deliver 870km of a multimodal rail line.

The joined Estonian Declaration of Intent on Digital Construction (August 2017) aimed at implementing BIM throughout all life-cycles of the Rail Baltica Project shows the necessity for political support to BIM. The current experience from neighbouring countries using BIM shows that it can save up to 20% on construction costs. The goal is to streamline the planning and building process and to optimise costs. According to the Ministry of Economic Affairs and Communication joining the digitalisation initiative is considered to send a signal to the construction sector and the designers that wish to participate in the future calls for this project. The project is further considered to deliver better functionality.

A call by RB Rail announced the tender for the development of a detailed BIM strategy for the Rail Baltica railway project. The tenders to be submitted in March shall address the following components: common BIM and CAD standards and guidelines, asset management systems, formats and structure of files and folders, level of detail as well recommendations for the IT infrastructure, common data environment and roles and responsibilities.

In the case of this transnational project there are now concrete common procurement procedures and BIM standards. Using EU standards the project aims to identify a BIM strategy in order to set the guidelines and data environment for the multiple standards and phases of the project. As the project is one of the first joint project of three EU countries the three countries established the company RB Rail which coordinates the tender and procurements.

For more information see:
website railbaltica: http://www.railbaltica.org/about-rail-baltica/
website Ministry Estonia https://www.mkm.ee/en/news/rail-baltica-project-joined-estonian-declaration-intent-digital-construction
website railbaltica BIM Strategy: http://www.railbaltica.org/tenders/development-of-detailed-bim-strategy-for-rail-baltica-railway/
https://www.dvz.de/rubriken/region/laender/osteuropa/single-view/nachricht/rail-baltica-bringt-europa-zusammen.html

4. International and European experiences: BIM in selected cases

In this research we focus on six case studies in which we identify national policy frameworks and BIM strategies. In some cases, we also present implementation examples of BIM in city and infrastructure development. The case study selection derives from desk research, document analysis, stakeholder analysis and our own previous research on Smart Cities and Resilient Cities and is informed by the Catapult Future Cities work. The main case study selection criterion was that the countries are relatively advanced in BIM development. A European focus was considered useful to relate the UKs activities within somewhat similar political and administrative cultural environment. Pragmatic considerations such as availability of information in English or German applied in addition. The case studies chosen are

1. *USA*
2. *United Kingdom*
3. *Denmark*
4. *Germany*
5. *The Netherlands*
6. *Singapore*

For each of the case studies the policy framework and national initiatives will be summarised highlighting the main stakeholders and experiences of success, and in some case examples of BIM implementation.

4.1. USA

The USA has been a pioneer in the usage of BIM. The General Services Administration (GSA) formulated the National 3D-4D Programme in 2003, which mandated BIM adoption for Public Building Services. The GSA is responsible for the construction of federal facilities and therefore has a leading role in promoting BIM. In 2007 the GSA mandated the use of BIM for validation of projects for all of their projects, essentially leading to BIM obligation for governmental projects from 2008 onwards. Despite the absence of a national strategy this early promotion of BIM for governmental projects has provided a thriving background for the development of trust and collaboration experience for all partners involved, which then later transmitted into the usage of BIM in private developments. The government pushed considerably for a development of a BIM community and partnered with a wide range of institutions. In 2009 Penn State University developed a leading role in the voice of BIM for facility owners. BIM requirements have been raised for example by the US Army Corps of Engineers, Departments of Transport, Air Force, or Coast Guards. As such not only the GSA, but several governmental institutions were instrumental in the usage of BIM e.g. in education establishments, healthcare facilities or airports. In the meantime, the NBIMS-US project from the National Institute of Building Sciences buildingSMART has developed standards to foster innovation in construction processes and infrastructure development.

4.2. United Kingdom

The United Kingdom aims to transform the UK into a BIM world leading nation within a relatively short timeframe. The ambitious programme started in 2011 with the UK Government Construction Strategy. The strategy sets the goal to require BIM on all governmental projects by 2016. The UK strategy foresees the implementation of BIM in Levels ranging from Level O BIM to Level 3 BIM (see excursus). This initial 5-year programme led to the BIM Level 2 mandate in April 2016. The identification of what is to be understood under BIM was redefined and concretised in this period based on initial experience.

In order to assist the implementation of this plan a UK BIM Task Group was established. This Task Group aimed to assist clients and the supply chain through an intensive collaboration between government departments, industry, academia and estate clients. In the revised Government Construction Strategy 2016-2020 the UK restates its ambition to develop a strong BIM-led construction sector. The announcement of the budget in March 2016 marks the start of the Digital Built Britain strategy. The goal is to deliver reductions in whole-life costs, develop a low-carbon industry and improve productivity by using intelligent building models and commit to Level 3 BIM. The Digital Built Britain Strategy describes BIM 3 as a broad approach. The UK approach to BIM seeks to set in motion experiments by private stakeholders with these new tools, which then will be defined over time. The government set up the Centre for Digital Built Britain to support the implementation of BIM. [1]

Excursus: UK BIM Levels

BIM Level 0: No collaboration, Output via paper or electronic documents. → Overcome by industry

BIM Level 1: Includes a CAD Common data environment and 3D-modelling for concept development, models are not shared between team members, and hence limited digital collaboration → Current status

BIM Level 2: Collaboration in the form of data exchange between the team members to develop 3D CAD models. The basic idea is to operate in a common file format, which allows to data sharing and combination to check between the different model elements. The formats for data sharing are e.g. the Industry Foundation Class.

The UK Government redefines refined its definition of level 2 BIM as containing the following seven components in 2014:

- PAS 1192-2:2013 Specification for information management for the capital/delivery phase of construction projects using building information modelling
- PAS 1192-3:2014 Specification for information management for the operational phase of assets using building information modelling
- BS 1192-4 Collaborative production of information. Part 4: Fulfilling employers information exchange requirements using COBie – Code of practice
Building Information Model (BIM) Protocol
- GSL (Government Soft Landings)
- Digital Plan of Work
- Classification

BIM Level 3: The overall goal is to digitise the entire life-cycle and constitute collaboration between all stakeholders. Level 2 BIM has no integrated arrangement in leveraging BIM data. The goal in Level 3 BIM is to facilitate complete synergy through a single, shared project model saved into a central cloud-based repository.

[1] *For further information on BIM in the UK see as well the CDBB Mini Project Urban Planning and BIM, https://www.cdbb.cam.ac.uk/CDBBResearchBridgehead/2018MiniProjects/2018MP_Allmendiner*
Or: Machine Learning and AI in the Built Environment
https://www.cdbb.cam.ac.uk/CDBBResearchBridgehead/2018MiniProjects/2018MP_Lindenthal
Or: The Uptake of Digital Tools, Standards and Processes in Innovation in the UK House Building Industry: opportunities and barriers to adoption
https://www.cdbb.cam.ac.uk/CDBBResearchBridgehead/2018MiniProjects/2018MP_Burgess

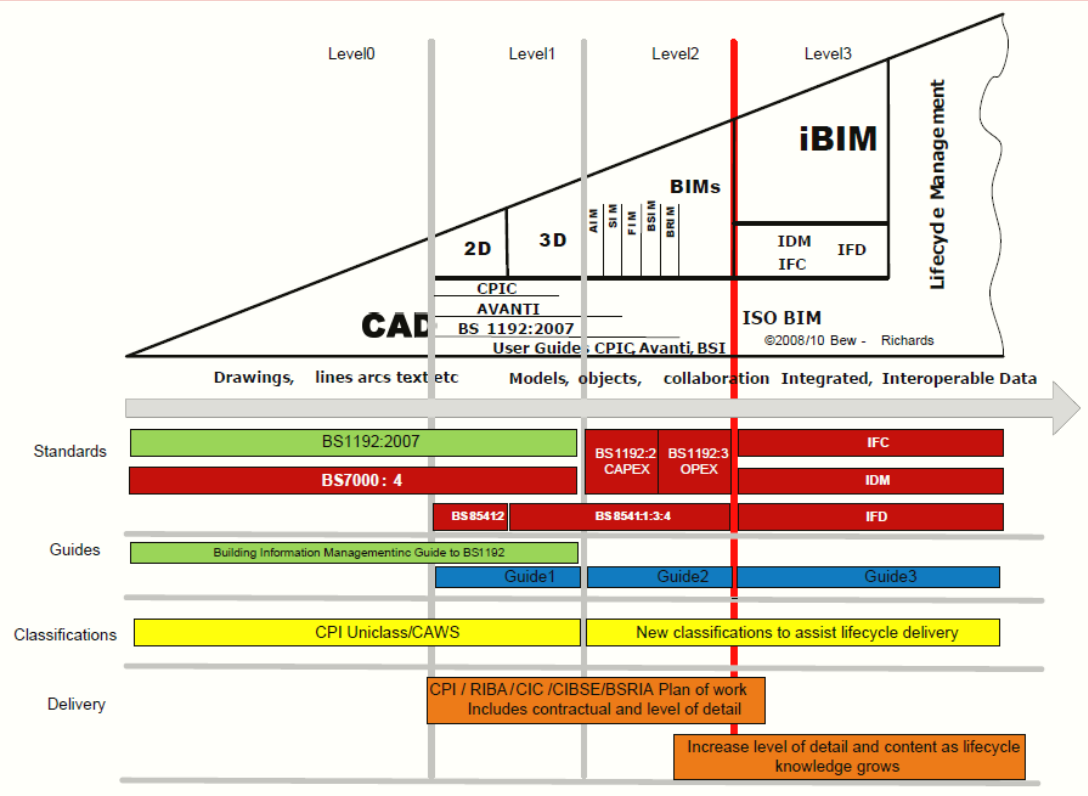
The Digital Built Britain strategy describes the approach in four elements.

Level 3A – enabling improvements in the Level 2 model

Level 3B – enabling new technologies and systems

Level 3C – enabling the development of new business models

Level 3D – capitalising on world leadership



Source: BIM Hub https://thebimhub.com/2016/04/28/level-2-to-level-3-collaboration-a-culture-shift-o/#.WrVN6macZE4

For further information see NBS (2016) BIM levels explained. Available at: https://www.thenbs.com/knowledge/bim-levels-explained

4.3. Denmark

Scandinavian countries are early and strong supports of BIM development. According to Smith (2014), the initial focus of Scandinavian countries was to embrace the ArchCAD software early and adopt model-based design. Countries advocated for interoperability and open standards to allow an integrated approach. The use of Industry Foundation Class (IFC) certification provided the background. IFC is a vendor-neutral file format. It allows to share models and work independently and at the same time in one software.

Denmark is BIM world leader. The Danish government took a leading role in the development of BIM classification standards, which later influenced the European debate. The Danish government took an approach to lead by example. The Danish Enterprise and Construction Authority has promoted BIM since 2007 (Jensen & Jóhannesson 2013).

In 2007 a regulation was adopted that covered all public construction projects. The Palaces & Property Agency, the Danish University Property Agency, the Defence Construction Service are examples or governmental institutions who were mandated by the government to use of BIM in all their projects. As of 2013 projects that are fully or partly financed by the government and exceed the amount of 5mDKK need to adopt BIM. This marked a tightening of the governmental decree including the use of classification, use of digital communication, use of 3D models, quantities in tenders, use of digital handover, use of digital registration of errors. A simple implication of the Danish BIM experience was that first a project-web and a standard for file and folder naming was developed.

One of the first clients for BIM were the developers of the Aarhus University Hospital which involved more than 3D information, including, for example, room schedules. Other examples include the use for offshore windfarm planning, construction, servicing and facility management. A challenge today is still the provision of a common data environment and the coordination of project management and implementation.

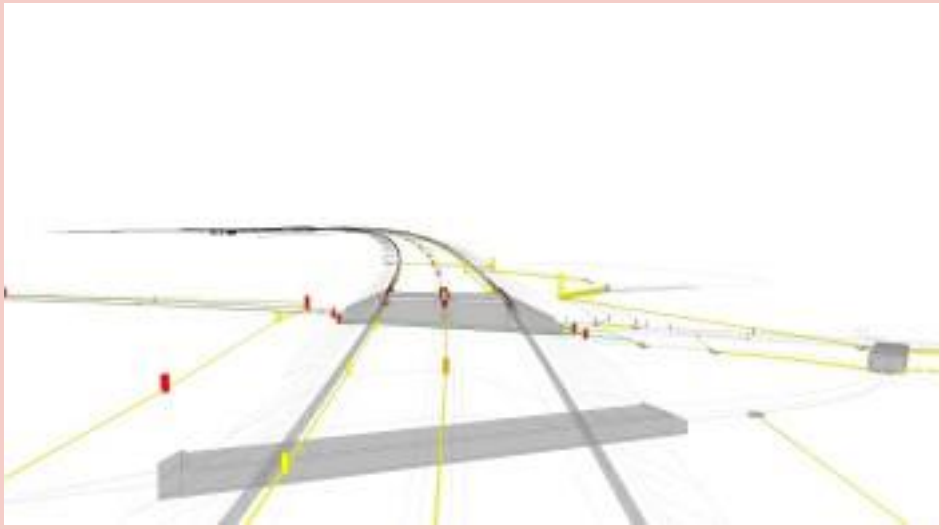
The Danish experience highlights that it takes years after the new technology is employed until benefits can be seen. It also takes time to get all contractors on board and experience to make the most of this new technology. However, a challenge was that similar to other countries partners and projects have been mandated to employ BIM before having been educated in it. This has been a challenge for the actors to actually accept BIM for practical purposes and for the implications of this new regulations and law to be understood and aligned with the initial goals. The cooperation with the industry and the support of the government are essential for BIM implementation. At the same time, the Danish example shows that adopting BIM and starting to work with BIM will show the challenges and the ambiguity or implications of national regulations and standards. The process of amending the regulatory framework in order to be able to be taken up takes time.

Example of BIM application: The Holstebro Motorway

The Holstebro Motorway project is an example in which the Danish Road Directorate elected to use BIM software. The new highway is planned for a 24,2-mile length with a proposed budget of DKK 3,768 billion. The project involves eight interchanges through local towns, over four railway crossings requiring bridges, two valley bridges across streams and a fauna bridge to passage environmentally protected areas for minimisation of environmental impact. The highway is expected to be completed by the end of 2018.

The idea to use BIM in this particular project includes information data from the full life-cycle integrated with GIS Data. The BIM project foresees that after the completion of the construction the data can be collected and migrated to an integrated GIS and asset management system which can support the subsequent highway maintenance. The ultimate goal behind the use of BIM therefore is a long-term reduction of costs in the operation and maintenance phase. A challenge in making use of BIM effectively was to organise a workflow that ensured data sharing between internal and external project partners during the entire lifecycle. This meant developing CAD and engineering standards. The software used were from Bentley Systems including interoperable data exchange based on further software links with. Micro Station, Navigator, Descartes, OpenRoads MXRoad, and Power Civil.

The Danish government aims to foster its digital construction initiative with this project and to introduce collaboration of this kind into construction industry as well as to showcase how BIM can facilitate the reuse of digital data, resolve conflicts during the design and construction phase and to create an exemplary platform.



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For further information see:
Danish Road Directorate:
http://www.nvfnorden.org/library/Files/Sanne%20Attermann_Welcome%20to%20Denmark%20_the%20Danish%20Road%20Directorate.pdf
https://www.engineering.com/ElectronicsDesign/ElectronicsDesignArticles/ArticleID/11543/Denmark-Puts-BIM-to-the-Test.aspx
https://academy.autodesk.com/course/112841/bim-highways-and-transportation

4.4. Germany

The German construction industry has recently been shaken up by a number of major public-sector projects that are considered to have gone fundamentally wrong. Projects went far over the initial budget and delivery of the projects was late, often by years. The most prominent examples are the Berlin-Brandenburg Airport, Stuttgart 21 railway station or the concert hall Elbphilharmonie in Hamburg. This record of poor performance gave a momentum to BIM. One reaction already in 2013 was that a Commission was launched that looked into the reform of construction of major projects. The goal was to develop greater confidence in major projects, spend public funds efficiently and preserve Germanys reputation in planning and construction. The Commission's Action Plan acknowledged the BIM opportunities. This Action Plan stressed the need for planning before the building process and the active use of available data. However, it was clear at this stage that the education of BIM is an important foundation to be able to deliver BIM and to convince the construction industry of the need for its take-up.

Whilst Germany is relatively behind in the usage of BIM in international comparison since 2015 there has been considerable movements driven by the Ministry for Transport and Digital Infrastructure. The Ministry announced a BIM mandate for 2020 in 2015. This mandate requires that all projects under the responsibility of the Ministry use BIM by 2020. BIM entered public procurement rules in April 2016. A BIM working group was developed named planen bauen 4.0, which had the essential task to roll-out a plan for BIM (BMVI 2015).

The result is a phased introduction of BIM (Stufenplan): a preparatory phase, a pilot phase and an implementation phase. In phase 1 the goal is to develop BIM environments and select projects for the

second phase. This timeframe is used to determine legal and technical frameworks and standards. In the second phase, from 2017 to 2020 the goal is to implement four pilot projects with BIM to gain experience in practical implementation of BIM. These pilot projects aim to achieve performance level 1, develop guidelines and samples for the use of BIM, clarify legal ambiguities and develop concepts for databases. In October 2016 the ministry decided to include two further projects. The third phase aims to regularly use BIM in the implementation of largescale projects by 2020 on the BIM performance level 1-2. This includes (1) the definition of the "client-information-requirements" (AIA) on data needs needs, (2) data delivery in digital form, (3) request of vendor-neutral data formats in the tendering to enable the data exchange, (4) BIM inclusion in contracts, (5) definition of processes and interfaces, (6) creation of a "common data environment" and exchange of data.

The plan "Planen Bauen 4.0 recognizes standardisation as an important element of BIM implementation. The plan agreed to have the Industry Foundation Class (IFC) as the common data format, similar to Denmark and Norway. The first tier for standardisation is run by the Association of German Engineers (VDI) or through the German Institute for Standardisation (DIN). VDI2552, which has been drafted by the VDI was developed in cooperation with responsible authorities. Since February 2018 the DIN SPEC 91391 "Gemeinsame Datenumgebungen für BIM Projekte" provides a standard for a common data environment.

Challenges for implementation within Germany are that 16 autonomous and semi-autonomous states and local authorities are important drivers for public spending and governmental projects. The shared responsibility and the strong competence of local authorities in building provide a challenge to prepare BIM regulations. Another impediment for BIM adoption is the lack of knowledge about BIM, wherefore education is considered a major step.

Example of BIM application: Six Pilot Projects

The German Ministry has chosen six pilot projects to test, promote and develop BIM. These include two railway projects and two road projects. The Ministry launching BIM has the competence on infrastructure, wherefore it comes as no surprise that the chosen projects are all infrastructure projects:

- Railway project: Tunnel Rastatt, tunnel to be developed as part of a new route

- Railway project: Bridge Filstal, railway bridge to be developed as part of a new route

- Road project: Bridge Petersdorfer See, replacement of an existing bridge at the A19

- Road project: Viaduct Auenbachtal (Südverbund Chemnitz), crossing of the Auenbach valley

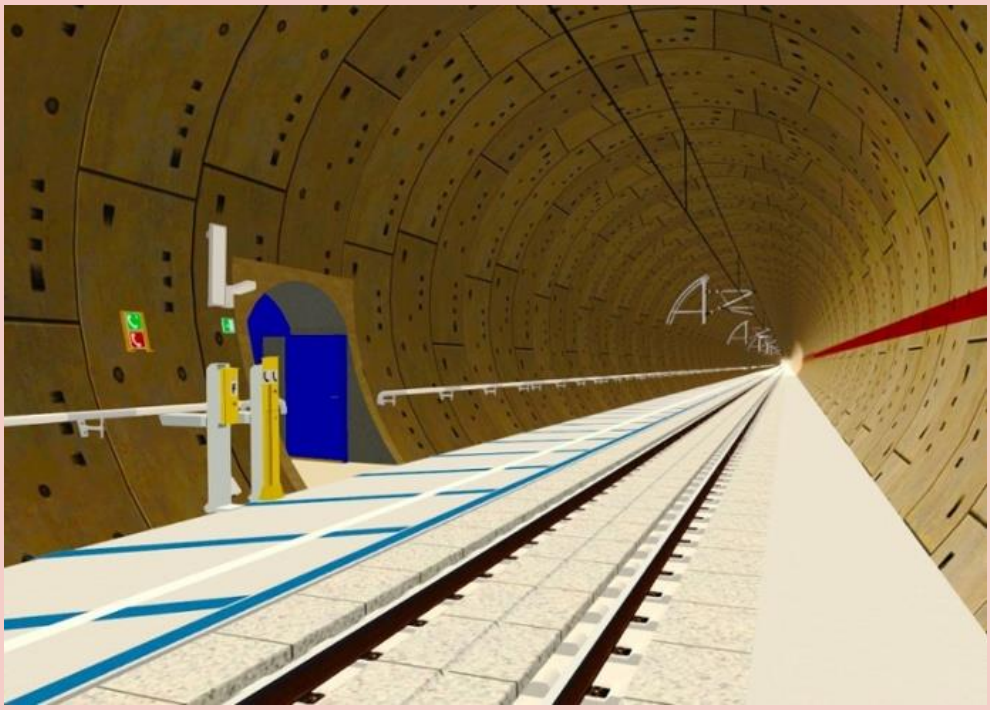
- Road project: B31 Immenstaad-Friedrichshafen, a new construction of the approximately 7 km long section of the B 31 west of Friedrichshafen through the area of shore of Lake Constance to Immenstaad

- Road project: B87 Eilenburg – Mockrehna, including the planning and investigation for a new construction for the expansion of the B87 on a length of 13,5 km.

To take an example and to further indicate the scope of the pilot projects, we summarise two railway projects. The Tunnel Rastatt is a part of the route between Karlsruhe and Basel and aims to dig two tunnels of a length of 4,2km. The German Railway company "DB Netz AG" handles the project and the modelling. BIM was used for information provision, collision checks, plan development, checking construction process planning and performance description. A 5D model will help the controlling process. The Railway Bridge in

Filstal is a new route between Wendlingen and Ulm with complicated construction parameters in the height of 85m. The Bridge will be of 485x473 meters. Initial use of a 3D model to develop the geometry will be followed up by a 4D and 5D model for planning and execution. The goal here is to facilitate communication between all involved parties through cloud-based applications.

In general BIM was used for different purposes, including the planning of complex projects through 3D and using the data as a basis for the construction purposes. Borman et al. (2017) have identified that a challenge is that "BIM was only used in parallel to conventional drawing-based practices".



Source: © http://planen-bauen40.de/project/projekt-3/

For further information see Bormann et al (2017) and BMVI (2016) or http://bim4infra.de

4.5. The Netherlands

Whilst the Netherlands are at the forefront of BIM development the surprise is that there is no strong governmental mandate. The way implementation went forward in the Netherlands is through the development of projects, support of education and institutional structures on the one hand, and development of open standards on the other. In contrast to other countries Van Nederveen et al (s.a.) argue that Dutch companies and people have used BIM for more than twenty years. Acknowledging that different CAD vendors have started offering 3D modelling since several decades, these models were used by one party only. The new BIM-developments have expanded this focus towards involving external parties and providing cloud-based collaboration. In contrast to our experience from other countries included in this research Van Nederveen et al.'s status report on BIM in the Netherlands highlight the role of projects and private initiatives in the BIM roll-out.

The development of standards dates back to the 90s, where the development of VISI as a standard for communication in building projects based on transactions and messages was developed. Visi is the Dutch

Information Exchange Standards in the Netherlands. The Netherlands provided an international example. Visi is used internationally due to its inclusion as part 2 – 'Interaction Framework', of the ISO-standard 'Building information Models – Information Delivery Manual'. Further today there are requirements for data structures in object type libraries. These need to comply with the international standard IFC.

BIM usage was taken up by architects and engineers gradually making its way down to contractors. The governments influence was little at this stage as BIM developed and usage spread through collaboration, interactions and updates by industry. A further success factor in implementation was that the early developments of standards provided clarity to contractors.

Two initiatives are argued to be instrumental for the Dutch way. Consistent with internet research, Van Nederveen et al. name the COINS project, the BIM week and the Dynamic BIM Initiative. The COINS project was initiated in 2003 by around 30 organisations from the construction industry. The COINS software was developed with the aim of enhancing communication between partners in the construction and design phase.. COINS refers to a Dutch integrated, complementary standard for exchanging digital information and includes support for systems engineering. CB-NL is a Dutch standard that connects object libraries for objects and spaces in the built environment. The BIM Case Week was an initiative to bring professionals together organised in 2007 and 2008 and 2010, helping develop awareness of BIM in the construction community. Since these early initiatives further developments have helped foster BIM further. These include the foundation of the Bouw Informatie Raad in support of transition to building with BIM, the BIMregister, which collects and shares BIM experiences and the BIM Loket promoting open BIM standards.

Governmental organisations, such as the Central Government Real Estate Agency require BIM. Today Rijkswaterstaa (the Dutch General Directorate for Public Works and Water Management) uses BIM in their projects with a value of around € 3 billion worth every year. Rijkswaterstaat is responsible for design, construction, management and maintenance of the main infrastructure facilities in the Netherlands. These include the road network, waterway network and the water system.

4.6. Singapore

Singapore, a sovereign city-state in Southeast Asia, became known as one of the Four Asian Tiger economies, all of which experienced rapid industrialisation. Singapore is not only recognised as a world-leading financial centre. As information and communication are regarded as pillars of economic success it is not surprising that Singapore is as well considered as an advanced user of BIM. Singapore sought BIM-Level 3 development in 2015. In comparison the UK aimed to reach the goal of BIM Level 2 by 2016.

Singapore's path towards BIM began in 2000 with the establishment of the Construction and Real Estate Network (CORENET) programme. The goal was to use information technology in the construction industry allowing information sharing amongst the different project participants (Smith, 2014).

In 2011 the Building and Construction Authority (BCA) set a long-term target "to raise the productivity of the sector by up to 25% over the next ten years. One of the ways to do this is through accelerating the widespread adoption of the Building Information Modelling (BIM) technology." (BCA 2011). Supported by a roadmap in 2010 the target was to achieve 80% construction industry use of BIM by 2015 (BCA 2011). A major element in achieving this goal was Singapore's policy to collaborate with governmental procurement entities and make the use of BIM obligatory for their projects from 2012.

In 2012 the BCA published a BIM Guide and gave further notification and requirements of BIM use (BCA 2012). Kaneta et al. describe this guide as the first of governmental plan that demystifies BIM and "gave clarity on the requirement of BIM usage at different stages of a project (Kaneta et al. 2016, 1306). Following the delivery of BIM plans, the BCA supported the execution of BIM Plans through the "BIM Essential Guide for BIM Execution Plan" (BCA 2013).

The CORENET programme was expanded by the e-Plan system mandatory to use for new building projects over 5,000 m^2 (Singapore Government 2016). This system provides a platform for architects and engineers to check their development applications for regulatory compliance. Singapore now requires automated models to check BIM e-submission compliance.

Apart from providing a regulatory background and guidance in BIM delivery Singapore further incentivised the use of BIM through a BIM Fund and BIM awards. First launched in 2012 the BIM Fund is an important element for capacity development and for industries to build up collaboration. The funds can be used for training, consultancy, hardware as well as for software collaboration. Since 2015 the government has also launched the so-called BIM awards for two categories - organisation and project. To support capacity building Singapore developed an academic programme for BCAA BIM Specialist Diploma with first intakes in 2011. Apart from these financial and educational activities Singapore promotes experiences and best-practices examples. The set-up of the http://bimsg.org/ homepage by local BIM stakeholders serves as an essential platform for information experience. BCA and buildingSMART Singapore have developed a library of existing projects and design objects and collaboration guidelines.

BIM Examples – Marina Bay Sands Singapore

The redevelopment of Singapore is centred around the Marina Bay Sands. The vision was to develop an integrated resort that would provide a signature skyline and a Garden City by the bay. The Architect Moshe Safdie developed the idea which then was engineered by Arup. The whole development included an esplanade, garden areas, an art gallery, a flttaing platform, a belix bridge, an ArtScience Museum, the the waterfront Promenade, the financial centre and the Marina Bay Sands Hotel and Sky Park.

The whole area was developed by using BIM. The deep basement and geotechnical challenges of the project could be resolved through the use of BIM. For example, a realistic 3-D analysis model was developed to represent the towers and to identify their behaviour (e.g. deformation or wind-induced movements, stresses between elements) and resolve coordination. This holistic approach is essentially City Information Modelling.

The Singapore office of Arup utilised BIM whole working on the North-East Line project, the ArtScience Museum, The Helix and the Singapore Sports Hub. The ArtScience Museum designed as a Lotus Flower was inaugurated in 2011. 3-D Modelling played a pivotal role. Arup estimates that through the use of 3-D models work that could have taken years was completed in three days allowing to understand the right dimensions, the right size and forces of each of the structural elements.

One of the reason for a strong BIM engagement in Singapore is the country's regulation that all architectural, structural, mechanical and engineering plans are to be submitted electronically via BIM for regulatory approval. Singapore led by example by commissioning landmark projects to BIM experienced engineers.

(Source of the Image Wikipedia, redistributable under the CC BY-SA 3.0 license)

For more information see: The Arup Journal: Marina Bay Sands Special Issue 1/2012 and Arup website: https://www.arup.com/news-and-events/news/archive/marina-bay-sands-artscience-museum-in-full-bloom?query=Marina%20Bay

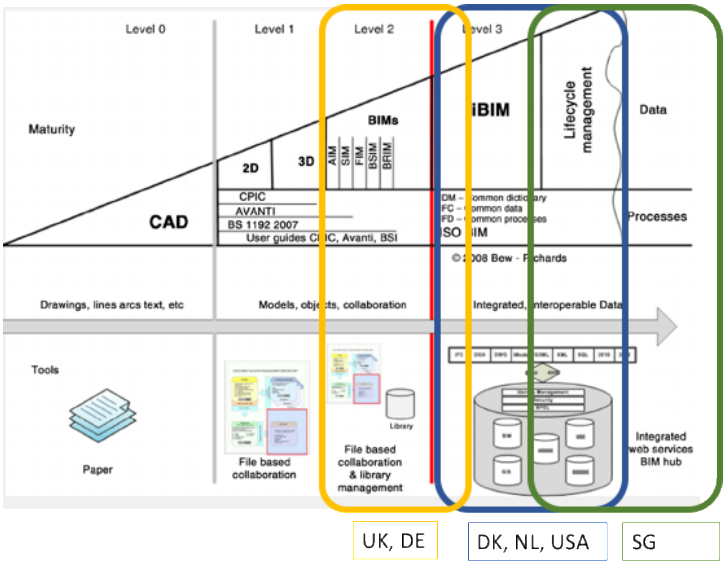
5. Comparative analysis: Strategies and Lessons Learnt

5.1. Comparative Analysis of National Strategies

In general, one can summarise that there is a considerable difference as to BIM take-up and performance. Singapore is far ahead and has reached level 3, making the next step to CIM.

Denmark, the Netherlands and the USA are relatively ahead and are able to use BIM 3. However, this does not mean that this is common use. Often pseudo-BIM solutions are used. The United Kingdom and Germany are relatively well developed in their BIM – journey and have developed the foundation for BIM 2 to be regularly used.

Table 5 BIM Level performance of case study countries.



Source: own estimation and elaboration, graphic retrieved from Bimhub

The illustration 5 indicates the authors estimation of the extent to which BIM Levels are made use of in projects in different countries and how far discussions have moved. It has to be acknowledged that every attempt of such kind does not represent the edges of the spectrum, or in other words leaves out the pioneering projects. Each BIM project is different and has a different approach as regards to the extent of which BIM is used in the different project phases. The UK examples shows for instance that the UK approach as such focusses on the development of a rather holistic BIM implementation through its policy support. However, when it comes to the implementation of projects, the use of BIM has not yet reached these ambitions. Despite giving a general good overview, thinking of BIM in "levels" has its shortcomings. Therefore, it has to be noted that despite the early introduction of BIM-Levels the UK is moving away from this rhetoric focussing on the whole lifecycle. The identification of BIM levels has been helpful in identifying the needs for harmonisation and standard setting.

Another element to consider when analysing the current BIM journeys is the overall strategic framework a country employs to foster BIM. In reaching BIM standard, however, countries are developing rather different strategies. These processes are very dynamic and are currently laying the foundations for future BIM deliveries.

The analysis of different countries strategies to foster the use of BIM in the construction industry shows a significant diversity, as one might expect. Each strategy has its own advantages and disadvantages and depends highly on the characteristics and functioning of the industry (e.g. commonalities, contracting or reliabilities).

In short, strategies include the public sector taking the lead, incentives for BIM adopters and requirements on calls, removal of impediments, capacity building and best practice examples.

Table 6 gives a comparative overview of the strategies indicating the regulatory, financial and other elements, the focus, the timing and the leading stakeholders.

To summarise, common elements in BIM strategies are the definition of standards and support of BIM through requirements in tenders on governmental projects, in particular for infrastructure projects. Few countries have developed a particular financial incentive through dedicated BIM funds. Singapore is an exception in the use of a dedicated fund. Several countries highlighted the role of education in order to enable the community to deliver and work with BIM. Education can be seen in the form of workshops, conferences and the awareness raising through marketing campaigns. Some countries supported the development of BIM study courses or private education institutions that offer courses to become a BIM-manager. These private initiatives for certified BIM-managers have not been taken up in this analysis. Singapore is the only country yet to have gone as far as to make use of e-submissions for planning and regulatory approval, which fosters BIM in all projects. Interestingly in all countries apart from the Netherlands, which have a world renowned record, BIM is led by governmental initiatives.

Table 6 Overview of countries BIM strategies.

Countries	***Regulatory framework***	***Financial framework***	***Other elements***	***Focus***	***Timeframe***	***Leading Stakeholders***
USA	*BIM obligatory for government projects from 2008, standard development.*	*Indirectly through governmental projects,*	*Support from federal governments, private stakeholders and universities supporting education*	*Initial focus on public service buildings*	*Start in 2003, BIM mandate 2007*	*Public entities and organisations*
UK	*BIM mandate for public procurements, obligatory for government projects by 2016, development of standards*	*BIM projects reflected in budget and financial support of institution such as CDBB,*	*Development of institution and support of BIM community development, EAC industry is involved in BIM definition through UK Taskgroup*	*Focus on infrastructure and private buildings*	*Start in 2011, BIM mandate 2016*	*Government with the support of a Task Group including leading BIM companies*
Denmark	*BIM mandate for public projects, early development of standards, constant re-evaluation of framework*	*Indirectly through obligation on governmental projects of a certain size,*	*Marketing efforts*	*Focus on public service buildings and infrastructure*	*Promotion started in 2007, BIM mandate 2012*	*Led by governmental institutions*
Germany	*Development of standards and phased implementation, involvement of federal states*	*Indirectly, through governmental projects,*	*Support of 6 Pilot Projects to gain experience, set-up of a working group focus on education*	*Focus on infrastructure*	*Start in2016, BIM mandate by 2020*	*Government's Ministry of Transport and Digitalisation*
The Netherlands	*No governmental mandate, state agency today in tenders require BIM standard development*	*Indirectly, through governmental projects*	*Marketing campaign, BIM weeks organised by private companies, standard development based on technological experiences*	*Initial focus on private buildings, designed by architects etc., public projects focus on infrastructure*	*Start of debates in the 90s, early projects leading to standards by 2003, 2012 open BIM standards*	*Led by AEC industry stakeholders*
Singapore	*BIM mandate, BIM Level 3 obligatory on all buildings above 5000sqm from 2015, construction projects have to go through e-submission*	*BIM Funds, and indirectly through governmental projects*	*Awards and promotion of best practice marketing, BIM study course enabling a wide education*	*All kinds of projects*	*Start in 2000, BIM mandate by 2012*	*Led by Government*

Based on our research and in view of the international BIM community developing rapidly, one of the main questions arising is which policy frameworks and national strategies are successful. Importantly, each strategy needs to consider their national legal system with its division of regulatory competences. It as well as needs to consider the stakeholder that build the (potential) BIM community.

The European BIM Taskforce Group highlights the need for four strategic areas of action to be targeted by a strategic framework for public sector BIM programmes:

- *Grow industry capacity (e.g. pilot projects, trainings, increasing use of strategic lever to grow capacity, case studies, monitoring)*
- *Communicate vision and foster communities (e.g. engage industry stakeholders, create networks, events, media and dissemination)*
- *Build a common collaborative framework (e.g. legal and regulatory framework, data and process standards, skills, tools, guidance)*
- *Foundation of public leadership (e.g. vision and goals, sponsor, funded programme, aligned strategy)*

This diamond developed by Adam Matthews, the chair of the EU BIM Taskforce, identifies the main areas in which policy interventions are taking place (cf. EUBIM Taskgroup 2017, p. 24), maintaining that in order to develop BIM going beyond the construction phase a holistic policy approach is needed (Matthews, 2018).

Following the analysis of the six respective strategies summarized above countries that were starting to engage in BIM early have not pursued as a holistic approach, as e.g. now Germany or the UK are taking. For countries such as the USA who have adopted BIM mandates early, the uptake of BIM to some extent remains with public buildings. The rapid development of digitalisation opportunities, and the potential for the use of BIM data for a variety of purposes and in particular for urban developments, indicates the need of a constant adjustment of BIM strategic frameworks.

5.2. Lessons learnt and recommendations

There are not too many lessons that can be generalised, as the individual situation of each construction industry and the commonly used elements need to be considered. The Dutch way is unique, given that in many countries there is not such an innovative tradition in construction. In general, the research suggests that a provision of a governmental framework and the amendment of the legal systems plus the definition of standards are somewhat the basis for BIM development.

Recommendation: Development of strong governmental mandate and amendment of legal frameworks, including the development of standards and e-submission platforms.

Countries that approach BIM through a number of complementary initiatives are more likely to hasten BIM up-take. Apart from education initiatives, interviews have revealed the strong importance of marketing aspects. The hesitation in the construction industry to change ways of doing things is not too be underestimated, and the advantages for the individual contractor or subcontractor are not clear enough to lead to immediate action. The incentives provided by governments, in particular, through infrastructure projects help to enable a BIM community to deliver BIM projects. Due to the very specialised infrastructure industry direct spill-overs to the housing industry are, however, unlikely, or at least will take time

Recommendation: Marketing and Education are underestimated necessities to compliment the governmental frameworks.

Apart from BIM mandates, and financial incentives the role of the public sector is limited if the full spectrum of governance levels are not involved. The national level may develop mandates, guidelines and so forth. As

long as the lower governmental levels are hesitant in engaging in the first part of the construction phase, the planning phase and collaboration in the common data environments that BIM provides, it is a difficult sell to expect engagement from private companies. Due to the strong competence of the urban level in many countries urban planning is an important vehicle for BIM take-up.

Recommendation: Dedicated strategies of governments to involve and educate sub-levels. This can include guidelines, workshops as well as the promotion of success stories.

BIM has a momentum with many places exploring ways to develop as smart cities. With a rising number of initiatives, the impacts of stand-alone marketing effects are decreasing. BIM can give a new momentum to rethink the future city development.

Recommendation: Support programmes for cities to develop a BIM strategy and name a BIM representative. For European Union countries the Cohesion and Regional Policy could offer a way to support innovation in the construction sector in the next funding period.

An element of success is the use of a diverse and complementary set of tools that target different stages of the planning, design, implementation and maintenance phase (see section 2 in this report) as well as that they target the different stakeholders involved in the construction process. These elements range from technological standards (broadband and high-speed data access), digital authorities, regulatory frameworks, financial incentives, marketing and education, pilot projects to best-practice examples or BIM awards

Recommendation: Develop a diversified and complementary strategy targeting different construction phases and stakeholders.

6. Concluding remarks and further research

This research has been exploratory in nature, starting with an analysis of international experiences and identifying the role of cities in the roll-out of BIM. The case-study driven approach enabled us to identify the different elements of BIM strategies. National BIM strategies often develop step-by-step, whilst a comprehensive and a more integrated approach can help to identify challenges and barriers. This comparative analysis can provide impetus to diversify national approaches.

Importantly, the research indicated that BIM delivery is largely still dependent on the national level. In order to actually make use of BIM, however, it is important that cities take up BIM, and even move towards CIM. In order to support this, and to better understand how cities can be supported further research is needed:

- *In what ways do current activities of smart cities relate to BIM? What support is needed to better link BIM with smart city approaches?*
- *After BIM has been established to some level in the Architecture, Engineering and the Construction Industry some cities are experimenting in using intelligent modelling for city development. In what ways does BIM need a coherent CIM strategies? What are the drivers and barriers for CIM implementation? What experiences with CIM exist and how is it possible for cities to make use of BIM to develop CIM? What are the security challenges? How can BIM and CIM be integrated?*
- *How is the integration of data between different types of BIM projects possible?*

- *What are the social consequences of BIM and a further digitalisation? What are the legal consequences of BIM standards and process (e.g. as regards to liabilities, authorship, etc.) In what ways can data protection be secured while still delivering the best service possible? Who accesses what kind of data and how can transparency be ensured?*
- *What are the economic effects of and barriers to BIM take-up for SMEs? In what ways does the current process favour big companies? What type of BIM experts are needed in office and on-site jobs?*
- *What role can urban planning take and what changes in planning regulations are needed to enforce BIM in planning processes? What governmental levels need to be involved and under what circumstances?*
- *Which stakeholders are hesitant BIM uses and who would need to be targeted by Marketing campaigns?*
- *What role can urban and regional planning play in supporting BIM use? What type of policies are needed or need to be aligned to support BIM (ranging from insurance support to planning itself?) At what levels need these policies to be delivered?*

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