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I. OSOBNÍ A STUDIJNÍ ÚDAJE

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Srovnání implementace BIM v České republice a Španělsku

Název diplomové práce anglicky:

Comparison of BIM implementation in Czech Republic and Spain

Pokyny pro vypracování:

1) Úvod, definice problematiky, vymezení cílů a výstupů práce.
2) Obecné principy implementace BIM, rešerše.
3) Implementace BIM v ČR.
4) Implementace BIM ve Španělsku.
5) Srovnání implementace BIM v ČR a Španělsku.
6) Případové studie.
7) Závěr, diskuze.

Seznam doporučené literatury:

EASTMAN, C.: BIM Handbook. 2. New Jersey: John Wiley & Sons, Inc., Hoboken, New Jersey, 2011. ISBN 978-0-470-54137-1.
Ministerstvo průmyslu a obchodu: Koncepce zavádění BIM v ČR (2017).
Matějka, P.: Rizika související simplementací Informačního modelování budov (BIM), disertační práce, 2017.
https://www.koncepcebim.cz/

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III. PŘEVZETÍ ZADÁNÍ

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Datum převzetí zadání Podpis studentky

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03.01.2021 Veronika Laurenčíková

Srovnání implementace BIM v České republice a Španělsku

Comparison of BIM implementation in the Czech Republic and Spain

Anotace

Tato diplomová práce se zaobírá porovnáním procesu zavádění metody informačního modelování staveb na úrovni státu v rámci České republiky a Španělska. Práce nejdřív popisuje způsob, kterým se autorka rozhodla přistupovat k dané problematice, zejména ve smyslu postupování v rámci vzájemného srovnávání vybraných států. Následně práce poskytuje individuální rozbory procesu zavádění BIM z pohledu obou států, které jsou vzápětí porovnány z hlediska několika kategorií a vyobrazeny ve shrnovací tabulce. Výsledky porovnání jsou následně předmětem závěru a finální diskuze, ve které autorka zpětně hodnotí volbu způsobu přistupovaní k problematice porovnávání České republiky a Španělska z hlediska zavádění BIM na úrovni státu. Doplňující kapitolou je také analýza výběru případových studií, které poskytují know-how o aplikaci BIM v praxi.

Annotation

This diploma thesis deals with the comparison of the process of implementing the building information modelling method on a country scale within the Czech Republic and Spain. At first, the thesis describes in what way the author had decided to approach the issue, especially in terms of proceeding within the mutual comparison of selected countries. Subsequently, the thesis provides individual analysis of the process of implementing BIM from the perspective of both countries, which are in turn compared in terms of several categories and represented in a summary table. The results of the comparison are consequently the subject of the conclusion and the final discussion, in which the author retrospectively evaluates the choice of her approach to the issue of comparing the Czech Republic and Spain in terms of BIM implementation on a country scale. An additional chapter is represented by an analysis of a selection of case studies that provide know-how about the application of BIM in practice.

Klíčová slova

BIM, informační modelování staveb, zavádění BIM, Česká republika, Španělsko, případová studie

Keywords

BIM, building information modelling, BIM implementation, Czech Republic, Spain, case study

Content

1. Introduction

Ever since the beginning of time, there has been an undeniable sense of growth and development present among us. Our society, as we know it nowadays, has been moulded throughout centuries in order to become sustainable and prospering, to satisfy not only our basic needs, but to provide us with comfort and endless possibilities. Nevertheless, with every scientific breakthrough, every technological progress or medical discovery, change is never easy. We often get scared of the unknown, uncomfortable in a foreign environment and defensive against anything new and unfamiliar. That is also the case of progress in the field of civil engineering, also known as part of the so-called AEC sector (architecture, engineering and construction).

Needless to say, the construction industry has undergone major development over the years that has created a solid foundation of its exerted methods and well-known standard procedures, which is consequently also the reason for difficult change implementation in the present. However, as the rest of the world advances, progress in the AEC sector has become inevitable as well. The most important thing in the construction industry is currently to unify its every segment in order to improve their interoperability, therefore become completely digital by using building information modelling (also referred to as BIM).

BIM is nowadays considered the latest trend and the future of the construction industry. Even though it's known worldwide, each country approaches its implementation in a slightly different way and in its own time and pace. Some of them might be just starting with the whole process while other ones could be quite far along. Countries that are more advanced in the process might have already dealt with some difficulties or come across an unexpected development. Whether that's a minor pullback or a major issue, there is no choice but to overcome those in order to move forward, which provides help and invaluable insight for all other participants. Therefore, it is important to observe, compare and evaluate BIM implementation on an international scale for the purpose of using the acquired knowledge to the benefit of everyone involved.

1.1 Subject definition

This thesis deals with the differences of approaching BIM implementation in two European countries – the Czech Republic and Spain. At first, it examines the history and the current state of the implementation process in both of these countries and in turn it provides in-depth research of case studies containing more specific information on the matter, explaining the difference in dealing with BIM implementation of both parties mentioned above.

1.2 Specification of objectives and desired outputs

The ultimate objective of this thesis is to provide better insight into BIM implementation in the Czech Republic and Spain, as well as to examine the differences against its general principals. The thesis also aims to compare the implementation process in both countries historically and as part of moving forward. At last, its goal is also to provide additional research on the matter regarding the current situation in the construction industry.

The practical part of the thesis is focused on real case studies in the Czech Republic and Spain, their in-depth analysis, evaluation and comparison with the theoretical knowledge acquired beforehand. The main output is to draw a conclusion based on the resources at our disposal and to shed more light on the discovered differences in order to possibly improve the strategy of BIM implementation.

In summary, the objectives and outputs are shown in **Table 1**.

Objective No.1	Theoretical analysis of general principles of BIM implementation from the state's perspective
Objective No.2	Theoretical analysis of BIM implementation in the Czech Republic from the state's perspective
Objective No.3	Theoretical analysis of BIM implementation in Spain from the state's perspective
Objective No.4	Comparison of the acquired theoretical knowledge about both countries
Output No.1	Analysis of BIM-related case studies in the Czech Republic
Output No.2	Analysis of BIM-related case studies in Spain
Output No.3	Comparison of the results of BIM-related case studies in both countries
Output No.4	Conclusion drawn based on discovered similarities and differences

Table 1 – Objectives and outputs [1]

1.3 Research

The construction industry is not particularly proactive in terms of taking part in country-scale maturity studies, especially concerning building information modelling. The so-called BIM maturity refers to *“the quality, repeatability and degrees of excellence in delivering a BIM-enabled service or product” [2, p.1]* and it is usually being examined through various frameworks, however most of them are not applicable across macro organizational scales, such as a country scale.

1.3.1 Noteworthy BIM publications approach

The lack of interest in creating suitable metrics to assess this kind of BIM maturity is one of the reasons which led a few members of the AEC industry, including Bilal Succar who specialises in BIM performance assessment, to propose an approach to comparing the BIM maturity of countries based on three metrics related to noteworthy BIM publications (also referred to as NBPs). There are several types of publications concerning BIM that can be considered noteworthy. According to this paper, the NBPs are “*publicly-available documents developed by various industry and academic entities; aimed at a wide audience; and intended to promote BIM understanding, regulate BIM implementation or mandate BIM requirements” [2,* *p.2]*. In this case, the authors had chosen Australia, the United Kingdom and the United States to compare with one another, based on their mutual similarities in the construction sector. After providing the results of BIM adoption surveys in each of the initially selected countries, they proposed three qualitative metrics that can be used, in addition to survey data, to determine the level of BIM maturity and adoption on a country scale. The applicable metrics were as follows: the availability of NBPs, their distribution across BIM knowledge content and their relevance across markets. This approach to assessing the BIM maturity of countries was created mainly to encourage others to participate in more studies and experiments concerning this matter and to initiate a discussion on the subject. However, it is quite extensive and it requires a thorough research of each selected country's NBPs, which is also highly time-consuming. For this reason, the focus of this thesis is ultimately on BIM implementation in much larger sense. It examines certain characteristics and milestones that could potentially be common for both, the Czech Republic and Spain, as well as it illustrates the theoretical foundation with real life case studies within the scope of a better grasp on the concept of the actual practice.

[2]

1.3.2 Author's approach

The author of this thesis approached the matter from the point of view of implementing a new technology in general, since introducing an innovation on a national scale is a very complex process and there need to be some ground rules set at the beginning as a stepping stone in order to be able to analyse and compare BIM implementation from the point of view of the Czech Republic and Spain objectively. Initially, the author examines general principles of implementing a new technology into a single company, which are in turn expanded to a larger level and adjusted to fit the implementation process on a country scale as well. Subsequently, these principles are being review and adapted to the implementation of building information modelling on a national scale. According to these general steps, the process of implementing BIM in the Czech Republic and in Spain is analysed individually in the following two chapters. Subsequently, both countries are compared in terms of various aspects and characteristics of BIM implementation. The comparison results in assessing what they could potentially learn from each other, what they have in common and in contrary, what they do differently and could change or improve. In addition, this thesis also analyses the application of BIM into practice in both chosen countries through a selection of case studies. Even though they provide invaluable feedback and insight into using BIM in real life construction, there is only a limited part dedicated to their representation, since it is very difficult to compare the level of BIM implementation in different kinds of projects that deal with various forms of applying BIM and are executed under a whole lot of subjective conditions.

The entire comparison process of the two selected countries starting with introducing general principles of implementing a new technology and ending with evaluating mutual characteristics and impact of both countries is represented in **Figure 1**.

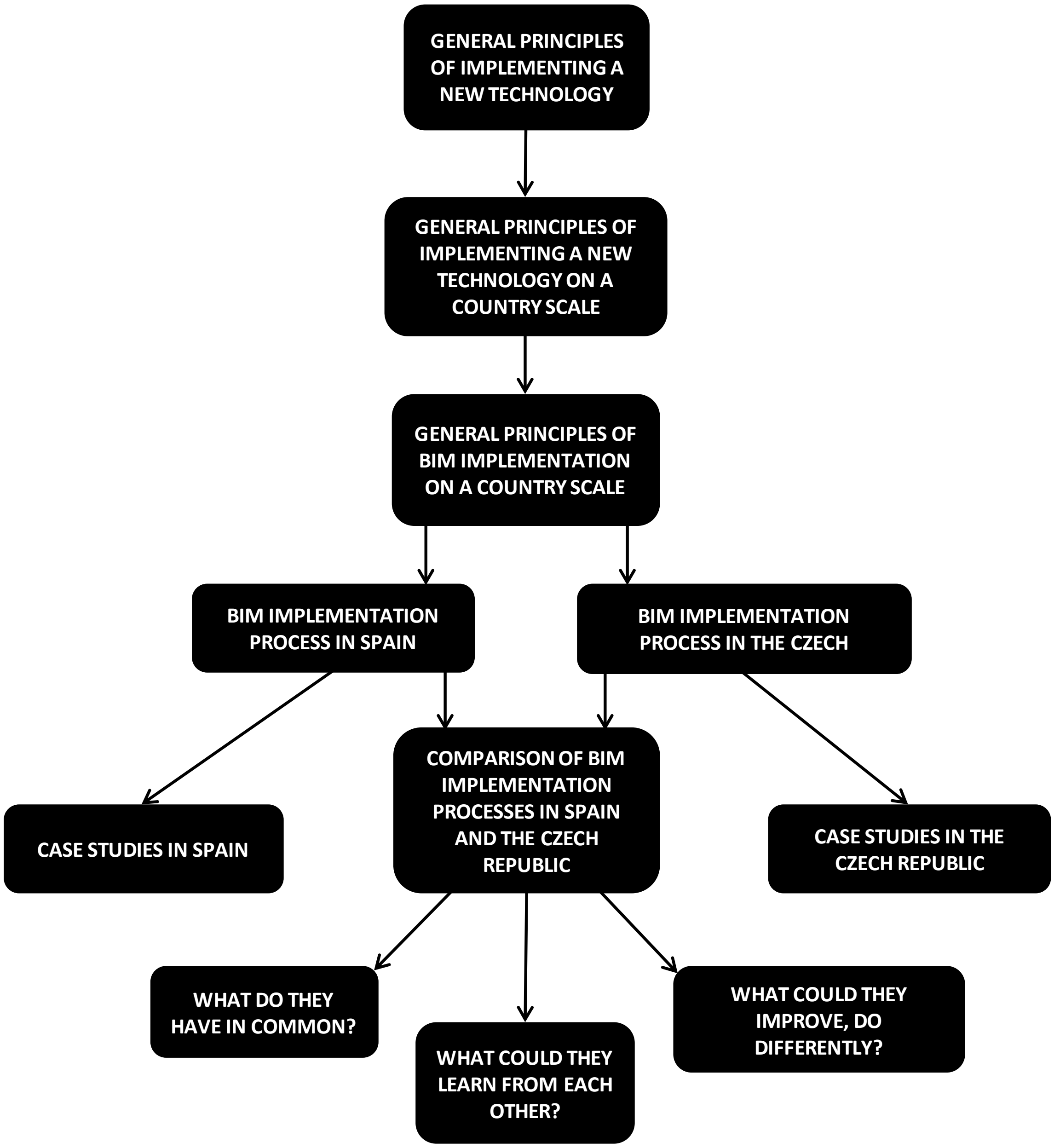

Figure 1 – Scheme of the comparison process [1]

2. General principles of BIM implementation from the state's perspective

An integral part of implementing any change within the scope of an entire country is to initially determine its general principles that serve as a guide throughout the whole process and provide support in time of need. An innovation on a national scale is usually very complex and it's easy to lose sight of the right path and deviate from the initial plan or to get confused and forget a step or two in the process. Therefore, setting some ground rules at the beginning is crucial.

Since building information modelling is from the most part a development in digitization, general principles of implementing a new technology can be in this case applied as a stepping-stone. However, these guidelines represent a very broad approach to change implementation and in order to apply to BIM specifically, they need to be adjusted accordingly. This chapter is therefore dedicated to identifying basic principles of implementing a new technology in general and in turn using those to create an adjusted version that can be applied as part of a BIM implementation process on a country scale.

2.1 Implementation of a new technology in general

The most common approach to productivity improvement in any given field is to implement a change in the technology department and provide better tools and innovative procedures in order to reduce possible performance gaps. While implementing a new technology within a company, there are a few basic principles that can be applied globally in various fields.

First of all, it is necessary to set initial expectations and goals that are meant to be achieved by introducing the new technology into practice. Usually the main focus is on cost reductions, increased productivity or quality of merchandise and services.

Besides that, it is important to create a solid support and training system, so that every company employee understands the technology in question as best as possible within their capabilities, so they don't feel intimidated by the change, but rather confident in their newly acquired skills and knowledge.

It is equally important to take enough time while implementing a new technology, even though naturally there is always a desire for quick improvement, it is generally not efficient. It should be approached carefully, taking into account possible risks while creating a proper strategy for pilot projects and their evaluation.

Another important step in introducing an innovation is to remain transparent throughout the whole process. The more sense of understanding and insight there is on the part of employees, the more acceptance and motivation will stem from it in the long run. This applies especially if the potential benefits of the technology development were explained to everyone involved, since they can affect them personally as well.

An integral part of the educational process while implementing a new technology is to focus on feedback and stress its importance on many occasions. Without collecting and addressing feedback, there is no way of knowing with certainty if the implemented technology is actually working the way it is supposed to, not to mention if it is, in fact, beneficial to the company and its employees as planned.

The final and equally, if not more, important step in introducing an innovation into a company is to keep on monitoring its ongoing use after its successful implementation. There should be a team, or at least an individual, dedicated to overseeing the implemented technology in order to notice any potential setbacks or upgrade requirements that need to be dealt with immediately or over a period of time.

[3], [4]

These principles are very generic and can be applied universally across many different fields, including the construction industry. Even though, they are commonly intended to be used on a scale of a single company, it is possible to extend their reach onto a much larger scale, in this case it would include construction companies, engineers, architects, facility management companies, educational institutions, state authorities, project designers and many others within the construction field across a whole country. This way, there is a general direction in which the state can proceed also in case of BIM implementation, however it would be preferable to use it in a sense of a basic guide and adjust it as need may be, in order to make it more efficient.

2.2 Principles of BIM implementation

Taking general principles of implementing a new technology into account, there are several steps within the BIM implementation process that this thesis deals with. Considering, that the theoretical analysis is being executed from the point of view of the state, the author of the thesis initially examines the Czech Republic and Spain in terms of providing a BIM implementation strategy, setting up initial expectations, goals and requirements for the foreseeable future. Subsequently, each country is being analysed and reviewed in the department of education and training related to building information modelling, as well as its promotion throughout the construction industry. It is necessary to examine how each state deals with overseeing the whole BIM implementation process, how it adjusts to feedback and how it provides transparency. Subsequently, the related question of changes in legislation needs to be addressed as well, since it affects the whole construction industry and it is necessary in order to implement BIM completely, throughout the entire AEC sector. Since this way it is now only a single company that is subjected to change, but rather the whole state, it is also crucial to appoint specific individuals and teams responsible for carrying out all necessary action in order to ensure a successful course of the BIM implementation process. Last but not least, concerning implementation of an innovation in general, it is also convenient to cooperate with others that have dealt with the same issue in the past, in this case it means cooperation on an international level. The following chapters are dedicated to a few of the BIM implementation aspects on a larger scale, however there is a more detailed analysis of the matter within the Czech Republic and Spain in Chapter 3 and Chapter 4, respectively.

2.2.1 Universal standard availability

Regarding the BIM implementation process in general, there are several organizations that provide the fundamental information and procedures required to begin this journey without much difficulty.

One of the most influential ones among them is an association of organizations founded in 1995 called buildingSMART International. It has individual branches in multiple countries around the world and it is "*the international authority for a set of standards known as the Industry Foundation Classes (IFC) which deal with process, data, terms and change management for the specification, management and effective utilization assets in the built asset industry" [5]*. The intention of buildingSMART International is to promote and encourage *"the development and active use of open internationally-recognized standards, applications, training and certification procedures" [5]* as well as to *"lead the digital transformation by enabling efficient communication, better collaboration and digital* *workflows throughout all phases of the project and asset lifecycle" [5]*. This organization also initiated the concept of openBIM, the universal approach to a cooperation based on open standards and work procedures throughout the entire lifecycle of buildings and structures, which is the reason why it is currently known worldwide as the International Home of openBIM.

[5]

Among other organizations that are indispensable for BIM implementation we ought to mention the International Organization for Standardization (ISO), based in Geneva, that *"coordinates the organization, creation and publication of approved technical standards" [7]* (including IFC) and the European Committee for Standardization (ECS), also known as CEN (Comité Européen de Normalization) which is a non-profit organization that *"brings together the National Standardization Bodies of 34 European countries" [6].* Both of these organizations develop and publish standards which are being used on a large scale and adapted by each country individually to establish the foundation of BIM implementation on a national level.

[6], [7]

The most significant standard concerning BIM adopted by many countries over the years is considered ISO 19650 drafted in February 2017 based on available British standard BS 1192 in relation to the Publicly Available Specification PAS 1192-2 *"which have already been shown to help users save up to 22 % in construction costs" [8]*. The original proposal of *"ISO 19650 Organization of information about construction works - Information management using building information modelling" [8]* standard consisted of two parts. The first part outlined *"concepts and principles and provided recommendations on how to manage building information" [8]* while the second part provided *"information management requirements in the delivery phase of assets" [8].* The final version of this standard was officially published in January 2019, with two additional parts (ISO 19650-3 and ISO 19650-5) in 2020 concerning management of the operational phase of built assets and security-minding BIM. ISO 19650 is particularly significant because it applies to the whole life cycle of a built asset, therefore it provides way more efficient collaboration on projects considering its promotion from British to an international level.

[8]

2.2.2 Mutual cooperation

Implementing a change worldwide doesn't have to be necessarily equally difficult and time-consuming for each part of the globe as could be expected. Certainly, the beginning is considered the hardest, as there are many variables that cannot be predicted in advance, therefore the possibility of making mistakes is increased. However, once the initial phase is complete, there is plenty of room for improvement in the given field, such as better time and cost management, higher organizational and educational skills or easier handling of unexpected situations. Naturally, the BIM implementation process is no exception.

For instance, the first ones in Europe to have felt the need to integrate building information modelling into their everyday lives and require its mandatory use in public procurement were the Nordic countries at the beginning of the 21st century, particularly Finland, Norway, Sweden and Denmark. For those, the implementation had been quite tricky, because they were entering an unknown territory with a lot of expectations and they had to be prepared to deal with the unexpected, one way or another. However, because of their courageous acts and valuable revelations, a major opportunity arose for other European countries. Ever since the first pilot projects had been launched and standards published, there was a possibility of using them in the advantage of others, as an example to follow. This was primarily noticeable in the case of the United Kingdom, that reached the level of maturity of the Nordic standards in a short period of time and announced the mandatory use of BIM in public works tenders since April 2016, as part of their strategy created in 2011. British standards were developed by creating a national regulatory framework for the use of BIM through the series of PAS standards 1192 (Publicly Available Specifications), based for the most part on the knowledge acquired from the BIM implementation processes in the Nordic countries mentioned above. Subsequently, other European countries started to implement similar strategies in order to get resembling results, which leads to the formation of the "*Handbook for the introduction of Building Information Modelling"* by the European

Public Sector, published by the EU BIM Task Group - a collaboration of public sector organisations across 21 countries, whose ultimate objection is to *“bring together national efforts into a common and aligned European approach to develop a world-class digital construction sector” [10].*

Summing up, regarding the principals of BIM implementation, based on the mutual cooperation amongst European countries in the past, the most appropriate and applied approach to the implementation process is through the public sector, thus the requirements of the mandatory use of BIM in public works construction and infrastructure tenders and compliance with initially established standards.

[9], [10]

2.2.3 Application of theoretical knowledge into practice

Same as it is with any other new technology or innovation, different aspects of BIM implementation into practice need to be empirically tested and reviewed. At the beginning of the whole process, pilot projects need to be launched, explored and evaluated over time. Nevertheless, to observe and assess the impact of using BIM in practice, as well as getting proper feedback, any kind of project involving BIM employment can be used through the execution of a case study.

In general, case studies can be used within the scope of a single project or even multiple projects of similar characteristics. They consist of a description of an initially selected case, an explanation of the methodology of research which follows directly by a presentation of the results of its actual execution along with their evaluation.

The same procedure applies to BIM-related case studies. However, the implementation of building information modelling has many faces, therefore it can be observed across many fields, from different points of view and with regards to various circumstances. Even though the case studies may differ in a lot of ways, all of them have merit providing they had been properly executed and they propose a conclusive evaluation based on the acquired results and possibly their future utilisation.

3. BIM implementation in the Czech Republic

In order to compare various aspects of BIM implementation in the Czech Republic and Spain, it is necessary to examine them within each of these countries separately at first. Therefore, this chapter is dedicated to the BIM implementation process in the Czech Republic, following most of the general principles concerning the subject, such as the universal implementation strategy, standard and information availability, organizations involved in the process, application in practice and overall degree of BIM readiness on a national scale.

3.1 Standard and information availability

First of all, BIM implementation in the Czech Republic has been managed and promoted by many organisations over the years, the oldest one being the Czech BIM council (CzBIM for short) – *"an independent platform for popularization, promotion, standardization and development of BIM in the Czech Republic" [11]* created in 2011, when BIM implementation on a national level was considered for the first time on a large scale. This association focuses on keeping continuous communication amongst its members and their gathering at least once a year in order to discuss the future development of raising awareness of building information modelling in the AEC sector and to come to a mutually beneficial agreement on how to proceed. The Czech BIM council is essentially built on five fundamental activity pillars which secure the national promotion of BIM. They consist of BIM popularisation amongst both professional and lay public, promotion of BIM methodology throughout the formation of new legislation and standards, connection between experts from many fields immediately concerning BIM, education in general as well as with regard to a specific target group and finally, involvement of experts from practice or academic spheres in several projects and work groups. The results of all the work that CzBIM is doing are among other things presented at the BIM DAY conference annually held in Prague. This special event is organised mainly for the purpose of demonstrating current trends and information in the field of digitization and building information modelling and a vision into the future. Its focus is on the practice in the AEC sector, in the Czech Republic as well as in the rest of the world. Even though the Czech BIM council was initially created to promote

BIM in general, nowadays its focus is mostly on the actual practice and BIM related issues.

[11]

Even though the Czech Republic doesn't have its own branch of buildingSMART International, they are constantly mutually cooperating on the development of standards in order to secure unified approach to BIM implementation as much as possible. This concerns mainly the adoption of the OpenBIM Initiative in relation to the IFC data format, the Information Delivery Manual and the buildingSMART Data Dictionary.

In relation to national standards, the Czech Republic also adopted the use of ISO 19650 published by the International Organization for Standardization, the same way as many other countries around the world did.

[5], [12]

Concerning the promotion of BIM, advertisement of up-to-date information about its implementation process, and communication among professionals in the construction industry, it is necessary to mention the existence of the Czech Agency for Standardization (CAS) which is currently the most significant organization in the Czech Republic that provides all of the above. This agency is among other things responsible for the execution of a huge amount of measures concerning BIM implementation specified by the government, most of which were defined in a published document by the Ministry of Industry and Trade (MIT). Since there is a lot of important information related to this particular document, its content is examined closely in the following chapter.

[13]

3.2 BIM implementation strategy

As it was mentioned above, in September 2017 the Ministry of Industry and Trade published a document called *“BIM Implementation Strategy in the Czech Republic” [14]* (for further notice referred to as *“the Strategy”*) as a guideline to BIM implementation in the Czech Republic in the following ten years. It included a schedule of recommended measures with several milestones marked on a timeline

(**Figure 2**), the most significant one being the imposition of a BIM obligation for above-threshold public works contracts since the beginning of 2022. The state of fulfilment of the schedule along with the current situation is annually brought to attention and discussed as part of BIM DAY organised by the CzBIM association mentioned above.

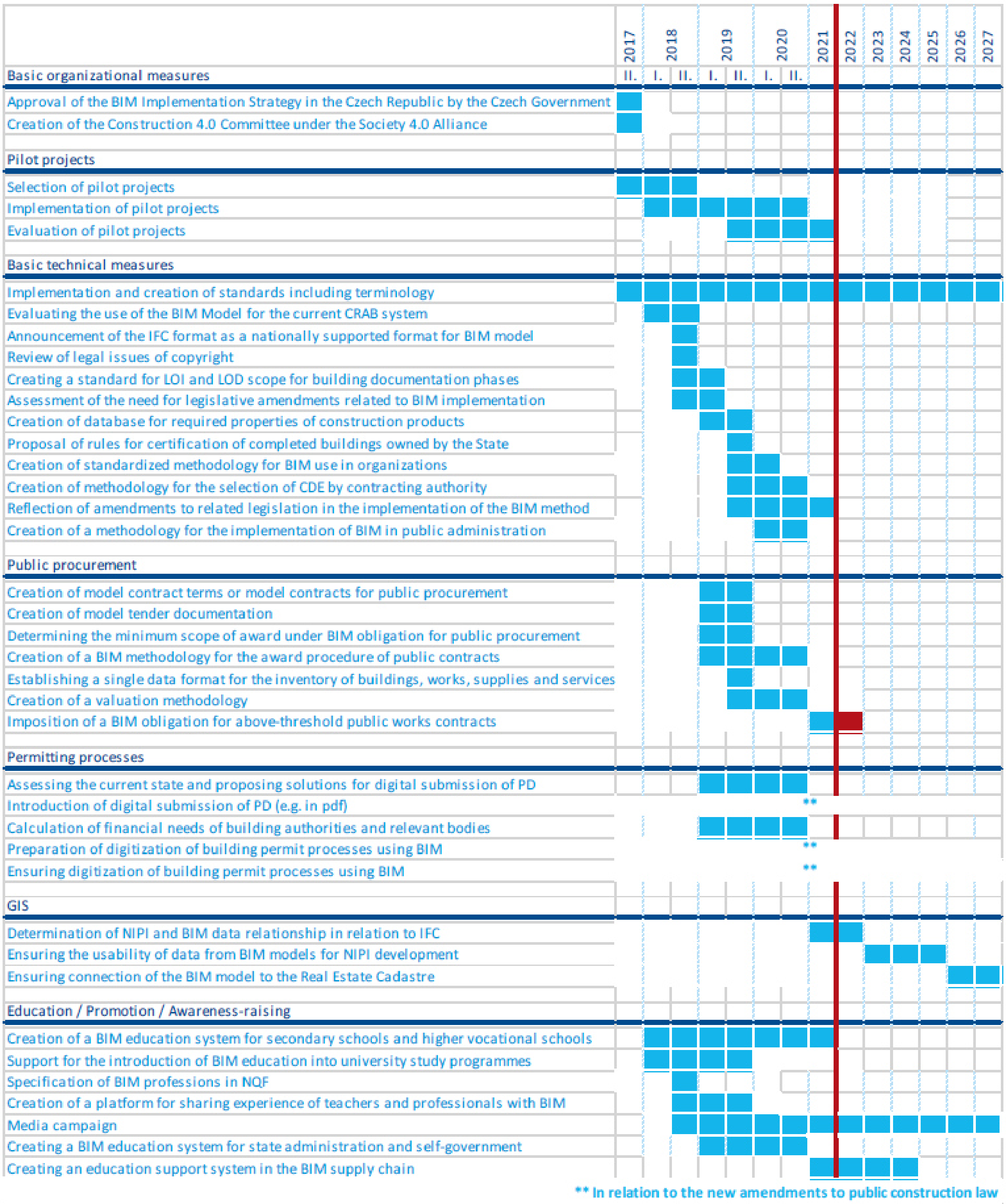

Figure 2 – Schedule of recommended measures [1]

For the purpose of abiding the obligation set on the beginning of 2022, it is necessary to *“assess and clearly define the scope of the obligation and more precise specification of what will be required as BIM” [14].* All of the above-threshold public works contracts should therefore, according to *the Strategy,* meet all of the requirements defined as three main areas – obligatory BIM execution plan (BEP) bound by the contract, submitted 3D model in an open IFC format and obligatory use of common data environment (CDE) for sharing project information.

The Strategy also mentioned some of the long-term benefits of using BIM, such as savings in costs and time, improved communication among all project participants, increased transparency, lesser environmental impact and many more, while explaining how they could potentially become invaluable in each process throughout the entire lifecycle of a building.

Another important matter on the agenda was related to the *"requirements for the properties of construction products and elements for the creation of a building information model" [14],* as it is necessary to ensure the quality of the transmitted data and software interoperability by establishing certain standards, such as stable open data formats (IFC being the only format at the time that *"complies with ISO 16739 and contains the definition of the parameters of the individual elements of the model, which the software can already transmit between each other" [14]*).

The Strategy focused also on the importance of pilot projects, since they are in general the key in implementing any new trend into practice. The launch of pilot projects is essential not only to improve the methodology, but also to adjust the existing standards as well as to create advanced procedures and contractual terms and conditions within the BIM implementation. In addition, the use of BIM in practice is crucial for further education which is another issue that *the Strategy* deals with.

According to foreign experience, an effective cooperation between educational institutions and practice creates many opportunities for mutual improvement of both respective fields. *The Strategy* divided BIM education into two basic categories, first one being current workers that need to adapt to new procedures and undergo the change management process and the second one being new workers that should be prepared by educational institutions such as secondary schools and universities, to be able to eventually join the current workers in the future practice. For these institutions the recommended development is to implement specific subjects and courses concerning BIM into their program while teaching students not only about software and 3D modelling, but rather about the whole life cycle of a built asset in relation to BIM. Concerning the first category, the change management process should be established with the help of a professional at a general level, but also individually in order to create secured and comfortable environment for each worker.

There are several other fields that *the Strategy* deals with, such as Facility Management (FM), Geographic Information Systems (GIS), construction 4.0, technical standards, public procurement, legislation and a few others, which are equally relevant, however their development related to BIM implementation needs to be addressed additionally in the future, as well as that of some fields already mentioned above, since there is a lot of variables which may deviate their approach to establishing certain changes and upgrades moving forward.

A substantial part of *the Strategy* consists of recommendations related to each of the topics mentioned in the document. It concerns all of the parties participating in the lifecycle of a building, including *"architects, engineers, contractors, investors, building owners, building managers, software manufacturers, government institutions, research laboratories, universities and other members" [14]*. After all, it is up to them to join the process and unite in order to create an environment in which they can collaborate easily with one another and provide the interoperability of everyone involved as a huge step leading to success of the national BIM implementation.

[11], [14]

3.3 Review and adjustment according to the current situation

The current state of fulfilment of the schedule of recommended measures presented in *the Strategy* is monitored and reviewed by the Ministry of Industry and Trade (MIT) with the cooperation of the Czech Office for Standards, Metrology and Testing (COSMT) while the results are being simultaneously published online. The execution of measures resulting from the schedule is taken care of by the Czech Agency for Standardization (CAS) mentioned above, which became active as of January 2018 as a state contributory organization established by the COSMT.

[15]

In December 2018, the government discussed a document called *"Information on the fulfilment of BIM Implementation Strategy in the Czech Republic"* (for further notice referred to as *"the Information"*) submitted by the MIT in September 2018. *The Information* was supposed to evaluate the course of performance of the schedule introduced in *the Strategy* during the period between

October 2017 and August 2018. It concluded a successful launch of all activities that had been planned for the first half of the year 2018 as well as of a few others that began ahead of the scheduled time. Overall, 22 out of 38 measures have been set in motion while several specialised organizations and educational institutions became involved in the process and helped with the procurement of seminars and conferences concerning the subject of BIM implementation. The observed period was therefore declared successful and confirmed the ability of the Czech Republic to perform tasks in order to achieve the objectives set by the provided schedule.

[15]

On November 21st of 2019, the first International Summit dedicated to the implementation of *the Strategy* has been held in Prague, the capital of the Czech Republic. The Summit was organised by the CAS agency in cooperation with the Ministry of Industry and Trade and it included professionals from all around Europe. More than 240 registered participants from different fields attended this event, beginning with members of the state administration and ending with independent entrepreneurs. The Summit took place throughout the whole day which has been divided into three sections. The first one focused on the stages of fulfilment of recommended measures provided by *the Strategy* and the importance of digitization, unified methodologies and cooperation of state officials within the Czech Republic. The second section was dedicated to guest participants from various parts of Europe that presented the public procurement approach in relation to building information modelling in each or their respective countries as well as the activities and latest news concerning digitization of the construction industry. The final section concluded that so far, the BIM implementation strategy in the Czech Republic has been going in the same direction as that of most European countries and that we share the same priorities, such as the importance of securing open data standards that provide better interoperability, unification of the classification system and carrying out pilot projects while sharing their results. The whole event was completed by a panel discussion that focused on answering questions submitted throughout the day by representatives of several significant organizations in the BIM implementation field. The International Summit therefore confirmed that cooperating with other countries during an implementation process while sharing ideas, visions and over time achieved results proved rather beneficial and in accordance with the general principles of BIM implementation.

[16]

Nowadays, the last known information about the fulfilment of recommended measures published in *the Strategy* confirms that the Czech Republic is proceeding in line with the initial plan. According to a log of an online meeting of the BIM commission members from February 2020, there is currently a new act about BIM in preparation. However, the official statement says that according to a few members the act is *“not coordinated in terms of terminology or substance, shows inconsistency of concepts and non-existence of a substantive intent and is currently in violation of the Legislative Rules of the Government” [17].* Since the necessary adjustment takes time, it might cause a considerable delay, which could eventually also lead to a possible delay in terms of fulfilling the recommended measures provided by *the Strategy*, including the mandatory use of BIM in public procurement. Nevertheless, as of now, it is still only an assumption, since there is lack of an official statement on behalf of the government, so the current belief is in the obligation being imposed on time.

[17]

4. BIM implementation in Spain

Following Chapter 3, Chapter 4 deals with the BIM implementation process in Spain in a similar way. It examines the adoption of general principles of implementing BIM on a national level by the Spanish government and in turn reviews its most significant aspects in order to possibly compare the differences on each part in Chapter 5.

4.1 Standard and information availability

First and foremost, one of the most important steps in BIM implementation is the provision of general standards and up-to-date information on a national scale, which is usually being secured by numerous organizations entrusted by the government. As it was mentioned before, there are several branches of buildingSMART International in various countries including Spain, whose individual branch referred to as the buildingSMART Spanish Chapter is considered one of its most significant organizations concerning the implementation of BIM.

It was founded in 2012 and its main objective ever since has been the development and promotion of open data formats and encouragement of the use of BIM nationwide while sharing data and information within the entire buildingSMART International organization. One of the most significant events organized by the Spanish Chapter in cooperation with BIM Academy and CAATEEB (*"Col·legi d'Aparelladors, Arquitectes Tècnics i Enginyers d'Edificació de Barcelona"*) is the European BIM Summit held annually in Barcelona.

The main intention of this international congress is to share and discuss BIM methodology in the world in order to improve international cooperation in BIM implementation. The first European BIM Summit took place in 2015 and among other things it consisted of several Spanish institutions signing and publishing a letter of intent and scheduled goals for the adoption of BIM in Spain. This document described the goals for the following years up to 2020, starting with agreeing on a BIM mandate before the beginning of 2017, followed by adopting IFC standards, guidelines, classifications and processes of digital delivery models while keeping in mind their integration into cities and defining common protocols for sharing information and interoperability. The schedule ended with the goal of requiring the use of BIM in all new construction and renovation projects in all phases from design to maintenance until the end of 2020, which eventually became reality.

[5], [18], [19]

Concerning standards availability, the main source of Spanish standards are organizations that operate on an international level, such as the International Standards Organization (ISO) that provided first BIM standards in 2015, the most significant one being ISO 16739 which requires the use of IFC (Industry Foundation Classes) in public tenders and ISO 19650 that defines information management requirements in relation to the use of BIM.

[8], [18]

Apart from the ISO standards that are being developed on an international scale, Spain also has its own organization that deals with standards within the country. It was formerly known as the Spanish Association for Standardisation called UNE, appointed by the Ministry of the Economy, Industry and Competitiveness. However, in 2017 UNE *"changed its name and corporate purpose and transferred its commercial activity (conformity assessment, training and information services) to AENOR" [20]* and became the new Spanish Association for Standardization and Certification responsible for the development of technical standards and certifications on a national scale. AENOR has been cooperating with several other organizations in order to promote BIM in Spain through standard distribution since 2012.

[19], [20]

In order to promote BIM on the market and share current information, EUBIM congress takes place on the campus of the Polytechnic University of Valencia (UPV). The abbreviation refers to the BIM international conference held annually in the city of Valencia, ever since 2012.

Over the course of EUBIM 2014, the participants from the academic field agreed that *"the publication of the BIM academic manifesto should call for a training plan for a Collaborative BIM integrated among all academic institutions, nationally and internationally" [19].* The main objective of this plan was to serve as a helping tool in pursuit of an improvement of student, teacher and professional training in the construction sector on both national and international level.

[19], [21]

In 2015 the Spanish Ministry of Development has supported the foundation of the Es.BIM project, *"a group open to all agents involved (administrators, engineers, builders, universities, professionals, etc.) whose main mission is the implementation of BIM in Spain" [22].* It was created in order to accelerate the spread of BIM throughout the Spanish construction industry in both public and private sectors, to promote digitization and the use of BIM during the entire lifecycle of a building or an infrastructure, to spread awareness of the need to adapt the national legislation to BIM methodologies and develop national standards concerning the use of BIM.

Since the foundation of the Es.BIM initiative, there have been many practical experiences of BIM processes used in construction and infrastructure projects shared within the Es.BIM online portal which is accessible by construction companies and other members of the AEC sector. These construction and infrastructure jobs are also known as pilot projects. For each project, the following information is covered: *“name of the company that has carried out the project, date and images of the project, specific data (size of the area, level of detail, client, budget, time period, etc) - not all of which have been provided for all the projects, purpose or use of BIM in the project, benefits gained by the stakeholders” [22].* By providing this information *“organisations and companies encourage the adoption of BIM methodology as a global cross-departmental strategy, establishing policies that help setting staggered goals and planning required training. They also encourage staff to share best practices and lessons learnt from their practical experience, to allow continuous improvement on BIM methodologies and to correct eventual deviations” [22].*

Another important part that the Es.BIM initiative takes part in worth mentioning is the responsibility for data and information management. It requires carrying out *“a thorough review of existing international rules, standards and common practices” [22]* and subsequently comparing it with “*the current situation in the Spanish AEC Industry and recommending changes to the traditional roles as well as identifying new tasks to be developed for different types of projects at different stages. By analysing existing documentation and best practice from different countries and international standards, the Spanish initiative tried to benefit from the larger experience of BIM implementation in other places all over the world. At the same time, given the fact that some of the responsibilities and related liability in projects in Spain are regulated by law, it was necessary to adapt the findings to match the existing legal framework in Spain” [22].*

[10], [22]

The Es.BIM has also been dealing with the transposition of the EU Directive 2014/24/UE that the Spanish construction industry has been subjected to since February 2014. This regulation has been established in order to *“modernize European Government procurement and reduce costs in the 28 EU member states. It allows member states to encourage, specify and even require the use of Building*

Information Modelling in construction projects financed by European public funds as of 2016" [23]. In response to this directive, the Spanish government took action quite promptly by establishing a commission for BIM methodology implementation on a national level by the Ministry of Development in July 2015, scheduling the regulatory approval of this EU Directive for 2018 and its compulsory use in public tenders for building construction in 2018 and for infrastructure in 2019.

[23]

4.2 BIM implementation strategy

Since Spain consists of 17 autonomous communities and 2 autonomous cities, the implementation of BIM on a national scale might seem quite difficult. Each community could approach the process in a different way, even though they are a part of the same country. Therefore, the presence of unified Spanish standards is crucial in order to avoid chaotic implementation that leads to unnecessary setbacks, waste of time and money and an overall lacking system.

As it was mentioned above, the first BIM implementation plan was created in 2015 over the course of the European BIM Summit held in Barcelona. Several countries signed a letter of intent and scheduled goals for the adoption of BIM in Spain for the following five years. The most important point of the implementation strategy was the requirement for the mandatory use of BIM in public procurement, since according to several other countries that had dealt with BIM implementation prior to Spain, it is the best way to secure its use throughout the entire construction industry. However, there was not an official published strategy provided by the government, besides the requirement for the mandatory use of BIM in public procurement as of December 2018.

[19], [24]

In 2017 *"The QBIMInvest Project (supported by the Universidad Europea de Madrid) has conducted a survey on the implementation of Building Information Modelling in the Spanish AEC industry" [23]*. Targeted categories of the survey were mainly *"architects, technical architects, building engineers, civil engineers, highway engineers and industrial engineers working in the construction sector" [23],* but also several *"professors in the Building Technology & Management Department at the*

School of Architecture, Engineering and Design" [23]. The presented results of this survey showed that the Spanish market was at the time "*very immature in terms of collaborative work with BIM, with superficial knowledge and partial application in the design stage, used mainly as a drawing and modelling tool" [23].* According to the survey, the use of BIM tools in the construction stage proved to have been minor. They were being used only in stages of the design. "*However, the concern regarding intellectual property disputes that had been expressed in other studies conducted in countries that are more advanced in the use of these tools has not been detected, which could also be considered a lack of maturity" [23].* In addition, the survey showed that the BIM 3D models had not been developed until they became "*as-built models used as part of operation and maintenance stages, that should supposedly benefit most from the use of these tools" [23].*

[23]

4.3 Mandatory use of BIM in public procurement

Since March 2018, the use of BIM in public works tenders has been proclaimed recommended, which helped with moving its implementation process along, however it was still not quite sufficient.

According to the Es.BIM record from April 2018, 37% of Spanish companies had believed that BIM is not a priority, resulting in need of more binding measures, such as mandatory use of BIM in public works tenders. The report also indicated that BIM has been mainly used during design and construction phases of the building lifecycle so far and very little in other areas, such as facility management and maintenance, which is essential in order to take full advantage of the BIM potential.

Following this record, in December 2018 the use of BIM in public works construction tenders has become mandatory, as previously approved and advertised by the Spanish government.

In July 2019 the use of BIM in all public works infrastructure tenders has become mandatory as well.

[25]

4.4 Guide to public procurement in relation to mandatory use of BIM

Since the use of BIM has become recommended and eventually mandatory in all public works construction and infrastructure tenders, construction companies started to realize that it's truly here to stay, therefore a new issue came into existence, a sudden need for a universal guide to help everyone involved understand at least the basic principles of BIM contracting. This matter has been dealt with by the College of Technical Engineers of Public Works that in cooperation with the Ministry of Transport, Mobility and Urban Agenda and twelve experts in the methodology published a 192 pages long document called *"Guide to support contracting with BIM requirements"* (for further notice referred to as *"the Guide"*).

Its main purpose has been to facilitate the work of Civil Engineers and related professionals in public procurement processes with BIM requirements. *The Guide* was presented as part of an 18 days long conference held throughout Spain, including various presentations given by prominent speakers, some of whom have also participated in the writing of the document. The conference, conducted as a training process and a source of up-to-date information, was offered free of charge by the College of Technical Engineers of Public Works since it was, along with the development of *the Guide*, sponsored by a grant from the Ministry of Transport, Mobility and Urban Agenda.

It consists of ten chapters in which the current status of BIM in Spain and on an international level is explained and piece by piece it reveals different stages of BIM strategy. It refers to relevant standards and provides information on BIM technologies, contracting, CDE, bidding and delivery requirements, BIM management, information planning and eventually an analysis of a real case BEP. *The guide* basically gathers all prior knowledge necessary to face a tender with BIM requirements and serves as a *"common element of knowledge transmission" [9]* amongst all parties related to the construction industry and as *"an instrument of change in their mentality" [9]*. It is nowadays considered the latest manual in dealing with all public works and infrastructures requiring building information modelling.

[9]

5. Comparison of BIM implementation in the Czech Republic and Spain

The differences in BIM implementation in the Czech Republic and Spain were assessed and reviewed in several categories. Since BIM implementation from the state's perspective is a very complex process with a lot of variables and aspects that need to be taken into account, there could be potentially many more categories and subcategories to analyse and compare. However, this thesis deals with only a few of them that are considered as the most important ones from the point of view of the author.

5.1 BIM implementation strategy including the mandatory use of BIM requirement

Initially, both countries were compared in terms of having a general implementation strategy in place which is a basic requirement for introducing any kind of innovation on the market. The Czech Republic officially introduced its strategy in 2017 by the Ministry of Industry and Trade in a published document completed by a 10-year plan of action. On the other hand, Spain focused more on creating specialised task groups and organizations without publishing an official statement by the government in terms of specific plans in the future, apart from the requirement of mandatory use of BIM in public procurement set in 2015 by the Ministry of Development. However, at the same time multiple institutions that deal with the BIM implementation process have signed a published letter of intent and scheduled goals for the adoption of BIM in Spain, including the request of using BIM in public procurement. Therefore, even though each of these countries approached the matter of setting up an initial strategy in a slightly different way, they came to the same result, the Czech Republic chose a more direct method through an official document created by the government while Spain primarily created specialised organizations and task groups which afterwards took care of publishing their strategy with respect to the requirements of the government.

Consequently, the second major step of the entire implementation process to compare from the perspective of a nation was the requirement for mandatory use of BIM in public procurement. As it was mentioned above, both countries approached this matter in the same way and issued an official request by the government. The

Czech Republic set the deadline for all above-threshold public works tenders to January 2022, however it is not yet possible to determine if this requirement will be met on time. On the other hand, Spain set the deadline for public works construction tenders to December 2018 and for public works infrastructure tenders to July 2019. Both of these scheduled terms were complied with and in addition the Spanish government published *the Guide* in order to help each member of the construction industry to be able to properly deal with the requirements for mandatory use of BIM in public procurement.

5.2 International cooperation

Concerning the national standard availability, both countries chose to adopt the international standards published by the International Organization for Standardization (ISO). The most important standard that they share is considered ISO 19650, which applies to the whole life cycle of a built asset and defines information management requirements in relation to the use of BIM.

According to the theoretical analysis, the Czech Republic and Spain share the vision and ideas of buildingSMART International and are cooperating on BIM implementation with other countries through this organization. The only difference is that Spain has got its own chapter that is dedicated to oversee and encourage the implementation process in accordance with buildingSMART International principles, while the Czech Republic uses other organizations for this purpose. In any case, the intention of both countries has always been to benefit from their cooperation with various members of the construction industry on an international level.

In relation to international standards and interoperability, both countries have adopted the use of IFC open data format, since it complies with ISO 16739 which requires its use. The choice of IFC is also related to the cooperation with buildingSMART International which supports and shares advanced standards created by the International Organization for Standardization.

5.3 National tools for BIM implementation

One of the most important tools for BIM implementation on a national level are without a doubt specialised agencies and organizations that are responsible for the execution of all necessary measures and recommended actions in order to comply with the initial strategy and its adjustments over the course of time. In case of the Czech Republic, this representative is considered the Czech Agency for Standardization (CAS) created following the publication of *the Strategy* and active since January 2018. CAS is responsible for overseeing the entire BIM implementation process within the country which includes cooperating with multiple agencies and individuals on national and international level, organizing events for BIM promotion and discussing BIM related issues, providing up-to-date information and most of all, executing all necessary steps in order to implement BIM in accordance with *the Strategy* provided by the Ministry of Industry and Trade. In Spain, the representative organization for control and regulation of BIM implementation is Es.BIM, created in 2015. Its main objective is the same as the one of CAS, to promote BIM and ensure its implementation throughout the entire construction industry in compliance with initially scheduled goals and intentions, while gathering and sharing information about numerous pilot projects, promoting digitization and the use of BIM and providing reliable methods of communication within the construction sector and related units. In summary, both countries created specialised organizations that are dedicated to and responsible for the execution and supervision of all necessary measures in order to ensure BIM implementation according to their initial plans and strategies.

Concerning the promotion of digitization and the use of building information modelling on the market, CAS and Es.BIM are considered the main source in the Czech Republic and Spain, respectively. Each of them organizes various events in order to support continuous communication, sharing of up-to-date information and discussing BIM related issues. The Czech Agency for Standardization organizes for instance the BIM DAY conference annually held in Prague, whereas Es.BIM promotes BIM through events such as the European BIM Summit and the International BIM conference.

5.4 Education and know-how

In terms of education and gathering and applying know-how, both countries approached the matter in a very responsible way. Each of them takes great interest in cooperating with educational institutions, such as secondary schools and universities. Their main goal is to incorporate courses designed specifically to explain the use of BIM throughout the entire life cycle of a built asset into their agendas. Part of their BIM education process consists also of providing the current workers within the construction industry and related institutions with a change management process including educational seminars and help from professionals that are trained in dealing with different aspects of BIM in real life construction.

In addition, both countries have launched numerous pilot projects in order to gain first-hand know-how, since practice is its biggest resource. Pilot projects carry all the important information and by applying BIM into practice as part of several projects, there is a very high probability rate of gaining invaluable insight into BIM-related issues which in turn provides knowledge necessary for their solution and moving forward. The results of BIM application in practice are usually published on an online platform or presented over the course of BIM-related events. Numerous projects are also used in variously oriented case studies concerning the use of BIM throughout the AEC sector. Some of them have been chosen as examples to illustrate the theoretical analysis which represents the main part of this thesis and are presented in Chapter 6.

In summary, the results of the comparison of BIM implementation in the Czech Republic and Spain are presented below in **Table 2**.

BIM implementation steps	**The Czech Republic**	**Spain**
Implementation strategy	*"BIM Implementation Strategy in the Czech Republic"* – officially published strategy by the Ministry of Industry and Trade in 2017	No officially published strategy provided by the government, but a letter of intent and scheduled goals for the adoption of BIM in Spain signed by multiple institutions that deal with the BIM implementation process

Mandatory use of BIM in public procurement	Mandatory use of BIM in all above-threshold public works tenders since January 2022.	Mandatory use of BIM in public works construction tenders since December 2018. Mandatory use of BIM in all public works infrastructure tenders since July 2019.
National standards availability	Adoption of international standards published by the International Organization for Standardization (ISO 19650)	Adoption of international standards published by the International Organization for Standardization (ISO 19650)
Cooperation on implementation on an international level	Cooperation with buildingSMART International through national organizations	Cooperation with buildingSMART International through buildingSMART Spanish Chapter
Open data format availability	Adoption of the IFC open data format	Adoption of the IFC open data format
Organizations dedicated to executing all necessary measures in order to ensure BIM implementation according to the initial plan	The Czech Agency for Standardization (CAS)	Es.BIM
BIM promotion on the market	Promotion through the Czech Agency for Standardization (CAS), the Czech BIM council (CzBIM), BIM DAY and other conferences and gatherings held periodically	Promotion through Es.BIM, European BIM Summit, International BIM conference (EUBIM) and other conferences and gatherings held periodically
BIM education	In progress	In progress
Pilot projects execution	In progress	In progress

Table 2 – Comparison of the Czech Republic and Spain [1]

6. Case studies

In order to examine the implementation of building information modelling into practice up to date, this thesis applies one of the most favoured research strategies available, commonly known as case studies. According to the Cambridge Dictionary, a case study is defined as *"a detailed examination of a particular process or situation over a period of time"*. In this case, the examination is focused on various BIM implementation processes throughout the construction industry, including the presentation of their initial purpose, means of execution, acquired knowledge and the possibility of its further application.

The role of case studies presented in this thesis is mainly to provide a few examples of actual BIM implementation into practice and to illustrate different kinds and ways of applying and using building information modelling within the construction industry. Since there are countless possibilities of BIM utilization in practice, it is quite difficult to compare the level of its implementation based solely on a few randomly chosen case studies. Therefore, this chapter is dedicated mostly to the visualization of the general theoretical knowledge in real life construction and serves as a complementary section to the main theoretical part.

[26]

6.1 Case studies in the Czech Republic

For the purpose of simple disposition and differentiation, to begin with the focus is on three case studies carried out within the Czech Republic. The first one of them deals with the application of BIM in a small-scale reconstruction project of a historically significant building located in Obecnice, a small-size Czech village. The second case study examines the use of BIM in relation to the life cycle assessment as part of a project of an experimental residential building in Prague, capital of the Czech Republic. The final case study is about BIM utilization in historical reconstruction of the Vinohrady Synagogue located also in Prague. All three of them are examined separately, since they have been chosen randomly and each one of them has a unique approach to BIM application and the use of its diverse properties on various built assets.

6.1.1 Case study No.1 – Small-scale reconstruction project in Obecnice

6.1.1.1 Introduction

One of the most familiar advantages of implementing BIM into practice is the realisation and application of a 3D construction model. This has been, among other things, brough to attention by a fellow student of the Czech Technical University (CTU), Lukáš Kozel. According to Kozel's case study, presented as the practical part of his diploma thesis focused on the use of BIM in small-scale reconstruction projects, a 3-dimensional model of a small-scale construction could potentially benefit its owner as well as the construction company in many ways.

In this case, the BIM methodology was used on a historically significant building in a village called Obecnice. Kozel presented it as a parochial house which was no longer being used at the time, because of its need of full reconstruction. He dedicated a huge part to an extensive structure description focusing on each and every part in great detail, for the purpose of creating the 3D model with as much accuracy as possible.

[27]

6.1.1.2 Methodology

For the purpose of creating the reconstruction model, Kozel used a computer program called Autodesk Revit, version of 2016. The model was based on the original drawings in 2D provided by the owner. Initially, the author created a 3-dimensional representation of the original building and in turn he proposed a new design including the restoration of all damaged parts and several building modifications. The established model eventually consisted of three phases – original, remaining and new structures, all differentiated by colour. In addition, it was imported into a simulation program provided by the same company, called Autodesk Navisworks, version of 2018, for the purpose of clash detection which is essential for the model adjustment. Once the model's been finished, it was possible to compare the differences in time and cost consumption in the phase of creating the design between the standard 2D process and its upgraded 3D version. The implementation of BIM methodology was primarily described by the author as a helping tool in the phase of design, which is the most common way of using it, however it can come in handy on many other occasions, such as during bid processing, project documentation and bills of quantity revision, creating schedules, construction site organisation, construction compliance with current legislation, even facility management.

[27]

6.1.1.3 Results

In this case, the use of BIM methodology resulted in portraying many benefits of a 3D model application across various fields within the construction industry, which are as follows.

First and foremost, it provides the owner with a digital visualization of the project in its final form before any of the construction work begins, so that they can have a better idea of how the building will look like after the reconstruction is finished and they can suggest potential client changes. The model can be upgraded anytime during the ongoing reconstruction as well, so any change implementation is operational and can be accepted within the possibilities of the structure.

In addition, the use of BIM methodology may prove to be advantageous also in communication coordination between the owner, designer and general contractor. The role of BIM coordinator in this case would be to ensure proper ways of communication among all interested parties even before the beginning of the design phase. This way, the owner can propose the requirements for the construction model through the BIM coordinator so that the designer can implement them right away and adjust according to any additional requests until the design proves satisfactory. Adding the BIM coordinator into the process ensures the cooperation of everyone involved, generally with the obligation of abiding the initially set terms and conditions. An important part of this cooperation is providing individual parts of the model for regular collision revision.

If we're dealing with a reconstruction project of a historically significant building, such as Kozel's, there are usually multiple engineering companies cooperating on the design, therefore it is possible to discover numerous collisions among different professions. The most common collisions are those of utility lines and incorrectly joined building elements. The clash detection is especially important in case of reconstructions, since their quantity and associated risk are much higher. In case of the parochial house, the results of the collision test showed a missing outlet between each chimney entity and the roof, as well as an improper connection of a bearing wall and the ceiling structure caused by an incorrect hight setting of the wall. These mistakes, when captured on time with the help of the 3D model, can be easily corrected while saving the costs of having to fix them later on, when the reconstruction is already in motion.

The author also highlighted the benefits of using BIM methodology in relation to legislation. Thanks to the three-dimensional representation of the building it is way easier and quicker to check if all building parameters are in accordance with current legal regulations. It can be also helpful during an ongoing construction process to verify the accuracy of various operating procedures and in turn determine whether all of the previously planned work is feasible.

Finally, the author compared the differences in time and cost consumption between the common approach and the BIM methodology implementation. The results showed that even though the use of BIM to procure the design of the building is more financially demanding, it proved to be very efficient in the process of the project realisation since it helped greatly decrease the construction costs in terms of more accurate bills of quantity estimate.

[27]

6.1.2 Case study No.2 – BIM related to life cycle assessment, experimental residential building in Prague

6.1.2.1 Introduction

One of the biggest fields of interest concerning all kinds of industry in general has always been their environmental impact. Naturally, the construction industry is no exception, which is the reason why an inseparable part of BIM implementation is also its connection to the life cycle assessment (LCA). The potential challenges of LCA in relation with the use of BIM are represented in a case study of an experimental two storey residential building from 2019, provided by members of the

Czech Technical University (CTU) located in Prague. In their work, they focused on the utilisation of a BIM model with all relevant environmental characteristics for LCA analysis. Initially, they pointed out the need of digitization of the AEC sector while stressing out the importance of BIM serving as the key factor of an evolution in the technology department.

Since the connection between BIM and LCA is provided mostly by incorporating the environmental parameters into a BIM model, the focus of the case study was from the most part on the Level of Development (LOD) of the model. *"The LOD in terms of incorporating environmental data can be divided in two parts: Aggregated Data Method and Element Data Method" [28, p.2]*. The Aggregated Data Method is a simplified method of modelling, mostly used for material base comparison. It is based on aggregating the environmental data while neglecting certain elements in order to reduce their number included in the model, therefore simplify the LCA process while using a model developed in LOD 200-300. On the other hand, by using the Element Data Method, which is a detailed method of modelling, it is possible to calculate a precise environmental impact of a building based on its use of material. In this case, the model is usually developed in LOD 350-400 while containing detailed geometrical data of the building without neglecting most elements. Even though this method is highly accurate, it is way more time consuming than the simplified Aggregated Data Method, which is why it is important to decide which parameter is the priority at the beginning of a project.

[28]

6.1.2.2 Methodology

The main objective of the case study was *"to develop a flexible construction system for a new generation of multifamily residential buildings capitalizing on synergy of non-bearing light timber-based structures with a light bearing structures from high performance concrete with maximal utilization of advanced prefabrication technologies" [28, p.2].* In order to achieve this goal, the authors used the Autodesk Revit software to create a design model of the experimental residential building in LOD 300 with the application of the Aggregated Data Method and a construction model in LOD 400 with the application of the Element Data Method. In addition, they also decided to create an as-built model in LOD 500 incorporating all parameters necessary for further use by the Facility Management and a dashboard showing real-time data from the incorporated sensors. To evaluate the environmental impact of the designed elements they chose to use the SBToolCZ scheme, *"a Czech national sustainability certification scheme similar to BREEAM or LEED" [28, p.2].* It can be applied for all residential buildings and *"it is based on complex evaluation of environmental, social, economic and location-related quantitative and qualitative indicators" [28, p.2].* The resulting scores are eventually awarded by a bronze, silver or gold certificate.

[28]

6.1.2.3 Results

Since the case study originated in 2019, it is still a work in progress and the results at the time were not entirely conclusive. However, it provided the current status of the design model of the experimental building which was meant to be built in the spring of 2019 at the University Centre for Energy Efficient Buildings (UCEEB) of Czech Technical University (CTU) in Prague. The model has been developed in LOD 300-350 while containing all relevant structures with the respective environmental data, such as primary energy input and global warming potential. *"The environmental data has been taken out of the Envimat database, the Czech catalogue of the environmental parameters of building materials" [28, p.3].* During the modelling process, the team has dealt with several difficulties. It concerned mostly environmental data quality and consistency, quality of the model and its LOD and software limitations, for instance in terms of volume deviation. These obstacles were caused mainly by the lacking methodology and legislation concerning the process of implementing environmental data into a BIM model. Nevertheless, the use of BIM related to the application of the Aggregated Data Method of the environmental data implementation proved widely beneficial since it allows simple comparison of different material bases. Incorporating the basic environmental data is also an easily replicable process which can be very convenient for further use.

Because of the delay in the construction phase, the idea of the design phase including the implementation of all relevant data being used to benefit and support the operational phase could not have been examined yet. Therefore, the results at the time were not available. However, the authors of the case study described its future focus being to incorporate the sensors data into the BIM model, as well as all environmental data following the SBToolCZ scheme and to create a methodology that could allow them to replicate the acquired knowledge across the market.

[28]

6.1.3 Case study No.3 – BIM in historical reconstruction, the Vinohrady Synagogue in Prague

6.1.3.1 Introduction

An incomparable case study concerning the use of BIM was created through the Erasmus international exchange program and published in 2012. Its uniqueness rested upon its focus on virtual reconstruction of a historical building in Prague which no longer exists since it was demolished halfway through the 20th century. Since its property has gained a new function since the destruction of the building, there was no point in its physical reconstruction. However, a virtual restoration of a cultural heritage seemed important as it could bring the society closer to what a foregone era looked like and preserve it for future generations. For this reason, it has been decided that the building would be reconstructed through the application of building information modelling. The historical building that this case study focused on was at the time the largest synagogue in Prague, originally located in a neighbouring city called Královské Vinohrady which eventually became a part of the Czech capital. It was built between 1896 and 1898 and it was an expression of wealth of the local Jewry. The building was designed in neo-renaissance style and it consisted of a rather symmetrical plan and elevation. It was visually divided into three parts: the main nave and two side buildings. The appearance of the synagogue was rich in decoration and the interior included a particularly interesting lighting which made it an extraordinary historical building. However, it was severely damaged over the course of the Second World War and finally torn down in 1951.

[29]

6.1.3.2 Methodology

The main approach to the virtual reconstruction process was inspired by a strategy that had already been tested on a similar project in Vienna. At the beginning, there were lots of resources in need of processing. *"A listing of all possible sources is referenced in a so-called "metafile", which acts as a resources metadata table" [29, p.3].* All resources are therefore handled in a spreadsheet that is capable of following a chronological structure in a chosen project as well as in several others whereas a strict database structure would be dependent on a single project. *"Most of the material for this reconstruction was obtained from the archive of the Prague Jewish Museum and included plans, documents, drawings and pictures." [29, p.4]* According to the authors of the study, there was an overflow of graphic entities (photographs, plans) and a lack of specialized literature with hard facts. All images had to be reviewed and compared in order to provide as accurate representation of the synagogue as possible. Each of them has been assigned basic properties such as type of image, its purpose, specific location, date and additional comments. All gathered information about the building was therefore saved within a single spreadsheet that could be variously filtered and adjusted to show different properties of the synagogue and simplify its virtual reconstruction process. Since the project contained a large amount of data, the process was fragmented into two parts, setting up a basic building structure which afterwards led to expanding the complexity of the model. This way it would be easier to access and work with each part of the project, even alter it in the future. It also led to simpler and faster application of the BIM methodology. For this purpose, the authors of the reconstruction had opted to use the ArchiCAD 15 software created by Graphisoft which provides several tools that could be beneficial while creating the 3D model of the building. One of those is the *Renovation filter* that usually shows different stages of a reconstructed building. Even though it is not commonly used for this kind of historical projects, in this case it served as a useful tool for the differentiation of sets of objects with different materiality within the model that can be either shown or hidden, based on what is currently needed. The authors of the case study mentioned several ArchiCAD tools that have been upgraded over the years and provided sufficient support while creating the model, however they also pointed out that the tools still presented certain flaws and limitations that prevented them from using the software to its full potential.

[29]

6.1.3.3 Results

According to the results of the case study, it was not possible to create intelligent, parametric objects through the use of BIM that could be used in other similar reconstructions, since the size of the selected project proved to be too large. Even though the chosen software offered a lot of updates and improved tools, most of them are *"still exclusively focused on contemporary building practice" [29, p.9]*. For the purpose of better utilization of ArchiCAD, the authors recommend the software developers to provide access to *"even more user-friendly set of tools to create custom objects and perhaps a cloud, to share these objects with other academic or personal users" [29, p.9]*. However, the use of building information modelling in this case showed also a set of advantages, such as custom geometric modelling, story administration, layer allocation and others. Even though this project proved to be too vast in size, the idea of making various adaptable objects suitable to use in similar projects through small parametric alterations is still valid, it is just one of the things that need to be examined in the future as part of another project. Finally, the use of BIM in order to create photo-realistic images and 3D prints of the historical synagogue that no longer exists proved to be satisfactory and a great asset in terms of restoring memories of this construction masterpiece. However, according to the authors it would be even better to implement a more interactive visualization technique to truly bring the building to life, so the viewers could examine the model themselves, which is an interesting idea for a future use of the case study.

[29]

6.2 Case studies in Spain

This chapter presents three various case studies concerning Spain, each one of them being unique in terms of different ways of BIM implementation. First up is a case study that deals with the use of BIM in small construction projects for commercial franchises throughout Spain, followed by a case study focused on implementing BIM in the restoration project of the former Royal Tobacco Factory located in Seville. The last case study explores the use of BIM in mutual synergy with the Lean Construction paradigm in a public construction project of the Multipurpose Building extension at the University of Alicante. As well as in the previous chapter, all of these studies are presented in separate sections and are examined and reviewed individually, since they are very distinctive and they serve mainly to extend and illustrate the theoretical knowledge of different ways of using BIM in practice.

6.2.1 Case study No.1 – Small construction projects for commercial franchises in Spain

6.2.1.1 Introduction

The impact of using BIM can be observed in small construction projects as well as in those of large scale. Although it is not adopted as much, the promotion and use of the so-called Little BIM is equally important. It has been explored in more detail in a case study published in 2020 that focused on featuring BIM methodology as a suitable tool for small construction projects of commercial franchises, since the repetition of certain fixed elements is involved as a key factor. According to the case study, *"previous quantitative studies have reported on the feasibility of 4D planning of graphic systems versus conventional systems in construction projects, to conclude that even though conventional planning was shown to be 20% faster than 4D simulation, the latter was featured as 40% more efficient in terms of visual monitoring of the process and also 40% more efficient in terms of data updating" [30].* It was therefore appropriate to compare the implementation of BIM methodology in cooperation with photogrammetry and the standard CAD method within the project of commercial franchises in order determine whether it is truly as advantageous as advised.

[30]

6.2.1.2 Methodology

The study focused on 121 projects of commercial franchises across Spain *"in the ambit of perfume and cosmetic industries which were developed between 2011 and 2016 and were based in both BIM and CAD methodologies" [30].* During the data acquisition process, the following information was collected: *"size and measurement data for the sample set of 121 projects, times for data collection and for CAD vs BIM-3D data processing, times for decision making since date of project delivery and times for project execution and opening since the beginning of working activities" [30].* As a first step, *"the potential correlations among the variables related to the size of the shops were identified," [30]* in order to obtain average measurements and calculate their mutual deviations. The acquired data was afterwards processed by both BIM and CAD methodologies, while using photogrammetry as a support tool for BIM processing. Eventually, two type projects were presented and executed, each under one of the protocols mentioned above. The results of both projects were thoroughly evaluated, variously compared and in addition, *"a multiple regression analysis was carried out. The net present value (NPV) was used to assess the investment profitability" [30]*, while accounting for the internal rate of return (IRR) as a complementary measure. *"Costs derived from the use of BIM, as compared to ordinary costs, were assessed by means of the calculation of the return on investment (ROI)" [30],* in regard of the following: "*hardware and software costs including BIM and photogrammetry, labour monthly costs, estimated time for training for the use of BIM software and processing and photogrammetric capture processes, loss of productivity during training and increase of productivity after training" [30].*

[30]

6.2.1.3 Results

As a result, the case study showed that *"the support photogrammetry and standardization of BIM processes improve traditional processing times. The main difference between the two methodologies lies in the fact that CAD processing requires the repetition of implantation of elements in different views (plant, elevation, profile, sections, etc.), while such process is automatically carried out in BIM.*

Furthermore, technical specifications of BIM elements are associated to metadata, which definitively speeds up their handling and post processing" [30]. Savings in time were also observed in the period between the date of the initial investment decision into a project and the date of its delivery, more specifically by 5,98 days in average in favour of the use of BIM methodology. Moreover, the regression model for 3 and 6 independent variables that has been carried out accounting for the execution time differences showed no instability when a new variable was taken into account. Concerning the productivity and the return on investment, the results were also satisfying on behalf of the use of BIM. Their calculation was carried out by creating a simulation of the franchise after its opening including daily invoices, gross estimated profit and labour costs provided by the Spain's National Statistics Institute. *"The gained productivity was computed as 27.2%, and the ROI corresponding to the first year was found to be 41.88%" [30].* Therefore, *"the computer simulation performed for the various options for BIM versus CAD implementation costs served as a clear justification for the investment on BIM protocols" [30].*

In conclusion, the case study showed that the implementation of BIM in small projects might be considered a contribution to sustainable construction, since it manifested as a huge improvement in the economic field. Even though the savings didn't represent a relevant amount (which might have been caused by the small size of the projects with no significant differences in terms of previous data collection and processing stages), the productivity and execution time largely improved and in turn both profitability and the return on investment became optimized. The application of the BIM methodology supported by photogrammetry also proved to be effective in terms of execution error and material cost reductions. The results of this case study were validated only in the scope of small construction projects and as a further line of research, the implementation of the reported methodology is being encouraged also as part of larger and more complex projects.

[30]

6.2.2 Case study No.2 – Restoration of the Royal Tobacco Factory in Seville

6.2.2.1 Introduction

An interesting case study published in 2019 explored the use of BIM *“as a useful technology to program and manage security during the restoration of the façade of an important historical building” [31]* located in Seville, the formerly known Royal Tobacco Factory. The construction of the factory began in 1728 and took almost 40 years to finish. *“In 1950, the decision was taken to convert the tobacco factory into the seat of the University of Seville, so the internal layout of the building had to undergo major transformation in order to adapt to its new function. Today, it is one of the oldest preserved industrial buildings in Europe” [31].* However, after almost three centuries of its existence, it was necessary that its exterior underwent a partial restoration as well, since the material used on the external façades and patios had gradually deteriorated.

Because of the historical and monumental importance of the building, *“design activities were faced not only with the delicate operation of identifying the appropriate operational techniques of intervention on the building, but with the dynamic analysis of spatial and temporal flows of construction resources, technological, human and material, and of the necessary preparations in terms of support logistics, in site that is both degraded and of significant importance for the community” [31].* Additionally, it had to be taken into account that the access to the building had to be allowed continuously over the course of the work in progress, therefore, it required *“ensuring the highest levels of safety for operators and users” [31].*

[31]

6.2.2.2 Methodology

In order to carry out a modelling experiment aimed at optimizing the levels of safety and organization of the restoration site, the worksite layout and the modelling of the scaffolding were developed” [31] with a prior use of the Work Breakdown structure (WBS). This provided *“a general index of the works, containing the codes* *used by the software to define each work phase" [31].* Afterwards, two comparing software were used for the simulation phase of the construction - STR Vision CPM and Navisworks Simulate. *"STR Vision CPM is an Italian software of quantity surveying that contains a BIM platform for the IFC model vision" [31].* On the other hand, *"Navisworks Simulate belongs to the Autodesk group and can be used to perform simulations based on a time schedule" [31].* Both software were used for each of the levels of the WBS, resulting in the creation of realistic project simulations of the works throughout the duration of the construction site.

One of the most important parts of the project was the design of the previously mentioned scaffolding, which had to be adjusted to the exact position of the façade elements. To ensure that there would be no collisions, all parts of the scaffolding had to be found in an existing catalogue and remodelled from scratch. *"Each element of the catalogue used in the model has been redesigned with a LOD 350-400, starting with the geometric information provided in the catalogue" [31].* Since the scaffolding was also used as a cover of the point of access to the building for the personnel during the executed restoration work, the BIM model pointed out all of the safety measures required in order to ensure their protection, especially against the danger of falling objects.

[31]

6.2.2.3 Results

Through the use of building information modelling, the project of restoration of the former tobacco factory was able to meet all of the safety requirements and according to the case study, its results can in turn serve as *"a development platform for a methodological guide for construction and safety professionals on the types of safety management which BIM can conduct" [31]* or for a way of using the information in BIM to generate a safety model. *"Although the issue of the organization and safety of construction sites is a relevant one for the optimization of the building process, only a limited number of studies continue to address the matter of how to design and manage safe construction based on the use of BIM and fewer still focus on restoration sites. It is very important to be able to predict and anticipate the interferences and the unforeseen events that may occur on the construction site because they represent the greatest risks in the safety field" [31].* That being said, it should be taken into consideration that *“safety is not a phase of the project, but it is a constant that accompanies all the project timeline and every work package” [31]*, therefore the focus of using BIM in the construction industry should be directed also on this particular matter.

[31]

6.2.3 Case study No.3 – BIM in relation to Lean Construction, public construction project at the University of Alicante

6.2.3.1 Introduction

A unique case study concerning the implementation of building information modelling has been carried out at the University of Alicante. It was quite exceptional, since it was the first case study of its kind in Spain that applied the use of BIM and Lean Construction in combination as mutual facilitators. According to a prior literature review of the case study, these two paradigms were previously used mostly as independent approaches to performance improvement during the construction process. However, on an international level, there has been a small amount of studies focused on using BIM along with the Lean Construction tools and principles in order to take full advantage of their potential.

This case study had built on the theoretical foundation of some of those studies and applied and reviewed the implementation of BIM in mutual synergy with one of the most representative tools of Lean Construction called the Last Planner System on a public construction project in Spain. *“This tool allows an agile and proactive management during construction work, moving away from some traditional project management methods, such as the critical path method that only allows a late detection of deviations” [32, p.3].* This way, there is better overview of the executed work which ensures enough time to face changes and unforeseen events that may occur during the construction process in a way that is sufficiently reliable in order to simply adjust to the deviations and avoid any rework tasks or re-planning.

[32]

6.2.3.2 Methodology

The research methodology of the case study consisted of three main phases. In the first phase, the authors provided basic theoretical knowledge on using BIM and Lean Construction, both separately and in mutual synergy, and identified their outcomes.

In the second phase, they presented the development of the case study carried out during a construction phase of a public building extension, the Multipurpose Building III at the University of Alicante, with the application of both paradigms mentioned above. The research consisted of the 3D model development which was updated on multiple occasions throughout the entire construction process. In addition, *"researchers used the Navisworks BIM management tool in the look ahead and weekly meetings, to visualize possible clash detection and to analyse potential constraints about design, pre-requisites, spaces, information, building materials or resources" [32, p.8].* All potential constraints or clash detections were captured and properly registered through the so-called BIMcollab tool which secured a simple and efficient way of communication through the open IFC format. It was selected specifically in order to support Lean Construction in relation to the constraints log. It provided updated information throughout the entire construction process and complete transparency since it was accessible for all parties involved in the project from any device. This way, the Last Planner System recorded all of the required information automatically without needing someone to enter it manually.

Finally, in the third phase the authors provided an analysis of the obtained data and compared it to that of other public projects which had been using traditional project management methods.

[32]

6.2.3.3 Results

The results of the case study showed significant improvement in the public construction project development and delivery with the use of BIM and Lean Construction synergy. According to the contract, the project was supposed to be finished in 15 weeks, but there were several deficiencies recorded over the course of its development which would have caused a 4-week delay, if it wasn't for the improvements in terms of productivity, workflow, health and safety and environment provided by the mutual synergy of building information modelling and the Lean Construction paradigm. Since BIM directly supported the lean objectives, such as easy communication, transparency, immediate re-planning and proactive management and at the same time Lean Construction facilitated the adoption and use of BIM, the project delivery time was eventually 14 weeks, thus 3 weeks before the deadline. In addition, the avoided costs were estimated at approximately 86 thousand euros, which represents 4,3% of the building costs being roughly 2 million euros, not to mention the costs of overlaps in time and breach of contract in terms of the delivery deadline. For the accuracy of the research, it is also important to mention that neither the general contractor nor 13 of its subcontractors had any previous experience with BIM or Lean Construction tools. The results of the case study were therefore conclusive in terms of providing empirical evidence of the BIM and Lean Construction synergy benefits. The case study showed that the two paradigms effectively empower each other and established that their simultaneous application in practice has many advantages.

[32]

7. Conclusion

This thesis was dealing with the implementation of building information modelling from the perspective of two European countries – the Czech Republic and Spain. An analysis of the implementation process in both countries was performed, on the basis of which a comparison of several characteristics of implementing BIM on a country scale was carried out. The theoretical knowledge was eventually complemented by three exemplary case studies within each country that provided information about the use of BIM in practice.

7.1 Summary and generalization of the acquired knowledge

After the approach to the process of comparing the implementation of BIM in the Czech Republic and Spain has initially been set, general principles of introducing a new technology into a company were examined in **Chapter 2**. Since the process of implementing something new on a country scale is in general composed of multiple similar processes on a smaller scale, these principles provided a solid foundation on which the author could built. The general principles were therefore slightly adjusted and raised to a higher level to fit the needs of implementing the BIM method within the scope of a country. Afterwards, the BIM implementation process in other countries was described and their cooperation was presented as a key factor in order to improve the method over time and learn more from each other. **Chapter 2** also provided information about several world-known organizations whose interest is to promote building information modelling on an international level, provide up-to-date information and facilitate the cooperation of all interested parties. The importance of case studies was also brought to attention, since they carry significant know-how about implementing BIM into practice.

The following **Chapter 3** was dedicated to the BIM implementation process in the Czech Republic from the state's perspective. The main part of this chapter was focused on *the Strategy*, which contained a time schedule of recommended measures concerning BIM implementation on a country scale. The most important milestone within the timeline was considered the imposition of a BIM obligation for above-threshold public works contracts. Since this requirement is scheduled for the beginning of 2022, it has not been reached yet. However, **Chapter 3** includes a description of the current state of fulfilment of the schedule and suggests that this requirement could be met on time, since according to the available resources the rest of the recommended measures have been executed in accordance with the scheduled timeline. Apart from *the Strategy,* **Chapter 3** examined several other characteristics of the BIM implementation process that were also considered significant in order to be compared afterwards.

In the same sense, **Chapter 4** that followed was dedicated to the BIM implementation process in Spain from the state's perspective. It described a similar approach of the country to the matter with emphasis on the importance of imposing the obligation of mandatory use of BIM in public procurement as well. Since Spain began to implement the building information modelling method on a country scale earlier than the Czech Republic, the requirements for mandatory use of BIM in public works construction tenders and infrastructure tenders have already been met, in December 2018 and July 2019 respectively. In relation to this obligation, **Chapter 4** also mentioned *the Guide*, a document that should help all members of the AEC sector navigate through the public procurement processes with BIM requirements. Apart from the mandatory use of BIM in the public sector, **Chapter 4** as well as the previous chapter focused also on a few other characteristics of the BIM implementation process, such as standards availability, execution of pilot projects or BIM promotion.

The crucial part of the thesis is considered **Chapter 5**, since it consisted of the comparison of the Czech Republic and Spain in terms of implementing BIM on a country scale. The results of the comparison showed that the two selected countries were in an agreement on the majority of the compared points. Both of them have adopted the IFC open data format and the international standards published by the International Organization for Standardization, ISO 19650 to begin with. They have also both cooperated with the buildingSMART International over the course of the BIM implementation process and continue to do so, the difference being only in ways of mediating information – Spain has its own buildingSMART Spanish Chapter whereas the Czech Republic uses other official bodies to exchange information with this significant international organization. Furthermore, each country has its national organizations dedicated to executing all necessary measures in order to ensure BIM implementation according to their initial plan, such as pilot projects execution, provision of education and others, including the inseparable BIM promotion. In the Czech Republic it has been the Czech Agency for Standardization while in Spain it has been Es.BIM. Even though the Czech Republic published its intended goals for implementing BIM as part of an official document issued by the Ministry of Industry and Trade and Spain has declared its intentions only through a letter signed by institutions not directly connected to the government, their goal was in fact the same. It rested in proclaiming a general strategy with several milestones in need of being reached on time in order to progress with the process of BIM implementation on a country scale. Each country chose the path through public procurement and required mandatory use of BIM, which in the Czech Republic concerned all above-threshold public works tenders since January 2022 and in Spain all public works construction tenders since

December 2018 and public works infrastructure tenders since July 2019. Considering all of the compared points, it is clear that both countries have approached the BIM implementation process in a very similar way, with only a few areas that slightly differ from one another.

In order to complement the theoretical knowledge comparison and providing better insight into BIM implementation in practice, **Chapter 6** consisted of six case studies, three within the Czech Republic and another three within Spain. Even though all of them proved that building information modelling is in fact progressing in various aspects and provides more possibilities now than ever, it is very difficult, if not impossible, to actually compare the differences among them, since they deal with very different fields of the construction industry. While on the part of the Czech Republic, there is a case study of BIM in relation to a small-scale reconstruction project, life cycle assessment and virtual reconstruction of a non-existing building, on the Spanish side there is one about BIM in relation to small construction projects for commercial franchises, a restoration of a great historical building and Lean Construction. Even though a few of these case studies might seem similar in a certain way, they all vary in terms of size, means of execution or purpose (difference between virtual and actual reconstruction). Therefore, they cannot be sufficiently compared in terms of BIM implementation within two countries. However, they carry invaluable know-how about the use of BIM in practice, including its advantages and flaws, which is necessary in order to improve its implementation process and progress in the future.

7.2 Evaluation of objectives achievement

In order for this thesis to become valid and beneficial in any kind of way, it should meet all of the initially set objectives. The first one to achieve was a theoretical analysis of general principles of BIM implementation. The required analysis was based on basic principles of implementing a new technology in general and it was carried out as part of **Chapter 2**. The second objective was met in the following **Chapter 3**, which examined the theoretical knowledge about the BIM implementation process in the Czech Republic. On the other hand, **Chapter 4** provided an analysis of the entire BIM implementation process in Spain, with respect to maintaining equally specific information in order to compare the theoretical knowledge acquired in relation to both countries respectively in **Chapter 5**. Therefore, the last two initially set objectives were accomplished as well.

7.3 Discussion

For the purpose of this diploma thesis, the author chose to approach the issue of comparing two European countries in terms of BIM implementation from the state's perspective through a series of steps starting with adjusting general principles of implementing a new technology to more specific ones tailored to BIM implementation on a country scale and ending with drawing a conclusion based on the acquired knowledge. This approach is only one of many others that could be used for the same purpose and it was chosen because it is effective and not excessively time consuming. The results of the comparison of theoretical knowledge within both countries showed that they have a lot in common in terms of BIM implementation from the state's perspective. However, it is important to note that the compared points were selected subjectively and there is a huge number of other aspects of the BIM implementation process that could be examined as well, that might possibly lead to the discovery of more differences. That is why solely on the basis of this thesis it cannot be undoubtedly determined whether the two countries in question share the same ideas in every aspect of the matter or if they are dealing with some of them completely differently. Nevertheless, it has been proved that the general approach of both countries is in fact very similar. Even though Spain had begun the entire implementation process earlier on, thanks to its international cooperation the Czech Republic is not far behind. There is only one question that still remains unanswered, it concerns both countries and what they could improve. In general, it is still important to strengthen BIM promotion through official means of communication with both public and private sector along with mutual cooperation and understanding, which also applies to the two selected countries. Additionally, in terms of the Czech Republic, it is essential to adjust and complete the preparation of the new BIM act so it can become officially valid and guide the construction sector through the BIM implementation without any major difficulties.

Resources

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List of abbreviations

2D – two-dimensional

3D – three-dimensional

4D – four-dimensional

AEC – Architecture, Engineering and Construction

AENOR – Spanish Association for Standardization and Certification

BEP – BIM Execution Plan

BIM – Building Information Modelling

CAATEEB – Col·legi d'Aparelladors, Arquitectes Tècnics i Enginyers d'Edificació de Barcelona

CAD – Computer Aided Design

CAS – Czech Agency for Standardization

CDE – Common Data Environment

CEN – Comité Européen de Normalization

COSMT – Czech Office for Standards, Metrology and Testing

CTU – Czech Technical University

EU – European Union

FM – Facility Management

GIS – Geographic Information Systems

IFC – Industry Foundation Classes

IRR – Internal Rate of Return

ISO – International Organization for Standardization

LCA – Life Cycle Assessment

LOD – Level of Development

MIT – Ministry of Industry and Trade

NBP – Noteworthy BIM Publication

NPV – Net Present Value

PAS – Publicly Available Specification

ROI – Return On Investment

UCEEB – University Centre for Energy Efficient Buildings

UNE – Spanish Association for Standardisation

UPV – Polytechnic University of Valencia

WBS – Work Breakdown Structure

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