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Building Information Modelling adoption in the European Union: An overview

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ABSTRACT

Building information modelling (BIM) is one of the most promising recent developments in the Architecture, Engineering, Construction and Operation (AECO) industry. However, its adoption remains a challenge for the AECO industry because it requires a shift to a new way of working, leading to a current discrepancy in the adoption of BIM in the EU. The paper aims at assessing the gaps in the BIM adoption between the 28 EU countries and the barriers related to its implementation. The methodology adopted here is twofold: first, secondary data are given by a systematic literature review, completed with the review of current projects funded by the European Commission, and dealing with fostering the BIM adoption. Second, primary data are provided by a questionnaire survey to classify BIM initiatives regarding policies, the level of adoption and the barriers encountered in the 28 EU countries. In order to grade the heterogeneity of BIM adoption in the EU, we have classified the countries into four categories with different levels of awareness, from early adopters (BIM already mandated) to countries without any plan. The survey has enabled the analysis of twenty barriers to BIM adoption using the four grades in relation to the respondent country. We found barriers that are acknowledged by all countries irrespective of their level of BIM adoption. Other barriers have been already tackled by the early adopters but not by the newcomers who have yet to experience some of these issues. Finally, the assessment of the disparities of BIM adoption within the EU can help the European Commission towards unifying European standard on BIM.

1. Introduction

Across the world and in Europe, the Architecture, Engineering, Construction and Operation (AECO) industry faces challenges in relation to construction projects that are fragmented and, in many cases, not particularly well integrated. The consequences are negative regarding energy efficiency, cost, sustainability, resource depletion, the wellbeing of end-users, and efficiency of installers [1,90,91]. Meanwhile, the AECO industry is experiencing one of the biggest recent developments: the arrival of new technologies such as Building information modelling (BIM). The economy is entering into the digital revolution that is more important than the shift from paper to computer. The BIM process gives a framework to set up collaborative work in the construction industry and therefore gives the way to improve the overall quality of the whole value chain. BIM is a faster and more efficient method for construction management, it enhances design and construction qualities and reduces rework during construction [2]. BIM technology allows the creation of an accurate virtual model of a building, that is first digitally constructed. This model can be used throughout the entire value chain from design to demolition, allowing all the stakeholders to work collaboratively rather than in a fragmented manner [4].

BIM implementation requires significant technical expertise and in the short-term increases the operating costs of businesses in relation to implementation and training costs. These requirements, together with the construction industry's well-known resistance to change [5,7], have generally hindered the rate of adoption of BIM. Many studies have however shown that BIM's benefits clearly outweigh its disadvantages hence the government's drive for adoption in various developed countries [6,9–11,13,92].

The BIM adoption is now a world concern, and in developed countries, some related studies are becoming comparatively old [3,28]. Recently developing countries have also engaged studies on the implementation of BIM. For example in Egypt [14], have examined the

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status of the adoption of BIM and building energy models in architectural firms [14]. In Malaysia, Hanafi et al., 2018 have studied the organizational readiness of BIM adoption through architectural practices [15]. In India [17], have studied the implementation of BIM from the architects' and engineers' perspective [17]. In China, [18]; the barriers against the adoption of BIM have studied [18]. This helps to demonstrate the different rates of adoption around the globe.

In the European Union, some countries are early adopters (e.g. Finland, Netherlands and Denmark). Although Finland has not yet mandated BIM usage, in 2007, the Finnish government's own real estate owner mandated BIM usage in its own projects managed by the national agencies of State Properties and Senate Properties [7]. Even if the literature on BIM has progressively increased during the last decade, other countries currently do not yet have any specification about the use of the BIM process (e.g. Bulgaria, Greece and Malta) [20].

From a European standpoint, it seems crucial to ensure that all the EU countries engage in a collective effort based on common ground and to ensure that they are working towards a common goal and direction. If not, the BIM European standardisation may be weakened, as highlighted by the EU BIM Task Group, "*Without this top-down leadership, the sector's low and uneven adoption of information technology is likely to continue which would limit its opportunity to significantly improve productivity and value for money*." The handbook delivered by the EU BIM Task Group *"is a direct result of the European Commission's call for* funding *to form a European public sector network sharing best practices on BIM and for the development of a handbook of recommendations"* [21]. It appears that a fundamental requirement is to avoid the gap between the EU countries getting worse. For that, measures should be taken at an EU Level [21]. Regarding BIM divergence in the definitions and practices, a response needs to be given for the current non-standardised approach leading inevitably to a fragmented market. Difficulties resulting from the various practices and skills across Europe have created barriers to working in different markets. Although the European Commission is working to tackle the discrepancy in the application process of BIM, we still need to have a clear picture of the stage of BIM adoption in the EU to foster a narrowing of the gap.

This paper aims to assess BIM adoption across the EU and to raise the issues and risks of divergence across different national markets. To fulfil this aim, we define three objectives:

(i) To conduct a comprehensive systematic review to identify the current awareness and use of BIM in EU countries and the major barriers to BIM implementation.
(ii) To perform a survey to complement the findings of the systematic review. We have conducted a survey across the 28 EU countries regarding BIM implementation, the government position and the main barriers to BIM adoption.
(iii) To introduce recommendations based on the analysis of the findings of the two previous objectives.

2. Research method

We first collected data through a systematic review to help to design the questionnaire for primary data collection. The systematic literature review was conducted in the academic field, but also included official documents from the European Commission and reports/projects dealing with BIM implementation in Europe (Fig. 1). This paper focuses on the 28 European countries as currently defined by the European Union.[1]

2.1. The systematic review

Secondary data came from a systematic literature review where

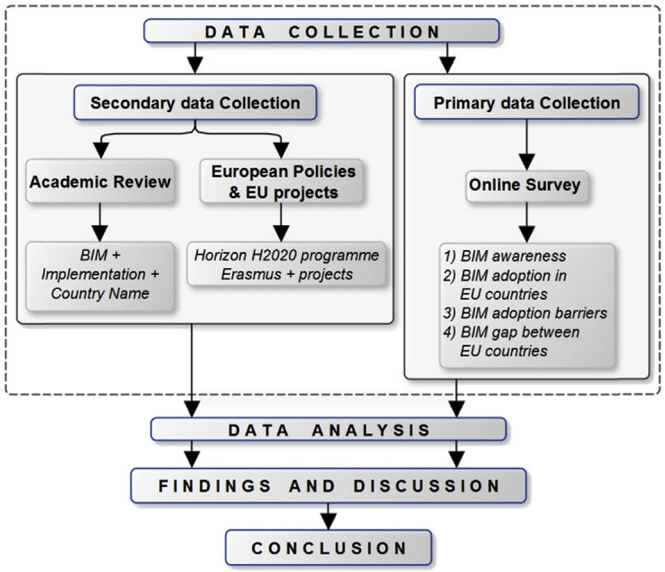

Fig. 1. The methodology for this study.

journals papers, conferences papers and book chapters written in English were collected using Scopus as a search engine. Scopus was used because it is the largest abstract and citation scientific database of peer-reviewed literature, and it offers the highest reliability in comparison with other databases [22,23].

The search field type was the "Article Title, Abstract, Keywords". The method used for the systematic review, split into six stages, was based on the PRISMA statement flowchart [24] summarised in Fig. 2. Stage 0 is related to search questions definition. A generic search was conducted using the keywords method. Two search criteria were used to be consistent with the aim and objectives (see Fig. 2 stage 1). The keywords used for the first criterion were "BIM AND (Country name)" OR "BIM" AND "Europe" OR "World" AND "Implementation" OR "Adoption." For the second search criteria, "BIM" AND "Adoption" AND "Barriers" were utilized. Stage 1 focused on setting the search criteria and removing duplicates which left 187 outputs for research first criterion and 49 for the second one.

During the stage 2, documents titles were assessed, and 120 papers in total were found to be ineligible because they are related to "infrastructures" or out of topic, (Outside Europe, or just cited the name of the country used as a search word). For example, the titles "Using BIM for the last planner system: Case studies in Brazil" [25] and ".BIM bamboo: A digital design framework for bamboo culms" [26].

At stage 3, for both criteria, one hundred and sixteen abstracts were read for the eligibility assessment, and fifty-four documents were excluded because they were found to be out of search questions established in phase 0. For example, due to their focus, such as the use of BIM on heritage buildings [27] or the analysis of risk and rewards of adopting BIM for SMEs in the UK [29].

For stage 4, from sixty-two papers, two were dismissed for their unavailability [30,31] and the remaining sixty assessed by full-text reading. Because of this, thirty-two papers were excluded due to their irrelevance. For example, the paper "Changing roles of the clients, architects and contractors through BIM" was excluded because it's focused on the use of BIM for hospitals only [32]. Another example is the paper "Building information modelling: the UK legal context" excluded because it deals only with the legal context of BIM adoption in the UK [33]. Finally, twenty-six publications addressed the BIM implementation in various European countries (11 Journals papers, 10 Conferences papers, 5 Review papers and one book chapter).

[1] https://europa.eu/european-union/about-eu/countries_fr#tab-0-1.

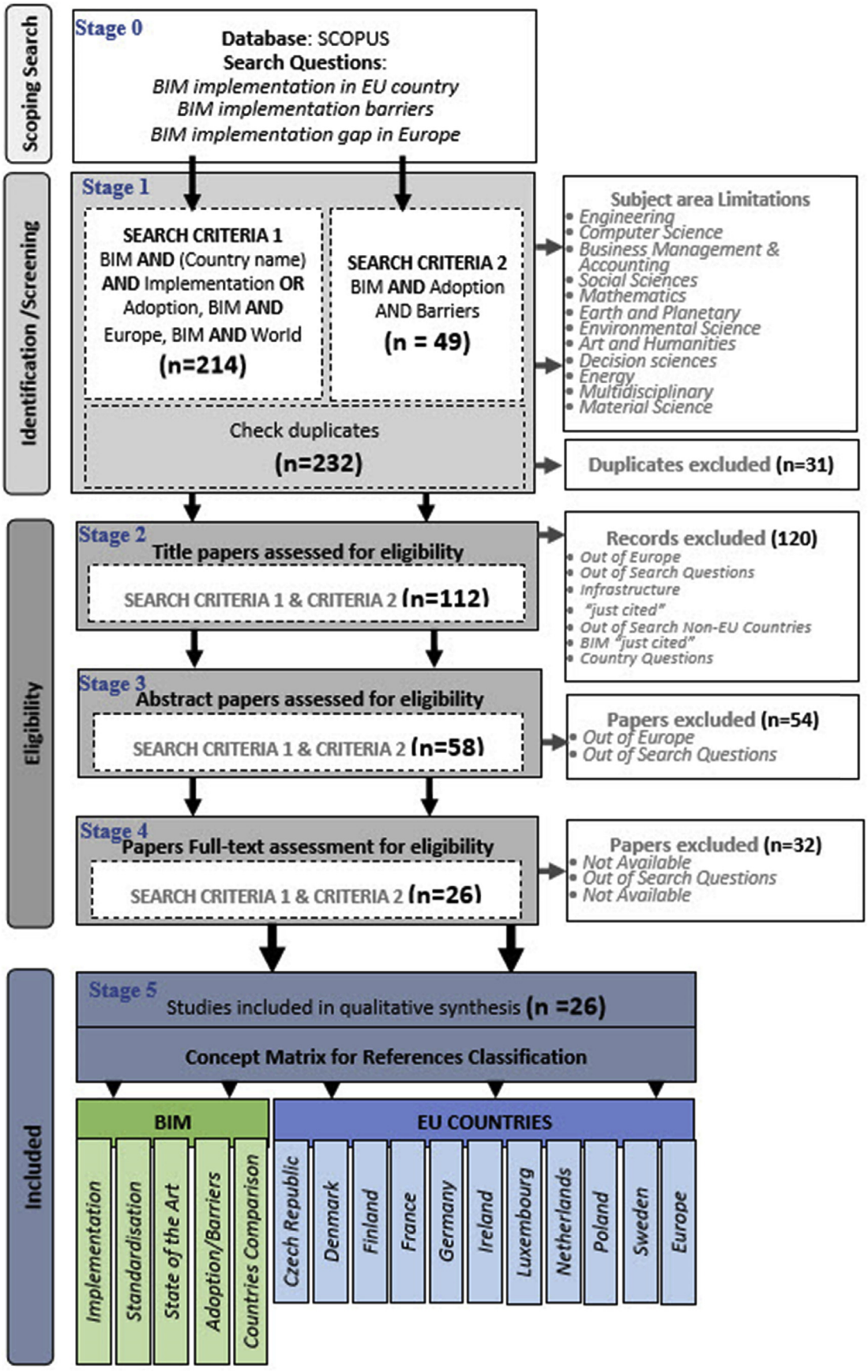

Fig. 2. Prisma Flowchart for the systematic literature review.

2.2. Initiatives across the world and European Directives/policies

In addition, secondary data was also collected from reports about BIM implementation in Europe. The projects funded by the European Commission within the H2020 framework were also studied because they have the political backing of Europe's leaders and the Members of the European Parliament.[2] Moreover, the selection and monitoring of the research projects funded by the EU are highly challenging ensuring the reliability of the reports. The search engine used is the Community Research and Development Information Service (CORDIS) website. Words such as "BIM", redefined by the programme "Horizon 2020" and content "Project". Six relevant projects were found and analysed.

2.3. Questionnaire survey

As professionals are key actors in the implementation of BIM in the construction industry, we sought their opinion through an online questionnaire. We used an online questionnaire due to the geographical spread of the 28 EU countries. The survey was processed through the Bristol Online Survey (BOS) run by the University of Bristol. The survey took place between the 3rd March 2017 and the 30th May 2017. The questionnaire was reachable via a link emailed to participants.

The purposive sampling was adopted [34–36] because we had to pick BIM professionals from each of the 28 European countries. Authors have decided to have a representative sample composed of 6 BIM professionals per country to send them a request via LinkedIn with the aim of getting at least one response per country and 50 respondents in total. The selected sample was purposely targeting people with a position with a high level of responsibilities in the companies and knowledge in BIM. The population picked out is architects, engineers, contractors, facility managers, BIM Managers, training providers among others. A combination of the first author's private contacts and three groups on LinkedIn were used: The international "BIM expert group" (approximately 60,000 members), the International BIM Consultants (approximately 3600 members) and Women in BIM (approximately 500 members) [37].

For each LinkedIn Group, we clicked on account of the first 200 members, following this, we checked their location from the account and listed them. In these groups, each of the members was checked and selected by their expertise in BIM and their countries they are working in. LinkedIn provides this information as part of the profile information of each account that is clicked. We also used the Google search engine by typing "*BIM expert" AND "the name of the country*". Then the profile of the potential respondent was checked on LinkedIn to make sure that the potential respondents are working in BIM area and that they have a key role in the company. Once we had six potential respondents for a given country, we stopped picking respondents from that country and so on.

Then, we addressed an email to the potential respondents as follows: *"In the context of my PhD, I am interested in BIM in Europe. I am looking for people who are involved in this area. I wanted to get your perspective, and I will be glad if you can accept to be connected".* After checking up to 3000 people and when we have had 6 people per country willing to give their perspectives, we stopped searching. Therefore 168 requests were sent, amongst them 110 accepted to be involved in the survey. An email with the questionnaire's link was sent to the 110 potential respondents: "*Thank you for accepting my invitation to connect. In the framework of my thesis, I am conducting an academic survey on the use of BIM in Europe. I will be very grateful if you can spend 10 min to answer the questions using the following link:* https://coventry.onlinesurveys.ac.uk/bim-in-europe*".* After ten days, follow-up emails were sent in order to increase the response rate (Table 1).

Eventually, a total of 51 respondents filled the questionnaire, giving a response rate of 46% which is close or better to similar studies [38–42].

Table 1
List of the countries and the number of professionals contacted, survey sent and filled.

Countries	Survey sent	Survey filled
Lithuania	5	3
Finland	5	3
Croatia	4	2
Poland	5	1
Hungary	2	1
Spain	4	1
Latvia	5	3
Belgium	5	1
Greece	3	1
Germany	4	2
France	4	3
Slovakia	4	3
The UK	3	1
Austria	4	3
Portugal	5	1
Romania	4	3
Cyprus	4	3
Italy	3	1
Estonia	4	2
Denmark	4	1
Sweden	4	2
Ireland	4	1
Slovenia	5	2
Bulgaria	4	1
Malta	3	1
Luxembourg	4	2
Netherlands	3	1
Czech Republic	2	2
Total Questionnaire sent	110	
Total Questionnaire filled		51

The questionnaire was structured in four sections described in Table 2. The set of questions of section 4 of Table 2 was designed according to the literature review and aimed at getting information on *BIM awareness, State of the art in BIM implementation in your country, BIM implementation barriers and BIM in Europe.* Two types of structuration were used for the questionnaire: multiple choice (single or multiple answers) and Likert scale questions (scale of 1–5). (Table 2).

3. Data analysis

3.1. Reliability of questionnaire data

The SPSS (Statistical Package for Social Sciences) computer package was used to analyse the Likert scale questions in the questionnaire and their responses. These are the questions under part '4.2 - BIM adoption barriers' shown in Table 2. Results revealed a mean value of 61.8 and a standard deviation value of 6.98, showing the standard deviation is at just over 10% value of the mean. This shows good consistency between the responses of the professional respondents, depicting some level of reliability in the responses received. Following the advice of social scientists and statisticians, such as [43–45] among others, the reliability of the responses was checked further statistically using the Cronbach's alpha coefficient. The fundamental objective of the Cronbach's alpha test is to examine if the questions in the questionnaire and the corresponding responses scale actually measure the construct they were intended to measure, which relates to BIM adoption barriers to its, by checking the consistency of the data.

The dimension of Cronbach's alpha coefficient is between 0 and 1, and as a general rule, George and Mallery [46] suggested 0.7 as the minimum acceptable score and 0.8 as a sign of decent internal consistency. The results of the test are displayed in Table 3. The resulting

[2] https://ec.europa.eu/programmes/horizon2020/en/what-horizon-2020.

Table 2
Questions asked in the online questionnaire.

1 – Consent		
2 – Identification		
Questions text	Rank values	Question type
Company name Current role City/Country Email address	Non-relevant	Single line free text question
3 - Company Description		
Questions text	Rank values	Question type
What is the business sector of your company?	Architecture, Engineering, Project Management, Quantity Surveyors, Construction, Training, Others	Multiple choice questions, multiple answers
What is the sector of your company?	Public, Private, Both	
What is the size of your company?	0-5 Employees, 6–20 Employees, 21–50 Employees, 51–100 Employees, 100 + Employees	
4.1 - BIM adoption		
Questions text	Rank values	Question type
In your opinion, what is the state of the art in BIM implementation in your country?	Early Adopters", "Late Adopters" and "Very Late Adopters	Multiple choice questions, multiple answers
4.2 - BIM adoption barriers		
Questions text	Rank values	Question type
In your opinion, what are the cultural and individual issues?	Lack of awareness Cultural change required Resistance to change (cultural/staff) Lack of demands Doubt about ROI, the vision of benefits BIM is not yet mature BIM is too complex	Multiple choice questions, multiple answers
In your opinion, what are the economic and technology issues ?	ICT barriers Lack of in-house expertise/skilled personnel shortage Lack of training/education in universities Interoperability of BIM software/data translation Cost of BIM implementation (Software & Training)	
In your opinion, what are the political and legal issues?	Lack of Government lead Lack of guidance for BIM implementation and utilisation Lack of National standard, procedures and guidelines Lack of new or amended form of construction contracts Legal issues: Data ownership and responsibilities Change in procurement methods Insurability issue Property Rights issues	

Table 3
Results of reliability analyses of the Likert scale questions in the questionnaire.

		1st run	2nd run	3rd run	4th run
Overall Cronbach Alpha Coefficient		0.757	0.786	0.792	0.805
S/N	Questions (variables)	Cronbach's Alpha if Item Deleted			
4.2.1.1	Lack of awareness	0.731	0.776	0.782	0.793
4.2.1.2	Culture Change Required	0.730	0.779	0.785	0.796
4.2.1.3	Resistance to change (cultural/staff)	0.725	0.774	0.779	0.790
4.2.1.4	Lack of demands	0.732	0.778	0.783	0.796
4.2.1.5	Doubt about Return on Investment (ROI), vision of benefits	0.733	0.779	0.785	0.797
4.2.1.6	BIM is not yet mature	0.719	0.771	0.778	0.792
4.2.1.7	BIM is too complex	0.721	0.772	0.781	0.796
4.2.2.1	ICT barriers	0.735	0.782	0.787	0.799
4.2.2.2	Lack of in-house expertise/skilled personnel shortage	0.733	0.782	0.789	0.800
4.2.2.3	Lack of training/education in universities	0.732	0.779	0.785	0.796
4.2.2.4	Interoperability of BIM software/Data translation	0.745	0.792		
4.2.2.5	Cost of BIM implementation (Software & Training)	0.752	0.796	0.803	
4.2.3.1	Lack of Government's lead	0.720	0.768	0.773	0.785
4.2.3.2	Lack of guidance for BIM implementation and utilisation	0.724	0.772	0.780	0.791
4.2.3.3	Lack of National standard, procedures and guidelines	0.723	0.770	0.776	0.790
4.2.3.4	Lack of new or amended form of construction contracts	0.730	0.778	0.785	0.796
4.2.3.5	Legal issues: Data ownership and responsibilities,	0.732	0.783	0.791	0.804
4.2.3.6	Change in procurement methods	0.726	0.777	0.784	0.797
4.2.3.7	Insurability issue	0.718	0.770	0.776	0.787
4.2.3.8	Property Rights issues	0.715	0.767	0.775	0.788
4.2.4.1	In your opinion, what is the state of the art in BIM implementation in your country?	0.786			

Cronbach's alpha coefficient from a first run of the test was 0.757, showing an acceptable consistency and reliability of the questionnaire responses.

To scrutinize the data further for possible improvement, and establish if responses to some questions in particular reduced the quality of the result, the third column of Table 3 titled 'Cronbach's Alpha if Item Deleted' was inspected. According to Field [43]; if a variable (i.e. responses to a question) is reducing/worsening the overall reliability and consistency of data and therefore is not as good a measure of the construct as other variables, its associated Cronbach's alpha coefficient would be higher than the overall coefficient (0.757) [43]. Such a variable can be removed, and the test re-ran on the remaining variables. A total of four tests were run in this analysis. From Table 3, questions' responses (i.e. variables) 4.2.4.1, 4.2.2.4 and 4.2.2.5 had higher associated Cronbach's alpha coefficient than the overall Cronbach's alpha coefficient in the first, second and third runs of the test respectively. For every next run, the questions' responses with higher associated Cronbach's alpha coefficient in the previous run was removed. After removing these three questions' responses from each run, Cronbach's alpha coefficient became 0.805 in the fourth and last run, depicting very reliable responses. In this final run, there were no questions' responses (variable) with a higher associated Cronbach's alpha coefficient than the overall Cronbach's alpha coefficient of 0.805 (see the 6th column of Table 3). This means data for the remaining questions and associated responses have high consistency and reliability and highly measure the construct. However, since the Cronbach's alpha coefficient was acceptable when all questions are considered together, none of the questions and their responses was discarded for the remaining analyses and discussion of this paper.

3.2. Initiatives across the world and European directives/policies

3.2.1. Initiatives across the world

Before focusing on Europe and its 28 countries, it may be useful to check if initiatives could be found across the world regarding BIM implementation. There is a collaboration between the UK, Ireland and the USA to deliver the NBIMS-US standard improvement. "*Through this agreement, our friends in the UK and Ireland will be helping to provide content for NBIMS-US™ as they develop a national standard governing BIM for the UK and Ireland. This contribution, combined with the efforts of other BuildingSMART member nations, will help us to grow the content of NBIMS-US™ (National Building Information Modelling Standard – United States) exponentially in a much shorter period of time than we could do ourselves*" [47]." Another initiative taking place in Oceania is the union of two countries to set up a Revit (software used in the BIM process) standard that will be used by both countries Australia and New Zealand (Australia and New Zealand Revit Standard) (ANZRS) [47]. The NBS International Report [48], written by five countries (UK, Canada, Denmark, Japan and the Czech Republic) has the aim to improve construction information for design professionals through the International Construction Information Society (ICIS).

Some organizations such as the Institute of International Studies and Training (IIST) in Japan aimed to facilitate exchanges of experience and know-how between EU and Japanese business and thus improve competitiveness and cooperation between each country. The International BIM implementation guide [49], published by the RICS (Royal Institution of Chartered Surveyors) based in the UK is a form of guidance note highlighting BIM international high-level principles. Another initiative based in the UK is the BRE Academy/ALPIN: BIM International Education (2015).

And the last initiative is driven by the International Standard Organization, ISO/WD 19650-2: Organization of information about construction works - Information management using Building Information Modelling.

3.2.2. Initiatives in Europe

Several European initiatives around BIM were found. First, the European Union Public Procurement Directive (EUPPD) published in January 2014 allows all 28 EU member states to encourage, specify or mandate the use of BIM for publicly funded construction and building projects in the EU by 2016 [50]. The 28 EU members must follow the same path as the UK, Netherlands, Denmark, Finland and Norway in the construction sector. In fact, it mentioned that "*for works contracts and design contests, Member States may require the use of specific electronic tools such as building information electronic modelling tools or similar*". In 2016, a guide was also made available [51].

The European Commission has co-founded the EU BIM Task Group, for two years (2016–2017) aiming to bring Europe into a common and aligned approach in the construction sector and unifying BIM policy across Europe. The project involves fourteen EU countries for designing a handbook explaining the common practices and principles for European countries [52]. The handbook was delivered in 2017 and gives general guidance and action recommendations for harmonization of the BIM strategy at a European level [21]. The BIMTrain EU project (2013–2015) addressed the lack of relevant skills, knowledge and tools related to BIM during the building construction process. The aim was to promote the use of BIM technology in the Baltic States through the development of a BIM training tool, which can be used by academic institutions and private companies. The main project outcome was the creation and adoption in various languages of the BIM training tool (English, Lithuanian and Latvian). The training in BIM was dedicated to both educational institutions and private companies. The training system, BIM tools and methodologies are available online [53]. The project CERTI4TRAIN (2014–2016) funded by Erasmus + and based on CertiTrain project (2013–2015), focused on the provision of Continuous Vocational Education & Training (CVET) and the development of an EU certification scheme to facilitate mobility of trainers within Europe [53]. The BIM4VET (2014–2017) purpose is to give an overview of the BIM curriculum in European countries. The project goal is the classification, standardisation and certification of a BIM training programme. In fact, the main outcome will be a repository of BIM expertise and Method of BIM qualification maturity assessment, classification of BIM curriculum in EU and BIM actor competence matrix and finally training recommendations. This project will give an overview of the BIM curriculum offer in Europe [53]. BIM4PLACEMENT (2016–2018) is an Erasmus + funded project that is still ongoing. The aim is to develop key competencies in building and construction linked to BIM in the area of VET education [54]. Recently granted, the BIMplement and NEWCOM (2017–2020) projects aim to develop a qualification & certification scheme for blue-collar workers by using BIM process [55,56]. The BIMEET project will provide a harmonized skills matrix related to BIM and energy efficiency. The sustainability of the project will be done thanks to the accreditation scheme developed during the project [57]. The TRAINEE and BIMcert projects (2018–2019) are focusing on market-based skills for sustainable energy efficient constructions [58,59]. The projects BIM4REN, BIM-SPEED (2018–2022), and BIMERR (2019–2022) are dedicated to improve the efficiency of the renovation of existing buildings [60,61]. BIM4REN targets specifically residential buildings and the two others aimed at improving energy efficiency [62].

All these European programmes aim at fostering the BIM implementation through Europe. Each country, such as the United Kingdom or France is, at the same time developing National programmes to facilitate BIM adoption [63,64]. But, as highlighted in the EU BIM Task Group Handbook this will increase the risk of divergence across Europe and raise new barriers for working in different markets increasing the cost of compliance to the construction sector [21].

3.3. Academic literature review findings

In Table 4, papers selected as relevant to the topic were analysed,

Table 4
The papers (Journals, Conferences & Reviews) addressing BIM implementation in EU countries.

Type of Documents	Paper's Number	AUTHORS	BIM						Countries													
			Implementation	Standardisation	State of the art	Countries Comparisons	Adoption assessment	Barriers /Challenges	Czech Republic	Denmark	Finland	France	Germany	Ireland	Luxembourg	Netherlands	Poland	Sweden	UK	Europe	Outside EU
Journals Papers (11)	(1)	Wong et al. (2010)	✓			✓				✓	✓										✓
	(2)	Gustavsson et al. (2012)			✓													✓			
	(3)	Jensen & Jóhannesson (2013)	✓			✓				✓											✓
	(4)	Eadie et al. (2013)	✓																✓		
	(5)	Rezgui et al. (2013)	✓					✓											✓		
	(6)	Maradza et al. (2013)	✓	✓		✓													✓		
	(7)	Samuelson & Björk (2014)			✓													✓			
	(8)	Hooper (2015)		✓														✓			
	(9)	Young & Lee (2016)	✓			✓														✓	
	(10)	Alreshidi et al. (2017)	✓					✓											✓		
	(11)	Dainty et al. (2017)	✓					✓											✓		
Review (5) Book Chapter	(12)	Khosrowshahi & Arayici (2012)	✓			✓		✓			✓								✓		
	(13)	Cheng et al. (2015)	✓			✓														✓	
	(14)	Grimes et al. (2015)	✓																✓		
	(15)	Abdirad (2017)	✓				✓												✓		
	(16)	Kassem et al. (2015)	✓			✓				✓	✓					✓			✓		✓
Conference Papers (10)	(17)	Kouider et al. (2007)	✓					✓											✓		
	(18)	McAuley et al. (2012)	✓											✓							
	(19)	Maradza et al. (2013)		✓															✓		
	(20)	Smith (2014)	✓			✓				✓	✓								✓	✓	✓
	(21)	Kiviniemi & Codinhoto (2014)	✓					✓											✓		
	(22)	Kubicki & Boton (2014)	✓			✓				✓	✓				✓			✓			✓
	(23)	Davies et al. (2015)	✓									✓						✓	✓	✓	
	(24)	Juszczyk et al. (2015)			✓				✓								✓				
	(25)	Aibinu & Papadonikolaki (2016)	✓													✓					
	(26)	Bekr (2017)	✓			✓		✓					✓								✓

and a matrix was set up aiming to classify the 28 documents according to the European countries and BIM. The classification was made using six categories that were directly sourced from the content of the papers reviewed: (i) Implementation, (ii) Standardisation, (iii) State of the Art; (iv) Country comparisons; (v) Adoption Assessment and (vi) Barriers/ Challenges. For the European countries, results show that 11 countries had a minimum of one paper related to one category (Table 4). The UK has a total of 16 documents including five Journal papers addressing BIM implementation in the UK [19,65,66,68], barriers associated with BIM adoption, and BIM standardisation [70]. Furthermore, three review papers were in the search area among them one developed a roadmap for BIM implementation and one addressed specifically costs related to BIM implementation, Table 4. Kassem et al. went further and compared BIM publications (guidelines, protocols and requirements) from eight countries aiming to organize the knowledge and facilitate their access [71]. In addition to that, Abdirad proposed to set up grounds for BIM implementation assessment via a thematic framework [72]. Sweden, Finland and Denmark counted 5 papers each. Sweden totalled three Journal papers related to, IT technology adoption [73] and organization in the construction sector [39] and BIM standardisation [74]. Two Journal papers were found for Denmark [75,78].

3.3.1. Comparison between countries

The study made by [16] involved the continent level and [77] specifically France, Sweden and the UK. For Finland, one among the five documents is a Journal paper addressing BIM Implementation by comparing various countries across the world [78]. and the other addressing BIM implementation in various countries, Denmark, Finland and Norway, USA, Singapore and Hong Kong [78]. Jensen et al. proposed a comparison between Denmark and Ireland regarding BIM implementation in order to use the experience of Nordic countries for the Icelandic AEC industry [75]. Jung and Ghang proposed a numerical chart for assessing quickly the level of BIM adoption and implementation. They focus on three regions, North America, South Korea and Western Europe [79]. Cheng and Lu reviewed the public efforts for BIM implementation in four regions, the United States, Asia, Australasia and Europe [12]. The category the most addressed by the 26 documents is BIM implementation, barriers and challenges associated with it and countries comparison. In fact, ten papers have made a comparison between various countries. Smith conducted a literature review on BIM implementation across the world, including some European countries (the UK and Scandinavian region) [69]. The literature review showed that there was no comparison between all EU countries regarding BIM implementation.

3.4. Online survey

3.4.1. Respondent background and company

Respondents were asked to provide background information on their discipline and the size of their company. The Company size more than 50 Employees represent (39%) followed by small companies with a maximum of 5 Employees (33%). Companies having a size between 6 and 50 Employees are the less represented (28%). Respondents are distributed in much the same way across all types of company size. The sector of activity of the majority of respondents is Architecture (63%). Project management and training sectors represent 53% of the respondents. Facility Managers, Quantity Surveyors and Construction sectors account for 16–18% of respondents. The total is more than

Table 5
BIM implementation mandatory date in EU countries and their classification according to BIM adoption level (Online Survey May 2017).

Sources	Regulation/ Adoption State	Already Mandated countries							Already planned countries							Will be planned countries						Not yet planned countries							
		Finland	Estonia	Luxembourg	Sweden	Denmark	Netherlands	UK	Austria	Lithuania	Germany	Italy	Spain	Poland	Portugal	France	Latvia	Slovakia	Croatia	Czech Republic	Ireland	Slovenia	Cyprus	Romania	Belgium	Bulgaria	Greece	Hungary	Malta
Questionnaire	Date of BIM mandate	2002/2007	2013	2016	2015	2012	2012	2016	2020	2018/2020	2016/2020	2016/2017	2018	2020	2020	planned	planned	planned	planned	planned	planned	x	x	x	x	x	x	x	x
	Early Adopters	✓✓✓				✓	✓	✓		✓✓						✓	✓			✓	✓			✓					
	Late Adopters		✓✓	✓✓	✓✓				✓✓✓	✓	✓	✓		✓	✓	✓✓		✓✓	✓	✓		✓✓	✓	✓	✓			✓	
	Very Late Adopters										✓		✓			✓	✓✓	✓	✓				✓✓	✓		✓	✓		✓
CitA Report	Date BIM adoption Verifications	2007			No Regulation	2007	No Regulation	2016	2018		2020	2016	2018		No Regulation	2017				No Regulation					No Regulation				

100% because some companies have activities in multiple sectors.

3.4.2. BIM adoption/awareness

The BIM awareness, targeted via 3 questions is part of the primary data provided by the questionnaire. Table 5 summarises the results and gives a classification of the 28 European countries, in three categories: *(i) Early Adopters, (ii) Late Adopters, and (iii) Very Late Adopters*. The confidence of the results is low due to the number of respondents per countries (represented by three respondents while others are represented by two or one respondent). Therefore, other sources of information were used to check the BIM mandate date of Table 5. For example, the CitA report [82], the NBS International BIM report [48], the SmartMarket Report [83] and the European Analytical Report [84]. Most dates were consistent with the questionnaire, except for Denmark (2007 in the CitA report) and for Italy according to CoBuilder, the BIM will be mandatory in three stages with a start in 2019 and to be mandatory for all projects in 2022 [8]. From left to right, in Table 5, responses are more scattered. For early adopters, BIM is already used, and respondent knowledge about it is consistent, whereas the late-comers respondent response is more variable.

As illustrated in Table 5 and according to the questionnaire results, 25% of the EU countries have already mandated the use of BIM and 25% have already planned the date to mandate its adoption. More than one-fourth of Europe has no plan yet for BIM implementation.

Results showed very low BIM adoption levels in most countries and a big gap between early adopters, late adopters or very late adopters (Fig. 3, Table 5).

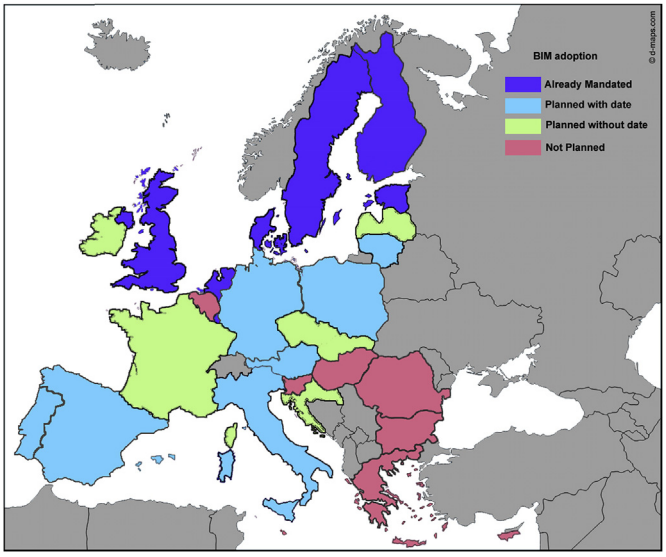

Fig. 3. State of the Art of BIM adoption across Europe according to the questionnaire and verification of results (May 2017).

3.4.3. BIM implementation barriers

Kouider et al.,[7] highlighted the significant barriers and obstacles to the use of BIM. They agreed that the greatest resistance came from the unwillingness of practitioners to change traditional working practices [7]. However, there are more barriers already identified in the literature and listed in Table 6.

To complement the assessment of the main barriers for BIM adoption in the 28 EU countries, questions with a Likert scale (Strongly agree, Agree, Disagree and Strongly Disagree) were asked. For the analysis of the responses, the scale was simplified, "strongly agree" and "agree" were merged together in Table 6. The 28 EU countries were also grouped in four categories according to Table 5 on their BIM adoption level: *(a) Already mandated, (b) Already planned, (c) Will be planned and (d) Not yet planned*.

To analyse the results of the questionnaire regarding the origin of the respondents (from 4 different groups), we have calculated the mean of the four group responses in the last column of T*able 6*. If the coefficient of variation is greater than 0.03 (3%), then the value of the mean is considered not relevant, and some correlation with the origin of the respondent is sought. Therefore all the values of mean plotted in the last column have a coefficient of variation smaller than 3%.

For the other results, to study the correlation between the responses and the origins of the respondent company, we have only considered the two extreme groups ("Already Mandated" and the "Not Planned Yet") in order to study the highest gap between the countries. We have calculated the relative difference between the columns "Already Mandated" and the "Not Planned Yet" in %. We have therefore divided the difference of the two columns by the sum of both, times 2. When this result, in absolute value, is greater than 0.24 (24%), we will discuss the correlation considering this value as relevant compared to the actual variation of the data.

3.5. BIM adoption disparities across Europe

3.5.1. Awareness of the gap impact: questionnaire results

The respondents were questioned about their awareness and opinion regarding the gap between EU countries. The results revealed that 51 respondents are aware of the existing gap (Fig. 4). Sixty-three per cent of them considered that the difference between BIM adoption across Europe would have an impact on the EU economy. Eighty-eight per cent of the respondents considered that an EU BIM standardisation

Table 6
Barriers for the EU countries, according to the questionnaire and the literature review.

	Questions	(Numbers refer to articles listed in Table 2)							% of strongly aggree and agree				
		Finland	Sweden	Denmark	UK	Germany	France	Czech Republic	Ireland	Already Mandated	Already planned	Will be planned	Not planned yet	Mean, Coef. Var. <3%
Cultural and individual issues	*Lack of awareness*				(10)					67%	83%	85%	100%	C-
	Cultural change required		(23)	(3)	17)(22)(23)		(23)			92%	92%	85%	93%	90%
	Resistance to change (cultural/staff)		(7)	(3)	(28)(5)(6) (10)(12)(22)					83%	100%	77%	86%	86%
	Lack of demands				(11)(12)					75%	100%	69%	93%	NR
	Doubt about ROI, vision of benefits		(7) (23)		(28)(10)(11) (12)(17)(22)					50%	67%	92%	79%	C-
	BIM is not yet mature				(10)					33%	58%	38%	14%	C+
	BIM is too complex				(28)(17)					25%	25%	62%	43%	C-
	Age factor reluctance for change				(17)									
	Lack of motivation				(10)(11)									
	Trust issues				(10)									
	Lack of practical use				(11)			(24)						
Economic and technology issues	*ICT barriers*		(7)		(5)(10) (11)(12)(22)	(28)		(24)		58%	67%	31%	50%	NR
	Lack of in-house expertise /skilled personnel shortage		(7)(8)		(13)(28)(10) (11)(12)			(24)		83%	100%	100%	86%	92%
	Lack of training/education in universities				(28)(5)(6) (10)(11)(12)	(28)	(23)			75%	92%	77%	93%	84%
	Interoperability of BIM software/data translation		(7)		(28)(5)(10)(3)				(18)	75%	58%	77%	36%	C+
	Cost of BIM implementation (Software & Training)		(7)		(5)(10)(11) (12)(17)(22)			(24)	(18)	50%	75%	69%	79%	C-
	Processes/Collaboration issues/new working practices		(8)(23)	(3)	(13)(5)(6)(10) (12)(17)(23)		(23)		(18)					
	Lack of research and development				(17)									
	Data management/Exchange/storage/Tracking/		(7)		(5)(10)(12)				(18)					
	Classification		(8)											
	Roles & Responsibilities				(10)(22)									
	Project team fragmentation		(23)		(5)(6)(10)									
	Risk of various approaches development		(8)											
	Lack of common interest software vendor's				(22)									
	Lack of development of new FM systems		(23)											
Political and legal issues	*Lack of Governement lead*		(8)					(24)		50%	100%	92%	93%	C-
	Lack of guidance for BIM implementation and utilisation		(8)		(13)					75%	75%	85%	93%	82%
	Lack of National standard, procedures and guidelines		(7)(8)		(28)(10)(3)	(28)			(18)	58%	100%	92%	93%	C-
	Lack of new or amended form of construction contracts	(16)			(5)(10)					100%	83%	77%	86%	86%
	Legal issues: Data ownership and responsibilities	(16)		(16)	(5)(10) (12)(17)				(18)	67%	67%	77%	50%	C+
	Change in procurement methods				(5)(10)(17)					75%	83%	100%	71%	NR
	Insurability issue				(10)(17)					33%	58%	38%	43%	C-
	Property Rights issues	(16)	(23)		(5)(10)(17)(23)		(23)			25%	50%	38%	36%	C-
	Security issues/Liability		(7)		(10)(12)				(18)					
	Lack of legal framework		(23)		(22)(23)		(23)	(24)	(18)					

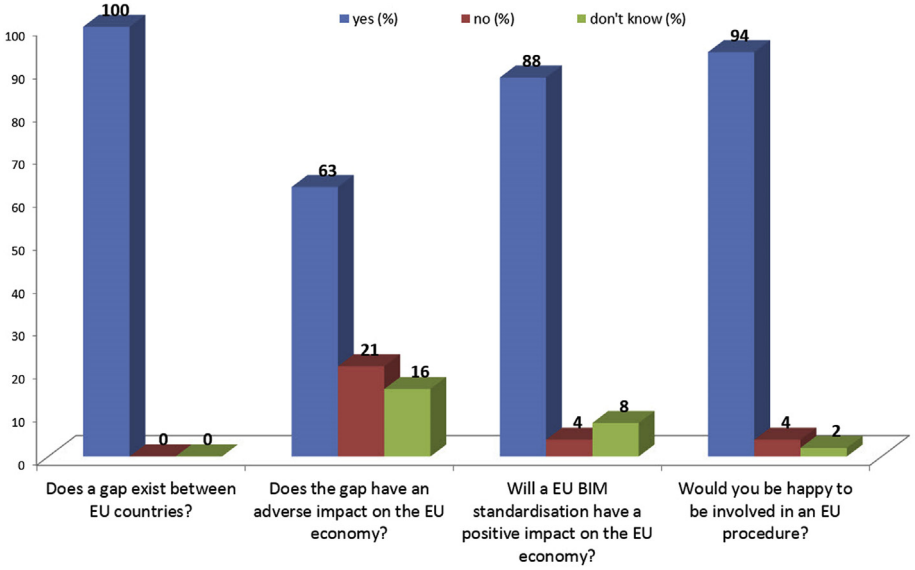

Fig. 4. Awareness of the European gap in BIM implementation from the questionnaire.

would help to smooth the gap. And 94% of them would volunteer for the march toward the standardisation of BIM across Europe to avoid the widening gap between "the haves and have-nots".

4. Discussion

In Table 6, we have divided the responses regarding the barriers, into three sets:

(i) the ones acknowledged with less than 3% of the coefficient of variation between respondents' groups, where we consider the mean value as consistent irrespective of the respondent group.
(ii) the ones where the responses can be correlated with the category of the respondent. (coefficient of variation greater than 3% and the difference between the column "Already Mandated" and the "Not Planned Yet" divided by the sum of both times 2, greater than 24%). The cells of Table 6 have a C+ or C-.
(iii) The data which are not represented in the two previous sets, and noted NR (no relevant correlation) in the last column.

In the set (i), six barriers are acknowledged by more than 82% of the respondents (highlighted in yellow in the last column of Table 6): "Cultural change required", "Resistance to change (cultural/staff)", "Lack of in-house expertise/skilled personnel shortage", "Lack of training/education in universities", "Lack of guidance for BIM implementation and utilisation", "Lack of new or amended form of construction contracts". As this type of barriers is acknowledged by all the respondent groups, it is not possible to rely on existing established strategies to tackle them. New initiatives must be developed.

Set (ii) of barriers can be divided into two types. The barriers have already started to be tackled in the mandated BIM group, due to their older practice (marked with a C-): "Lack of awareness", "doubt about ROI (return on investment)", "BIM is too complex", "cost of BIM implementation", "Lack of Government lead", "Lack of National standard, procedures and guidelines", "insurability issues", "Property Rights issues". For this type of barriers, the "already mandated" category has fewer concerns, showing that the experience of this group would certainly help to smooth the gap of the "not planned yet" group.

The second type of barriers of this set is marked by a C+ in Table 6. These barriers are less acknowledged by the "not planned yet" group, because the respondents have not yet perceived these barriers, due to their lack of practice of BIM. This is the case for: "BIM is not yet mature", "Interoperability of BIM software/data translation", "Legal issues: Data ownership and responsibilities". Again, for this type of barriers, the "already mandated" group experience can help to accelerate the uptake of BIM skills of the "not planned yet" group.

In the set (iii) we have the following barriers: "ICT barriers", "Lack of demands", "Change in procurement methods". There is no consensus clearly linking the concern to any set, (marked NR in Table 6). However, the ICT barriers seem less relevant than the two others with a range of 31%–67% compared to a range of 69%–100%.

In Fig. 4, to avoid asymmetries that could have harmful implications for the construction sector, BIM implementation had to be mandated in a good way [66] and at a European level. In fact, policies should be set to serve those who have resources and power but also the smallest companies [85]. If BIM implementation policies are not correctly framed, the "Matthew Effect" where the rich get richer will be an unavoidable risk. As a matter of fact, for SMEs and small projects, the barriers to BIM implementation appear more important than the advantages generated by its adoption [7].

5. Recommendations

5.1. Gap growth risk and the EU construction market

Across the world and in Europe, the same awkwardness has followed construction projects which are fragmented and silo working. Also, the inadequate information management was identified as leading inevitably to an unsustainable performance of the Architectural, Engineering, Construction and Operation Industry (AECO). The low productivity highlighted in the report "*Rethinking productivity across the construction industry*" due to poor coordination between the various stakeholders, will keep on if the gap of BIM implementation is not reduced [86]. The use of BIM process implies a significant change for the EU countries enabling them to reduce the cost of projects but also "tremendously boost the EU industry's global competitiveness in winning international building contracts." The early adopters, mainly large companies, would quickly harvest benefits from it.

The current lag between the BIM users and the low productivity of the others will then be increased. Therefore, the gap between large companies and SMEs, EU countries and inequalities in the national market or EU market will keep growing [87].

5.2. Discrepancies in BIM adoption: mobility of workers and skills recognition

The construction sector is moving from a local scale to a European scale, pushing the boundaries. Indeed, the current trend is to develop a construction project in different parts of the globe [88]. This tendency is hugely stimulated by the use of BIM-cloud technologies that provide a real-time communication platform (J [89]. It implies that the construction project has to face national issues but also international issues (different BIM workers skills and different culture, skills recognition). The international dimension will continuously be increased by the use of the BIM process. Migration starts to be an important factor in the labour distribution in Europe [84]. So, technical aspects of BIM process need to be taken into account, but also other parameters should be examined such as the work culture [7].

It is imperative to investigate how to reduce the gap between EU countries in BIM implementation to open new market opportunities across the EU, especially for SMEs (Small & Medium Enterprises) by helping them to penetrate markets abroad. They have to be working to the same standards so that all companies are able to engage and work effectively with partners within the EU without any problem. Regarding the European scale, the recognition of skills is a mandatory step. With skills recognition and BIM European standardisation, the rules of the labour market will profoundly change and enhance transparency between countries to facilitate mobility of construction workers within Europe, while also improving Europe's competitiveness.

5.3. Aggravation of the non-attractivity of the blue-collar professions

Currently, the BIM process is widely used during the design phase. Lastly, the use of BIM during the asset lifecycle including on-site activities, facility management and EOL management would enable the valuation of blue-collar professions and establish continuity in the use of new technologies [4]. All the stakeholders involved in the asset lifecycle (White and Blue collars) will be able to enter the revolution brought by BIM in the construction sector. Blue collar professions would become more attractive, and then the shortage of workers could be fixed. As highlighted in the European Commission, the bad image of the construction sector lead to a youth labour shortage. In fact, the age of the construction sector workforce is a real barrier to the uptake of BIM. The digitalisation of the sector which is blossoming worldwide might be a great opportunity to attract youngsters to the construction industry [84].

5.4. Benefits of the BIM adoption standardisation

As highlighted by the EU BIM Task Group, to enact BIM adoption by the entire EU countries, a common EU BIM implementation should cover four foremost areas: People & skills, policy, technical and process. These areas must be defined and developed uniformly across EU countries. To avoid damaging consequences due to the BIM adoption gap across Europe, a European standard on BIM need to be developed. Three main benefits of a common European approach are identified. First, it will accelerate national efforts by pulling up the latecomers. By learning from the others, each EU country will accelerate its own BIM initiatives. Secondly, by avoiding to “reinvent the wheel”, by using the good practices, standards and guides developed by early adopter countries will lead to costs reduction for BIM implementation initiatives. Lastly, the trade barriers will be reduced at a shared cost.

6. Conclusion

A real BIM awareness dynamic has started to be observed worldwide and across Europe. The economic, societal, cultural and political variations that affect BIM implementation cannot be synchronically implemented in all EU countries. This research provides a picture of the heterogeneity of the BIM uptake in the EU, thanks to the analysis of the literature review and the online questionnaire. Although the number of respondents is very small in comparison to the number of people working within the construction sector in Europe, we have drawn on informed opinion and hence are able to offer a unique insight. The results reveal that BIM implementation at the national level does not yet exist in some countries while some EU countries have been using BIM technology for more than a decade.

Despite the positive impact on the productivity and the Architecture Engineering Construction and Operation Industry recognition, the use of BIM still encounters reticence and various barriers depending on the EU countries.

We have highlighted the main barriers to BIM adoption by a questionnaire disseminated in all EU countries and compared the results with the barriers described by academics. If nothing is done on a European scale to tackle the barriers, then it might become difficult for BIM latecomers to adopt BIM and work at the same standard as the BIM early adopters. This may hinder cross border projects and collaborations. EU countries need to have a common ground by sharing the best practices, enabling BIM leading countries to pull the late adopters upwards. Exactly how this will be achieved is open to further investigation.

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