Analysis of the use of BIM in Croatian construction industry

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Preliminary note

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The use of BIM in Croatia has not as yet been sufficiently investigated and, in that respect, this research aims to find out what is the current situation with BIM application in the Republic of Croatia. The results show that 20 to 25 percent of companies use BIM, 25 percent of designers use BIM software, while the use of BIM by other participants in the project is disturbingly low. Croatia has still not passed the basic zero level of BIM use, although positive trends of movement toward level one can be discerned. The authors call for urgent standardisation of BIM and appropriate adjustment of regulatory framework.

Key words:

BIM, construction industry, Croatia, regulation, level of maturity, trends

Prethodno priopćenje

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Analiza primjene BIM-a u hrvatskom graditeljstvu

Korištenje BIM-a u Hrvatskoj nije dovoljno istraženo, pa je cilj ovog istraživanja saznati kakvo je stanje u vezi s primjenom BIM-a u Republici Hrvatskoj. Rezultati pokazuju da: 20 do 25 % poduzeća primjenjuje BIM, 25 % projektanata koristi BIM programe, a među ostalim sudionicima projekta primjena je zabrinjavajuće mala. Hrvatska još uvijek nije prešla osnovnu razinu 0 kod primjene BIM-a, iako se naziru pozitivni trendovi prema razini 1. Ovim radom zazivamo na njegovu što skoriju standardizaciju i prilagodbu zakonskih norma.

Ključne riječi:

BIM, građevinarstvo, Hrvatska, regulacija, razina zrelosti, trendovi

Vorherige Mitteilung

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Analyse der Anwendung des BIM im kroatischen Bauwesen

Die Nutzung von BIM in Kroatien ist nicht ausreichend erforscht, daher ist es das Ziel dieser Untersuchung, die aktuelle Situation in Bezug auf die Anwendung von BIM in der Republik Kroatien herauszufinden. Die Ergebnisse zeigen, dass: 20 bis 25% der Unternehmen BIM anwenden, 25% der Projektplaner nutzen BIM-Programme, und bei den übrigen Projektbeteiligten ist die Anwendung besorgniserregend gering. Kroatien hat noch immer nicht die Grundstufe 0 bei der Anwendung von BIM überschritten, obwohl man positive Trends zur Stufe 1 beobachten kann. Mit dieser Abhandlung fordern wir dessen baldige Standardisierung sowie die Anpassung der gesetzlichen Normen.

Schlüsselwörter:

BIM, Bauwesen, Kroatien, Regulierung, Reifegrad, Trends

1. Introduction

Construction industry is based on complex projects and one of key problems of construction delays are messy construction sites, complex and dangerous working conditions, poor quality of work and numerous life-threatening accidents on construction sites [1]. In addition, the market is becoming more demanding, and projects are becoming increasingly complex. One of solutions may lie in the introduction of new digital technologies in construction industry, as they are expected to contribute to more productive and effective project management [1]. Therefore, digitalization has a strong impact on construction industry. It involves implementation of specific software tool, e.g. tools for static analysis, calculation, planning and monitoring construction, maintenance of buildings and other activities. Regardless of the increasing development and implementation of numerous information tools for the needs of construction industry, the digitalization of construction industry still remains at the very low level. McKinsey's Global Institute for Digitalization Index (MGI) for Europe is very low because construction industry is highly localized and fragmented [2], and its digitization lags far behind other industries (e.g. IT, pharmaceutical industry, petroleum industry, etc.) [3].

An increasing use of information technology in market settings has led to development of the Building Information Modelling (BIM) concept that unites professionals and participants by means of a single BIM model. BIM model (shared database) enables effective project management at all stages of the project (initiation, planning, realization, use and maintenance) [4]. Given the great advantages of the application (eg. analysis and coordination of element collisions, reduction errors, rework and costs, increase control, faster decision making, etc. [5, 6]), BIM is a concept in construction which enjoys wide application in many states, and on the other hand in some countries its application is still small. According to the Smart Market Report 2013 [7], 55 % of US contractors exhibited very high to high levels of BIM implementation, while this percentage for France is 39 %, for Germany 37 %, Australia 33 %, Canada 29 %, the United Kingdom 28 %, Japan 27 %, Brazil 24 %, South Korea 23 %, and New Zealand 23 % [7]. As to recent research, the results published in NBS International BIM Report 2016 [8] reveal that 81 % of construction companies in Denmark applied BIM, while this percentage for Canada was 71 %, for the United Kingdom 50 %, for Japan 49 %, and for the Czech Republic 30 % [8]. Participants predicted that in 2019 the percentage of BIM implementation in all participating countries will range from 73 % (Czech Republic) to 93 % (Denmark) [8]. The implementation of BIM in the United Kingdom is monitored annually. According to the NBS National BIM Report 2019, 69 % of respondents use BIM, 29 % are aware of the need for its implementation, and only 2 % of the respondents are not familiar with the BIM concept [9]. Furthermore, by comparing the level of BIM application in 2015, Jung and Lee [10] show that BIM is most extensively used in North America where it has been applied for 8.5 years and that the rate of BIM implementation is 73 %. North America is followed by Oceania

(application 7.7 years; implementation level 65.5 %), Middle East and Africa (application 5.9 years; implementation level 60 %), Europe (application 5.3 years; implementation level 55.9 %), South America (application 3.4 years; implementation level 55.7 %, and Asia (application 4.9 years; implementation level 46.4 %) [10]. Also, execution is the project phase in which the level of BIM implementation is the highest in North America, Asia, South America, and Oceania, while in Europe, the Middle East and Africa BIM implementation rate is the highest at the project design phase [10]. Results of the research on BIM implementation in the Middle East [6] (countries like Saudi Arabia, the United Arab Emirates, Kuwait, Oman, Bahrain, Qatar, Yemen, Jordan, Lebanon, Iraq, Syria, Egypt, Sudan, Libya, and Algeria) show that 20 % of organizations in construction sector apply BIM, while the greatest number of BIM projects are in the United Arab Emirates, and the smallest in Lebanon and Jordan [6].

Although BIM is recognized as a new way of digitalization in construction sector, its implementation still varies greatly by markets, companies, and projects [11, 12]. This is due to the lack of a single general standard for BIM implementation (e.g. PAS standard, ISO standards, etc.) [2, 11]. The ISO 19650:2018 series is currently under development, ISO 19650-1: 2018 [13] and ISO 19650-2: 2018 [14] have been published, while ISO 19650-3: 2018 [15], ISO 19650-4:2018 [16], and ISO 19650-5: 2018 [17] are at various stages of development. In addition, governmental regulations on BIM application also contribute to its wider application, although this has been done in some countries only (e.g. UK regulated BIM application in 2011), Spain planned to do it in 2019, and Germany in 2020 [11]). Also, close economic cooperation between states where BIM implementation is at the low level and countries where BIM is mandatory, raises awareness about the importance of BIM application on projects (e.g. widespread use of BIM in the UK has favourably affected its implementation in the Middle East) [6]. In conclusion, a study that investigated the way of doing business in an international company that operates in a number of European countries (where BIM use was optional in 2018) proves than market position has a great impact on the level of BIM use on projects [11]. There are various market-related factors that influence the use of BIM in companies. The first one is the necessary organizational adaptation of enterprises for BIM implementation, i.e. the change of business operations, which is a significant issue for most big companies [2, 12]. If BIM implementation does not cause changes at all levels of management, it is usually unsuccessful and results in additional costs only. On the other hand, the high cost of BIM tools and appropriate hardware makes BIM implementation more difficult in small companies, which usually work on smaller-scale projects, where BIM use is not required by the client [2,11]. Furthermore, the high cost of BIM implementation and the lack of BIM experts makes companies dependent on self-education with regard to BIM tools and, when the company doesn't have enough BIM knowledge, BIM is usually used as a mere software tool [6]. The type of the company (contractor, design studio) also affects business changes as related to BIM implementation, which has also not been standardized. The highest level of problems

regarding BIM use involves projects, i.e. the inter-organizational (project) level, which is the most difficult to standardize because each project has unique features such as design, budget, etc. [11], with completely different participants in the project team [12]. Contractors and designers are more successful in BIM use compared to other stakeholders because the BIM use feedback and benefits are the fastest. On the other hand, investors use BIM at the lowest level because they are often unfamiliar with its benefits [2], as can also be seen in the project maintenance phase [6]. The use of various software tools (CAD, BIM, etc.) and BIM implementation at various maturity levels (software, BIM processes, etc.), disrupts collaboration between project participants, although it is precisely collaboration that is one of basic postulates of the BIM concept [11, 18]. This encourages the fragmentation of industry and project participants, and incompatibility of BIM tools, which in turn hinders interoperability and collaboration [2, 11]. This has an impact on the low level of BIM implementation in contractor companies, because they are often forced to model a BIM object in order to analyse it with their own BIM software, and then do the calculation and planning [2, 11]. The use of BIM also involves change in the tasks and responsibilities of individual participants [2, 11], and imposes the need to introduce new professional roles in industry (e.g. BIM manager, BIM coordinator, BIM technician, etc.) [19, 20].

The European Directive 2014/24 / EU shows that the European Parliament and Council encourage BIM implementation as a future trend in construction industry [21]. Moreover, the European Union established the EU BIM Task Group to create a common European approach to digital development of the world-class construction sector in 2016 [22]. However, partial studies on some countries show very uneven level of BIM awareness and BIM implementation within the European Union and beyond [2, 6, 7, 8, 10, 11, 22-24]. The implementation of BIM is mandatory in many countries, which greatly and favourably influences the rate of BIM implementation in construction companies [2, 11, 22, 23]. However, to adopt and establish regulations that would make the use of BIM mandatory, BIM should first be introduced to the companies, and an environment requiring its use on the market should be established [25]. The first step is to raise awareness about the need for BIM implementation, while BIM standards and regulations should be developed in the second step [25]. The last step before development of regulations involves continuous professional development of BIM and provision of incentives for buying BIM tools and hardware [25]. Collaboration between scientists and construction companies is crucial for raising both awareness and the level of BIM implementation [19, 26]. The reason is to enable detection of problems on projects, to encourage scientists to solve them, and to put in place mechanisms for higher education in this area, including also BIM integration in lifelong education of engineers [19, 26]. Hence, the application and comparison of BIM in different markets in various countries has become a very common topic of scientific research [2, 6, 7, 8, 10, 11, 22, 23, 24]. Research on the application of BIM focuses on the current state-of-the-art, which is the basic information for further actions aimed

at encouraging its wider application [10]. In addition to looking for causes of varying degrees of implementation and application of BIM, research is also important for the dissemination of knowledge and experience of different users in different conditions and markets that will promote the spread of BIM awareness and encourage global standardization [11, 22]. All this also promotes a uniform understanding of digitalization objectives in the entire construction sector.

In 2015, BIM was applied in 0 to 25 % of companies operating in Croatia [5]. Also, the results [5, 27] show that 37.8 % of the study participants have never heard of BIM technologies, and that 66 % of them are unfamiliar with and do not see the importance of regulations that would support BIM application [5]. Such a low level of BIM implementation is confirmed by the non-existence of representative BIM projects [24]. Nevertheless, national governments and public institutions have taken some actions to raise BIM awareness. In this respect, it should be noted that Croatian government has its representatives in the EU BIM Task Group. A BIM workshop has been organized with 12 representatives of the state administration [28, 29]. Also, *The BIM Manual for implementation in the Public Sector* has just been translated into Croatian. It constitutes EU BIM Task Group publication on the European level [28]. Furthermore, Croatian Standards Institute has been translating the ISO standard (e.g. HRN EN ISO 12006-3: 2016 [30], HRN EN ISO 19650-1: 2019 [31], HRN EN ISO [32]) for the application of BIM in the Republic of Croatia [24]. Moreover, the Croatian Chamber of Civil Engineers published General Guidelines for BIM Access in Construction in 2017 [33], as a part of the project entitled BIM Guidelines for Architects. In addition, it is stated in literature that BIM research conducted by Croatian scientists is on the rise [19, 24, 27, 29, 35, 36] and that BIM has become a part of higher education in civil engineering [27, 35].

This research is motivated by low level of BIM implementation and awareness in Croatia, and is aimed at collecting the current state-of-the-art and comparing results with other countries, which will enable definition of guidelines for further BIM development on the Croatian market, but also periodic publication of articles about the trend of using BIM and digital technologies in the sphere of construction. Therefore, the first part of this paper focuses on research methodology, while the results are presented in the second part of the paper. The discussion includes comparison of BIM implementation in Croatia over the period of three years (2015, 2016, and 2017), comparison with results obtained in other countries, and directions of BIM development in the European Union. Guidelines for further application of BIM on Croatian market are given in the concluding section of the paper.

2. Methods

A survey on BIM implementation in Croatian construction industry, conducted in 2016 and 2017, is presented in this study. The Smart Market Report [7] and BSI International BIM Report 2016 [8] were used in the composition of questions.

There were 96 participants in the survey conducted in 2016, and 493 participants in the one conducted in 2017. The results are presented as an analysis of the participants' responses to survey questions, which gives an insight into BIM implementation in Croatia over the above mentioned two-year period. The first type of questions (one analysed question) is based on picking one of the answers offered in survey. The second type (4 analysed questions) determines the level of technology use, where four answers where offered (1 - didn't use, 2 - occasionally used 3 - mostly used 4 – used most of the time). The third type of questions (21 questions analysed) relates to the degree of participants' agreement with the offered assertion, where the Likert scale with grades 1 to 3 was offered (1 - disagree, 2 - neither agree nor disagree, 3 - agree) or 1 to 4 (1 - strongly disagree, 2 - mostly disagree, 3 - mostly agree, 4 - strongly agree). The level of reliability of the measuring scale was tested by the Cronbach's alpha coefficient of 0.764 and it can be concluded that the set measuring scale had a satisfactory level of reliability.

Statistical analysis was conducted in such a way that the percentage ratio shows the number of participants that answered a specific question. Unanswered questions were not analysed. Furthermore, the comparison of responses was based on the Relative Importance Index (RII), where the higher the RII index value the greater the importance of the observed parameter or better perception of the respondents. In addition to the RII index, the comparison was made by Friedman's (for more dependent samples) and Wilcoxon (for two dependent samples) test. If the p-value is lower than alpha, then there is a significant difference between the observed groups, while a higher than alpha p-value means that there is no significant difference between the observed groups. In both cases the alpha value is 0.05. The Wilcoxon test was also used as an after-investigation test if the Friedman test showed a significant difference between the observed samples when the alpha value depended on the number of tests (for three tests the alpha was 0.017, while it was 0.005 for ten tests).

3. Results

First, the structure of participants in the 2016 survey is presented. Results show that 60.64 % of participants were employed in micro-companies, 23.40 % in small companies, 11.70 % in medium-sized enterprises, and 4.26 % in big companies. Based on the income, 75.82 % were micro-enterprises, 16.48 % were small enterprises, 3.30 % were medium-sized enterprises, and 4.40 % were big enterprises (Figure 1). Furthermore, most of the participants were architects (53.85 %, Figure 1), civil engineers (36.26 %, Figure 1) and mechanical engineers (9.89 %, Figure 1). 58.98 % of participants belonged to the operational management category, 26.92 % were middle management, and 14.10 % were senior management. As to civil engineers, 84.81 % of the respondents were designers and 15.19 % were other civil engineers (Figure 1). The structure of respondents for the survey conducted in 2017 was similar to the one performed in 2016. Results show that 58.86 % of participants were employed in micro-companies, 18.53 % in small enterprises, 10.59 % in medium enterprises and 12.02 % in big enterprises (Figure 2). When participants were analysed according to company income, it was established that 69.29 % were from micro-enterprises, 12.86 % from small enterprises, 7.68 % from medium-sized enterprises, and 10.17 % from big enterprises (Figure 2). Furthermore, most of the respondents (56.10%) were in the construction profession (37.80% of them were architects and 6.10% were other professions) (Figure 2). In addition, 72.22% of participants were part in operational management, 11.32% were the middle management, and 16.46% were part of senior management. Observing the type of participants in construction, 62.17% of respondents were designers, 21.27% contractors, and 16.56% were others (Figure 2).

3.1. Use of BIM in Republic Croatia in 2016

According to the results from 2016 to 2017 (Figure 3), 38.89 % of participants did not use BIM technology, 37.78 % used it occasionally, 13.33 % used it often, and only 10.00 % of BIM survey participants used it most of the time.

Figure 1. Structure of participants in survey conducted in 2016

Figure 2. Structure of the participants in the survey 2017.

How often did you BIM in the last year?
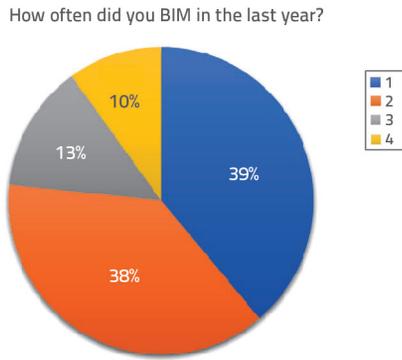
Figure 3. The use of BIM technology among participants in 2016.

Figure 4 shows that 41.66 % of the survey participants consider that the implementation of BIM should be mandatory on all major publicly funded construction projects in the Republic of Croatia, 40.28 % of participants have different opinion, and 18.06 % consider that the use of BIM should not be mandatory.

The legislative framework of the Republic of Croatia should require the application of BIM in all major construction projects financed from public funds.
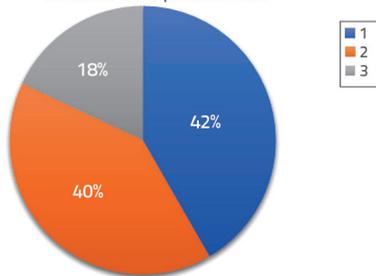
Figure 4. Opinion of Respondents about the following statement: Legislative framework of the Republic of Croatia should require use of BIM on all large public construction projects

3.2. Use of BIM in Republic Croatia in 2017

Table 1 shows that 61.15 % of respondents (3 - 41.21 %; 4 - 19.94 %, Table 1) believe that BIM is a 3D computer program, 64.70 % (3 - 27.16 % ; 4 - 37.54 %, Table 1) believe that BIM implementation is too expensive for their company, and 70.58 % (3 - 35.41 %;

4 - 35.17 %, Table 1) believe that the Republic Croatia should require BIM implementation on all large public construction projects. In addition, 81.01 % (1 - 43.58 %; 2 - 37.43 %, Table 1) of respondents consider that the education of engineers is insufficient for acquiring necessary BIM competencies, while the respondents have different opinion regarding the existence of a quality training program for BIM use (1 - 17.66 %; 2 - 35, 63 %; 3 - 37.43 %; 4 - 9.28 %, Table 1).

Moreover, only 21.12 % of respondents use BIM in their company, while 23.81 % do not plan to use BIM at all (Figure 5). 55.07 % of respondents did not use BIM on projects, but 31.06 % plan to use it within 2 years, 16.77 % plan to use BIM within 5 years, 5.38 % plan to use BIM within 10 years, and 1.86 % plan to use BIM within 15 years (Figure 5).

Within how many years will your business be ready to use BIM?
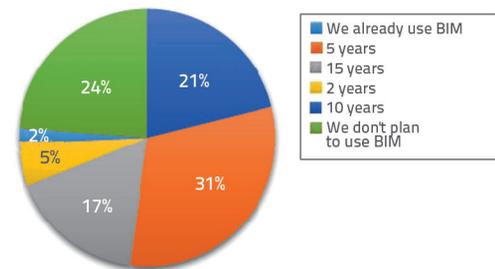
Figure 5. Respondent's answers to the question: Within how many years will your business be ready to use BIM?

According to Table 2, 70.86 % participants (3 - 46.73 %; 4 - 24.13 %, Table 2) believe that the assistance of a consultant is necessary for BIM implementation, while 63.18 % (3 - 47,76 %; 4 - 15,42 %, Table 2) consider that assistance is necessary for BIM implementation. Comparing the results with the Wilcoxon test, there is a significant difference in the opinion of respondents (p-value less than 0.05, Table 2) about the importance of the consultant's presence in the observed project phases, while the presence of the consultant is more important in the BIM implementation phase (RII for the implementation phase is 0,72 while it is 0.67 for the application phase, Table 2).

Table 1. Agreement with the statements in the survey

Statement	Grades			
	1	2	3	4
BIM is 3D software	17.85 %	21.00 %	41.21 %	19.94 %
BIM implementation is too expensive for our company	14.81 %	20.49 %	27.16 %	37.54 %
Engineers acquire necessary BIM competencies through education	43.58 %	37.43 %	14.97 %	4.02 %
There is a quality BIM training program on the market	17.66 %	35.63 %	37.43 %	9.28 %
Republic of Croatia should require use of BIM on all large public construction projects	14.71 %	14.71 %	35.41 %	35.17 %

Table 2. Reflection on the importance of consultant's assistance in BIM implementation and use

Grades	Consultant is needed in:	
	BIM implementation	Use of BIM
1	8.29 %	10.20 %
2	20.85 %	26.62 %
3	46.73 %	47.76 %
4	24.13 %	15.42 %
RII	0.72	0.67
Wilcoxon's test	p<0.05	

Table 3. Frequency of using CAD, 3D and BIM technology

Grades	In the last year, how often did you use:		
	CAD	3D	BIM
1	38.88 %	48.08 %	65.94 %
2	18.79 %	25.00 %	17.03 %
3	12.53 %	10.26 %	5.68 %
4	29.80 %	16.66 %	11.35 %
RII	0.58	0.49	0.41
Friedman's test	p<0.05		
Wilcoxon's test	p<0.017 (sva tri slučaja)		

Results on the use of technologies in Republic Croatia during 2016 and 2017 show that 38.88 % of participants did not use CAD technology, 48.08 % did not use 3D technology, and 65.95 % did not use BIM technology (Table 3). Furthermore, 29,80 % used CAD technology most of the time, 16,66 % used 3D technology, and only 11,35 % of respondents used BIM technology most of the time (Table 3). These results point to a significant difference in use of these technologies during the observed period, as confirmed by the results of Friedman's test (p-value less than 0.05, Table 3) and Wilcoxon's test (p-value less than 0.017, Table 3). Respondents most often use CAD technology (RII is 0.58, Table 3), which is followed by 3D technology (RII is 0.49, Table 3), and BIM technology (RII is 0.41, Table 3).

According to the results, the greatest advantage of BIM implementation lies in the improvement of coordination between participants (3 - 32.32 %; 4 - 60.61 %; RII is 0.88, Table 4), while a slightly smaller number of respondents emphasize project improvement (3 - 36.88 %; 4 - 49.09 %; RII is 0.83, Table 4) and competitive advantage (3 - 34.02 %; 4 - 52.83 %; RII is 0.84 , Table 4) as benefits of BIM use. This is confirmed by the Wilcoxon test, which shows no significant difference (p-value greater than 0.017, Table 4) when comparing two advantages, project improvement and company competitiveness.

Furthermore, respondents feel that project participants are generally not ready to use BIM. According to the results, 85.65 % of participants believe that contractors are not ready (1 - 43.58 %; 2 - 42.07 %, Table 5), 80.26 % that supervising engineers are not ready (1 - 28.61 %; 2 - 51.65 %, Table 5), 76.46 % that

Table 4. Reflections on benefits of BIM use

Grades	Benefits of using BIM		
	a) BIM improves collaboration of project stakeholders	b) Use of BIM improves project success	c) Use of BIM improves company competitiveness
1	1.77 %	4.68 %	3.87 %
2	5.30 %	9.35 %	9.28 %
3	32.32 %	36.88 %	34.02 %
4	60.61 %	49.09 %	52.83 %
RII	0.88	0.83	0.84
Friedman's test	p<0.05		
Wilcoxon's test	p<0.017 (a − b; a − c); p>0.017 (b − c)		

Table 5. Reflections on readiness of using BIM by project participants

Grades	Who is ready to use BIM?				
	a) Investors	b) Designers	c) Supervision	d) Contractors	e) Suppliers
1	32.58 %	18.54 %	28.61 %	43.58 %	31.22 %
2	42.36 %	50.73 %	51.65 %	42.07 %	45.24 %
3	19.80 %	26.10 %	17.47 %	11.59 %	21.69 %
4	5.26 %	4.63 %	2.27 %	2.76 %	1.85 %
RII	0.49	0.54	0.48	0.43	0.49
Friedman's test	p<0.05				
Wilcoxon's test	p>0.005 (a − c; a − e; c − e); p<0.005 (other cases)				

Table 6. Reflections on regulations for BIM use in individual project phases

Grades	Republic Croatia should regulate used of BIM in the phase of:				
	a) Licencing	b) Planning	c) Designing	d) Execution	e) Maintenance and use
1	23.68 %	23.80 %	13.47 %	12.25 %	13.99 %
2	22.42 %	23.04 %	10.72 %	8.75 %	13.99 %
3	35.77 %	34.68 %	41.15 %	43.00 %	40.72 %
4	18.13 %	18.48 %	34.66 %	36.00 %	31.30 %
RII	0.62	0.62	0.74	0.76	0.72
Friedman's test	$p < 0.05$				
Wilcoxon's test	$p > 0.005$ (a − b; c − d; c − e); $p < 0.005$ (other cases)				

Table 7. Analysis of BIM technology implementation by profession

Grades	Analysis of use of BIM in professions:					
	a) Architecture	b) Electrical engineering	c) Geodesy	d) Civil Engineering	e) Mechanical Engineering	f) Others
1	55.17 %	100.00 %	25.00 %	72.16 %	66.67 %	85.71 %
2	19.54 %	0.00 %	25.00 %	16.08 %	11.11 %	14.29 %
3	7.47 %	0.00 %	25.00 %	4.31 %	11.11 %	0.00 %
4	17.82 %	0.00 %	25.00 %	7.45 %	11.11 %	0.00 %

Table 8. Analysis of BIM understanding by profession

Grades	Participants' concurrence with the statement: BIM is 3D software (analysis by profession)					
	a) Architecture	b) Electrical engineering	c) Geodesy	d) Civil Engineering	e) Mechanical Engineering	f) Others
1	15.29 %	33.33 %	25.00 %	19.31 %	12.50 %	25.00 %
2	19.75 %	16.67 %	0.00 %	22.77 %	25.00 %	0.00 %
3	40.76 %	50.00 %	50.00 %	41.58 %	12.50 %	75.00 %
4	24.20 %	0.00 %	25.00 %	16.34 %	50.00 %	0.00 %

suppliers are not ready (1 - 31.22 %; 2 - 45.24 %, Table 5), 74.94 % that investors are not ready (1 - 32.58 %; 2 - 42.36 %, Table 5), while 69.27 % consider that designers are not ready (1 - 18.54 %; 2 - 50.73 %, Table 5). Thus, most designers are ready to use BIM (RII is 0.54, Table 5), while contractors (RII is 0.43, Table 5) are the least willing to use BIM. Significant differences in the readiness to use BIM when designers and contractors are compared with other project participants are also shown by Friedman's test (p-value less than 0.05, Table 5) and Wilcoxon's test (p-value less than 0.005, Table 5).

The results also show the following: 79.00 % (3 - 43.00 %; 4 - 36.00 %, Table 6) of the respondents feel that the use of BIM should be mandatory in the planning phase, for 75.81 % of them (3 - 41,15 %; 4 - 34,66 %, Table 6) it is necessary in the design phase, and for 72,02 % of them (3 - 40,72 %; 31,30 %, Table 6) it is necessary in the maintenance phase. On the other hand, the participants have different opinions on whether the Republic Croatia should regulate the use of BIM in the licensing phase (1 - 23.68 %; 2 - 22.42 %; 3 - 35.77 %; 4 - 18. 13 %, Table 6) and in the planning phase (1 - 23.80 %, 2 - 23.04 %; 3 - 34.68 %; 4 - 18.48 %, Table 6). In other words, regulation of BIM

implementation is crucial for the execution phase (RII is 0.76, Table 6), important for the design phase (RII is 0.74, Table 6), and the maintenance and use phase (RII is 0.72, Table 6), while it is not so important for the planning phase (RII is 0.62, Table 6). The differences between phases are also confirmed by the Friedman test (p-value less than 0.05, Table 6), while the results of the Wilcoxon test show that there is no significant difference when comparing the licensing and conception phases, design and implementation, design and maintenance phase (p-value) is greater than 0.005, Table 6). For detailed analysis, the use of BIM in different activities and among project participants was analysed. The results on the use of BIM technology by industry show that BIM is used by 25.29 % of architects (3 - 7.47 %; 4 - 17.82 %, Table 7), and 11.76 % of civil engineers (3 - 4.31 %; 4 - 7.45 %, Table 7). As a very small number of respondents from other sectors participated in the survey (electrical engineering - 1.83 %; geodesy - 0.81 %; mechanical engineering - 2.03 %; other - 1.42 %, Figure 2), the results shown in Table 7 do not represent relevant data to make conclusions on the use of BIM in other professions. However, they do confirm the generally low level of BIM use in Croatian construction sector.

Table 9. Analysis of BIM technology used by project stakeholders

Grades	Analysis of BIM technology used by project stakeholders					
	a) Investors	b) Consultants	c) Designers	d) Supervising engineers	e) Contractors	f) Suppliers
1	79.17 %	84.62 %	56.07 %	81.25 %	83.33 %	90.00 %
2	20.83 %	15.38 %	18.93 %	12.50 %	12.50 %	10.00 %
3	0.00 %	0.00 %	8.93 %	0.00 %	0.00 %	0.00 %
4	0.00 %	0.00 %	16.07 %	6.25 %	4.17 %	0.00 %

Table 10. Analysis of BIM understanding by project stakeholders

Grades	Participants' concurrence with the statement: BIM is 3D software (analysis by stakeholders)					
	a) Investors	b) Consultants	c) Designers	d) Supervising engineers	e) Contractors	f) Suppliers
1	15.79 %	30.00 %	16.54 %	4.55 %	24.14 %	50.00 %
2	26.32 %	20.00 %	21.05 %	27.27 %	18.97 %	0.00 %
3	52.63 %	50.00 %	41.35 %	36.36 %	39.66 %	25.00 %
4	5.26 %	0.00 %	21.05 %	31.82 %	17.24 %	25.00 %

Table 8 presents an analysis of BIM understanding across different engineering disciplines. 64.97 % of architects believe that BIM is only a 3D software (3 - 40.76 %; 24.20 %; Table 8), and the same view is shared by 57.92 % of civil engineers (3 - 41.58 %; 16.34 %, Table 8). Thus, the results confirm that in almost all industries BIM is still considered to be a mere 3D software and, as in previous question, the results for electrical engineering, geodesy, mechanical engineering and other professions cannot be considered relevant due to a small proportion of participants from these professions that took part in this research.

According to results shown in Table 9, 25 % of designers confirm the use of BIM (3 - 8.93 %; 4 - 16.07 %, Table 9), and the same applies to 6.25 % of supervising engineers (3 - 0 %; 4 - 6. 25 %, Table 9) and 4.17 % of contractors (3 - 0 %; 4 - 4,17 %, Table 9). As a small number of other respondents participated in the survey (investors - 5.11 %; consultants - 2.66 %; suppliers - 2.04 %, Figure 2), the results presented in Table 9 do not represent relevant data for making conclusions on the use of BIM in other professions, but confirm the generally low level of BIM use in Croatia (100 % of investors, consultants and suppliers stated that they did not apply BIM, Table 9).

Furthermore, the analysis of BIM understanding by participants showed that most participants consider BIM to be a 3D software. Moreover, 68.18 % of supervising engineers indicated that BIM is a 3D software (3 - 36.36 %; 31.82 %; Table 10), just like 62.41 % of designers (3 - 41.35 %; 4 - 21.05 % , table 10), 57.89 % of investors (3 - 52.63 %; 4 - 5.26 %, table 10) and 56.90 % of contractors (3 - 39.66 %; 4 - 17.24 %, table 10), while consultants (3 - 50 %; 4 - 0 %, table 10) and suppliers (3 - 25 %; 4 - 25 %, table 10) have expressed different opinions. As stated before, due to the small number of survey participants who declared themselves as investors, consultants and suppliers, the above results do not provide relevant insight into the use of BIM among these participants.

4. Discussion

The analysis of results shows that BIM was applied in 23.33 % companies in 2016 (participants who use it often and most of the time), and in 21.12 % companies in 2017 (participants who stated they already use BIM). Compared to 2015, when 0 to 25 % of Croatian companies used BIM [5, 27], it is obvious that the level of BIM use on Croatian market did not grow over the three years. Comparing the use of BIM in Croatia with the latest research on BIM use on the international level, it can be seen that 69 % of companies operating in the United Kingdom use BIM [9]. It can be concluded that the level of BIM use in the United Kingdom is by 45 % higher compared to the situation in Croatia. The level of BIM use in Croatia is scientifically lower compared to developed countries in Europe and worldwide, while it is similar to Middle East countries, where 20 % of the companies use BIM [6].

Furthermore, the results for 2015 show that BIM awareness was quite low, i.e. that 37.8 % of participants did not hear about BIM technology, and most participants did not see importance of BIM related regulations [5, 27]. However, results from 2016 and 2017 show that awareness about the importance of BIM has increased. Respondents plan to use BIM within two years (most of them), aware of the benefits that the use of BIM brings to business (the biggest advantage is that BIM improves coordination between project participants). Furthermore, the results show that project participants in the Croatian market are generally not ready for full BIM implementation, i.e. designers are the most prepared and contractors are the least willing to use BIM. This has been confirmed by a detailed analysis of BIM use by respondents, where designers stand out as the most diligent BIM users (25 % of survey participants apply BIM), while architecture has been identified as the industry in which BIM is widespread (25.29 % apply BIM, 17.82 % of which work most of the time in

BIM environment). On the other hand, other project participants (supervising engineers, contractors, investors, consultants, and suppliers) have shown disturbingly low percentages of BIM use. In fact, investors, consultants, and suppliers do not apply BIM at all, while it is used by 4.17 % of contractors only. Moreover, it is evident that the interest and knowledge about BIM standards has increased in 2016 and 2017. However, most participants feel that BIM implementation in Croatia should be mandatory. On the other hand, while awareness of BIM benefits increased the three years, it is still at a low level, as the corresponding results show that 65.94 % of participants do not use BIM, 61.15 % consider BIM to be a 3D software only, 23, 81 % never plan to use BIM and think that BIM implementation should be regulated even though project participants in Croatia are not ready to use it. Misperception about the meaning of BIM and work in a BIM environment is also confirmed by an analysis of BIM's understanding of activities and project participants where most of them still consider BIM to be just a 3D software tool.

The results also confirmed the barrier to the implementation and application of BIM on the market [2, 11], which is the lack of a generally accepted criterion. The obstacles to BIM use in companies (high cost of BIM tools and hardware, necessity of consultant's assistance during BIM implementation, and insufficient BIM education of civil engineers) and on projects (lack of representative BIM projects on the Croatian market, differing willingness of participants to use BIM, use of various incompatible tools, and non-recognition of BIM professions) [2, 11, 18, 20], were also noted.

The maturity of BIM use is almost at level 2 in some countries, while in Croatia it is still at level 0, which has slowly begun to move towards level 1. This is due to the fact that no BIM standard has so far been implemented in Croatia (only guidelines exist), and there is no Object Data Library. Thus, due to low level of BIM use, BIM models that would allow communication between BIM project participants have still not been designed. Finally, steps for easier use of BIM [25] confirm that the market is not yet ready for BIM regulation. The key factor is still raising awareness about importance of BIM use in companies. Over time, the criteria, standards, appropriate training and incentives are certainly the factors that will create an environment for positive BIM standardization that would raise the quality in Croatian construction sector and enable greater competitiveness on the international market.

5. Conclusion

Since there are is no BIM standardization, no Object Data Library, and no representative BIM project models in Croatia, the

maturity level of BIM implementation in Croatia is at level 0 with a positive trend towards level 1. This research was prompted by the low level of BIM use on Croatian market in 2015, and its objective was to obtain appropriate data on the importance of BIM in Croatia. An adequate survey method was used to obtain data on BIM use in 2016 and 2017 in Croatia. The results show that the use of BIM did not increase significantly over the three-year period. Only 21.12 % of Croatian companies used BIM in 2017. These results are quite concerning when compared to developed countries in Europe and worldwide, where the use of BIM is at a very high level.

A detailed analysis of the understanding of BIM use in project activities and by project participants has confirmed the low level of BIM use in Croatia, where architecture as an engineering profession, and designers as project participants, stand out with the highest level of BIM use, but also with a misunderstanding of the BIM concept (understanding BIM as merely a 3D software). The application of BIM by other project participants reveals disturbingly low rates of BIM use. Since the distribution of survey participants is different in each year (different percentage of companies by size, income, profession, etc.), the results of the survey cannot be used to make highly accurate conclusions on the status of BIM use by profession or type of company. Therefore, the results show only a broad state-of-the-art of Croatian market and can be used to make conclusions about the application of BIM in construction sector in general.

In conclusion, Croatian market is still not ready for BIM standardization at any stage of the project, as it would cause misapplication of BIM (which would mainly be used as a software tool without understanding the BIM process) and business dissatisfaction. When considering steps to facilitate the implementation of BIM [25], Croatia is still at the first step, which involves raising awareness about the importance of BIM use. Only when this awareness has been raised, and the use of BIM brought to a higher level of maturity, it will be possible to start drafting BIM standards and proceed with standardization in this area. Translating and adapting existing standards to create Croatian standards, and increasing the level of relevant education and subsidies, will certainly contribute to a wider application of BIM.

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