BIM adoption and maturity anno 2021: a large scale empirical study on the current state of affairs

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Abstract. This large-scale study aims to get insight in the level of BIM adoption and maturity in the Dutch construction industry. In this study, the focus is on BIM users, BIM non-users and those that are unaware and do not use BIM in six subsectors (principals, architects, engineers, contractors, suppliers and mechanical engineers) and the construction industry as whole. In total 725 respondents participated in this interview-based study, 235 of them actually used BIM (the BIM-users) and 342 knew about BIM but did not use it (the BIM non-users). The remaining 148 did not know about BIM and therefore were not able to answer the questions related to BIM and BIM-use. The architects and suppliers have the highest number of BIM-users, mechanical engineers and contractors the lowest. One third of the contractors and mechanical engineers in this study was not aware of BIM. For measuring BIM-maturity, firms were asked questions about BIM-strategy, organization- and project-structure, human & culture, BIM-processes, IT and data(-structure). The score for each criterion is a mean of the sub criteria that are part of that criterion. The overall BIM-maturity is a mean of these sub criteria. The overall BIM-maturity of the architects was the highest and of the principals and engineers the lowest. ICT component is the highest scoring BIM-maturity component within the entire construction sector while BIM-processes the lowest scoring component. The findings from this study can be used to inform organizations in specific subsectors of construction in which aspects of BIM they have to invest to increase maturity.

1. Introduction

Building Information Modeling (BIM) has increasingly been adopted in the construction industry [1]. This is not remarkably, since BIM is considered to be a core concept with a large impact on this industry. Siebelink et al. [2] defined BIM as "an object-based and multidisciplinary approach aimed at facilitating collaboration between parties and the integration of object-related information over the entire life cycle of an asset" (p. 1). While BIM is nowadays adopted in organisations all around the world, this does not mean that every organisation and its employees are aware of BIM, and even awareness does not mean that organizations decide to adopt BIM. Kassem et al. [3] compared the results of three larger BIM adoption studies (in Australia, North America, and the United Kingdom). Over these studies, four groups could be distinguished: (1) BIM users who are aware of BIM and actually use it, (2) the non-users who know BIM, but are not using it, (3) those that do not know nor use BIM, and (4) those that did not answer.

Several implementation and maturity assessment tools and models have been developed, compared and evaluated to study the BIM use of the actual BIM users (e.g. [2] [4] [5]). Wu et al. [5] reviewed nine of these tools and concluded that an universal applicable BIM maturity measurement tool is still lacking.

Siebelink et al. [2] analysed existing models and found five reasons for developing a new model to study BIM maturity in construction. This current study aims to get insight in the level of BIM adoption and maturity in the Dutch construction industry. To do so, this study focused on BIM users, BIM non-users and those that are unaware and do not use BIM in six subsectors (principals, architects, engineers, contractors, suppliers and mechanical engineers) and the construction industry as whole. The principals involve (semi-)public clients like municipalities, housing associations, educational institutions and government agencies. The engineers involve engineering and consultancy firms, while the mechanical engineers involve (technical) installers.

2. Research methodology

The researchers together with a marketing consultancy agency developed a questionnaire that was evaluated by a sounding board existing of 12 subsector representatives. The first part of the definitive version of the questionnaire focused on background information (e.g. number of organization's employees, type of organization) and familiarity with and use of BIM. To do so, the respondents answered the (Dutch) question "are you familiar with the term BIM, Building Information Modeling? And is it used within your organization?" This question resulted in three groups: BIM-users (those that know and use BIM), BIM non-users (those that are familiar with, but do not use BIM), and those who are unaware of BIM (not familiar with nor using BIM). The second part contains the (adjusted) BIM-maturity measurement tool of Siebelink et al. [2].

The marketing consultancy with years of experience in construction and trained interviewers performed the interviews by phone. This method was chosen, because (1) the online questionnaire response rate is limited, (2) vagueness and questions can be clarified and answered immediately, and (3) by making a phone call, it is easier to find someone with knowledge on BIM (use) within the organization to participate in this study. However, an exception was made for the suppliers, because this subsector responded easier on the request to participate online. Therefore, the suppliers participated mainly by telephonic interview but a small number participated online (n=5).

Table 1. Number of interviews among the construction subsectors and functions

Subsectors	Number of interviews
Principals	181
Architects	86
Engineers	84
Contractors	194
Mechanical Engineers	126
Suppliers	54
Total	725

In this study, 725 (of the 7776 contacted) respondents participated (response rate 9,3%) after being reached through the "Yellow Pages", Linked-In and a large database of the marketing consultancy (see Table 1 for a distribution among the subsectors). Of the participants, 13.6% were self-employed, 36.6% of the respondents worked for a 2-20 FTE company, 12.7% worked for ones with 21-50 FTE, 8.3% for an organization with 51-100 FTE, 5.0% for a 101-150 FTE organization, and 23.8% for an organization larger than 151 FTE. Of the respondents, 707 of the 725 were able to mention the organization's size. This diversity was included to prevent a bias because of organizational size. In addition, the function of the participant was also asked: 29.5% of the participants described themselves as a senior manager (which includes general, financial, or commercial director), 18.6% as project manager, whereas a small part of the participants mentioned having a BIM-related job (e.g. BIM-manager, BIM-coordinator).

For the first study aim, the adoption of BIM, a percentage of users, non-users and those that are unaware and do not use BIM was calculated for each subsector and the sector as whole (which is the

sum of all subsectors). Outlying subsectors (in terms of percentages users, non-users and unfamiliarity with BIM) were selected and discussed. For the second study aim, the current state of affairs concerning BIM-maturity, all 17 sub criteria (questions) on BIM-maturity were scored on a scale from one to three. A score of one means that a sub criterion is absent, two means that a criteria is partly present, and three means that it is sufficiently present. Those 17 sub criteria are part of six criteria: strategy, organization- and project structure, people & culture, BIM-processes, IT and data(-structure) (see Table 2). The score for each criterion is a mean of the sub criteria that are part of that criterion. The overall BIM-maturity is a mean of the 17 sub criteria.

Table 2. BIM-maturity criteria and sub-criteria

BIM-maturity criteria	Sub-criteria
Strategy	BIM vision and goals
	Management support
	BIM expert/working group/department
Organizational- and Project Structure	Tasks and responsibilities
	Contractual Arrangements
People and Culture	Personal motivation and willingness
	Education, training and support
	Collaborative attitude, openness and transparancy
Processes and procedures	Job instructions and procedures
	Process change
IT Infrastructure	Hardware and network environment
	Software
	BIM facilities
Data (-structure)	Information structure
	Object structure and decomposition
	Object libraries and attributes

3. Results

3.1. BIM in construction

The first aim of this study was getting insight in the adoption (rates) of BIM in Dutch construction. To do so, this study distinguished three groups based on familiarity with and use of BIM; the actual BIM users, the non-users (but being familiar with BIM), and those that are unaware of BIM. Almost one-third of all participants (representing the industry as whole) were BIM users, almost half of them (47.2%) BIM non-users, and one-fifth was unfamiliar with BIM. A detailed overview per subsector can be found in Table 3. Below, the outstanding subsectors for each group will be discussed.

The subsectors that stand out the most in *BIM use*, were the suppliers (59.3% of them uses BIM) and architects (67.4% users) On the other hand, the mechanical engineers (19.0% users) and contractors (21.6% users) stand out as subsectors, because of their relatively low percentages BIM users. For the *BIM non-users*, the engineers (60.7% is familiar with BIM but does not use it) and principals (53.6% non-users) stand out. This means that the vast majority of the participating engineers and principals were familiar with BIM but decided -for whatever reason- not to use it. On the other hand, the suppliers (33.3% non-users) and architects (31.4% non-users) stand out because of their relatively low percentages familiarity but not use. The last group is *not aware of BIM* and therefore has not made a conscious decision on the use of BIM. The most outstanding subsectors are the contractors (33.0% is unaware of

BIM) and mechanical engineers (32.5% unawareness). About one third of the contractors and mechanical engineers was not aware of BIM. On the other hand, the architects (with 1.2% being unaware of BIM) were the most outstanding subsector, followed by the suppliers (7.4%) and engineers (8.3%). BIM is partially or fully applied in 73,8% of the architects' projects and only in 43,9% of the projects of mechanical engineers. Supplier data could not be provided.

Table 3. Familiarity and use of BIM within each subsector (in % among user categories)

	Principals	Architects	Engineers	Contractors	Mechanical Engineers	Suppliers	Total
BIM user	29.3	67.4	31.0	21.6	19.0	59.3	32.4
BIM non-user	53.6	31.4	60.7	45.4	48.4	33.3	47.2
Unaware of BIM	17.1	1.2	8.3	33.0	32.5	7.4	20.4
Projects with BIM	48.3	73.8	52.4	54.3	43.9	-	57.1

3.2. BIM maturity in construction

The overall BIM-maturity and maturity of its components (strategy, organization and project structure, people and culture, BIM-processes, ICT, and data(-structure)) of each subsector and the entire industry can be found in Table 4. These averages were based on a three-point scale (1-3) with a minimum of one and maximum of three. An analysis of the outliers upwards and downwards for the overall BIM-maturity and its components will be given for each subsector will be given.

Table 4. BIM maturity score in the different subsectors of construction

Components of BIM maturity	Principals	Architects	Engineers	Contractors	Mechanical Engineers	Suppliers	Total
Overall BIM-maturity	2.24	2.54	2.27	2.44	2.44	2.38	2.39
Strategy	2.21	2.43	2.25	2.40	2.44	2.45	2.36
Organization and project structure	2.20	2.35	1.94	2.40	2.33	2.31	2.27
People and culture	2.18	2.43	2.08	2.37	2.33	2.39	2.31
BIM-processes	1.78	2.20	2.02	2.10	2.04	1.94	2.01
ICT	2.28	2.90	2.72	2.74	2.79	2.58	2.66
Data-structure	2.50	2.67	2.38	2.50	2.49	2.48	2.52

For the overall *BIM-maturity* (scaled from one to three) the most upwards outlier were the architects with an average of 2.54. On the other hand, the principals (2.24) and engineers (2.27) as subsectors stand out because of their low averages. The ICT BIM-maturity component is the best scoring component with an entire sector average of 2.66 and highest subsector outlier (the principals with an average of 2.90). The *BIM-processes* component was the lowest scoring component, with an average of 2.01 for the entire industry and the best scoring subsector having an average of 2.20, while both entire industry and highest scoring subsector averages were higher for the other BIM-maturity components (including the overall BIM-maturity).

For the *strategy* component, the highest averages can be found for the suppliers (2.45), mechanical engineers (2.44) and architects (2.43), whereas the lowest averages can be found for the principals (2.21) and engineers (2.25). For the component *organization and project structure* the highest averages can be found for the contractors and architects (with subsector averages of 2.40 and 2.35), while the lowest average can be found for the engineers (1.94). The highest subsector averages for the component *people and culture* can be found for the architects and suppliers (with 2.43 and 2.39) while the lowest averages can be found for the engineers and principals (2.08 and 2.18). For the *BIM-processes* component the highest averages were found for the architects and contractors (2.20 and 2.10), whereas the lowest can be found for the suppliers and principals (1.94 and 1.78).

For the *ICT* component, the highest averages can be found for the architects and mechanical engineers (2.90 and 2.79), whereas the lowest can be found for the principals (2.28). Remarkably is the large difference between the lowest subsector average and the one that follows (2.28 of the principals, followed by 2.58 of the suppliers). For the *data structure* component, the highest average can be found for the architects (2.67), while the lowest can be found for the engineers (2.38). Overall the highest averages for each component and the overall BIM-maturity can be found for the architects, while the lowest averages can be found at the principals and engineers. The architects can be seen as frontrunners, while principals and engineers as stragglers in terms of BIM-maturity.

4. Discussion

This study aimed to get insight in the current state of affairs concerning the adoption of BIM in the Dutch construction industry and BIM-maturity of the actual BIM users. First, the adoption of BIM in the subsectors and entire construction industry will be discussed, followed by the BIM-maturity.

4.1. BIM use in construction

Overall roughly one-third of the respondents was a BIM user, almost half knew BIM but did not use it, and one-fifth did not know BIM (and was also not using it). These percentages are comparable with the findings of a BIM adoption survey of 2013 in the United Kingdom. In that study, 31% of the 1000 respondents was actually using BIM (32% in the current Dutch study), 48% was aware but not using BIM (47% in the current Dutch study) and 21% was unaware and thus not using BIM (which was 20% in the current study) (Kassem *et al.* 2013). This raised questions concerning the development of BIM-adoption over the years, because those study results are more than seven years old. Does this similarity in percentages mean that the Dutch construction industry lag behind in comparison to the United Kingdom? Or does this mean that there is a balance point, a point upon which the percentage does not change over the years? Continuing this study in the Dutch construction industry will answer this question.

The most outstanding subsector are the architects, with 67.4% of them being a BIM-user, and 31.4% being a non-user or being unfamiliar with BIM. Also, the suppliers know a high percentage of BIM users (59.3%). On the other hand, contractors and mechanical engineers are two sectors with relatively low BIM-user percentages and high percentages of respondents not aware of BIM. Engineers and principals stand out because of relatively high percentages of being a BIM non-user. This group is familiar with BIM but decides not to use BIM. For most of the non-BIM using firms this could be a deliberate choice: BIM does not provide them the advantages because their firms or projects are too small.

Despite the large research interest in the adoption of BIM, less research focused on the adoption of and familiarity with BIM in the diverse subsectors. An Australian study of 2010 is one of the exceptions and presents the BIM use percentages of architects, contractors, engineers, owners and principals (and another category) [6]. The results of that study are not comparable with those of the current study, since engineers and contractors are the outliers in BIM use (with 75% of the respondents being a BIM user), which is definitely not the case for the current Dutch study. The outliers of the Dutch study found suppliers and architects to be the outliers (with 59.3% and 67.4% BIM users). These differences can be explained by the 10 years the studies differ (2010 versus 2011), and possibly differences between the countries. The suppliers as outlier raises questions. Is there a bias in the participating suppliers? Did the (Dutch) suppliers made a catch up in the decision to use BIM? The results of the broader (current) study

suggest that this could be the case, since 17 of the 32 participating BIM-using suppliers started with BIM between 2015 and 2018.

4.2. BIM maturity in construction

The lowest scoring BIM-maturity component was *BIM-processes*, because (1) the highest subsector average for that component being the lowest highest average (over the components) and (2) the lowest average for the entire (Dutch) industry. The best scoring BIM-maturity component was *ICT*, with the highest overall (entire industry) average of all components and the highest subsector average over all components.

Overall the highest averages for all BIM-maturity components and the entire maturity can be found for the *architects*. While on the other hand, the lowest averages for four out of six criteria and the overall BIM-maturity can be found at the *engineers* and *principals*. A possible explanation for the low averages of the principals can be found in the role they play in the construction chain, because they mainly play a role at the beginning of a project. They do not have clients who can enforce BIM.

After a general analysis of the overall BIM-maturity and components of BIM, a more detailed discussion will provided that focuses on the outliers of the 17 subdomains, as can be found in Table 2. The outlying scores on the maturity sub criteria or subdomains of the subsectors will be discussed.

The first thing that stands out when looking at the division of the *principals* over the levels is the relatively *low percentages* on the *highest levels* of maturity in 9 out of 17 subdomains. A remarkable exception to the overall image of this subsector is the relatively *high percentage* on the *highest level* of the *object structure and decomposition* subdomain. The most outstanding component for the principals is *IT infrastructure*, because of the *lowest percentages* on the *highest level(s)* combined with the highest percentages on the lowest levels for all three subdomains within this component. This indicates that the principals can improve on this component.

The *architects* stand out for their relatively *high percentages* on the *highest level(s)* for 10 out of 17 subdomains. An important reason is that architects think they can realize more customer value in design through using BIM. The outlying component is ‘processes and procedures’ because the architects as subsector had the highest percentage on both subdomains in comparison to the other subsectors. Another notable finding is that the 96.6% of the architects scored on the highest level(s) of both software and ‘hardware and network environment’ (part of the IT infrastructure). In contrast, there is also one remarkable relatively low percentage on the highest level, namely for ‘collaborative attitude, openness and transparency’. Together with the outliers to the higher end are the outliers to the lower end, since the percentage of architects is relatively low for seven of the 17 subdomains.

The *engineers* stand out for having the highest percentages on the lowest level for 10 out of 17 subdomains. Engineers seem to have lost their first mover advantage in recent years. Within these results, the component ‘people and culture’ are the outliers, since the engineers scored the *highest percentage* on the *lowest level* of all subdomains within these components. An exception to the 10 mentioned outliers are the highest percentages compared other subsectors on the lowest levels for the subdomains process change and software. In addition to that, the lowest percentages of engineers on the highest level can be found for three of the subdomains.

The *contractors* stand out on the IT infrastructure component for having no outliers to above or below in comparison to the other subsectors. For data (structure), they have the relatively lowest percentages on the lowest level for three out of the four subdomains within this component, and for ‘people and culture’ the lowest percentages on the lowest level for two out of three subdomains. For contractors, a major reason to start with BIM are external pressures of their clients.

The *mechanical engineers* as subsector stand out for having just 8 outliers in total on the highest and lowest level. Half of those outliers can be found for two subdomains, with a relatively low percentage on the lowest level combined with a high percentage on the highest level for ‘BIM vision and goals’ and ‘education, training and support’. In addition, the percentage on the highest level(s) of ‘BIM facilities’ (as part of IT infrastructure) is notable, since 91.7% of the mechanical engineers scores at least at level 3. Another notable outlier is the 0.0% at the lowest level of software. Working with BIM is enforced by other parties in the chain, such as construction firms and clients.

The *suppliers* stand out for having no outliers on the IT infrastructure component. All outliers (n=13) are relatively low percentages compared to the other subsectors, except for four. For 'collaborative attitude, openness and transparency', 'tasks and responsibilities' and 'object libraries and attributes' the suppliers are outliers because of the highest percentages on the highest level, and for 'object structure and decomposition' the highest percentage on the lowest level. A major reason to work with BIM is because it is enforced by their clients, the construction firms.

5. Conclusions and Further Research

This large-scale study aimed to get insight in the level of BIM adoption and maturity in the Dutch construction industry. It was found that, in general, a large group of firms in construction is not aware of BIM (20%) or does not use it (47%). Adoption among the architects and suppliers was the highest given the largest number of BIM-users. For mechanical engineers and contractors, the number of BIM-users was the lowest. For most of the non-BIM using firms this could be a deliberate choice: BIM does not provide them the advantages because their firms or projects are too small. The overall BIM-maturity of the architects was the highest and of the principals and engineers the lowest. In terms of the subdomains of BIM-maturity, the ICT component scored the highest within the entire sector while BIM-processes scored the lowest.

A limitation of this study could be that almost 50% of the participants describe themselves as a senior manager or project manager, roles that do not require them to be authors and creators of BIM models. A small part of the participants mentioned having a BIM-related job. This distribution of respondents may have influenced the maturity scores, in particular those related to the IT Infrastructure and Data (-structure) maturity dimensions.

This large-scale study was the first in what is likely to be a regular recurring monitoring of the adoption and maturity of BIM within the Dutch construction industry. As such, future findings can be compared with those of the current study. This will provide an opportunity to see whether the group of non-users will change in coming years and in which sectors this change will take place. It will also reveal in which sub domains BIM-maturity will change. The findings from this study can be used to inform firms in specific subsectors in construction in which aspects of BIM to invest to increase maturity. Informing firms in specific subsectors of the advantages and disadvantages they are likely to encounter in using BIM, could support them in deciding whether to use BIM.

Acknowledgments

We would like to thank BIM Loket for funding this project, and Sylvana Van Hensbergen and Henri Busker (USP Marketing Consultancy) for the support of the interviewers, dataset management and feedback.

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