Advantages and disadvantages of BIM use: differences between experiences of its users and expectations of its non-users

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Abstract: This large-scale study focuses on experienced and expected advantages and disadvantages of building information modelling (BIM) use in the Dutch construction industry, and its subsectors. 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. BIM-users were asked about experienced advantages and disadvantages, while BIM non-users were asked about expected advantages and disadvantages of BIM. Advantages and disadvantages mentioned are related to the influential unified theory of acceptance and use of technology (UTAUT) on the adoption and use of information and communication technology (ICT). The largest differences between expected and experienced advantages were found with the architects and contractors, while the largest differences between expected and experienced disadvantages were found with the mechanical engineers and suppliers.

Keywords: building information modelling; BIM; advantages; disadvantages; experiences; expectations.

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1 Introduction

Building information modelling (BIM) has its origins in 1975 and its scope has broadened over the years (Eastman et al., 2008). Latiffi et al. (2014) provided an overview of the development of BIM, from its precursors in the late 1970 s through to the 2010s. This analysis showed that, in the almost 40 years, BIM had not only expanded the phases of the construction process that it plays a role in, but also in its perspective or focus. Its earliest precursor (building description systems, BDS) focused on design in the pre-construction phase, while the introduction of BIM (in 2000) allowed it to be used from pre- to post-construction phases, and improved collaboration and communication (Latiffi et al., 2014). Latiffi et al. (2013) reviewed the application of BIM and provided an overview of each phase, demonstrating the extensiveness of BIM across the construction process.

This development is important in defining BIM, since BIM “needs to be analysed as a multidimensional, historically evolving, complex phenomenon” [Miettinen and Paavola, (2014), p.84]. Siebelink et al. (2018) reviewed the literature on BIM definitions and defined BIM by its five essential elements:

1 a multidisciplinary collaboration-facilitating approach

2 that integrates all object information

3 of the entire asset or project

4 for an asset’s life cycle

5 supported by information technology and digitally represented, often in 3D.

BIM and its implementation and maturity have been studied in several contexts, within and across countries (e.g., Siebelink et al., 2021; Prabhakaran et al., 2021). Many articles have been written about the benefits and challenges of the implementation of BIM (e.g., Doumbouya et al., 2016; Ghaffarianhoseini et al., 2017; Latiffi et al., 2013). However, there has been less research focused on the differences between the actual experiences of users and the expectations of non-users concerning the advantages and disadvantages of BIM across the entire construction industry and its subsectors. Two notable exceptions, are the studies of Akdag and Maqsood (2020) and Ahuja et al. (2018) into the implementation of BIM among Pakistani architects and Indian architects. The first concluded “with BIM, they [the Pakistani architects] achieve much more than they expect, even though they face several limitations" [Akdag and Maqsood, (2020), p.10]. The later analysed environmental, organisational and technological factors concerning BIM among adopters and non-adopters of BIM. This resulted in a list of drivers and inhibitors/barriers to the implementation of BIM for each factor type (e.g., the complexity of the software as technological inhibitor, or costs as organisational inhibitor) (Ahuja et al., 2018). This raises questions concerning the extent to which the expectations of BIM non-users match the actual experiences of BIM users.

This large-scale interview study will fill this gap in the literature by studying the expected and experienced advantages and disadvantages of BIM across the entire construction industry and its subsectors (principals, architects, engineers, contractors, suppliers, and mechanical engineers) of one country, in this case the Netherlands. The engineering subsector involves engineering and consultancy firms, whereas the mechanical engineers are the (technical) installers responsible for mechanical systems such as sanitary, elevators, escalators, and heating and air-conditioning. To this end, this study aimed to answer the following question: What differences are there between the expectations (of non-users) and the experiences (of users) in terms of advantages and disadvantages of BIM across the entire Dutch construction industry and its subsectors?

2 Methodology

This study on the advantages and disadvantages of BIM was part of a larger study into the implementation and maturity of BIM in the Dutch construction industry in order to gain an overview of the current state of affairs concerning BIM use in the Netherlands.

2.1 Approach

A questionnaire was developed in collaboration between a consultancy company and two university researchers. A concept version of this questionnaire was evaluated by 12 representatives from the various subsectors (as a sounding board) who gave suggestions that led to some questions resulting in the definitive version of the questionnaire. The first two parts of the questionnaire focused on background information (e.g., type of organisation, number of employees in the organisation) and the familiarity with and use of BIM. This resulted in three groups: BIM-users (know and use BIM), BIM non-users (know of, but do not use BIM), and the group that does not know about BIM (and also does not use BIM). The third part of the questionnaire, that forms the basis for this sub-study, was divided into two parts. One part was aimed for the BIM-users, and the other for BIM non-users. The open questions concerning advantages and disadvantages of BIM were the same for BIM-users and BIM non-users. There was no limitation on the number of advantages and disadvantages that a respondent could give. The expected and experienced advantages and disadvantages of BIM by the respondents are listed in left columns of the Tables 5 and 6 (advantages) and 7 and 8 (disadvantages) in Appendix 1.

The questionnaires were administered by a consultancy company with experience in this type of research. Trained interviewers of this company executed the questionnaires by phone. This approach was selected for three reasons:

1 the response rate with online questionnaires for the target group of this study is generally limited

2 any vagueness or questions of respondents can be resolved immediately

3 it is generally easier to identify the appropriate person with knowledge of BIM-use within an organisation by telephone.

An exception to this approach was made for the suppliers, since the consultancy company had the experience that this group can be more reliably reached online. Therefore, in addition to the telephonic interviews, a small number of suppliers (n = 5) participated online.

2.2 Respondents

7,776 potential respondents were approached for participation in this research. These respondents were reached through LinkedIn, the 'Gouden Gids' ('Yellow Pages'), which contains contact information on businesses, and a large database owned by the executive consultancy company. From these, 725 respondents participated in the questionnaire. Of these, 235 used BIM (32.4%), 342 knew of BIM but did not use it (i.e., BIM non-users, 47.2%), and 148 did not know BIM (20.4%). These 148 respondents that did not know BIM were excluded from further participation in the study. An overview of the number of participants by subsector, and the use and awareness of BIM is provided in Table 1.

In terms of organisational size, many of the respondents worked for a company with 2-20 FTE (36.6%) and a sizeable number for organisations with over 150 FTE (23.8%). In the other size categories, 12.7% worked for companies with 21-50 FTE, 8.3% for ones with 51-100 FTE, and 5.0% for an organisation with 101-150 FTE. The remaining 13.6% were self-employed. An overview of the employing organisation sizes for each subsector is presented in Table 2. 18 respondents were not able to mention the size of the organisation they were working for, therefore the total is 707 instead of 725.

Almost one-third of the participants described themselves as senior manager (general, financial, or commercial director). Surprisingly, just 2.8% (n = 20) described themselves as having a BIM-related job: 3D/BIM modeller (n = 5), BIM coordinator (n = 2), BIM manager (n = 10) and BIM producer (n = 3). The other job categories covered a broad range of functions (e.g., architect, ICT staff, marketing manager). An overview of the participants' functions for the individual subsectors and the overall sector can be found in Table 3.

Table 1 BIM awareness and use for each subsector

	Principals		*Architects*		*Engineers*		*Contractors*		*ME*		*Suppliers*		*Total*	
BIM user	53	(29.3%)	58	(67.4%)	26	(31.0%)	42	(21.6%)	24	(19.0%)	32	(59.3%)	235	(32.4%)
B.N.U.	97	(53.6%)	27	(31.4%)	51	(60.7%)	88	(45.4%)	61	(48.4%)	18	(33.3%)	342	(47.2%)
U.B.	31	(17.1%)	1	(1.2%)	7	(8.3%)	64	(33.0%)	41	(32.5%)	4	(7.4%)	148	(20.4%)
Total	181		86		84		194		126		54		725	

Note: ME – mechanical engineers; B.N.U. – BIM non-user; U.B. – unaware of BIM.

Table 2 Size of organisations (expressed in FTE) for each subsector

	Principals		*Architects*		*Engineers*		*Contractors*		*ME*		*Suppliers*		*Total*	
1 FTE	3	(1.8%)	23	(27.7%)	53	(63.9%)	2	(1.0%)	14	(11.3%)	1	(1.9%)	96	(13.6%)
2–20 FTE	8	(4.7%)	51	(61.4%)	24	(28.9%)	89	(45.9%)	81	(65.3%)	6	(11.5%)	259	(36.6%)
21–50 FTE	15	(8.8%)	8	(9.6%)	4	(4.8%)	44	(22.7%)	9	(7.3%)	10	(19.2%)	90	(12.7%)
51–100 FTE	16	(9.4%)	0	(0.0%)	0	(0.0%)	30	(15.5%)	5	(4.0%)	8	(15.4%)	59	(8.3%)
101–150 FTE	14	(8.2%)	0	(0.0%)	1	(1.2%)	10	(5.2%)	3	(2.4%)	7	(13.5%)	35	(5.0%)
>150 FTE	115	(67.3%)	1	(1.2%)	1	(1.2%)	19	(9.8%)	12	(9.7%)	20	(38.5%)	168	(23.8%)
Total	171		83		83		194		124		52		707	

Note: ME – mechanical engineers. Eighteen respondents were not able to mention the organisational size (in FTE), therefore the total is 707 instead of 725.

Table 3 Function of the participant

	Principals		*Architects*		*Engineers*		*Contractors*		*ME*		*Suppliers*		*Total*	
Counsellor	8	(4.4%)	1	(1.2%)	15	(17.9%)	1	(0.5%)	1	(0.8%)	0	(0.0%)	26	(3.6%)
3D/BIM modeller	0	(0.0%)	3	(3.5%)	1	(1.2%)	1	(0.5%)	0	(0.0%)	0	(0.0%)	5	(0.7%)
BIM coordinator	2	(1.1%)	0	(0.0%)	0	(0.0%)	0	(0.0%)	0	(0.0%)	0	(0.0%)	2	(0.3%)
BIM manager	1	(0.6%)	2	(2.3%)	1	(1.2%)	4	(2.1%)	1	(0.8%)	1	(1.9%)	10	(1.4%)
BIM producer	0	(0.0%)	1	(1.2%)	0	(0.0%)	2	(1.0%)	0	(0.0%)	0	(0.0%)	3	(0.4%)
Senior manager	2	(1.1%)	24	(27.9%)	35	(41.7%)	74	(38.1%)	70	(55.6%)	9	(16.7%)	214	(29.5%)
Project manager	76	(42.0%)	8	(9.3%)	5	(6.0%)	21	(10.8%)	7	(5.6%)	5	(9.3%)	122	(16.8%)
Others	92	(50.8%)	47	(54.7%)	27	(32.1%)	91	(46.9%)	47	(37.3%)	39	(72.2%)	343	(47.3%)
Total	181		86		84		194		126		54		725	

Note: ME – mechanical engineers.

2.3 Analysis

The percentage of respondents that mentioned a specific pre-identified advantage or disadvantage was calculated using Statistical Package for the Social Science (SPSS), version 26. Given that each participant could refer to more than one advantage or disadvantage, the sum of mentioned advantages or disadvantages for each subsector (and entire industry) was over 100%. Based on the percentages top-fives of the most frequently chosen advantages and chosen disadvantages were made for each subsector and the entire sector. A 'top-5' can include more than five items if equal numbers of participants identified a particular item (e.g., if advantage A and advantage B were both mentioned by 25% of the respondents, they share a place in the ranking). The top-five most frequently mentioned experienced and expected advantages and disadvantages for the Dutch construction industry and its subsectors will be compared. Besides the top-5 actual mentioned advantages and disadvantages, the number of advantages or disadvantages will be discussed. This has to be done with some care, due to the differences in numbers of respondents between the subsectors (i.e., 18 BIM non-using suppliers versus 97 BIM non-using principals).

3 Results

This section starts with a comparison between the top-5 experienced and the top-5 expected advantages for the entire construction industry and then its subsectors, followed by a more detailed analysis of the advantages. A similar comparison and analysis is then performed for the disadvantages. The advantages most commonly experienced by BIM users are shown in Figure 1 and presented in more detail in Appendix 1, Table 5. The most commonly expected advantages are shown in Figure 1 and in Appendix 1, Table 6. Similarly, the disadvantages most commonly experienced by BIM users are shown in Figure 2 and presented in more detail in Appendix 1, Table 7. The most commonly expected disadvantages are shown in Figure 2 and in Appendix 1, Table 8.

3.1 Experienced versus expected advantages of BIM use

3.1.1 The entire Dutch construction industry

Both BIM users and BIM non-users have five advantages in their top 5 (see Figure 1 and Appendix 1, Table 5 for experienced and Table 6 for expected advantages). There are three notable findings when comparing the perceived advantages put forward by the users and non-users. First, many users consider BIM's efficiency (26.9%, third place) and 'lower failure costs' (25.2%, fourth place) as advantages of BIM use, whereas fewer non-users perceive these to be significant advantages. Second, non-users expect 'good data/information interchangeability' (16.5%, fifth place) to be an advantage, whereas this advantage does not feature in the top-5 experienced by BIM users. Third, many non-users struggle to suggest any expected advantages of BIM use, with 18.8% of the BIM non-users answering 'do not know/no opinion' (third place in the top 5 of expected BIM use advantages).

3.1.2 Engineers

The first issue that stands out when comparing the experienced and expected advantages of BIM use by engineers is the large number of advantages experienced by many users (n = 10) in the top-5. Further, there is a strong consensus between BIM users and non-users: all six top-5 expected advantages (by BIM non-users) are experienced by the BIM users. The engineers with experience also identified three additional concrete advantages (the fourth additional aspect was 'other'): 'lower failure costs' (26.9%, first place), 'better overview/insight/control' (19.2%, third place), and 'more attractive designs' (15.4%, fourth place).

3.1.3 Architects

Both top-fives include seven advantages but the lists are not identical. The most remarkable finding is that two of the most widely experienced advantages among BIM users (efficiency, 32.8%, first place and lower failure costs, 19.0%, fourth place) were not widely foreseen by non-using architects. Many non-using architects anticipated 'integrates work of different groups' (18.5%, fourth place) and 'quicker design and detailed plans' (14.8%, fifth place) to be advantages of BIM use but this was not the experience of BIM-using architects.

3.1.4 Mechanical engineers

Here, both top-fives contain nine advantages and there is considerable agreement over the aspects seen as advantageous by both groups of mechanical engineers. One difference is that BIM-using mechanical engineers place the 'quicker design and detailed plans' in fifth place (12.5%) whereas the non-users do not widely see this as an advantage of BIM. Perhaps most noteworthy is that the most frequent response among non-using mechanical engineers to the question as to what the advantages of BIM could be was 'do not know/no opinion' (39.3%).

3.1.5 Contractors

The first difference to note between the top-5 experienced advantages among BIM-using contractors and the expected advantages (among non-using contractors) is in the number of mentioned advantages. The top-5 list of experienced advantages includes eight advantages, whereas the top-5 list of expected advantages includes only five. Many non-using contractors answered 'do not know/no opinion' (25.0%, first place) indicating that knowledge of the advantages of BIM is far from universal. Further, many in this group of non-users expected 'good data/information interchangeability' (14.8%, fifth place) to be an advantage but this did not feature in the top-5 experienced advantages among the BIM-using contractors. Moreover, BIM-using contractors experience 'better overview/insight/control' (33.3%, first place), efficiency (23.8%, second place), 'quicker design and detailed plans' (14.3%, fourth place), and 'shorter project duration' (11.9%, fifth place) as advantages but these were not envisaged by the non-users.

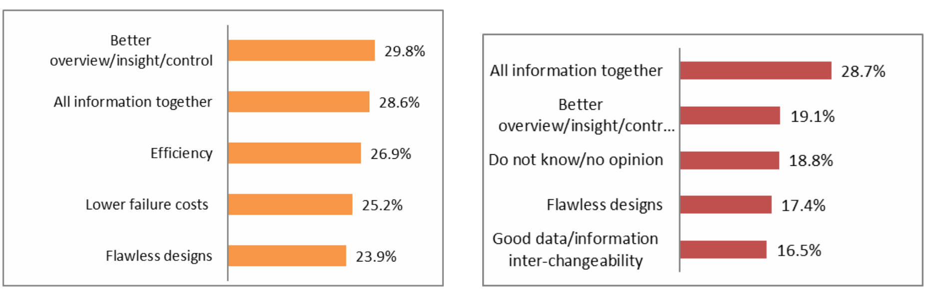
3.1.6 Principals

The only difference between the top-5 experienced and expected advantages by the principals in our sample is that two additional advantages were offered by the BIM users. This group mentioned ‘good data/information inter-changeability’ (20.8%, fourth place) and ‘better planning’ (17.0%, fifth place) as advantages, which are not envisaged by non-using principals.

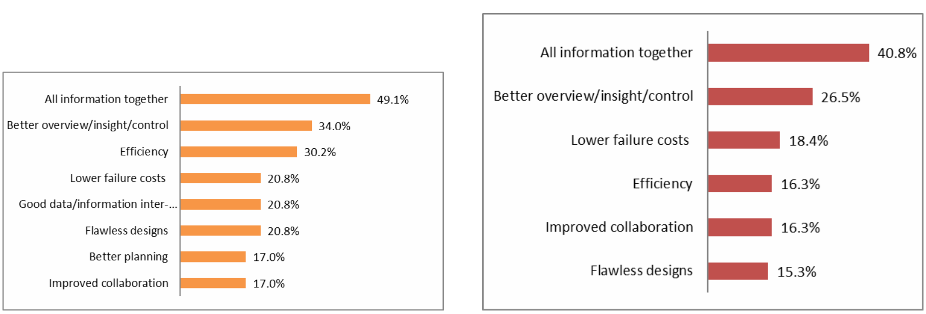
3.1.7 Suppliers

The BIM-using suppliers placed eight experienced advantages in the top-5, whereas the top-5 of non-users includes almost double that number (fourteen) of expected advantages. All the experienced advantages were envisaged as advantages by non-using suppliers. The five additional advantages expected by the non-users are ‘improved collaboration’ and ‘quicker design and detailed plans’ (10.0%, joint fourth place), ‘better planning’, ‘improved property management’ and ‘shorter project duration’ (5.0%, joint fifth place). The other frequent additional response was ‘do not know /no opinion’ (10%, fourth place).

Figure 1 (a) Top 5 experienced advantages (orange) and (b) top 5 expected advantages for entire sector and subsectors (dark red) (see online version for colours)



Total



Principals

Figure 1 (a) Top 5 experienced advantages (orange) and (b) top 5 expected advantages for entire sector and subsectors (dark red) (continued) (see online version for colours)

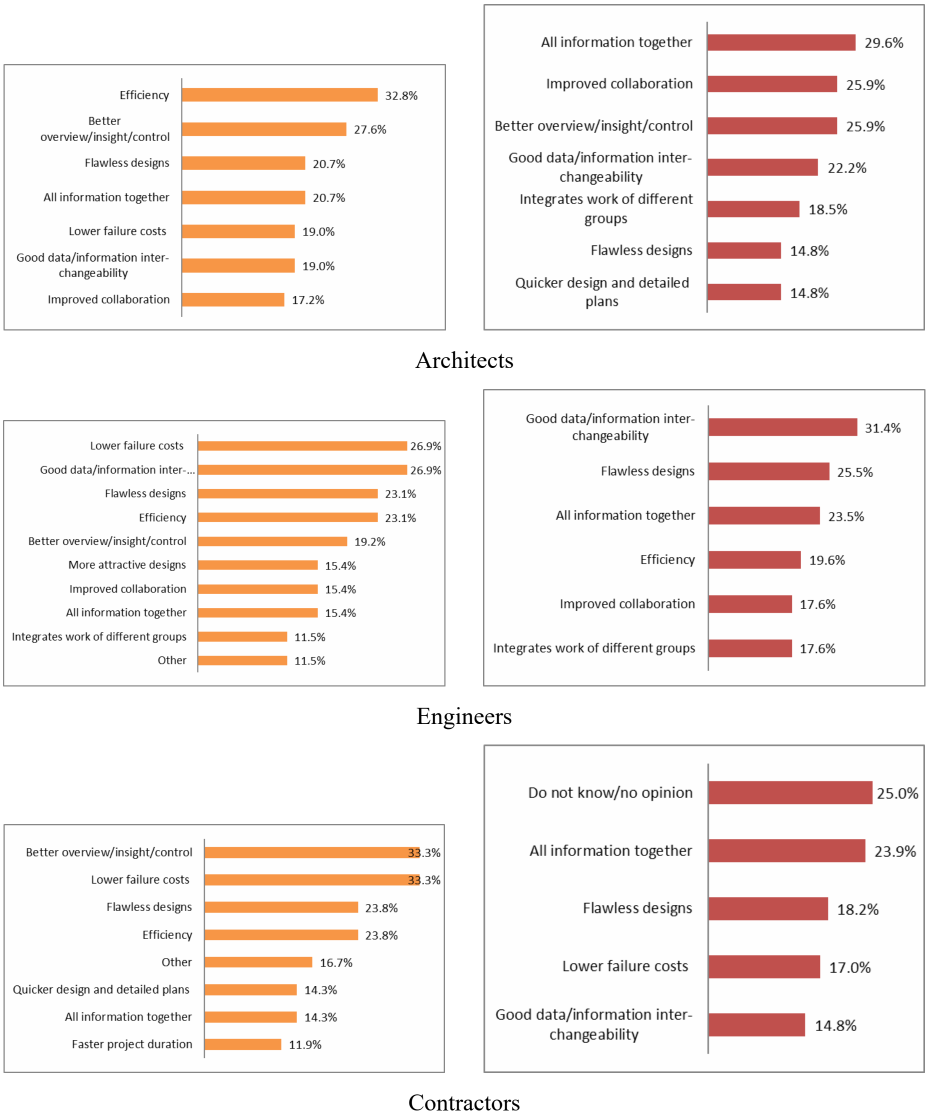
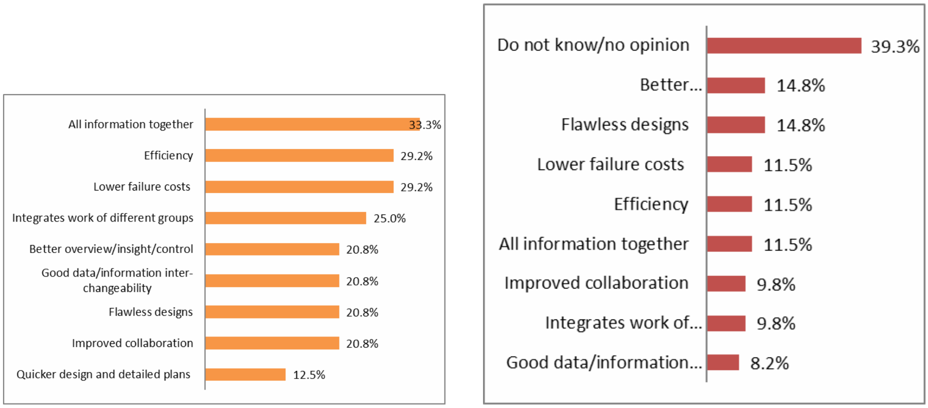
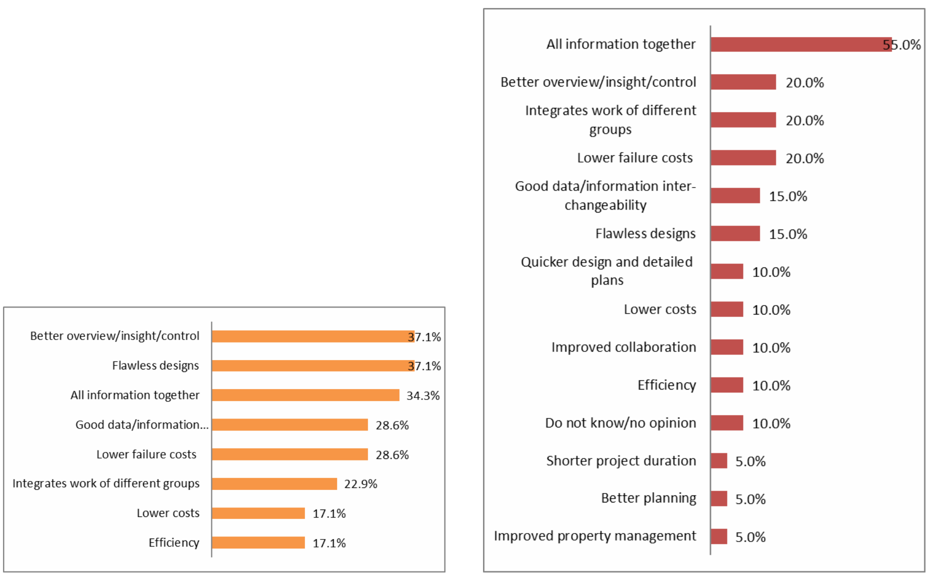


Figure 1 (a) Top 5 experienced advantages (orange) and (b) top 5 expected advantages for entire sector and subsectors (dark red) (continued) (see online version for colours)



Mechanical engineers



Suppliers

(a) (b)

3.1.8 Expected and experienced advantages: a top-5 analysis

Five of the experienced advantages are present in the top-5 of every subsector (n=6) and that of the entire construction industry: ‘all information together’, efficiency, ‘flawless design’, ‘lower failure costs’, and ‘better overview/insight/control’. Only two of these (‘all information together’ and ‘flawless design’) are in all the top-5 expected advantages. The other three (efficiency, ‘lower failure costs’, and ‘better overview/insight/control’) are in the top-5 expected advantages of four of the six subsectors. Efficiency is not widely seen as an expected advantage (i.e., not in the top-5) by the architects and contractors (and overall by the entire sector). 'Lower failure costs' is missing from the top-5 lists of the architects and engineers (and the entire sector), and 'better overview/insight/control' from the top-5 lists of the engineers and contractors.

3.2 Experienced versus expected disadvantages of BIM use

3.2.1 The entire Dutch construction industry

The initial comparison between the top-5 lists of the disadvantages experienced by BIM users and those anticipated by BIM non-users resulted in the remarkable finding that both lists include 'do not know/no opinion' and 'other' (i.e., a disadvantage not foreseen and included in the list of possible disadvantages). For more detail see Figure 2, and Table 7 for experienced and Table 8 for expected disadvantages in Appendix 1. As such, 13.4% (fifth place in the top-5) of the BIM-using respondents had not identified a concrete disadvantage of BIM. Perhaps less surprisingly, 31.4% (first place in the top-5) of the non-users could not identify specific disadvantages of BIM use. Many BIM users mentioned 'not every group is able to work/works with BIM' as a disadvantage (23.5%, second place), but this was not foreseen by many non-users. BIM non-users however mentioned the 'required training/knowledge' (18.9%, second place) as a disadvantage which had not been widely experienced by the BIM users.

3.2.2 Engineers

The BIM-using engineers have eight experienced disadvantages in the top-5, whereas the non-users have only five foreseen disadvantages in the top-5. Many of the non-using engineers expect BIM use to be 'too complex' (13.7%, fourth place), whereas BIM-users do not in general see this as an issue. However, BIM users have experienced that 'not every group is able to work/works with BIM' (26.9%, first place), BIM is 'not always suitable' (15.4%, third place) and its use leads to 'restrictions in the design/less freedom' (11.4%, fourth place), and 'requires much information (in an early stage)' (7.5%, fifth place).

3.2.3 Architects

The BIM-using and non-using architects agree on six disadvantages. One difference is that the users experience the 'required training/knowledge' as a disadvantage (15.5%, fourth place), whereas this was not anticipated by many of the non-users. The non-users on the other hand expect that BIM is 'not always suitable' and will lead to 'restrictions in the design/less freedom' (11.1%, joint fifth place). Further, 14.8% of the non-users has no concrete expectations regarding the disadvantages of BIM use (fourth place in the ranking).

3.2.4 Mechanical engineers

The most remarkable finding from the comparison of the views of the BIM-using and non-using mechanical engineers was the large number (12 in the top-5) of disadvantages experienced by the users compared with only five foreseen by the non-users. The second placed item in the top-5 disadvantages expected by the non-users was that BIM 'requires a financial investment/too expensive' (21.3%) which was not a major issue for the BIM users. The top-5 of the BIM-using mechanical engineers included seven experienced disadvantages that were not foreseen by non-users, namely that: ‘not every group is able to work/works with BIM’ (25%, first place), the ‘resistance to share details by different groups within the process’ (8.3%, fourth place), and ‘the interchangeability’, BIM is ‘not always suitable’, ‘BIM requires a cultural change in the sector’, BIM being ‘hard to understand/not clear what BIM is for’ and BIM ‘requires much information (in an early stage)’ (all 4.2%, joint fifth place).

3.2.5 Contractors

A large number of the BIM-using contractors had experienced that: ‘not every group is able to work/works with BIM’ (19.0%, second place), BIM is ‘not always suitable’ (14.3%, third place), and that its use ‘requires much information (in an early stage)’ (11.9%, fourth place). These experienced disadvantages were not widely anticipated by non-using contractors. Many of the non-users expected that BIM would ‘require a financial investment/is too expensive’ (10.2%, fifth place) and of ‘being too complex’ (11.4%, fourth place) to be disadvantages, while these were not issues widely raised by the users.

3.2.6 Principals

The top-5 expectations and experiences concerning the disadvantages of BIM among principals differed regarding two mentioned disadvantages. Many BIM users had experienced that ‘not every group is able to work/works with BIM’ (20.8%, third place), while this was not generally expected to be an issue by the non-users. However, non-using principals had concerns over the ‘required financial investment/[BIM being] too expensive’ (14.4%, fifth place).

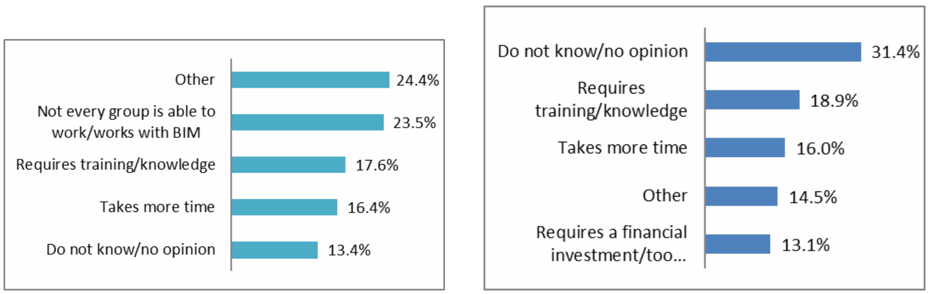
3.2.7 Suppliers

While the top-5 list of disadvantages experienced by users contained just five items, the non-using suppliers produced a much more extensive list of 12 concrete expected disadvantages. The most remarkable observation is that many BIM users experienced a ‘lack of one accepted format for BIM files’ (14.3%, fourth place) as a disadvantage while this did not appear on the much longer list provided by the non-users.

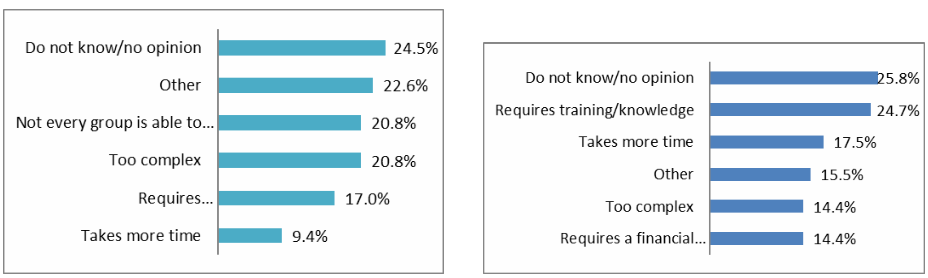
3.2.8 Expected and experienced disadvantages: a top-5 analysis

Three disadvantages can be found in the top-5 experienced disadvantages of all subsectors (and the entire sector): the ‘required training/knowledge’, ‘not every group being able to work/works with BIM’, and ‘others’ (i.e., other aspects not on our list of likely disadvantages). Although none of these is to be found in all top-5 expected disadvantages, the ‘required training/knowledge’ and ‘others’ categories can be found in five out of six subsectors and the entire sector, with the ‘required training/knowledge’ only absent from the architects’ top-5 and ‘others’ is missing in the top-5 expected disadvantages of the mechanical engineers. The most remarkable difference is that the widely experienced disadvantage of ‘not every group being able to work/works with BIM’ was only mentioned in the top-5 expectations of the architects and suppliers. None of the mostly mentioned expected disadvantages were included in the top-5 of every subsector, the only common item being ‘do not know/no idea’.

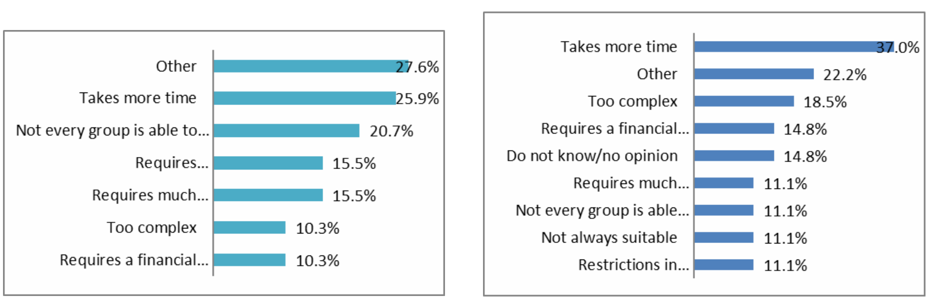
Figure 2 (a) Top 5 experienced disadvantages (light blue) and (b) Top 5 expected disadvantages (dark blue) for entire sector and subsectors (see online version for colours)



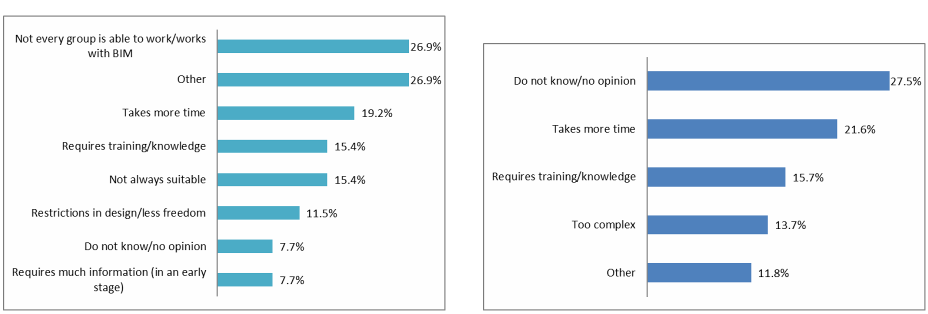
Total



Principals

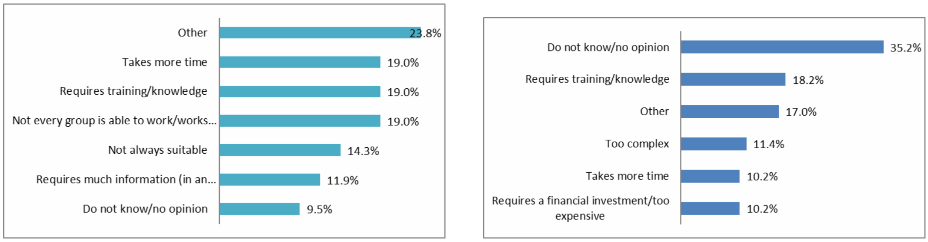


Engineers

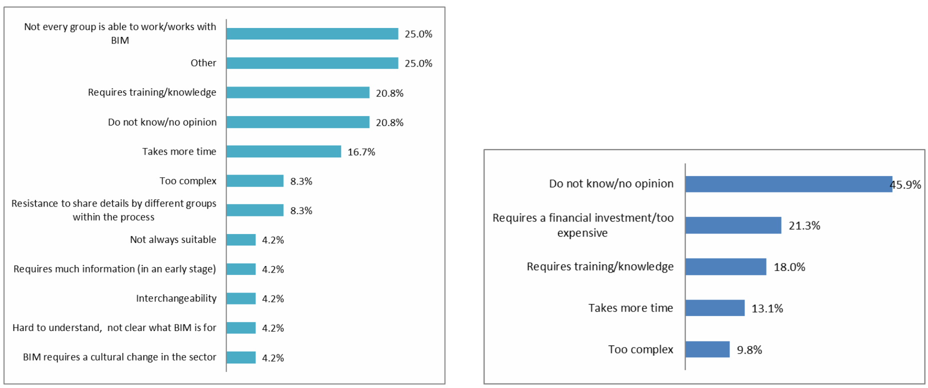


Architects

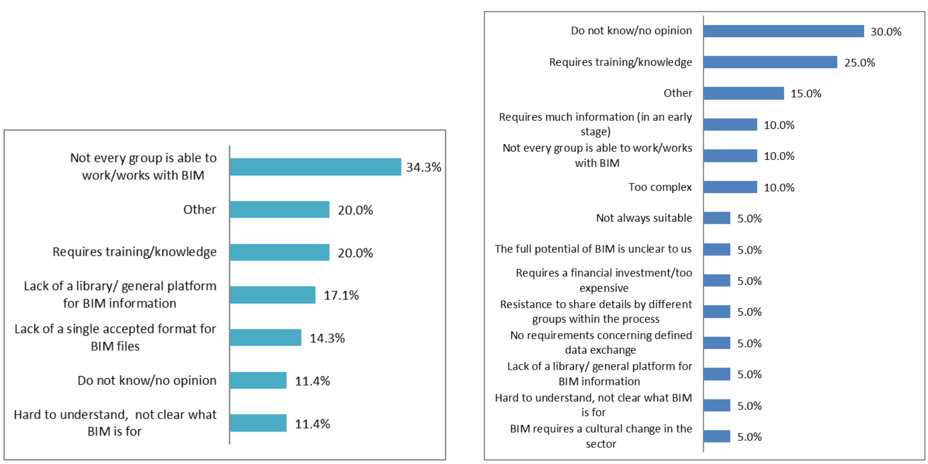
Figure 2 (a) Top 5 experienced disadvantages (light blue) and (b) top 5 expected disadvantages (dark blue) for entire sector and subsectors (continued) (see online version for colours)



Contractors



Mechanical Engineers



Suppliers

(a) (b)

4 Discussion

This study aimed to reveal the differences between the experienced advantages and disadvantages of BIM use by BIM users and the expectations of non-users for the entire Dutch construction industry and for its subsectors. To resolve this issue, 235 BIM users and 342 non-users (who were at least aware of BIM) participated in this study. The discrepancies between expectations and experiences can be used by organisations not yet using BIM to inform themselves of the advantages and disadvantages that are relevant for their subsector.

4.1 Expected and experienced advantages of BIM use

First, the comparison between the expected and experienced advantages of BIM for the entire construction industry will be discussed. In the subsequent comparison of the separate subsectors, the sectors characterised by a strong consensus between experienced and expected advantages will be discussed followed by those with less consensus.

When focusing on the entire construction industry, the most widely experienced benefits of BIM are: ‘all information together’, efficiency, ‘flawless design’, ‘lower failure costs’, and ‘better overview/insight/control’. These five advantages were included in the top-5 of all six subsectors (principals, architects, engineers, contractors, mechanical engineers, and suppliers) and in the sector as a whole, namely the entire Dutch construction industry. However, only two of these (‘all information together’ and ‘flawless design’) were in the top-5 expected advantages put forward by the non-users in all subsectors and the sector as whole, while the others (efficiency, ‘lower failure costs’ and ‘better overview/insight/control’) were identified by four of the six subsectors.

The most remarkable finding regarding the advantages of BIM use is that 18.8% of the BIM non-users across the entire Dutch construction industry had no concrete expectations regarding the advantages of BIM use. This raises questions concerning their decision not to use BIM, is this decision well thought through when they do not know the potential benefits of BIM?

When looking at the individual subsectors, there is much agreement between the using and non-using *mechanical engineers* on the advantages of BIM. However, and perhaps remarkably 39.3% of the non-users had no concrete idea of the advantages. The views of the non-using *principals* were also broadly in agreement with their experienced counterparts. Most notably the using principals included two advantages in their top-5 that were not foreseen by the non-users: ‘good data/information interchangeability’ and ‘better planning’ (in fourth and fifth places). All the leading advantages experienced by BIM-using *suppliers* were anticipated by the non-users. However, the non-users foresaw six additional advantages (all sharing fourth and fifth places). The advantages of BIM expected by the non-using *engineers* in this large sample study match those experienced by the BIM-using engineers. Further, the top-5 list of the BIM users includes four advantages not foreseen by the non-users. The most remarkable difference between the top-5 lists of the users and non-users is that the users’ most mentioned advantage (lower failure costs, 26.9%), was not in the top-5 advantages expected by the non-users.

There are four differences between the *architects’* top-5 lists of expected and experienced advantages of BIM use. Two experienced advantages (efficiency and ‘lower failure costs’) were not widely foreseen by non-using architects. However, the non-users anticipated advantages related to 'integrated work of different groups' and 'quicker design and detailed plans' that were not widely experienced by their using colleagues. The most remarkable finding is that the most widely experienced advantage among BIM-using architects (efficiency, experienced by 32.8%) was only foreseen by 11.1% of the non-users (sixth place). There were many differences between *contractors'* top-5 experienced and expected advantages. Perhaps most remarkably, 25.0% (in first place) of non-users had no concrete idea on the advantages of BIM. The main advantage experienced by using contractors (33.3%, joint first place) was 'better overview/insight/control' which was not even in the top-5 of the non-users. As such, the first-placed advantages of both users and non-users were not highly ranked by their less/more experienced colleagues.

4.2 Expected and experienced disadvantages of BIM use

Just as above for the advantages, the experienced and expected disadvantages for the entire sector and its subsectors will be discussed in turn. As before, the subsector discussion starts with those subsectors that have the greatest consensus and ends with those that have the least consensus between the experienced and expected disadvantages.

In terms of the disadvantages experienced by users, three were to be found in the top-5 of every subsector and the entire sector, namely: 'required training/knowledge', 'not every group being able to work/works with BIM', and 'others'. There was a greater mix of responses among the non-users with 'do not know/no opinion' the only response in the top-5 of all subsectors and the entire sector. However, the 'required training/knowledge' and 'others' disadvantages identified by the users were similarly identified by non-users in five of the six subsectors and the entire sector. The largest discrepancy was in terms of 'not every group being able to work/works with BIM' which was raised as an expected disadvantage by only two subsectors. The needed (software) training and lacking knowledge was also found to be (one of the) a high impact critical risk factor(s) for the adoption of BIM (Khoshfetrat et al., 2020). This implies that the implementation and option of BIM can be supported by supporting the required training and knowledge.

A significant number of both BIM users and non-users (13.4% of the users and 31.4% of the non-users) in this study sample covering the *entire Dutch construction industry* failed to come up with concrete examples of disadvantages of using BIM. An interesting question is whether this means that many users do not experience any disadvantages of BIM or are simply unaware of them?

Turning to the subsectors, the *principals*, whether users or not, were in broad agreement over the disadvantages of BIM, differing only in that there is one expected but not experienced, and one experienced but not expected, disadvantage. The using and non-using *architects* agree on six highly ranked disadvantages and disagree on four (three were expected but widely experienced, while one was experienced and not expected). A similar comparison among the *engineers* also found considerable agreement with four disadvantages appearing in both top-5 lists. The most notable distinction was that 'others are not able to work/working with BIM' was the most frequently raised disadvantage by users (26.9%) but did not appear in the top-5 of the non-users. The users and non-users in the *contractors* subsector agreed on four disadvantages. A further three disadvantages were experienced but not expected, and two were expected but not experienced. The top-5 of BIM-using *mechanical engineers* included 12 experienced disadvantages, suggesting that different users experience different issues, whereas the top-5 of the non-users indeed includes only five items suggesting they had more consistent expectations. Despite this imbalance in the number of disadvantages identified, one disadvantage expected by the non-users 'the financial investment/BIM being too expensive' (21.3%) was not one of the twelve items in the experienced top-5 disadvantages. Among the *suppliers* the most obvious difference is in the number of disadvantages identified. The users' top-5 included just seven items (two of them being 'others' and 'do not know/no idea') whereas the non-users gave more varied responses leading to twelve (of fourteen) specific expected disadvantages. In addition to the specific disadvantages, many respondents in both groups failed to come up any concrete issue, with both 'others' and 'do not know/no opinion' in the two top-5 lists. Despite the large number of expected disadvantages, one experienced disadvantage 'the lack of a single accepted format for BIM files' (14%) was not included.

4.3 Reasons to use or not use BIM

This study focused on non-users expected, and actual users experienced, advantages and disadvantages of BIM technology. Connecting the expectations and experiences found in this study to existing theory on technology acceptance and use can be a helpful step in gaining greater insight into the reasons for using or not using BIM. Therefore, the advantages and disadvantages mentioned in this study will be related to an influential model on the adoption and use of ICT: The unified theory of acceptance and use of technology (UTAUT).

The original UTAUT model was developed by Venkatesh et al. (2003), predicts that, in the end, the decision to use a technology is influenced by the following (four) factors:

1. performance expectancy - perception of the extent to which using a technology will help achieve the desired performance in work tasks
2. effort expectancy - the extent to which the individual finds the system easy to use
3. social influence – perceived importance associated with usage within the social context of organisations or the influence of senior management who believe one should use the system
4. facilitating conditions – perceptions concerning the environmental and organisational conditions that facilitate ease of use and support, and the extent to which an individual believes the organisation is there to support use of the system.

Mahamadu et al. (2014) applied the UTAUT model to the acceptance of BIM and developed an integrated BIM acceptance model. This model extended the original UTAUT model by adding an intermediate step between the five factors (the four original UTAUT factors described above and an additional one) and the use of BIM. The fifth factor is: security expectancy (5) – the extent to which relational, security or transactional risks support or impede BIM use. In this integrated model, these five factors (or perceptions of BIM) are seen as enabling or inhibiting attitudes (the intermediate step between the five factors and the use of BIM).

The vast majority of the advantages mentioned by the respondents can be related to the performance expectancy category (1). The disadvantages widely raised by both BIM using and non-using respondents can be related to the performance expectancy (1), effort expectancy (2), and facilitating conditions (4) categories (see Table 4 for a categorisation of the disadvantages). That is, the disadvantages mentioned are in general not related to the social influence (3) or security expectancy (5) categories.

Table 4 Disadvantages of BIM related to UTAUT model factors

	Performance expectancy	*Effort expectancy*	*Social influence*	*Facilitating conditions*	*Security expectancy*
BIM information available from a restricted number of suppliers	x				
BIM requires cultural change in the sector			x	x	
Hard to understand, not clear what BIM is for		x			
Lack of a library/general platform for BIM information				x	
Lack of a single accepted format for BIM files				x	
No requirements concerning defined data exchange				x	
Resistance to share details by different groups within the process				x	x
Requires financial investment/too expensive				x	
Requires training/knowledge		x			
The full potential of BIM is unclear to us	x				
Too complex		x			
Takes more time	x				
Restrictions in design/less freedom	x				
Overrated	x				
Not always suitable		x			
Not every group is able to work/works with BIM	x			x	
Unclear who is in charge/ responsible				x	
Interchangeability	x				
Requires much information (in an early stage)		x			
Too many software programs needed		x			

The negative expectations of BIM use on performance (1) by both users and non-users is based on the view that BIM consumes more time and that not every group is able to work/works with it. BIM users also mention the need to use many software programs as a disadvantage that lowers performance. The perceived disadvantage of BIM, in terms of effort expectancy (2), by the non-users is influenced by the expectation that BIM is hard to understand, is complex, and requires training/knowledge. Several of the disadvantages can be linked to facilitating conditions (4): the lack of a 'library/general platform for BIM information' and an accepted format for BIM files, resistance to share details by different groups within the process, and that BIM is expensive and requires a significant financial investment.

5 Conclusions

Overall, the main conclusion is that the expected advantages and disadvantages of BIM use envisaged by non-users differ from those experienced by users. The identified differences can be used to better inform non-users of the actual advantages and disadvantages of BIM use found by users in their subsector. This could be valuable in deciding whether to start using BIM.

This large-scale study was the first in what is likely to be a regular recurring monitoring of the implementation of BIM within the Dutch construction industry. As such, future findings can be compared with those of the current study. First, this will provide an opportunity to see whether the differences between experienced and expected advantages and disadvantages will narrow, such that the expectations of non-users more closely reflect the advantages and disadvantages experienced by BIM users. Second, this will also reveal whether the impressions of non-users regarding both advantages (where 18.8% answered 'do not know/no opinion') and disadvantages (31.4% answered 'do not know/no opinion') of BIM will become more concrete. The findings from this study can be used to help inform organisations in specific subsectors of the advantages and disadvantages they are likely to encounter in using BIM, which could support them in deciding whether to use BIM. Sharing experience, knowledge and best practices are also recommended to increase utilisation of BIM in real projects.

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Data availability statement

Some or all data, models, or code that support the findings of this study are available from the corresponding author upon reasonable request.

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Appendix

Expected and experienced advantages and disadvantages

Table 5 Advantages experienced by BIM users in subsectors and entire Dutch construction industry (total)

	Principals	*Architects*	*Engineers*	*Contractors*	*ME*	*Suppliers*	*Total*
All information together	*49.1%*	*20.7%*	*15.4%*	*14.3%*	*33.3%*	*34.3%*	*28.6%*
Traceable	3.8%	3.4%	3.8%	2.4%	0.0%	2.9%	2.9%
Improved collaboration	*17.0%*	*17.2%*	*15.4%*	4.8%	*20.8%*	11.4%	14.3%
Better planning	*17.0%*	6.9%	3.8%	9.5%	0.0%	5.7%	8.4%
Quicker design and detailed plans	11.3%	13.8%	7.7%	*14.3%*	*12.5%*	2.9%	10.9%
More thoughtful designs	11.3%	8.6%	3.8%	9.5%	0.0%	0.0%	6.7%
Dynamic/flexible	0.0%	3.4%	3.8%	0.0%	4.2%	2.9%	2.1%
Easier to convince clients/principals of the design	5.7%	1.7%	7.7%	2.4%	4.2%	2.9%	3.8%
Efficiency	*30.2%*	*32.8%*	*23.1%*	*23.8%*	*29.2%*	*17.1%*	*26.9%*
Flawless designs	*20.8%*	*20.7%*	*23.1%*	*23.8%*	*20.8%*	*37.1%*	*23.9%*
Good data/information interchangeability	*20.8%*	*19.0%*	*26.9%*	7.1%	*20.8%*	*28.6%*	19.7%
Improved property management	7.5%	0.0%	3.8%	0.0%	4.2%	5.7%	3.4%
Integrates work of different groups	15.1%	13.8%	*11.5%*	4.8%	*25.0%*	*22.9%*	14.7%
Lower costs	1.9%	1.7%	3.8%	9.5%	0.0%	*17.1%*	5.5%
Lower failure costs	*20.8%*	*19.0%*	*26.9%*	*33.3%*	*29.2%*	*28.6%*	*25.2%*
More attractive designs	9.4%	1.7%	*15.4%*	2.4%	4.2%	0.0%	5.0%
Better overview/ insight/control	*34.0%*	*27.6%*	*19.2%*	*33.3%*	*20.8%*	*37.1%*	*29.8%*
Design based on performance	1.9%	1.7%	3.8%	2.4%	4.2%	0.0%	2.1%
Shorter project duration	1.9%	5.2%	3.8%	*11.9%*	8.3%	5.7%	5.9%
Reduced calculation time	1.9%	1.7%	3.8%	2.4%	8.3%	0.0%	2.5%
Improved quality	3.8%	6.9%	0.0%	2.4%	0.0%	0.0%	2.9%
Other	13.2%	15.5%	*11.5%*	*16.7%*	8.3%	14.3%	13.9%
Do not know/no opinion	3.8%	3.4%	0.0%	2.4%	4.2%	5.7%	3.4%

Notes: ME – mechanical engineers. The % is the percentage of respondents that mentioned this advantage. The italic percentages are in the top 5 of the subsector or entire Dutch construction industry.

Table 6 Advantages expected by BIM non-users in subsectors and entire Dutch construction industry (total)

	Principals	*Architects*	*Engineers*	*Contractors*	*ME*	*Suppliers*	*Total*
All information together	*40.8%*	*29.6%*	*23.5%*	*23.9%*	*11.5%*	*55.0%*	*28.7%*
Traceable	3.1%	0.0%	2.0%	0.0%	0.0%	0.0%	1.2%
Improved collaboration	*16.3%*	*25.9%*	*17.6%*	6.8%	*9.8%*	*10.0%*	13.3%
Better planning	7.1%	0.0%	3.9%	6.8%	6.6%	*5.0%*	5.8%
Quicker design and detailed plans	8.2%	*14.8%*	3.9%	1.1%	4.9%	*10.0%*	5.8%
More thoughtful designs	5.1%	0.0%	0.0%	0.0%	4.9%	0.0%	2.3%
Dynamic/flexible	5.1%	0.0%	2.0%	1.1%	1.6%	0.0%	2.3%
Easier to convince clients/principals of the design	2.0%	0.0%	0.0%	0.0%	1.6%	0.0%	0.9%
Efficiency	*16.3%*	11.1%	*19.6%*	9.1%	*11.5%*	*10.0%*	13.3%
Flawless designs	*15.3%*	*14.8%*	*25.5%*	*18.2%*	*14.8%*	*15.0%*	*17.4%*
Good data/information inter-changeability	14.3%	*22.2%*	*31.4%*	*14.8%*	*8.2%*	*15.0%*	*16.5%*
Improved property management	7.1%	0.0%	0.0%	0.0%	0.0%	*5.0%*	2.3%
Integrates work of different groups	13.3%	*18.5%*	*17.6%*	5.7%	*9.8%*	*20.0%*	12.2%
Lower costs	3.1%	3.7%	0.0%	3.4%	0.0%	*10.0%*	2.6%
Lower failure costs	*18.4%*	0.0%	13.7%	*17.0%*	*11.5%*	*20.0%*	14.8%
More attractive designs	3.1%	0.0%	0.0%	0.0%	3.3%	0.0%	1.4%
Better overview/ insight/control	*26.5%*	*25.9%*	15.7%	13.6%	*14.8%*	*20.0%*	*19.1%*
Design based on performance	0.0%	0.0%	2.0%	0.0%	0.0%	0.0%	0.3%
Shorter project duration	4.1%	11.1%	5.9%	2.3%	1.6%	*5.0%*	4.1%
Reduced calculation time	2.0%	0.0%	3.9%	0.0%	1.6%	0.0%	1.4%
Improved quality	1.0%	0.0%	0.0%	1.1%	1.6%	0.0%	0.9%
Other	8.2%	3.7%	9.8%	10.2%	3.3%	0.0%	7.2%
Do not know/no opinion	6.1%	11.1%	15.7%	*25.0%*	*39.3%*	*10.0%*	*18.8%*

Notes: ME – mechanical engineers. The % is the percentage of respondents that mentioned this advantage. The italic percentages are those that can be found in the top 5 of the subsector or entire Dutch construction industry.

Table 7 Experienced disadvantages among BIM users in various subsectors and entire Dutch construction industry (total)

	Principals	*Architects*	*Engineers*	*Contractors*	*ME*	*Suppliers*	Total
BIM information is available from a restricted number of suppliers	0.0%	1.7%	0.0%	4.8%	0.0%	0.0%	1.3%
BIM requires a cultural change in the sector	1.9%	1.7%	3.8%	7.1%	*4.2%*	5.7%	3.8%
Hard to understand, not clear what BIM is for	5.7%	5.2%	0.0%	2.4%	*4.2%*	*11.4%*	5.0%
Lack of a library/ general platform for BIM information	0.0%	1.7%	0.0%	2.4%	0.0%	*17.1%*	3.4%
Lack of a single accepted format for BIM files	1.9%	3.4%	0.0%	0.0%	0.0%	*14.3%*	3.4%
No requirements concerning defined data exchange	1.9%	0.0%	0.0%	0.0%	0.0%	5.7%	1.3%
Resistance to share details by different groups within the process	1.9%	1.7%	3.8%	0.0%	*8.3%*	5.7%	2.9%
Requires a financial investment/too expensive	7.5%	*10.3%*	3.8%	7.1%	0.0%	5.7%	6.7%
Requires training/knowledge	*17.0%*	*15.5%*	*15.4%*	*19.0%*	*20.8%*	*20.0%*	*17.6%*
The full potential of BIM is unclear to us	0.0%	0.0%	3.8%	2.4%	0.0%	0.0%	0.8%
Too complex	*20.8%*	*10.3%*	3.8%	7.1%	*8.3%*	2.9%	10.1%
Takes more time	*9.4%*	*25.9%*	*19.2%*	*19.0%*	*16.7%*	5.7%	*16.4%*
Restrictions in design/less freedom	0.0%	8.6%	*11.5%*	7.1%	0.0%	5.7%	5.5%
Overrated	1.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.4%
Not always suitable	5.7%	8.6%	*15.4%*	*14.3%*	*4.2%*	2.9%	8.4%
Not every group is able to work/works with BIM	*20.8%*	*20.7%*	*26.9%*	*19.0%*	*25.0%*	*34.3%*	*23.5%*

Notes: ME – mechanical engineers. The % is the percentage of respondents that mentioned this advantage. The italic percentages are those in the top-5 of the subsector or entire Dutch construction industry.

Table 7 Experienced disadvantages among BIM users in various subsectors and entire Dutch construction industry (total) (continued)

	Principals	*Architects*	*Engineers*	*Contractors*	*ME*	*Suppliers*	Total
Unclear who is in charge/responsible	0.0%	3.4%	3.8%	0.0%	0.0%	0.0%	1.3%
Interchangeability	3.8%	1.7%	0.0%	0.0%	*4.2%*	8.6%	2.9%
Requires much information (in an early stage)	7.5%	*15.5%*	*7.7%*	*11.9%*	*4.2%*	5.7%	9.7%
Too many software programs needed	3.8%	1.7%	0.0%	2.4%	0.0%	0.0%	1.7%
Other	*22.6%*	*27.6%*	*26.9%*	*23.8%*	*25.0%*	*20.0%*	*24.4%*
Do not know/no opinion	*24.5%*	6.9%	*7.7%*	*9.5%*	*20.8%*	*11.4%*	*13.4%*

Notes: ME – mechanical engineers. The % is the percentage of respondents that mentioned this advantage. The italic percentages are those in the top-5 of the subsector or entire Dutch construction industry.

Table 8 Expected disadvantages among BIM non-users in the various subsectors and entire Dutch construction industry (Total)

	Principals	*Architects*	*Engineers*	*Contractors*	*ME*	*Suppliers*	*Total*
BIM information is available from a restricted number of suppliers	1.0%	0.0%	0.0%	1.1%	0.0%	0.0%	0.6%
BIM requires a cultural change in the sector	3.1%	7.4%	3.9%	3.4%	0.0%	*5.0%*	3.2%
Hard to understand, not clear what BIM is for	3.1%	3.7%	0.0%	4.5%	1.6%	*5.0%*	2.9%
Lack of a library/ general platform for BIM-information	2.1%	0.0%	0.0%	0.0%	0.0%	*5.0%*	0.9%
Lack of a single accepted format for BIM files	0.0%	0.0%	0.0%	1.1%	0.0%	0.0%	0.3%
No requirements concerning defined data exchange	1.0%	0.0%	0.0%	0.0%	0.0%	*5.0%*	0.6%
Resistance to share details by different groups within the process	2.1%	3.7%	0.0%	0.0%	0.0%	*5.0%*	1.2%

Notes: ME – mechanical engineers. % is the percentage of respondents that mentioned this advantage. The italic percentages are those that can be found in the top-5 of the subsector or entire Dutch construction industry.

Table 8 Expected disadvantages among BIM non-users in the various subsectors and entire Dutch construction industry (total) (continued)

	Principals	*Architects*	*Engineers*	*Contractors*	*ME*	*Suppliers*	*Total*
Requires a financial investment/too expensive	*14.4%*	*14.8%*	7.8%	*10.2%*	*21.3%*	*5.0%*	*13.1%*
Requires training/knowledge	*24.7%*	3.7%	*15.7%*	*18.2%*	*18.0%*	*25.0%*	*18.9%*
The full potential of BIM is unclear to us	3.1%	7.4%	0.0%	3.4%	0.0%	*5.0%*	2.6%
Too complex	*14.4%*	*18.5%*	*13.7%*	*11.4%*	*9.8%*	*10.0%*	12.8%
Takes more time	*17.5%*	*37.0%*	*21.6%*	*10.2%*	*13.1%*	0.0%	*16.0%*
Restrictions in design/less freedom	1.0%	*11.1%*	5.9%	3.4%	1.6%	0.0%	3.2%
Overrated	2.1%	0.0%	2.0%	0.0%	0.0%	0.0%	0.9%
Not always suitable	10.3%	*11.1%*	7.8%	5.7%	4.9%	*5.0%*	7.6%
Not every group is able to work/works with BIM	13.4%	*11.1%*	7.8%	6.8%	6.6%	*10.0%*	9.3%
Unclear who is in charge/responsible	1.0%	0.0%	5.9%	0.0%	0.0%	0.0%	1.2%
Interchangeability	1.0%	0.0%	2.0%	0.0%	0.0%	0.0%	0.6%
Requires much information (in an early stage)	5.2%	*11.1%*	2.0%	4.5%	3.3%	*10.0%*	4.9%
Too many software programs needed	1.0%	0.0%	0.0%	2.3%	1.6%	0.0%	1.2%
Other	*15.5%*	*22.2%*	*11.8%*	*17.0%*	8.2%	*15.0%*	*14.5%*
Do not know/no opinion	25.8%	14.8%	27.5%	35.2%	45.9%	30.0%	31.4%

Notes: ME – mechanical engineers. % is the percentage of respondents that mentioned this advantage. The italic percentages are those that can be found in the top-5 of the subsector or entire Dutch construction industry.