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RESEARCH PAPER

Yield-to-BIM: impacts of BIM maturity on project performance

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ABSTRACT
How does organizational experience (maturity) with building information modelling (BIM) impact on the broad implementation of BIM and on company performance? A survey of Dutch architectural, engineering, construction, and operation (AECO) professionals ($n = 890$) is used to examine their perceptions of the impact of BIM maturity on firm performance. Survey items included measures of BIM element maturity (*i.e.*, strategy, BIM uses, process, information, infrastructure and personnel), and key performance indicators (time, cost and quality performance). Surprisingly, the maturity of the BIM implementation strategy was the only reliable predictor of time, cost and quality performance. The result suggests that the impact of BIM maturity on project performance may be limited and it cautions against overoptimistic appraisals of BIM. In addition to the contribution to the literature on BIM performance, the paper should be of interest to the practitioner contemplating BIM investments.

KEYWORDS
assessment model; building information modelling (BIM); maturity; performance indicators; survey

Introduction

The architectural, engineering, construction and operation (AECO) industry continues to adopt building information modelling (BIM). Yet, performance benefits remain fairly unclear. By 2009, almost half the organizations in the AECO industry claimed to implement BIM – up 75% from 2007 (McGraw-Hill, 2009). The stated rationale for implementing BIM varies from sharing information to accelerating decision-making (Azhar, Hein, & Sketo, 2008; Grilo & Jardim-Goncalves, 2010) and utilizing information and communication technology tools aimed at cost reductions (Hartmann, Van Meerveld, Vossebeld, & Adriaanse, 2012; Haymaker & Fischer, 2001; Koo & Fischer, 2000). However, despite the proclaimed benefits of BIM regarding failure costs reductions and productivity increases, the construction industry does not show much improvements on these two aspects. This productivity paradox (Brynjolfsson, 1993) is surprising in light of ample case-based evidence highlighting successful utilization and implementation of BIM (Bryde, Broquetas, & Volm, 2013).

One possible explanation for the lack of visible macro-effects is low BIM maturity. In other words, organizations still have little experience with implementing BIM which hinders the effective and broad implementation of this new technology. In order to study the effects of BIM maturity on key performance indicators (KPIs), so-called BIM maturity models have been proposed that explicate the stage of development of BIM within an organization (Barlish & Sullivan, 2012; Chen, Dib, & Cox, 2014; Mom & Hsieh, 2011; Sebastian & Van Berlo, 2010; Succar, Sher, & Williams, 2013). Researchers have predominantly collected data on the relation between BIM maturity and KPIs by conducting case studies, while survey-based research has generally been limited to either issue in isolation (Barlish & Sullivan, 2012; Bryde et al., 2013; Giel, Issa, & Liu, 2012; Van Berlo, Dijkmans, Hendriks, Spekkink, & Pel, 2012). Notwithstanding the value of case study designs (Flyvbjerg, 2006), the underlying assumption that the overall BIM maturity of an AECO organization is directly linked to its KPIs has not yet been empirically tested.

This paper addresses this gap by presenting the results of a large-scale survey research with the goal to explore the relation between the two aspects of BIM maturity and organizational performance – labelled here as yield-to-BIM maturity – among 890 Dutch AECO professionals. The survey included items on the maturity of BIM elements (*i.e.*, strategy, BIM uses, process, information, infrastructure and personnel), *and* perceived time, cost and quality performance. Surprisingly, the results of the survey show few statistically significant

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effects. Only strategic maturity was found to be a reliable predictor of time, cost and quality performance. However, even for strategy, the associated effect sizes (including overall R^2) were small. The maturity of none of the other BIM elements was reliably related to any of the performance indicators. Generally, this research suggests that the impact of BIM maturity on project performance may be limited and it cautions against overoptimistic appraisals of BIM. Although the data pertain exclusively to Dutch organizations, the findings are representative of the wider BIM industry. This is because the Netherlands has one of the highest BIM adoption rates worldwide and can serve as a proxy for the many other countries with strategies to increase their adoption rate.

The paper is structured as follows. First, the existing BIM literature on organizational maturity and project performance is presented. Subsequently, the research method and key findings are reported. Finally, these findings are interpreted, the shortcomings of the study are discussed, and the conclusions of this paper are formulated.

Yield-to-BIM maturity: literature review

BIM is often defined as a set of interacting policies, processes and technologies to manage essential building design and project data in digital format throughout a project's life cycle (Succar, 2009, 2010; Succar et al., 2013). As such, many perceive BIM as 'a solution to the many inefficiencies in the construction industry' (Zuppa, Issa, & Suermann, 2009). In particular, through the implementation of BIM, organizations hope to increase their performance in delivering projects in terms of cost, time and quality (Bercerik-Gerber & Rice, 2009; Zuppa et al., 2009). Therefore, it is not surprising that, organizations in the fragmented AECO industry increasingly implement BIM for projects that are becoming more complex and difficult to manage (Alshawi & Ingirige, 2003; Chan, Scott, & Chan, 2004; Taxén & Lilliesköld, 2008; Williams, 2002).

In recent years a number of case studies have shown the positive value of BIM on project performance. These studies usually define project performance according to the Project Management Institute's Project Management Body of Knowledge that provides a comprehensive high-level framework encompassing several dimensions of project success (PMI, 2008). These include *coordination* (*i.e.*, unification, consolidation, articulation and integrative actions), *scope* (*i.e.*, defining and controlling what is and what is not included in the project), *time* (*i.e.*, accomplish timely completion of the project), *cost* (*i.e.*, planning, estimating, budgeting and controlling costs), *quality* (*i.e.*, quality planning, quality assurance and quality control), *organizations* (organize and manage the project team), *communication* (*i.e.*, timely and appropriate generation, collection, distribution, storage, retrieval and disposition of project information), *risk* (*i.e.*, increase the probability and impact of positive events, and decrease the probability and impact of adverse events), and *procurement* (*i.e.*, purchase or acquire the products, services or results needed from outside the project team to perform the work).

Examples of such studies include Barlish and Sullivan (2012) who calculated project cost (time performance) as the ratio of actual cost (duration) over budgeted costs (planned duration). This use of ratios immunizes the measures against the influence of absolute budget size and total project duration, thus facilitating cross-case comparisons. The study used this metric to measure BIM benefits in three cases of a tool installation department of a semiconductor manufacturing company, in which BIM and non-BIM projects in similar functional areas were compared. Results indicated a positive influence of BIM on cost and time performance.

In another example, Bryde et al. (2013) explored reported BIM benefits in a cross-section of 35 construction projects. Secondary data were collected from projects that utilized BIM and mentioned positive or negative effects of BIM use. Results showed that improved cost performance due to BIM was most frequently mentioned, closely followed by time and quality benefits. The finding of improved cost performance is substantiated by other case studies (Alshawi & Ingirige, 2003; Azhar et al., 2008), of which some even report an average BIM return on investment of 9486% (Azhar et al., 2008).

Contrary to these overly positive studies, other case studies have tried to shed a more nuanced light on the benefits of implementing BIM. These studies, usually based on in-depth single-case observations, provide many examples of how the implementation of BIM did not directly led to additional value in terms of time, cost or quality performance. These studies show that successful implementation of BIM depends on a high level of integration of the used information modelling technologies with a project's organizational processes (for some recent examples, see Davies & Harty, 2013; Hartmann et al., 2012; and Sackey, Tuuli, & Dainty, 2014). These studies usually attributed the missing success of BIM implementation efforts on the lack of individual knowledge of actors and processes that align these actors. The underlying argument is that BIM is potentially useful, but that individuals and organizations first have to learn how to use the new technology to reap the true benefits of implementing BIM. In other words, organizations have to build up their BIM maturity.

To support organizations in understanding their current BIM maturity, so-called BIM maturity models have been developed (Chen et al., 2014; CICRP, 2013; Giel et al., 2012; Mom & Hsieh, 2012; NIBS, 2007; Sebastian & Van Berlo, 2010; Succar, 2009). These maturity models are based upon various established organizational BIM elements (CICRP, 2013; Kaner, Sacks, Kassian, & Quitt, 2008; Khanzode, Fischer, & Reed, 2008; Leicht & Messner, 2008; McGraw-Hill, 2008, 2009, 2010a, 2010b; Nisbet & Dinesen, 2010), such as *strategy* (*i.e.*, mission, vision, goals and objectives, along with management support, BIM champions, and BIM planning committee), *BIM uses* (*i.e.*, specific internal and external methods of implementing BIM), *process* (*i.e.*, the means to accomplish BIM uses), *information* (*i.e.*, model structure, level of development and facility data requirements), *infrastructure* (*i.e.*, technological and physical systems to operate BIM), and *personnel* (*i.e.*, roles, responsibilities, education, training and change readiness). The models comprehensively evaluate implementations with respect to the aforementioned BIM elements and have been used to benchmark ‘quality, repeatability, and degree of excellence’ of BIM implementations (Succar et al., 2013). For example, Sebastian and Van Berlo (2010) have benchmarked 812 Dutch AECO organizations (Van Berlo et al., 2012). Their research showed that BIM maturity is usable for benchmarking BIM implementations and concluded that AECO organizations mainly strive for maturity at the organizational level (*e.g.*, strategy maturity), whereas process and information maturity are still low. These findings correspond to results of BIM maturity surveys in other countries, such as the US (Chen et al., 2014; Giel et al., 2012). Chen et al. (2014) also gathered perceptions of AECO professionals on the importance of each BIM element and concluded that process and information maturity were low, yet important, and deserve more attention.

While mapping organizations’ current BIM maturity is of interest, the findings of these BIM maturity assessments are arguably of little assistance to organizations having to decide how to allocate resources in BIM implementations. To support such allocation decisions, understanding needs to be developed about how different BIM maturity elements relate to the different aspects of project performance. This link has to be generalizable going beyond what can be shown by case studies. This study provides a first attempt to establish such a general understanding of the yield-to-BIM maturity link by using a survey of the Dutch industry, a national industry that is known for their high BIM implementation maturity worldwide. The next section describes the survey method on which the study is based.

Method

The survey procedure applied in this study entailed (1) the development of an online questionnaire including items on KPIs and the maturity of BIM elements, (2) pilot testing and revision of the questionnaire, (3) sampling of participants, (4) sending out invitations to potential participants, and (5) collecting as well as analyzing the responses.

Materials and procedure

The questionnaire solicited data on BIM maturity elements’ and KPIs’ time, cost and quality performance (in addition to the descriptive data of participants outlined below). To design the questionnaire, the authors consulted the literature for relevant metrics. Final selection of metrics was based on their suitability to measure and quantify research variables, practicality in terms of measurement, and scientific substantiation of their content. These metrics became the basis of a concept questionnaire by transforming them into Dutch questions, adding explanations and examples, programming them into an online survey application (LimeSurvey, 2014), and providing guidelines for answering. The concept questionnaire exclusively solicited categories or attitudes to statements on a six-point Likert scale to facilitate analyses on a large dataset (Leedy & Ormrod, 2010; Sapsford, 2006; Sillars & Hallowell, 2009). The authors chose a six-point Likert scale to force respondents to take a clear position towards specific questions and avoid the inclusion of bias caused by too many neutral responses.

The questionnaire contained 60 questions of which 14 were related to project performance, 20 related to BIM maturity and 24 related to participants and their organizations. Items on project performance entailed directly asking attitudes of participants on statements about their organization’s project performance. The statements were derived from success criteria of the Project Management Body of Knowledge (PMI, 2008) that were used in studies to analyze project performance (Barlish & Sullivan, 2012; Bryde et al., 2013; Kam, Senaratna, McKinney, Xiao, & Song, 2013; Suermann & Issa, 2008). To assess project (1) time, (2) cost and (3) quality performance, the researchers asked for attitudes on the following statements: (1) ‘My organization delivers projects according to contracted schedule’, (2) ‘My organization delivers projects according to contracted budget’, and (3) ‘My organization delivers projects according to contracted quality’.

Information on BIM maturity was assessed by presenting 20 sub-elements of BIM maturity with six possible descriptions each and directly asking participants to select the description that best fitted their organization. This assessment was similar to the Pennsylvania State University's Organizational BIM Assessment Model (CICRP, 2013), which the researchers tried to approximate as close as possible. Modifications to the original model were only made to allow online surveying of Dutch AECO professionals. This required converting the original model's Excel sheet into the online survey application, adding explanations and examples for further clarification, and translating the English model into Dutch. Other aspects of the original model, such as the number and content of sub-elements and their accompanying descriptions were unmodified. These 20 sub-elements related to six BIM maturity elements, of which five related to strategy, two to BIM use, two to process, three to information, three to infrastructure and five to personnel. For each of these sub-elements, six descriptions were tailored to its specific sub-element. These descriptions represented a range of six possible maturity levels: 0. Non-existent, 1. Initiated, 2. Managed, 3. Defined, 4. Quantitatively Managed, and 5. Optimized. The maturity levels themselves were not mentioned in the descriptions to minimize potential self-serving bias that could be facilitated by explicitly linking descriptions to maturity levels.

The concept questionnaire was checked for face and content validity using a pilot study. The pilot process involved 14 BIM and survey experts who provided individual feedback on adequacy of coverage and usefulness for exploring relationships between research variables. After analyzing the feedback, improvements were proposed, discussed, and implemented, and then tested in the next session. As a result of this iterative process, the concept questionnaire gradually evolved to the stage of the final version.

Participants

Nearly 25,000 AECO professional listed in the contact database of the largest Dutch computer-aided design (CAD) software reseller and Dutch consultancy agency were used in the survey to broadly sample the Dutch industry (Marshall, 1996). To reduce potential bias (Chang, 2013), the researchers omitted contacts from the database that did not seem to fit population characteristics (*e.g.*, not employed at Dutch AECO organizations). Emails with a request to participate were send out to 10 299 eligible individuals. The email included the questionnaire's URL, and it offered participants the opportunity to receive their BIM maturity profile based on their answers. The latter was included to exemplify content of research and incentivize response. To incentivize further response, raffle tickets for a theme park were included. After initial invitations on 3 June 2014, reminders were sent on 26 June 2014 and 30 September 2014. Participants joined the study by fully completing the questionnaire. Participants who responded by indiscriminately giving the same answer (Likert scale) on all questions were excluded from analyses. From a total of 10 299, 890 persons complied and returned adequately filled-out questionnaires (approximately 9%).

An exit poll (Table 1) was used to analyze the likelihood of bias by non-response. A total of 319 persons (3.1%) participated in the poll, of which 297 (93.1%) indicated their motives for deregistration. Two major motives for non-compliance were identified, *i.e.*, not involved with BIM (128 persons) and too busy (111 persons). Only 10 persons indicated that 'the questions and answers were unclear to them'.

The analyses are based on data from 890 participants who adequately complete the questionnaire. Figure 1 presents background characteristics of participants, which shows the participants' expressed agreement or disagreement on several statements using a symmetric six-point Likert scale. Almost all participants appear willing to adjust current practices to new technologies ($n = 859$, 96.4%) and like working with computers ($n = 849$, 95.3%). Moreover, most participants agreed with statements on being responsible for their organization's BIM implementation ($n = 683$, 76.7%), proposing BIM implementation improvements ($n = 664$, 74.5%), following latest BIM developments ($n = 650$, 73.0%), and performing recurring tasks with BIM if this would be faster ($n = 632$, 70.9%). Also, slightly more participants agreed than disagreed with the statement on being experienced in practicing BIM ($n = 504$, 56.6%), while a large minority agreed with being educated in using BIM ($n = 377$, 42.3%). On being skilled in BIM use, responses were balanced, with only slightly more participants agreeing ($n = 454$, 51.0%) than disagreeing ($n = 445$, 49.0%).

Table 1. Received motives for deregistration through exit poll.

Deregistration argument	*n*	%
'I am too busy to participate'	111	37.4
'I am (no longer) employed in the Dutch AECO industry'	49	16.5
'I am not involved with BIM'	128	43.1
'My organization has already participated in the survey via another invitation'	9	3.0
'My organization does not wish to share this information'	10	3.4
'My organization does not deal with BIM'	59	19.9
'The questions and answers do not concern my organization'	36	12.1
'The questions and answers are not clear to me'	10	3.4
Other	18	6.1

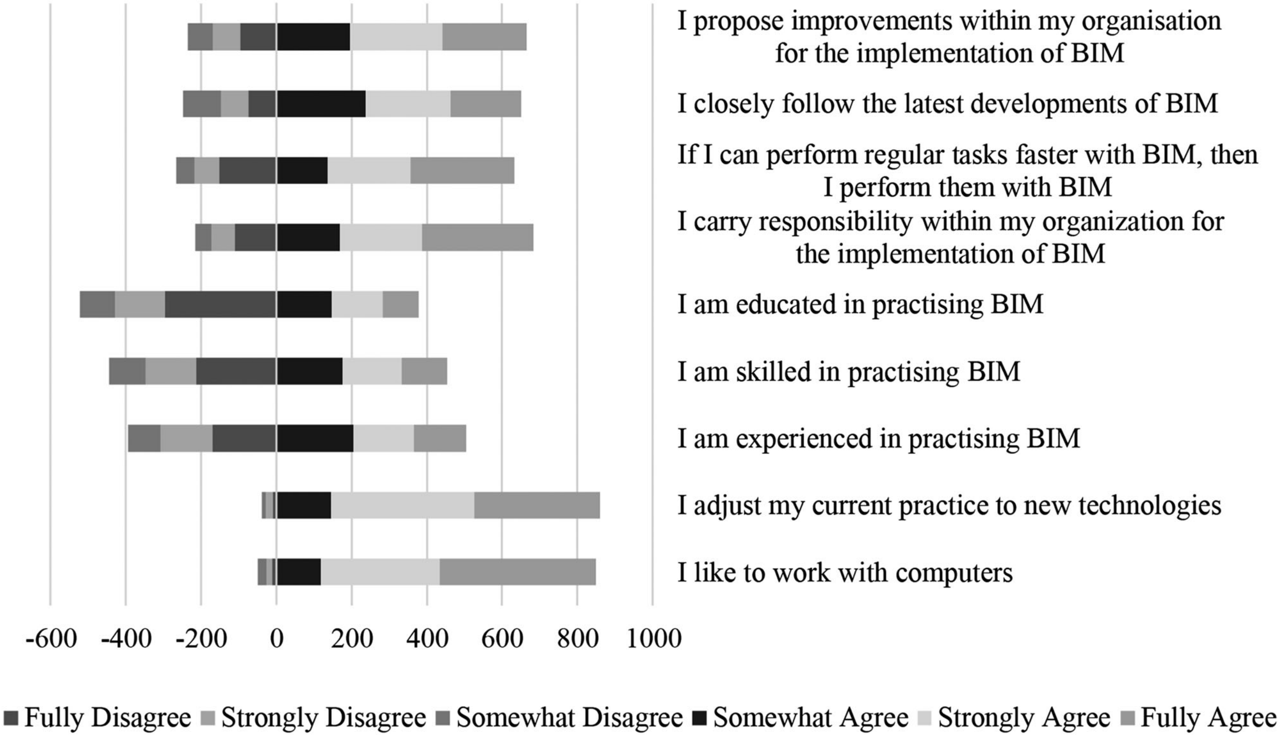

Figure 1. Background characteristics of participants ($n = 890$). Negative numbers represent negative attitudes: fully disagree, strongly disagree and somewhat disagree.

Figures 2–4 present additional background information. Most organizations ($n = 776$) operate in the residential and utility construction branch, while a minority ($n = 114$) operate in the civil engineering branch. The majority of organizations ($n = 517$) operate exclusively in the residential and utility construction branch. Furthermore, organizations are involved in all six project life-cycle phases, of which the average organization was involved in 4.4 phases. Most organizations are involved in the design ($n = 781$), preparation ($n = 791$) and/or realization phase ($n = 744$), while fewer organizations are involved in the inception ($n = 509$), definition ($n = 619$) and operation phase ($n = 479$). Moreover, all AECO disciplines are represented in our sample. The average organization is involved in 2.1 disciplines. Most frequently reported organization types were (sub-)contractors ($n = 305$) and architect ($n = 283$), while facility manager ($n = 119$) was the least frequently reported discipline.

Data preparation

To analyze data on BIM maturity, descriptions of BIM sub-elements were transformed into continuous variables on a 0–5 scale that represented possible maturity levels. Subsequently, to calculate the maturity level of

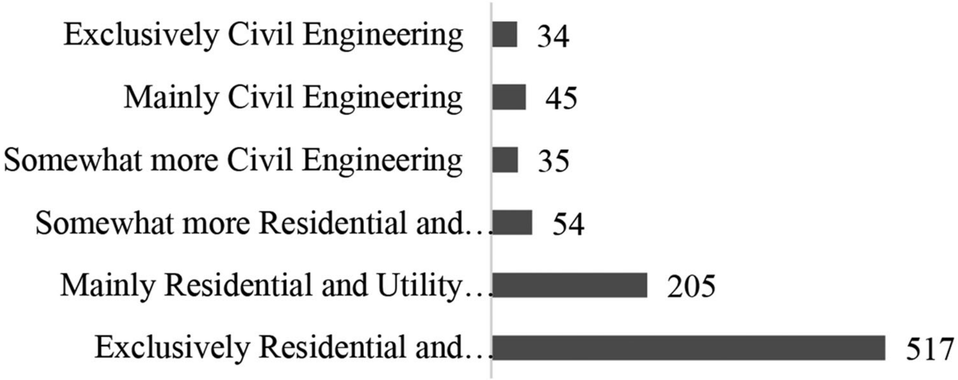

Figure 2. Overview of the branch in which participants' organizations operate ($n = 890$).

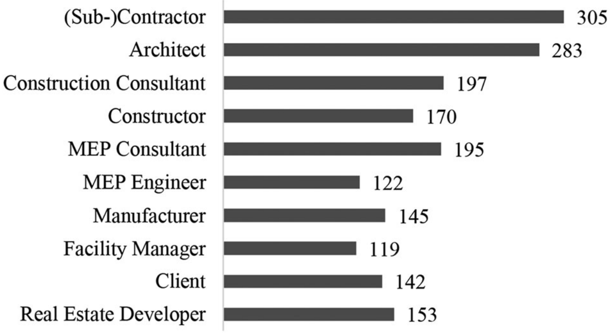

Figure 3. Overview of the project life-cycle phase in which participants' organizations are involved ($n = 890$).

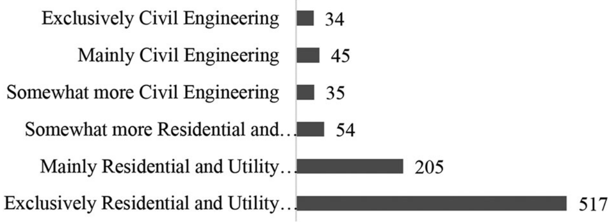

Figure 4. Overview of architectural, engineering, construction, and operation (AECO) disciplines practised by participants' organizations ($n = 890$).

each BIM element, the average level of sub-elements related to the BIM element was calculated. In doing so, BIM element maturity levels were converted into continuous variables by following the original procedure of the Pennsylvania State University's Organizational BIM Assessment Model (CICRP, 2013). Furthermore, attitudes to project performance were converted from Likert scales into continuous variables that ranged from 0 to 5. The following section describes the results of the analysis.

Results

Overview of research variables

Responses on project performance statements are presented in Figure 5. Most participants expressed favourable views on their organization's time performance ($n = 848$, 95.2%), cost performance ($n = 806$, 90.6%) and quality performance ($n = 852$, 95.7%). On average, participants ratings were highest for the quality statement (mean = 4.2, SD = 0.9), followed by the time statement (mean = 4.1, SD = 0.9) and finally the cost statement (mean = 3.7, SD = 1.0).

Responses pertaining to BIM maturity are presented in Figure 6. Tukey box plots show that data of strategy and infrastructure were symmetric, while data of BIM use, process, information and personnel were skewed right. Moreover, box plots show that BIM use possessed the largest interquartile range (IQR = 2.5), followed by infrastructure (IQR = 2.0), process (IQR = 2.0), strategy (IQR = 1.8), information (IQR = 1.7) and personnel (IQR = 1.6). Additionally, eight weak outliers (1.5 * IQR < > 3.0 * IQR) were identified for information and five for personnel, while other maturity element's whiskers remained within a 0–5 scale and thus contained no outliers. Furthermore, on average, maturity was highest for strategy (mean = 2.3, SD = 1.24), followed by infrastructure (mean = 2.0, SD = 1.31), personnel (mean = 1.5, SD = 1.13), BIM use (mean = 1.4, SD = 1.29), information (mean = 1.3, SD = 1.20) and finally process (mean = 1.2, SD = 1.57).

BIM maturity and KPIs

A Pearson correlation analysis was conducted to check for multicollinearity. Results of the Pearson correlation analysis are presented in Table 2. For the 890 responses, all Pearson correlation values were less than .80. Furthermore, most scores of BIM maturity elements and KPI were significantly correlated at 0.01 level. Also, cost and process ($r = .07$, $p = .04$), and quality and personnel ($r = .07$, $p = .05$) were significantly correlated at the 0.05 level. Moreover, there were non-significant correlations between quality and BIM use ($r = .05$, n.s.), process ($r = .04$, n.s.), information ($r = .06$, n.s.) or infrastructure ($r = .05$, n.s.). Likewise, scores of cost and infrastructure ($r = .05$, n.s.) were not significantly correlated.

As an omnibus test, a multivariate multiple regression analysis was conducted. All six BIM maturity elements were entered as independent variables and all three KPI as dependent variables. The results of this analysis (Table 3) showed a statistically significant effect of

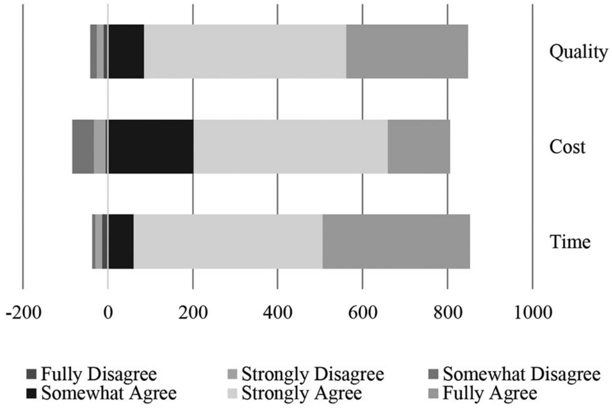

Figure 5. Responses on project performance statements. Negative numbers represent negative attitudes: fully disagree, strongly disagree and somewhat disagree.

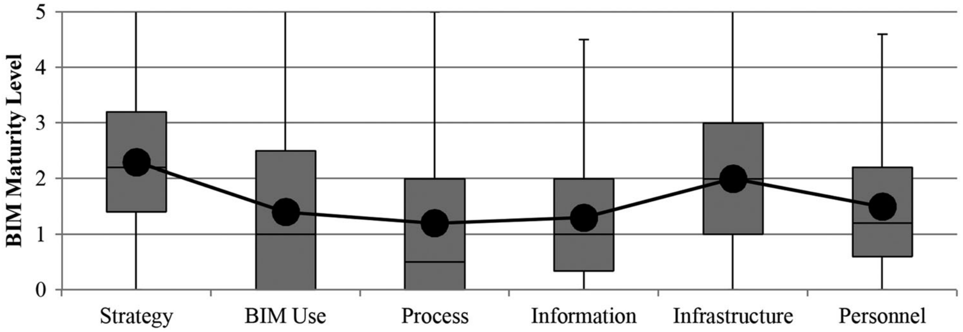

Figure 6. Responses pertaining to BIM maturity.

strategy (Wilk's Lambda = 0.986, $F(3,881) = 4.08$, $p < .01$). Furthermore, results indicated that effects of BIM use (Wilk's Lambda = 1.000, $F(3,881) = 0.13$, n.s.), process (Wilk's Lambda = 0.997, $F(3,881) = 0.95$, n.s.), information (Wilk's Lambda = 0.997, $F(3,881) = 0.76$, n.s.), infrastructure (Wilk's Lambda = 0.993, $F(3,881) = 2.16$, n.s.) and personnel (Wilk's Lambda = 0.999, $F(3,881) = 0.43$, n.s.) were not statistically significant.

Multiple regression analysis was used to test if BIM elements significantly predicted participants' ratings of performance. Results of the regression (Table 4) indicated that the six predictors explained 2.3% of the variance in perceived time performance ($R^2 = .02$, $F(6,883) = 3.396$, 95% CI = 0.00–0.04, $p < .01$). Furthermore, when time performance was predicted it was found that only strategy (Beta = 0.13, 95% CI = 0.11–0.17, $p < .05$) was a significant predictor. BIM use (Beta = 0.01, 95% CI = –0.07–0.08, n.s.), process (Beta = –0.03, 95% CI = –0.08–0.05, n.s.), information (Beta = –0.02, 95% CI = –0.10–0.06, n.s.), infrastructure (Beta = 0.05, 95% CI = –0.04–0.10, n.s.), and personnel (Beta = 0.02, 95% CI = –0.04–0.10, n.s.) did not add statistically significantly to the prediction of time performance.

Likewise, results of the regression (Table 5) indicated that predictors explained 3.1% of the variance in perceived cost performance ($R^2 = .03$, $F(6,883) = 4.744$, 95% CI = 0.01–0.05, $p < .01$). When cost performance was predicted it was found that only strategy (Beta = 0.19, 95% CI = 0.06–0.02, $p < .01$) was a significant predictor, $p < .01$. BIM use (Beta = 0.04, 95% CI = –0.07–0.08, n.s.), process (Beta = –0.08, 95% CI = –0.11–0.01, n.s.), information (Beta = 0.05, 95% CI = –0.04–0.12, n.s.), infrastructure (Beta = –0.09, 95% CI = –0.13–0.01, n.s.), and personnel (Beta = 0.05, 95% CI = –0.05–0.14, n.s.) did not add statistically significantly to the prediction of cost performance.

Moreover, results of the regression (Table 6) indicated that predictors could not statistically significantly explain variance in perceived quality performance ($R^2 = .01$, $F(6,883) = 1.903$, 95% CI = –0.00–0.03, n.s.). When the quality performance was predicted it was found that only strategy (Beta = 0.14, 95% CI = 0.02–0.19, $p < .01$) was a significant predictor ($p < .01$). BIM use (Beta = –0.02, 95% CI = –0.09–0.06, n.s.), process (Beta = –0.07, 95% CI = –0.10–0.02, n.s.), information (Beta = 0.03, 95% CI = –0.06–0.10, n.s.), infrastructure (Beta = –0.01, 95% CI = –0.07–0.07, n.s.), and personnel (Beta = 0.04,

Table 2. Correlations among and descriptive statistics for BIM maturity elements and key performance indicators (KPIs) ($n = 890$).

	Mean (SD)	Strategy	BIM use	Process	Information	Infrastructure	Personnel	Time	Cost	Quality
Strategy	2.3 (1.24)		.68**	.69**	.64**	.60**	.75**	.14**	.16**	.10**
BIM use	1.4 (1.29)			.68**	.64**	.62**	.65**	.11**	.09**	.05
Process	1.2 (1.57)				.64**	.60**	.68**	.10**	.07*	.04
Information	1.3 (1.20)					.32**	.65**	.09**	.10**	.06
Infrastructure	2.0 (1.31)						.69**	.11**	.05	.05
Personnel	1.5 (1.13)							.12**	.12**	.07*
Time	4.1 (0.9)								.12**	.07*
Cost	3.7 (1.0)									.51**
Quality	4.2 (0.9)									

Note: *$p < .05$;
**$p < .01$.

Table 3. Results of multivariate multiple regression analysis (n = 890).

	Wilk's lambda	F (3/881)	p
Strategy	0.966	4.08	0.01
BIM use	1.000	0.13	0.95
Process	0.997	0.95	0.41
Information	0.997	0.76	0.52
Infrastructure	0.993	2.16	0.09
Personnel	0.999	0.43	0.73
Time	0.966	4.08	0.01
Cost	1.000	0.13	0.95
Quality	0.997	0.95	0.41

Table 4. Results of multiple linear regression analysis for variables predicting time performance (n = 890).

Strategy	B	(SE B)	$β$	95% CI
BIM use	.092	.041	.125*	0.111–0.173
Process	.008	.037	.011	–0.065–0.080
Information	–.015	.031	–.025	–0.076–0.046
Infrastructure	–.019	.039	–.024	–0.095–0.058
Personnel	.031	.035	.045	–0.037–0.099
	.019	.047	.024	–0.074–0.113
R^2				
F (6,883)		.023**		0.004–0.042

Note: *$p < .05$; **$p < .01$.

Table 5. Results of multiple linear regression analysis for variables predicting cost performance (n = 890).

	B	(SE B)	$β$	95% CI
Strategy	.144	.075	.186**	.058–0.229
BIM use	.008	.043	.011	–.067–0.083
Process	–.050	.038	–.082	–.114–0.014
Information	.041	.033	.052	–.038–0.121
Infrastructure	–.063	.041	–.086	–.134–0.008
Personnel	.044	.036	.051	–.053–0.141
R^2		.031**		0.009–0.053
F (6,883)		4.744		

Note: *$p < .05$; **$p < .01$.

Table 6. Results of multiple linear regression analysis for variables predicting quality performance (n = 890).

	B	(SE B)	$β$	95% CI
Strategy	.074	.074	.142**	.023–0.190
BIM use	.043	.043	–.016	–.085–0.063
Process	.038	.038	–.067	–.103–0.023
Information	.032	.032	.029	–.055–0.101
Infrastructure	.040	.040	.005	–.066–0.073
Personnel	.035	.035	–.006	–.101–0.090
R^2		.013		–0.002–0.028
F (6,883)		1.903		

Note: *$p < .05$; **$p < .01$.

95% CI = –0.10–0.09, n.s.) did not add statistically significantly to the prediction of quality performance.

Discussion

The results suggest that the impact of BIM maturity on project performance may be limited. Surprisingly, few statistically reliable associations were found between maturity of BIM elements and KPIs, with strategy maturity as a reliable predictor of time and cost performance being the notable exception. But even here, the associated effect sizes (including overall R^2) were small. If taken at face value the results of the survey therefore show very little effect of a mature BIM implementation on project performance in terms of time and cost. The results are inconclusive about effects on project quality. The results of the survey point towards little effect of BIM implementations, even if the implementation is mature. Further, investments in BIM use, BIM processes, BIM information, BIM infrastructure, and BIM savvy personnel should show no yield on project performance. Investments in improving BIM strategy maturity however should show a small yield in time and cost performance. However, considering that this yield is only predicted to be 2.3% and 3.1% respectively, large investments in BIM strategy are not justified.

Moreover, the only factor that was reliably associated with performance enhancement is, arguably, a relatively vague concept. BIM strategy has been often defined in the literature as the combination of the other five BIM maturity aspects used in this survey. Considering now that these other five aspects did not correlate positive with project performance, the results of this survey further challenge the widely accepted high potential of BIM to improve project performance. All in all, the results of this survey challenge many of the commonly accepted assumptions of practitioners and researchers and point towards the necessity of a more nuanced position towards the sense and senselessness of BIM implementations.

The absence of a stronger yield-to-BIM maturity is even more surprising because one can safely assume that the respondents of the survey (with a significant response rate) are largely BIM managers or persons otherwise familiar with BIM. After all, the researchers sampled the Dutch industry perception using the database of the leading Dutch BIM software provider. Moreover, the majority of respondents were closely involved with their organization's BIM implementations by proposing improvements and assuming responsibility. Additionally, the familiarity of respondents with BIM as expressed in the answers to the demographic survey questions was high. Therefore, the data are most likely based on the *perception of BIM managers*, which – more than most others – are likely to speak of BIM in favourable terms and to stress the importance of the topic or attribute their own capacities. The potential presence of self-serving bias should therefore cause the data to be biased towards a positive attitude towards BIM.

The small effect sizes that our research yielded should be interpreted with care. Given the multiplicity of factors influencing project performance, large effect sizes cannot be expected in a model that includes only BIM element maturities as predictors. At the outset, the aim of the study was not to develop a good predictor model, but only to assess the reliability of associations between BIM maturity and project performance. The important point though is not about small effect sizes, but about the absence of reliable associations. Future studies should aim at reproducing the presented findings, perhaps using fewer factors and simplified survey instruments.

The results could also have been influenced by an inherent weaknesses of the used survey instrument to measure BIM maturity. For one, the measured BIM maturity was relatively high. This might be attributable to the high sophistication of the Dutch industry. It might, however, also point at direct problems of the instrument to measure BIM maturity adequately. Considering the fast pace of BIM technology development, the instrument might not represent the current state-of-the-art sufficiently any longer to allow for a balanced measure of BIM maturity. Future research should therefore try to reproduce the findings in this study with other BIM maturity measurement instruments.

Another possible shortcoming of the study is its sole focus on the Dutch construction industry. Because the Netherlands is one of the countries with the highest BIM adoption rate worldwide (Carneiro, Deborah, & Neto, 2012), the Netherlands is a good proxy for the entire worldwide AECO industry, once a high BIM adoption rate is achieved worldwide. However, while the Netherlands has adopted BIM quickly in the last decade and can be considered as one of the leading countries in BIM use, cultural aspects could have influenced the results of this study. The Dutch, for example, score relatively low on Hofstede's (1980) measure for 'masculinity' – a trait characterized by a high level of assurance – which could have cautioned survey respondents to characterize the performance of their company as overly positive. It would be interesting to see the results of comparative studies that conducted in countries with higher cultural levels of 'assurance', such as the US.

The conclusions need to be tempered with some qualification. A survey study has limitations due to what its approach entails. In particular, a survey method is only able to measure perceptions of project performance. Future studies should aim at directly measuring project performance using actual project data. Additionally, researchers should start conducting historical case study of failed BIM implementations to further support the results of the study presented here.

In addition, there is a potential problem of compression of results in our KPI measures. The responses were all quite positive, with only few participants voicing concerns about performance. It would be valuable to explore different measures that allow more variation in responses. More generally, the authors recommend further research to analyze the relation between BIM maturity and project performance with metrics other than the ones used in this study. Preferably, future research should strive for approaches that combine the representativeness of survey research with the inferential superiority of experimental research, such as natural experiments or instrumental variable approach (Varian, 2015).

Notwithstanding the potential weaknesses of the present study, it constitutes, to the best of the authors' knowledge, the most elaborate effort so far to directly measure the link between BIM maturity and performance perceptions. Additionally, the researchers took ample care during the design of the study following widely accepted survey study conventions and using a widely accepted instrument to measure BIM maturity. The survey also shows a significant response rate from a large sample. Therefore, the authors believe that the results of the study should be taken seriously into account both by researchers and practitioners, if only, to thoroughly reflect about the sense and senselessness of BIM implementations.

Conclusions

This paper has presented unique input to ongoing discussions on why and how organizations should implement BIM by presenting the results of a large-scale survey conducted in the Netherlands. Consistent with existing literature, the results of the study indicate the importance of strategy maturity. However, the effect size of strategy on cost and time performance was surprisingly low. Overall, also considering this study's scarcity of statistically reliable effects, the results are less consistent with the general notion that BIM maturity is substantively related to project performance and thus caution against overoptimistic appraisals of BIM. In light of the productivity paradox (Brynjolfsson, 1993), the more general lesson following from this research seems to be that one should not mindlessly implement information technology, whether it is related to the construction industry or not.

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No potential conflict of interest was reported by the authors.

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