PERCEPTIONS OF ORGANIZATIONAL BIM MATURITY VARIABLES WITHIN THE US AECO INDUSTRY

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ABSTRACT

In order to achieve a life-cycle use of building information models, it is critical that the Architecture, Engineering, Construction, and Operations (AECO) industry determine if it is moving closer to achieving a mature building information modeling (BIM) standard. With the wealth of BIM implementation/process assessment models that have recently been published, the question remains whether it is better to assess the maturity of BIM execution at the individual project level or rather to evaluate the maturity of BIM processes within individual organizations? Based on a survey of a diverse sample population of the AEC industry, this research examined the perceptions of the quality and level of development of current BIM execution trends within organizations. As BIM Capability may be one of the key performance indicators of organizational BIM Maturity, the study aimed to determine what factors contribute to the BIM Capability of organizations executing BIM (Succar 2009a). Statistical analysis revealed there was no significant relationship found between the organization type, roles of respondents or the proportion of projects which utilized BIM and the perceived BIM capability. However, there were small and medium positive correlations between organizations' annual revenue, the presence of organizational benchmarks as to whether BIM maturity was being evaluated and the indicated BIM Capability level of the respondents' organization. Further analysis also revealed a strong correlation between the personal BIM experience level of individual respondents and their resulting perception of BIM Capability within their firms.

Keywords: BIM, Construction, Maturity, Quality, Metrics

1. INTRODUCTION

As BIM adoption increases and the development of BIM processes and technology continues to evolve, the level and quality of its implementation varies radically across organizations within the AECO industry. The use of BIM has become yet another means for design and construction companies to position themselves above their competitors. As a result, BIM is often inconsistently executed due to the absence of structured guidelines or benchmarks. Without these organizations have no means to mature and improve their processes (Succar 2009a). In order to ensure that the industry is moving toward a mature BIM standard, it is critical that we first determine what factors that contribute to producing mature life-cycle oriented BIM-assisted projects. Thus-far, BIM maturity has been evaluated in one of two ways: at the individual project level or at the organizational level. The focus of this study is to determine and analyze the variables which contribute to organizational BIM maturity.

2. RESEARCH QUESTIONS

Succar (2009a) has proposed that there is a great difference between *capability* and *maturity* within organizations implementing BIM. He defines *BIM capability* as "the ability to perform a task or deliver a

BIM service/product" whereas, *BIM maturity* might refer to "the quality, repeatability, and degree of excellence with which BIM services are executed (p 20)". He also maintains that most organizations fall into one of three stages along their journey to implementing BIM.. *Capability Stage One* involves single disciplinary internal use of object-oriented modeling within a single project life cycle phase. *Capability Stage Two* entails model-based collaboration which occurs across disciplines. Finally, *Capability Stage Three* encompasses network based integration across disciplines and life cycle phases concurrently (Succar 2009b).

It is therefore suggested that the BIM Capability level of an organization may be a *strong* indicator of organizational BIM maturity, because it shows the degree to which an organization may be using BIM tools and processes and whether the model is truly being exchanged across the building life cycle. This study seeks to analyze which factors contribute to the BIM Capability level of organizations based on an industry wide survey. The research questions the respondents addressed included:

1. Is there a relationship between the type of organization implementing BIM and perceived BIM capability?
2. Is there a relationship between the respondents' roles within their organization and perceived BIM capability?
3. Is there a statistical difference in the perception of BIM capability between industry and academic respondents ?
4. Is there a relationship between an organizations' annual revenue and perceived BIM capability?
5. Is there a relationship between the presence of organizational benchmarks to evaluate BIM execution and the indicated BIM capability level being implemented within an organization?
6. Is there a relationship between whether BIM maturity is evaluated and the BIM capability indicated ?
7. Is there a relationship between the personal BIM experience level of respondents and their perception of their organization's BIM Capability?
8. Is there a relationship between the proportion of BIM-assisted projects that an organization has participated in and their perception of their BIM capability level?

3. BACKGROUND

3.1 BIM Maturity Developments

Though BIM may be considered a process specific to the fragmented AECO industry, it is highly supported by information systems and technology (Heron et al. 2010). Therefore, in quantifying the level of BIM readiness or maturity, many have looked at how other information systems (IS) investments are evaluated. Salah and Alshawi (2005) noted that IT performance measurement is highly dependent upon whether an IT investment is viewed as a product, a process or an organizational decision. This is a similar hurdle that must be determined when evaluating BIM maturity as well. There have been several attempts by industry leaders and academics to quantify the maturity of BIM implementation in recent years. The various maturity models and scoring systems tend to fall into two basic categories: those which rate the maturity of individual building projects based on use of different innovative means and those which rate or score the maturity of organizations who are implementing BIM processes.

3.1.1 National BIM standard's interactive capability maturity model (ICMM)

Perhaps most notably, in 2007 the National Institute of Building Sciences and the buildingSMARTalliance (bSa) published the first ever National BIM standard (NBIMs) which defined the quality and quantity of information required to be considered a "minimum BIM". More importantly, it introduced the first ever Interactive Capability Maturity Model (ICMM) to help BIM users evaluate their business practices and measure the degree in which their BIM-assisted projects implemented a mature BIM standard (NIST 2007). The ICMM was intended as a tool for internal use by project team members to measure BIM information management and to provide a means for companies to address the

continuous improvement of BIM processes. However, it was not designed for comparing BIM projects across organizations (Suermann et al. 2008).

The NBIMs' ICMM evaluates BIM-assisted projects based on eleven variables called "areas of interest" including: data richness, life-cycle views, change management, how roles or discipline are addressed, a change in business processes, the timeliness of response, change in delivery methods, graphical information, spatial capability, information accuracy and interoperability support. Each of these variables is rated against 10 levels of increasing maturity. The results are then weighted based on importance and a final maturity score can be awarded to a building project (NIST 2007). In 2007, the minimum BIM score was set at 20.1 with the intent to raise it incrementally with each new version of NBIMs.

Soon after the NBIMs was released, a testing team was established to conduct a study to assess the validity of the ICMM on a sample of BIM-assisted projects. Nine projects were evaluated from the Technology in Architectural Practice (TAP) BIM award winners of 2007. Using the ICMM, each project was scored by an external evaluator and then a secondary "blind" evaluator. The study showed no BIM score was more than 5% different and usually was only 1 or 2% different (Suermann et al. 2008).

Using a sample of 22 ICMM maturity scores awarded to the TAP winners in 2008, McCuen et al. (2012) later evaluated the capability maturity of BIMs within the industry as a whole in order to determine if the CMM could also be useful in determining the state of BIM execution among the AEC industry at large. Their analysis of the average scores among each of the 11 areas of interest revealed great variability among the different projects. The greatest differences in average scores were in the categories of business process and information accuracy. Similar to other surveys conducted in that same time period, it was found that the greatest maturity was in the area of graphical information development. Thus, the industry is well on its way to reaching maturity in the planning and design phase, but has much to be gained in the later phases of the building life cycle where integration and automation is still a new concept. It was also evident that the O&M stage of the building life cycle was the furthest behind in using the technology (McCuen et al. 2012; Suermann and Issa 2009).

3.1.2 BIM Maturity Index (BIMMI)

More recently, Succar (2009a) developed a BIM Maturity Index to address some of the limitations of NBIMs' ICMM which could be used to assess the maturity of potential project stakeholders. Succar's approach evaluated teams and organizations based on process, technology and policy rather than evaluating information management on a BIM-assisted project. His model is scalable for different organization types and utilizes five maturity levels based on 12 Key Maturity Areas (KMAs). Unlike the ICMM, which was created for internal self-assessment, his model offered four different types of evaluation, many of which utilize the rating of an external auditing agency. The BIM Maturity Index provides a scoring system and detailed set of suggested steps for achieving different benchmarks to help organizations assess and improve BIM process maturity (Succar 2009a).

3.1.3 Industry Trends

Additionally in 2009, Stanford's Center for Integrated Facility Engineering (CIFE) developed their VDC scorecard program which evaluates the maturity of VDC practices on individual construction projects. Using the results of four input survey forms related to the areas of planning, adoption, technology and performance, the scorecard measures the degree of innovation being achieved on building projects. Its intended objective is to benchmark new projects against past and present to compare BIM performance against industry standards and make recommendations to organizations for how to improve their BIM performance (CIFE 2011). The program was developed in 2009 and later revised in 2011. Each of the four innovation Areas are subdivided into 10 dimensions and then further calculated based on individual innovation measures. Unlike the ICMM and BIMMI models, the VDC Scorecard uses a percentile system instead of a maturity rating which is based on the level of innovation that is being achieved in each category. The different ranges include: Conventional Practice representing a score between 0-25%, Typical Practice representing a score between 25-50%, Advanced Practice representing a score between 50-75%,

Best Practice representing a score between 75-90%, and Innovative Practice representing a score above 90%. The program uses a weighting system to distribute points across the different Areas and Dimensions and is offered in an express, lite, and full version to accommodate varying levels of interest and time commitment (CIFE 2011).

Many software companies and consultants within the industry are also now beginning to offer services which evaluate an individual company's BIM maturity scores to help them compare themselves to their competitors. For example, VICO, Inc. developed their own version of a BIM scorecard for companies to assess their level of BIM integration. The scoring system is targeted toward construction managers and specifically evaluates BIM integration in areas of clash detection, scheduling and estimating. Each of those areas is graded on functionality and capability, best practices and enterprise integration (VICO Inc. 2011).

3.1.4 Building Owner Perspectives on BIM Maturity

Indiana University (IU) is one of few owner organizations to have developed a standard means for evaluating the BIM competency of potential designers and contractors on new projects in order to address the "BIM Wash" trend which plagues the AEC industry(Succar 2009b). With the help of a consultant, they developed a BIM proficiency matrix as part of the selection process for potential stakeholders. The matrix is used to score applicants based on eight general categories including: physical accuracy of the model, the presence of an Integrated Project Delivery (IPD) methodology, model calculation mentality, location awareness, content creation, construction data, as-built modeling and FM data richness. In the form of an excel spreadsheet, potential stakeholders must provide a description and concrete example of past projects in which they have participated that address each category. Based on their answers, IU scores each sub-category as part of the selection process for stakeholders (Indiana University 2009).

4. METHODOLOGY

Using a list-serve of members of the AECO industry, a survey was delivered primarily in an online monthly newsletter of Stevens Construction Institute, Inc. through a link to Zoomerang. It was also delivered to a number of construction blogs and other online networking websites such as Linkedin. The survey was live from December 2011- April 2012, consisting of 21 questions in a multiple formats. Of a total of 962 visits, the survey received 23 partials and 120 completed responses, representing a response rate of approximately 12%. This study focuses specifically on the contributing variables associated with organizational BIM maturity. First, descriptive statistics were derived from the raw data to gauge the status of organizational BIM implementation. Then Chi Square, Spearman's Rho and Pearson's Correlation techniques were used to analyze the relationship between a number of independent variables and the perceived BIM Capability level indicated by the respondents. Different analysis techniques were used for different types of variables depending on whether they were nominal, ordinal, or continuous in nature. For the strength of the correlation relationship, the interpretation followed was from the guidelines of Cohen (1988) with small r = 0.10-0.29;, medium r = 0.30-0.49; and strong r = 0.50-1.0.

5. RESULTS

5.1 Demographics

As shown in Fig 1, survey respondents came from a variety of different disciplines within the AECO industry However, the greatest proportion (40%) of the survey population of 118 indicated that they were employed by a construction manager/general contractor while 16% were in the consultant category and included several VDC/BIM specialists.

Within these organizations, respondents were also asked to describe their role within their company. The largest number of respondents (40%) categorized themselves as project managers/project engineers or indicated being in an upper management position in their respective organization (35%). The survey

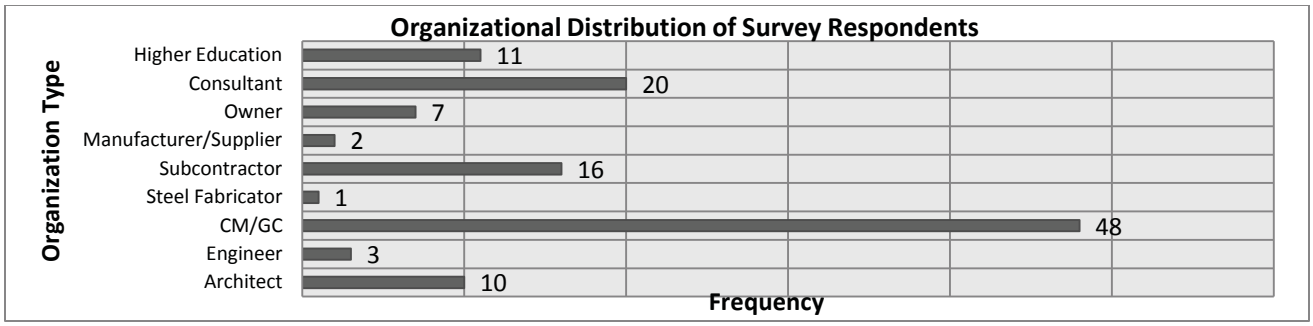

Figure 1: Organizational Distribution of Survey Responses

population was also asked which geographic region they most commonly worked in. The frequency of responses was almost equal across the different regions, as shown in Fig 2. However, the greatest proportion indicated that they had worked in the East North Central (Midwest). Additionally, the greatest number of the respondents (31%) indicated primarily working in the commercial market with the public (12%) and residential markets (10%) in close second.

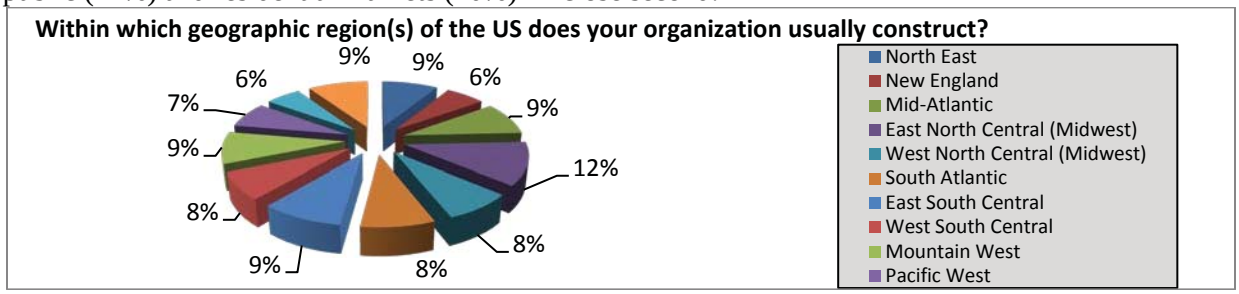

Figure 2: Distribution of Geographic Location Among Survey Responses

Survey respondents were also asked to indicate their organization's annual revenue. Of the 85 total respondents who answered that question, the greatest proportion (27%) indicated their organization had an annual revenue under $10 million. When asked about their personal BIM experience level, the greatest proportion of respondents indicated being beginner (31%) or intermediate users (24%) of BIM tools. Fig 3 shows the distribution of BIM experience level among the respondents.

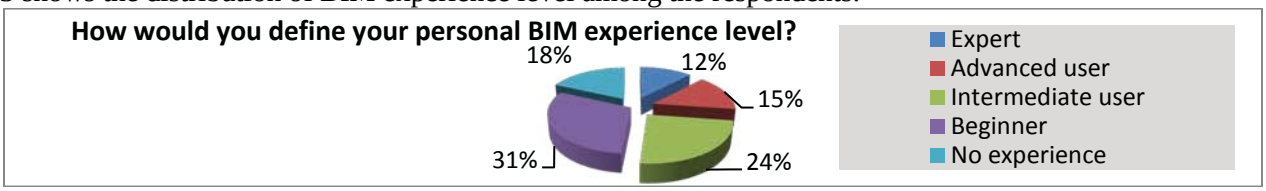

Figure 3: Respondent BIM Experience Level

Finally, in order to gauge the BIM experience level of the respondents' organizations as a whole, survey respondents were asked to indicate the total number of projects in which their organization had participated in the preceding year in one question and the number of projects of that total which implemented BIM in the following question. As shown in Fig 4, 51% percent of the total survey population indicated utilizing BIM on less than 10% of their projects and of that total 29% had not implemented BIM at all. The next largest proportion of respondents, representing 17% of the sample population, indicated using BIM on more than 90% of their projects. The overarching trend was that BIM was either fully integrated into organizations or not implemented at all as of the survey response date.

5.2 Organizational BIM Maturity Analysis

In order to gauge where most organizations perceived their BIM maturity, survey respondents were initially asked which Capability Stage, as proposed by Succar (2009a), they felt most reflected their organization's use of

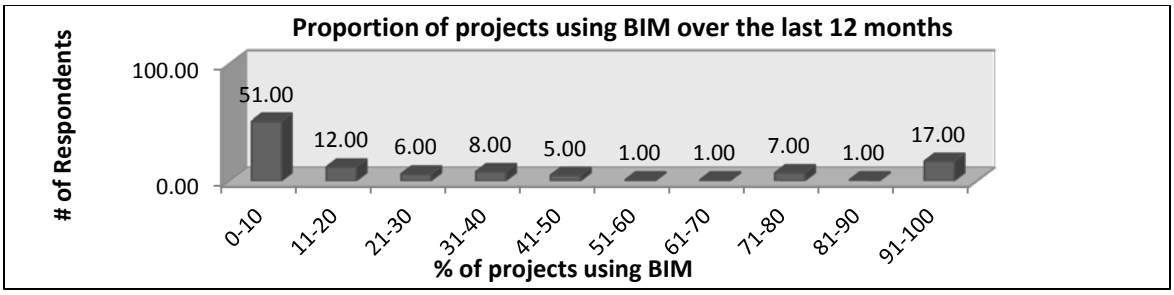

Figure 4: BIM Adoption by Survey Respondents

BIM. Fig 5 describes how the question was phrased in the initial survey design and indicates the proportion of respondents who fell into each BIM Capability category. Thirty-two percent of respondents indicated that they

were at *Capability Stage Zero* because they were not implementing BIM. Another 26% of those surveyed categorized themselves in either *Capability Stage One* or *Capability Stage Three*. However, after the design of the survey and further discussions with several industry experts, it was determined that there was not a clear understanding regarding the difference between BIM Capability Stage 2 and 3 among AEC professionals especially due to the similarity in how they had been phrased in the survey question.

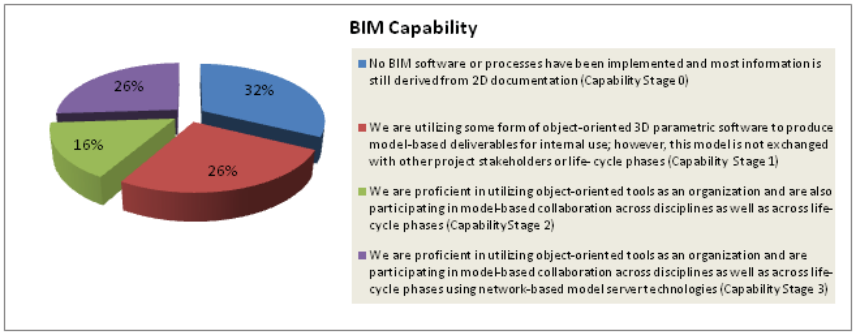

Figure 5: BIM Capability As Indicated By Survey Respondents

Additionally, when testing the relationship between the respondents' Organization Type and their perceived BIM Capability level, the original data violated the 5% rule of Chi Square analysis meaning that there were not enough respondents in each category who indicated being in Capability Stages Two or Three independently. For these reasons the two categories were combined and recoded into one category labeled as Capability Level 2. The researchers acknowledge that this is definitely a limitation of the study, but reasoned that distinguishing between internal use of BIM and multi-disciplinary exchange of BIMs were significant enough indicators of a company's BIM capability to draw conclusions from it. It should also be noted that for the bulk of analysis, BIM Capability was treated as an ordinal variable because the degree of BIM competency increases marginally within each stage.

During analysis, the initial Organization Types indicated by respondents in the survey were recoded into four major categories including: Designers, Contractors, Subcontractors and Consultants. Cross-tabulation between the respondents' Organization Type and their recoded perceived BIM Capability level was conducted. As shown in Table 1, 97 out of 120 cases (80.8%) had valid responses to both BIM Capability Level and Organization Type. Table 2 shows the results of the cross-tabulation analysis between those variables and the percentage of each Organization Type in their respective perceived BIM Capability levels.

As shown in Table 3, the Chi-square test for independence indicated that there was no significant association between respondent Organization Type and their perceived BIM Capability Level indicated at the 0.05 significance level ($p=0.911>0.05$). The researchers interpret this to mean that, within the sample population surveyed, the type of organization that respondents were employed by did not have a significant relationship with their perceptions of their organizational BIM Capability.

Table 1: Summary of Valid Cases Between Organization Type and Perceived BIM Capability

	Valid Cases		Missing Cases		Total Cases	
	N	Percent	N	Percent	N	Percent
Organization Type * BIM Capability	97	80.8%	23	19.2%	120	100.0%

Table 2: Organization Type and Perceived BIM Capability Cross-tabulation Analysis

			Perceived BIM Capability Level			Total
			0	1	2	
Organization Designer		Count	4	4	7	15
Type		% within Organization Type	26.7%	26.7%	46.7%	100.0%
		% within BIM Capability	12.1%	18.2%	16.7%	15.5%
		% of Total	4.1%	4.1%	7.2%	15.5%
	Contractor	Count	18	9	20	47
		% within Organization Type	38.3%	19.1%	42.6%	100.0%
		% within BIM Capability	54.5%	40.9%	47.6%	48.5%
		% of Total	18.6%	9.3%	20.6%	48.5%
	Subcontractor	Count	5	3	8	16
		% within Organization Type	31.3%	18.8%	50.0%	100.0%
		% within BIM Capability	15.2%	13.6%	19.0%	16.5%
		% of Total	5.2%	3.1%	8.2%	16.5%
	Consultant	Count	6	6	7	19
		% within Organization Type	31.6%	31.6%	36.8%	100.0%
		% within BIM Capability	18.2%	27.3%	16.7%	19.6%
		% of Total	6.2%	6.2%	7.2%	19.6%
Total		Count	33	22	42	97
		% within Organization Type	34.0%	22.7%	43.3%	100.0%
		% within BIM Capability	100.0%	100.0%	100.0%	100.0%
		% of Total	34.0%	22.7%	43.3%	100.0%

*BIM Capability Level 0 indicates no use of BIM, BIM Capability Level 1 indicates internal use of object-oriented modeling, and BIM Capability Level 2 indicates the exchange of BIMs across disciplines and life cycle phases.

Table 3: Chi-Square Test for Independence Between Organization Type and Perceived BIM Capability

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	2.091[a]	6	.911
N of Valid Cases	97		

* 3 cells (25.0%) have expected count less than 5. The minimum expected count is 3.40.

Additional analysis was conducted to determine the relationship between the annual revenue and the BIM Capability of the respondents' organizations. As Revenue and BIM Capability were both ordinal variables, the Spearman Rho correlation was used to analyze their relationship. The results indicated that there was a small, positive correlation between Revenue and perceived BIM Capability Level, having statistical significance at 0.05 significance level ($p=0.044<0.05$, $rho=.223$, $n=82$), as shown in Table 4. This is not surprising, as organizations with higher revenue may have more available funds to invest in

training and manpower related to BIM implementation which may result in more advanced use of BIM tools and higher BIM Capability.

Another key concept in measuring BIM maturity at the organizational level is the importance of organizations tracking or quantifying the success of their implementation strategies. Without a set of defined benchmarks and accurate records, companies cannot adequately move toward continuous improvement of BIM processes and may not achieve a mature BIM standard. When asked if benchmarks or metrics were established within their organizations to track the success of BIM execution, 65.2% of the respondents indicated that no such metrics had yet been established. Some of the methods used to benchmark organizational BIM processes which were referenced included: tracking software utilization and the scope of BIM components and requirements, tracking time associated with "BIM" processes", measuring modeling productivity by discipline, tracking ROI, and the use of the BIMMI in one instance. As BIM Benchmarking is a dichotomous variable, Pearson's r Correlation was used to analyze its relationship with respondents' perceived BIM Capability Level (Pallant 2011). As shown in Table 5, the analysis revealed there was a medium, positive correlation between the presence of BIM Benchmarks and the indicated BIM Capability with a statistical significance at the 0.01 significance level ($p=0.003<0.01$, $r=.345$, $n=74$). The researchers interpreted this to mean that organizations with BIM Benchmarking procedures may have higher perceived BIM Capability.

Table 4: Correlations Between Annual Revenue and Perceived BIM Capability of Respondents' Organization

			Revenue	Perceived BIM Capability
Spearman's Rho	Revenue	Correlation Coefficient	1.000	.223*
		Sig. (2-tailed)	.	.044
		N	85	82
	BIM Capability	Correlation Coefficient	.223*	1.000
		Sig. (2-tailed)	.044	.
		N	82	113

Table 5: Correlations Between Presence of Benchmarks and Perceived BIM Capability

		BIM Benchmarks	Perceived BIM Capability
BIM Benchmarks	Pearson Correlation	1	.345**
	Sig. (2-tailed)		.003
	N	79	74
Perceived BIM Capability	Pearson Correlation	.345**	1
	Sig. (2-tailed)	.003	
	N	74	113

**. Correlation is significant at the 0.01 level (2-tailed).

Similarly, approximately 10% of respondents indicated that they specifically measured BIM maturity on their projects. Therefore, Pearson's r Correlation was also used to analyze the relationship between BIM Capability and BIM maturity measurement because of its dichotomous nature (Pallant 2011). As shown in Table 6, there was a medium, positive correlation shown between BIM Maturity Measurement and perceived BIM Capability with statistical significance at the 0.01 significance level ($p=0.009<0.01$, $r=.350$, $n=54$). The researchers interpret this to mean that organizations with BIM Maturity Measurement strategies in place have a resulting higher BIM Capability.

Finally, the relationship between the *personal* BIM experience level of survey respondents (as reflected earlier in Fig. 3.) and their perception of their organizations' BIM Capability was analyzed. Both BIM Experience and BIM Capability are ordinal variables. Thus, Spearman Rho Correlation was used to analyze their relationship. As shown in Table 7, a strong, positive correlation was found between respondents' indicated BIM Experience level and their perception of BIM Capability within their

organization with statistical significance at the 0.01 significance level (p=0<0.01, rho=.571, n =113). The researchers interpret this to mean that organizations that have staff with perceived higher BIM experience may also have perceived higher organizational BIM Capability.

In addition to the preceding relationships, the authors tested several other associations between the remaining demographic variables and the respondents' perceived organizational BIM Capability.

Table 6: Correlations Between BIM Maturity Measurement and Perceived BIM Capability

		BIM Maturity Measured	Perceived BIM Capability
BIM Maturity Measured	Pearson Correlation	1	.350**
	Sig. (2-tailed)		.009
	N	56	54
Perceived BIM Capability	Pearson Correlation	.350**	1
	Sig. (2-tailed)	.009	
	N	54	113

**Correlation is significant at the 0.01 level (2-tailed).

Table 7: Correlation Between Personal BIM Experience Level of Respondent and Perceived BIM Capability

			BIM Experience Level	Perceived BIM Capability
Spearman's rho	BIM Experience Level	Correlation Coefficient	1.000	.571**
		Sig. (2-tailed)	.	.000
		N	120	113
	Perceived BIM Capability	Correlation Coefficient	.571**	1.000
		Sig. (2-tailed)	.000	.
		N	113	113

** Correlation is significant at the 0.01 level (2-tailed)

However, none of them showed any significant statistical relationships based on the survey population. First, there was no significant association found between the respondents' roles within their organization and their perception of BIM Capability. There was also no significant difference found between how higher education and industry respondents perceived BIM Capability. Additionally, the relationship between respondents' Geographic Region and their perception of BIM capability also did not satisfy 5% rule for Chi Square analysis. Finally, using Spearman Rho Correlation, the association between the proportion of BIM-assisted projects executed by an organization and the perceived BIM Capability was tested. There was no significant correlation indicated at the 0.05 significance level (p=0.371> 0.05, rho=.088 < 0.10, n =106.

6. CONCLUSIONS AND LIMITATIONS

Statistical analysis of the survey sample suggested that there was no significant relationship between the Organization Type of respondents or their personal role within their company and their perception of BIM Capability. Additionally, there was no significant difference found between the perceptions of academic and industry respondents of BIM Capability. Thus, the perceptions of BIM Capability were not expressively different between stakeholder groups. These findings are limited to the number and type of respondents within the sample. As discussed earlier, the survey population was not evenly distributed among the different stakeholder groups. There was also no significant relationship found between the proportion of projects which used BIM and the perceived BIM capability of an organization.

There were small and medium positive correlations between an organizations' indicated annual revenue, the presence of organizational benchmarks, whether BIM maturity was currently being evaluated and

respondents' perception of organizational BIM Capability level. In addition, a strong positive correlation was uncovered between the personal BIM experience level of the survey respondents and their perception of the BIM Capability of their firms. These results suggest that there may be some organizational factors which contribute significantly to an organization's BIM Capability, which according to Succar (2009a) may be a strong indicator of BIM maturity. However, one would caution making any major conclusions about the relationships described in this paper. Given the dichotomous nature of some of the variables studied and the fact that the measurement of BIM Capability is based solely on the perceptions and subjective opinions of respondents, it would be difficult to determine if these associations were not affected greatly by the respondents' optimism and logical correlations.

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