Discussion of the Construction Industry's Evaluation Survey

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Observation and evaluation of an entity is the first step towards modifying and improving it. By this motivation, a research was conducted to study the implementation of BIM throughout the industry and what they expect from graduates of construction programs, who are actually future job applicants. Although the direct outputs of the survey were presented in another paper before, the authors considered this point that the direct outputs of a survey are not reliable, and need more analysis. This paper uses the results of the same survey in order to have a good analysis of the construction industry regarding BIM implementation by cross-checking the answers. Making a focus group from the more advanced companies of the survey pool is the next step the authors took to clarify the dark spots of the survey results.

Key Words: BIM, Pedagogy, Survey, Construction Industry

Introduction

Criticizers often raise the issue in the construction industry that it lags behind technology. However, BIM is one of the exceptions of this trend (Johnson and Gunderson, 2009). Today, many construction companies in the US implement different aspects of Building Information Modeling (BIM) and Virtual Design and Construction (VDC). Despite its initial costs, BIM absorbed attention of the large owners like General Service Administration (GSA, 2006).

Considering these points, implementation of BIM is not clearly defined nor is it on a straightforward path. In addition to research centers and R&D departments of the construction companies, academia could play an effective role in directing this industry toward an effective path for implementing BIM. Direct observations as well as surveys and interviews study the current trend of the industry and provide the inputs of its analysis. However, something that is usually ignored is the validity of the responses of the surveys. Since one of the main parties involved in a survey is a "human", the outputs are not 100% reflective of his ideas. Before considering survey results for inputs of any analysis, they have to be analyzed to validate themselves. It is essential that the inputs of the main study, which the survey is designed for, are reliable. In order to reach this goal, the survey must be designed so that a causality clue of each question can be traced back to another question. The results must be cross-checked in order to determine the validity of the responses.

This paper aims at analysis of the raw data of a BIM survey throughout the industry (Taiebat & Ku, 2010). Although the main purpose of this paper is to purify the outputs of that survey and observing which answer comes from which company xpert, a marginal conclusion can be derived from the differences between what Authors (2009) concluded and what this paper concluded from the same survey by analysis of the results and cross check of each answer with the other answers and observation of their effects on each other.

Background

Howard and Bjork (2008) collected data from a number of international experts, and asked a series of questions about the feasibility of BIM, the conditions necessary for their success, and the role of standards. Their study was rather a qualitative study to evaluate the state of building information models in the industry and the conditions necessary for them to become more widely used. Their results indicated that BIM appeared too complex for many of the surveyed companies, and may need to be applied in limited areas initially. Standards are generally supported but not applied rigorously, and a range of these are relevant to BIM. Benefits will depend upon the building

procurement methods used, and there should be special roles within the project team in order to manage information (Howard & Bjork, 2008).

Center for Integrated Facility Engineering (CIFE) conducted industry interviews and surveys in 2006 and 2007, evaluated the state of the industry regarding BIM & VDC, and observed its progress within a year. It observed that all respondents use VDC for visualization. Work sequence planning and field work coordination were the other aspects that most of the interviewees took. Clash detection was mentioned as the "easiest value", and was used or planned to be used in the future. Estimation and quantity take offs were newly started to propagate through the industry, while some of the aspects like concept validation programming and accurate cost comparison of design alternatives were implemented by only a few sophisticated designers.

The literature review studied two more researches whose final goals were designing BIM courses in construction programs in academia. Johnson and Gunderson (2009) studied how ASC members implemented some new trends of construction in the academic programs. They planned to survey 126 member schools with a 34% response rate. Their results identified a wide range of adoption of BIM in those programs. Taylor et al. (2008) studied discrete courses in which BIM was taught. However, none of them presented any analysis of the courses' material and how they were designed out.

Methodology

As part of a larger research, a survey was conducted throughout the construction industry in order to obtain the expectations of construction companies regarding graduates of construction programs. The survey contained 25 questions in four sections (Appendix A).

The authors made this survey in a web survey application, Qualtrics, to send it to their target companies by email. They conducted a pilot study by submitting it to the other professors of their department and got their feedback to modify and revise it. After the approval of Institutional Review Board (IRB) of the university, the survey link was sent to a listserv via email. This survey was sent to 180+ construction companies, which were in collaboration with the school. After analysis of the survey data, the authors understood that some of the answers were off based, and may divert the results of the study by adding proxy to them. Therefore, they decided to cross check the answers and analyze them to get better conclusion out of the same survey results.

Despite the typical surveys, which make conclusion based on the answer that was selected most by the survey takers, this paper analyzed the results of the survey by cross checking them with the surveyed companies and the survey takers' profile. Generally, those responses which were subjective were cross checked by the information collected about the survey takers' profile, section two of the survey, and their opinion on the other subjective questions. On the other hand, those responses which were not subjective, but rather addressed the approaches that the companies took, were cross checked by the demographic data of the companies, such as total revenue or geographical spread, which act as indicators of the company size.

For the focus group, the researchers decided to make it from the advanced firms in the survey pool. Another questionnaire (Appendix B) was developed which was composed of mere essay type questions not to make a framework for the interviewee. The focus group companies were all provided with the options of either answer the survey questions online or turn the survey to a phone interview.

The Survey

The authors presented the structure, questions, and raw data of the survey in a paper (Taiebat & Ku, 2010) before. The questionnaire is presented in the appendix of this paper as well. To avoid redundancy, it is preferred not to present the raw results here and refer the reader to that paper in which these materials were explained in detail.

After the 10 days deadline, 50 companies returned the survey in which eight of them just entered one or two of the demographical questions. As a result, the survey software deleted these responses from the beginning and did not

publish them as its outputs. Forty two companies were in the published list of the survey data base, which returned a response rate of 23%. The software considered a question as an "answered question" if all the options of the question was responded. Based on that, it showed complete and almost complete surveys as shown in Figure 1.

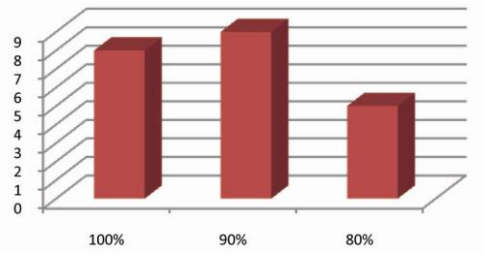


Figure 1: number of responses for almost complete surveys

Browsing through the responses, the authors figured out that a portion of the responders continued up to question 13, which was a tricky question, and did not go beyond that. Question 13 of the survey asked about the aspects of BIM that they use in their company, and whether they perform them in-house or out-source them. All 42 survey takers answered the survey up to this point, but some of them did not go to question 14. This question asked about the software and processes they took for implementing those aspects they picked in question 13. Since the answers up to this point were designed to evaluate the survey takers, not collecting data for the goal of the survey, those companies were discarded from the survey pool, and the acceptable results were reduced to 30.

Skimming through the results showed some facts on those who did not continue the survey. Between the 12 companies discarded from survey pool, most of them were companies with small annual revenue, i.e. less than $1M, and around half of them were subcontractors. One of them was a company which claimed to have projects in one state in the U.S. and the rest of its projects were out of the U.S. This company claimed on performing all of BIM aspects in-house (question 13). The last discarded answer was from a grading subcontractor with $50M revenue, which selected the "in-house" answer for all options of question 13. All these 12 companies were deleted from the survey pool, and 30 responses were accepted for analysis of the survey. This paper modifies the pure results of the survey based on these acceptable responses, and then tries to investigate and cross check them. Figure 2 shows the diversity of the survey pool regarding:

- Primary project types: Residential, Commercial, Office Buildings, Civil/Infrastructure, Industrial, & Retail
- Contractual roles: General Contractor, SubContractor, Consultant, Construction Manager, & Design Build
- Geographical spread of company: Northeast, South, Midwest, and West

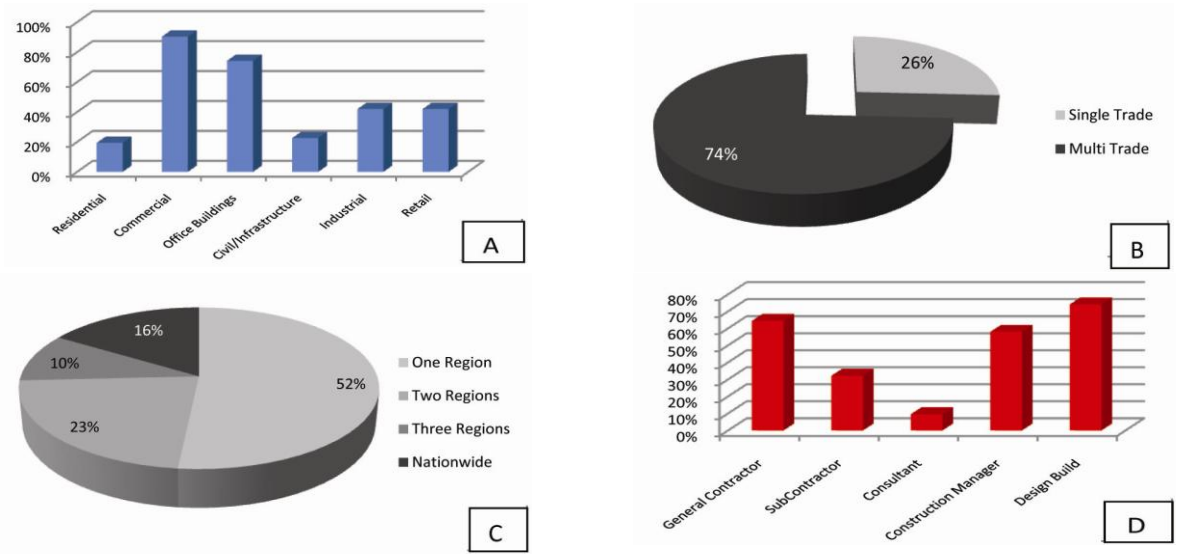


Figure 2: Demography of survey pool: project type A&B, contractual role C, and geographical spread D

Since they could select more than one option, the total of the percentages went beyond 100% (Figure 2A&B). Their answers to the question four revealed that the survey pool contains a diverse collection of companies, from less than a million up to nine billion dollars revenue per year. The number of the employees in the companies varied between 4 and 5000 persons with an average of 702 employees and standard deviation of 1246. Seven out of 30 survey takers had no experience with BIM, and four of them gave blurry answers to the question which asked about their personal exposure to BIM. That is when 19 of them, 64%, had a good understanding of BIM. Even some of those who did not have a good exposure to BIM were working in the companies which had a little experience with BIM, e.g. one year. None of these answers were disregarded since the authors needed a wider point of view of the construction industry.

Question 13 was one of the most challenging questions of the survey. Since the answer to this question was not subjective and dependant on the survey takers, but rather relevant to the company, this question was cross checked with the companies' data, such as their experience with BIM and their annual revenue. In this question, they were asked which aspects of BIM they are using in their company, and if they implemented them in-house or they out-sourced them. To analyze their responses, the authors divided them into two groups: companies with two or less than two years of experience with BIM, and companies with more than two years of experience with BIM. Figure 3 shows which aspects they used, regardless of in-house or out-source.

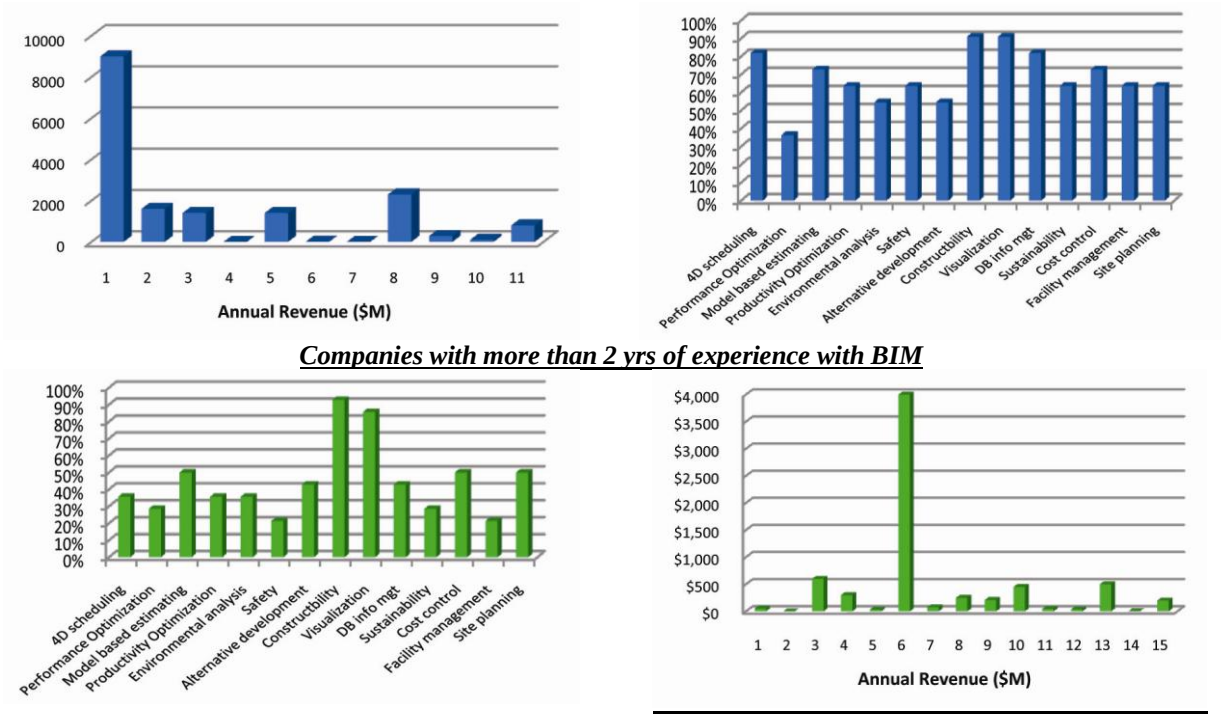


Figure 3: BIM aspects the surveyed companies use

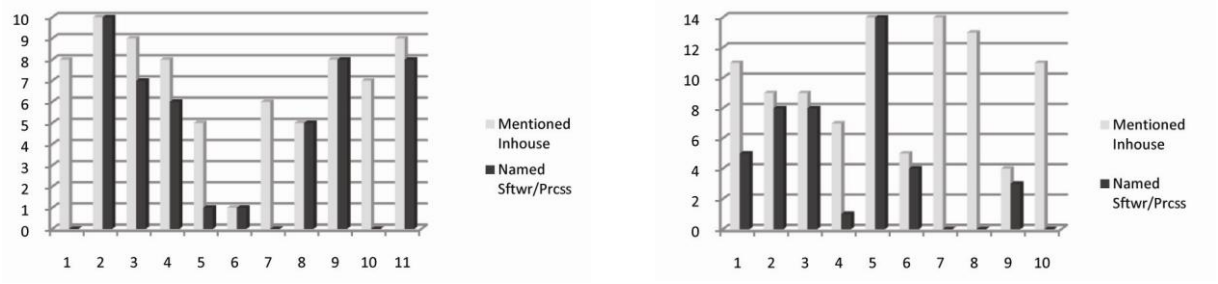
It shows that "Constructability" and "Visualization" are the most used aspects of BIM in all companies. Following this, companies with more than two years of experience with BIM selected "4D visualization" and "Database Information management", while those which have less than two years of experience with BIM mentioned "Model Based Estimating," "Cost Control," and "Site Planning" as the next aspects they implement.

As Figure 3 shows, those companies which had more than two years of experience with BIM were generally larger companies with more annual revenue, mostly around $1000M, and those which had not implemented BIM for more than two years were generally smaller companies, mostly with annual revenue of $500M. The right diagrams in figure 3 show what percent of each group used the mentioned aspects of BIM.

As mentioned before, this question was the last question answered by 12 companies. The next question was actually designed to validate their answers to question 13. The surveying software transferred those options they selected in question 13 to question 14, in order to ask them about the software they use and the processes they take. For

example, if they had answered to the option "4D Scheduling" as performed "In-House" or "Out-Source," but not "Not Implemented," the option "4D Scheduling" would be transferred to question 14, and there, the survey takers were asked to name the software they use and the processes they take to implement it. The other conclusion from these diagrams is the average of implementing those aspects in two groups of companies: where generally larger companies implemented more aspects with an average of ~70%, this was around 45% in the smaller companies.

Most of the respondents refused to answer to question 14 completely. Although the ways they used the software and the processes were completely customized by their own, and judgment of these answers is too hard, in very few cases they were off-based from the authors' point of view. For example, one of them mentioned Navisworks as a "Cost Control" software, or "DProfiler" as sustainability software. But since the number of these suspicious answers was negligible, as long as they named a software package for that aspect of work, it counted towards their answers. This could be justified by human error. The number of their responses to question 14 was less than the number of the options they responded in question 13 as "InHouse." Figure 4 compares the number of the aspects they mentioned in question 13 versus the number of the aspects they named a software package for in question 14.

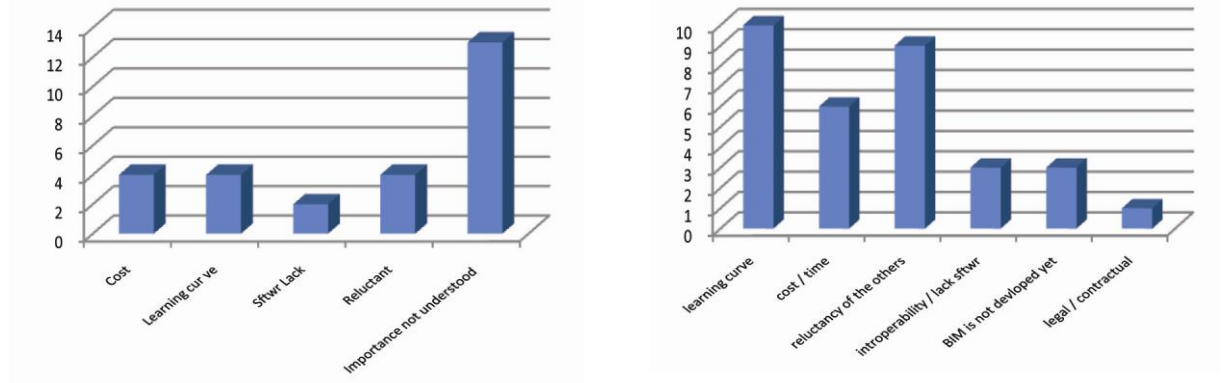


Companies with less than 2yrs BIM experience *Companies with more than 2yrs BIM experience*

Figure 4: Comparison between the number of the answers to question 13 and 14

To show the comparison more clearly, the authors decided to calculate the difference between the number of "mentioned InHouse" and "named Software/Process" and compare these two indicators between two groups. This difference in companies with more than two years experience with BIM (with an average of 5.4) was more than the other group (with an average of 2.7). This means that the answers of the second group were closer to reality, less exaggerated, and more reliable than the answers of the first group. A precise review of the answers to question 14 had authors conclude that the companies did not necessarily implement BIM software packages and processes for the work aspects mentioned in the survey. But rather they do "something" with IT for that aspect of the work. These questions will be further discussed when cross checked with question 21.

Questions 15 and 16 asked their opinion about the barriers for implementing BIM in the areas they do/do not implement BIM. These questions were designed as open questions to let them freely explain their opinion on the barriers, and the results were categorized by the authors. As Authors (2009) said, the majority of the answers to question 15 complained about the "learning curve" in different words, followed by "reluctancy of the other parties."



Areas they do not use *Areas they use*

Figure 1: Barriers of implementing BIM

As being showed in Figure 5, they implied that most of them have not understood the applications and functionalities of BIM. In order to have a more clear conclusion of the responses to these two questions, they were cross checked with the personal experiences of the survey takers with BIM. Since these two questions were subjective ones, they should be cross checked with personal profiles of the survey takers rather than with companies' profiles. Table 1 gives a better image of the responses and who gave them.

Table 1

Barriers of implementing BIM

The question	Years of experiences of survey takers	Their responses	
Barriers of implementing BIM in the areas they "use it"	1. No experience	- Legal issues - Not understanding of its functionalities	
	2. Less than a year	- Costs - Software limitations	- Reluctancy of other parties - Not understanding of its functionalities
	3. Between 1 and 2 years	- Learning curve	- Reluctancy of other parties
	4. More than two years	- Learning curve (educating everybody rather than a group)	
Barriers of implementing BIM in the areas they do "not use it"	1.No experience or less than a year	*These groups either did not answer or said "same as question 15"*	
	2. More than one year	- Find the right direction to be effective - Get the benefit of current ones and then proceed with the other ones	

It is clearly derived from Table 1 that the more experienced survey takers in the BIM realm gave better responses to these two questions. The individuals who had limited or no experience with BIM gave answers which were rooted from their fear of an "unknown path," while the more experienced ones gave more rational answers and showed that they know the way they are stepping in.

The authors decided to cross check these answers with the position of the survey takers as a factor that affects subjective answers. Although different tests were tried, no regression between the answers and the mentioned factor showed up. The reason could be either the limited number of the responses, or the effect of the other factors, which were more than this factor, and entered more proxies than this factor did in the results.

The other factor that could be considered to cross check with these two questions was "the way they train their employees on BIM." Although this was a factor that was rooted from the company rather than the individual who took the survey, it shows the effect of general factors which affect everybody in the company. The overall review of their training methods showed that the companies who did not have a structured framework for fostering knowledgeable and skillful personnel mostly complained on shortages of software packages, interoperability, and BIM as a concept which is not developed enough to be used.

Question 19 and 20 addressed the BIM committee in their company and if they have a policy of requiring everybody to be knowledgeable with BIM, or if a separate department handles all BIM works. Although the companies tried to introduce themselves as being well-equipped with BIM at the beginning of the survey, the survey questions helped them show their weaknesses in it. This time, more than half of them did not mention any policy regarding this issue. Figure 6 explains the responses more clearly.

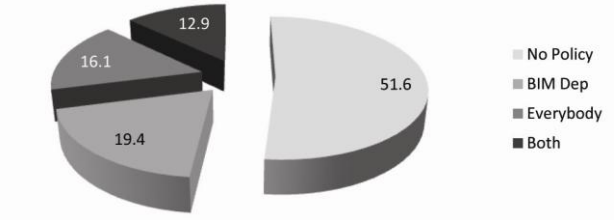


Figure 6: Policies of the companies for handling BIM affairs

Since this is not a subjective issue, it was cross checked with companies' experience with BIM. Almost all the companies which had a predetermined policy for this issue had more than five years of experience with BIM. The exceptions were: two companies with one year experience in BIM which had one person who handled all BIM works; one of them with a year of experience planned to train everybody (but not now); and a company with three years experience with BIM had a "Coordination Department" which handled all BIM affairs. With two exceptions, all the companies which had over $500M annual revenue had the policy of having everybody BIM knowledgeable whether they had a BIM department or not. And with one exception, all survey takers who had more than a year experience with BIM and announced their policy put it in option one or three i.e. having a separate BIM department or having both a department and requiring everybody to know it.

When asked about the structure of their BIM committee (question 19), the structures ranged from one to six persons in the committees. Most of them had around three to four persons in it. Reviewing their profile, the authors found the most high profile companies in BIM within this group. With one exception, all of them had the policy of requiring everybody to become BIM knowledgeable, whether they have a separate BIM department or not. It could be concluded that 3-4 members is a rational size for BIM department at this state of the industry.

Question 22, which was a subjective question, asked them to rank five functional areas of BIM knowledge (Table 2) according to importance (where one stands for the most and five for the least important).Table 2 shows two ways of making conclusions based on their answers. The first way is to see which area gained the most "ones" and name it as the most important. The alternative way is to convert the rankings 1-6 to grades 6-1 where six stands for the most important and one stands for the least important. Then sum up the grades and see which one gained the most grades and name it as the most important. When two different rankings show up, it is better to cross check the responses with other factors to see which answers are more reliable.

Table 2

Ranking of areas of BIM knowledge

Area of BIM knowledge	**First Method**			**Second Method**	
	Number of "one"s	Number of "two"s	**Ranking**	Score	**Ranking**
Model Specification	4	10	**2nd**	73	**1st**
Model Validation	3		**4th**	64	**2nd**
Model Access Management	4	7	**3rd**	55	**4th**
Model Version Control	1		**5th**	42	**5th**
Interoperability	6		**1st**	62	**3rd**

The most reliable conclusion from the two methods is that "Model Version Control" is of the least importance. The other results are arguable. Since this was a subjective question and the answers to this question was affected by the individuals who took the survey, the authors decided to cross check this answer with: 1. How exposed the survey takers were to BIM 2. How long the survey takers were working in the areas related to BIM 3. The educational background of the survey takers, and 4. Barriers of implementing BIM from their point of view.

Looking at the companies which ranked "Interoperability" five, half of them had almost no experience with BIM, and did not express any idea on barriers of implementing BIM. The two others who had the same idea were direct software experts, and one other respondent claimed to have 20+ years experience with BIM, while his company holds a ranking of around 50 in general contractors of the U.S. [ENR website]. The same evaluation was performed on those who ranked "Model Specification" five. Only two companies did that, and in expressing their opinion about the barriers, they either projected their reluctancy to the others, or directly confessed their lack of knowledge.

This is when almost all of the individuals who ranked either one of these two areas as "one" expressed their opinion on question 15 and 16 (Barriers of implementing BIM) in a way that showed their good understanding of BIM. Evaluation of their experience with BIM (question 9) and their exposure to BIM in their job (question 8) did not return any result which could be used to prioritize them over each other. The last analysis on this question that the authors decided to perform was to evaluate each individual's response, and see when s/he ranks one of these two

areas, how he ranks the other area. Again this test did not return any result. Therefore, the authors decided to play with two previous methods of ranking and determine the importance of each area in the survey takers' point of view.

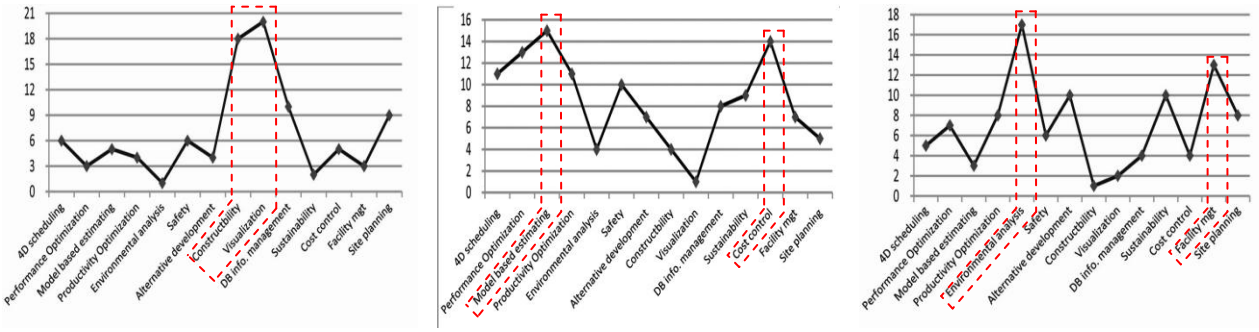
Table 3 uses a ranking method in which each area gets its grade by summing up the grades it got from the two previous ranking methods.

Table 3

Final ranking of areas of BIM knowledge

Area of BIM Knowledge	Rank in the 1st ranking method	Rank in the 2nd ranking method	Total points	Final ranking
Model Specification	2nd → 4points	1st → 5points	9 points	**1st**
Model Validation	4th → 2points	2nd → 4points	6 points	**3rd**
Model Access Management	3rd → 3points	4th → 2points	5 points	**4th**
Model Version Control	5th → 1point	5th → 1point	2 points	**5th**
Interoperability	1st → 5points	3rd → 3points	8 points	**2nd**

Question 22 was one of the most direct questions from the survey pool to be used in designing the curriculum of construction programs. The survey takers were offered the same options they had been offered in question 13, and they were asked to report whether they expect the graduates of construction programs, who are their future job applicants, to be knowledgeable with which of those options. They were asked to prioritize them by "Immediate," "Near Future," and "Far Future." Figure 7 shows the direct results which were presented before (Authors, 2009).



Immediate Near Future Far Future

Figure 7: Immediate, Far future, and Immediate needs of construction companies

As shows in this figure, "Constructability" and "Visualization" were the most immediate demanding areas of BIM knowledge. "Cost Control" and "Model based Estimating" were demanded for the near future, and "Facility Management" and "Environmental Analysis" were the less demanding areas from their point of view. In the following, their answers were cross checked to validate their response.

- *Immediate needs:* while the votes for "Constructability" and "Visualization" were 18 and 20, the number of companies which voted both of them as the immediate needs was 16. They ranged from very large companies to very small ones, nationwide to regional, and with a variety of revenue. The only survey taker mentioned both of these areas as the "far future" needs had no experience with BIM, and his exposure to BIM was "very little". Fourteen companies among these 16 ones performed both of these areas in-house. All of these cross checks led the authors to strongly affirm and endorse the responses to this part of the question. This result was in line with their answer to question 13 and the areas in which they invested more.
- *Near Future needs:* both "Cost Control" and "Model based Estimating" are related to 5th dimension of BIM i.e. cost. Those who mentioned at least one of these two areas as near future needs mentioned either "Constructability" or "Visualization" as the immediate needs. Those who mentioned both "Cost Control" and "Model based Estimating" as the immediate needs always mentioned "Constructability" or "Visualization" as immediate needs as well. These companies were those which were ahead of the others

and felt the future needs of the others as their own immediate needs. There was only one exception, who claimed his company was a nationwide company with $7M annual revenue. He was the one who mentioned current BIM packages as "unproven" ones.

- *Far Future needs:* as figure 7 shows "Facility Management" and "Environmental Analysis" gained 13 and 17 votes for far future needs. Only one company mentioned "Environmental Analysis" as the immediate need, which was the one that mentioned all of the options as immediate needs. Four companies out of these 13/17 companies gave all four answers of "Immediate" and "Near future" needs completely in-line with the majority of the survey pool's responses i.e. they mentioned "Constructability" and "Visualization" as immediate needs and "Cost Control" and "Model based Estimating" as near future needs. Six of them gave three answers out of the four answers in-line with the majority of the survey pool. In total, 10 answers out of 13/17 answers were within the trend.

These cross checks ensured the authors that the responses to question 22 are completely reliable and reflect the industry's vision.

As Authors (2009) said, question 24 retuned one of the most interesting results of the survey. Although it was expected that the industry requires the applicants to be ready to work, and prefer them to be skillful with software applications, the survey takers reflected the opposite point of view. Question 24 asked them whether they prefer their applicants to have the conceptual knowledge and understanding of BIM tools and processes or prefer them to have proficient skills with BIM software. Despite the expectations, few of the answers preferred proficient skills with BIM software. From the authors' point of view, the most relevant factor to this subjective question was the experience of the survey takers with BIM. Therefore, they decided to cross check this question with question 12. Figure 8A compares the experience of the survey takers with their answers to question 22.

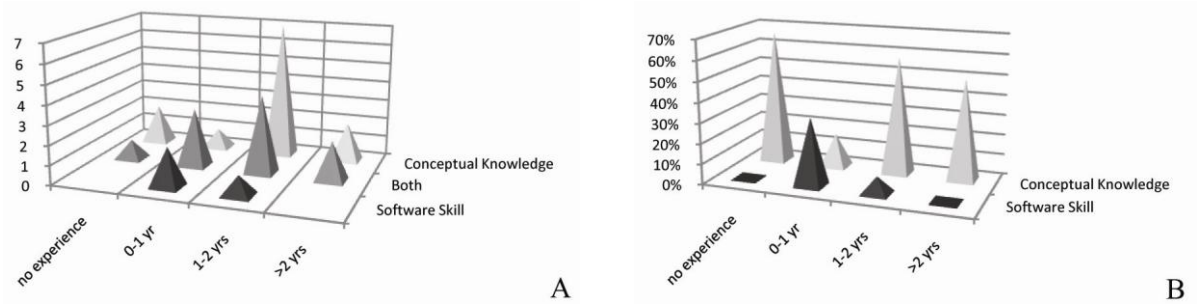


Figure 8: Construction companies' expectations of their future applicants

As shown in Figure 8A, the survey takers with either no experience or more than two years of experience with BIM did not ask for just proficiency with BIM software. For the first group (no experience with BIM) this could be interpreted as their fear of the "unknown unkown" path that they are stepping in. They require their future applicants to be their leaders in this road, rather than the followers who perform the tasks. But when looking at the response of the survey takers who had more than two years experiences, the interpretation must be different. This could be interpreted as they have already understood that the importance of conceptual knowledge of BIM is more useful for their company than being skillful in operating computer applications. This is when most of them mentioned the "learning curve" as a barrier for spreading BIM in their company. Their response to the next question clarified this point of view more.

The option "both" is usually selected as a conservative answer. If we delete those responses and consider the percentage of the responses in each group for either "Conceptual Knowledge" or "Proficiency in Software", the results would be as Figure 8B. As shown in this figure, the answer of newly exposed survey takers to BIM was different from the others. This could be interpreted as their immediate need for the applicants who run their new processes to see their results.

The last question asked them what BIM software they prefer to use. Figure 9 summarizes their results. Revit and Navisworks were the two most demanding applications they preferred their future applicants to be skillful with. One of the construction companies, whose strong status in BIM is clear for the authors, strongly said that they are not looking for specific software skills. It added that since there is a variety of software packages, they prefer a good

knowledge of BIM rather than proficiency in a specific package. This company did not mention any software. Three other companies had the same idea, but named some applications and added that having proficiency in these applications is not deal-breaking. Six other companies did not respond to this answer (or answered "none"), while they had answered the previous question "we prefer conceptual knowledge rather than proficiency in software", and just two of them answered "both" to the previous question. This could be interpreted as when they had seen this question before, they declined to answer it again. All these companies were among the most high profile companies with hundreds of millions or sometimes billions of dollars annual revenue.

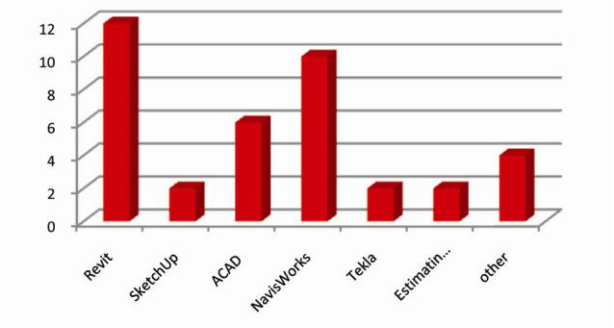


Figure 9: demand on specific software packages

Among the answers, one answer was "current IT packages are unproven", which was mentioned in the previous section. This company expressed its opinion about barriers of implementing BIM as "BIM is very new to the Facilities world, the IT aspects are straightforward, but engineering assumptions are limited, definitions are still being developed and revised, BIM benefits have yet to be proven", that all of them came from a lack of understanding of BIM.

Another specific observation in this survey was mentioning AutoCAD between BIM software packages. The survey takers definitely know that AutoCAD is not a BIM tool, but on the other hand, this tool is not completely replaced by BIM designing tools like Revit. This idea might account for the mentioning of this software in their responses. Almost everywhere that either Revit or Navisworks was mentioned, AutoCAD was mentioned as well. It could be concluded that this tool still works as a complementary tool with BIM packages and it is necessary to equip construction students with ACAD at this time.

Focus Group

As discussed before, question 13 and specially 14 were not answered properly by the survey takers, and was foreseeable for the researchers. The focus group interview was planned to cover such shortages in the general survey. Another questionnaire (Appendix B) was developed which was all essay type questions, not to make a framework for the interviewee. While they were exposed to five tasks they can take with information i.e. creation, modeling, analysis, management, and documentation, they all agreed on the "information management" as the primary role of the general contractor (GC). The five parts are presented accordingly. The goal of this part of the research is to study the current status of the construction industry in which advanced companies are working in.

Creating Information:

GCs usually do not create design information unless they are on a Design-Build contract in which GC/Subs help designer for creating information. GC is responsible for creating construction information such as site logistics e.g. storages, cranes, site access, etc. Time (schedule and sequence) and cost information are the other responsibilities of GCs. The other type of information recently GCs create is the information required for facility management, which is usually been transferred to the owner for the O&M of the project. Those are mostly the licenses and the information about special equipment used in the building.

Modeling Information:

The focus group mostly gets the BIM from the designer. Sometimes GCs have the subcontractor collaborate with the designer to produce BIMs in Design-Build contracts. In traditional contracts, it usually happens that subs re-build their model on top of the designer's model. The reason is the weak transfer of the model from the designer to subs. The interviewees declared that they do architectural, structural, and MEP modeling for the small and narrowly scoped projects. Besides, they do site logistics for large ones.

4D modeling of the schedule and sequence of the project (with Navisworks) is one of the models GC makes and uses frequently. The difference in the 4D models that different companies make is the level of detail they have, and whether they use them in office for the general review of the project or in the field for the daily operation. Some of the interviewed companies did not invest on the 3D-based estimating because either they did not trust the level of preciseness of the 3D model or they did not have the estimating database of the building components and activities while the bidding period is short. This is when some other firms purchased QTO, which they believe it is more powerful than Revit, and use it for all their estimates and cost analysis.

Although GCs do not do too much 3D modeling, all of the interview pool used Revit for general and in-detail modeling and mock up of the detail elements of the projects, and Sketch-up for rough modeling for their internal communication or quick presentation for safety purposes e.g. explaining a trench.

Information Analysis:

The GC analysis all the information it puts effort for creating and modeling it. In other word, they are created and modeled to be analyzed. Clash detection is the one that all companies started their BIM procedure with. The reason could be its quick return on investment and that they can see its direct result on improving the collaborative processes. Site logistics analysis is one of the main tasks of the GC. Although they do not implement BIM too much in this area, they do limited modeling and analysis of site access, crane and hoists, storages, and site environment. The authors got this point from the interview that the companies are investing very limited in this area than they pretend. 4D analysis was usually the second step for implementing what they call "BIM Processes" in the companies. Its level of the detail determines its application, which ranges from presentation for the owner to scenario analysis of sequencing/scheduling to daily usage in the field.

Information Management:

The major task of a GC regarding BIM is to manage the information. This is when the GC does not have a major role in 3D modeling. The interviewed GCs did this task by coordinating file sharing between all parties; managing access of the right person to the right information s/he needs; providing the useable file format either common exchange files or the required file for the targeted party. One of the interviewed companies made itself responsible for putting the discrete file from each party together and make a "federated file" for sharing with all the parties.

3D coordination falls under information management between the responsibilities of the GC. The reason is that the GC sets up and conducts the sessions in which subcontractors (and sometimes designers) coordinate their tasks. The interviewed companies presented different types of coordination sessions:

1. Weekly coordination sessions with all subs, in which they review their weekly and near future tasks.
2. Sessions between one party and one other party, and after all, one session between all of them and again one-by-one sessions.
3. Set a comprehensive session with all parties at the beginning to set up the BIM coordination plan based on milestones and determining who should attend which session.

Information Documentation:

Although all the interviewees responded to this question, their responses showed that they did not invest enough in this area to create a targeted framework for the documentation of the information. Most of them just kept records of what they made e.g. clash detection reports, 3D/4D models indicating status of the project in each phase of construction, cost estimations, etc.

The only document they create aiming at recording and using is the as-built of the building and the COBIE file containing the data of the major components of the facility for its O&M period.

Conclusion

Studying and analyzing the surveys and interviews, the authors categorized the expectations of the construction industry of the graduates of construction schools into two major groups:

1. The technical skills they need to have for using the BIM software
2. The knowledge they need to have to be aware of how to implement the BIM software to be helpful in construction processes.

It is directly told in the survey and interviews that proficiency in software knowledge is of less importance than the basic knowledge of BIM and its application in the construction processes. However, three software packages are in common use at this period of time by the advanced companies, which could be good platforms for the students to rehears on. They are Revit™, SketchUp™, and NavisWorks™. Although a thorough knowledge of them is not required, a basic knowledge of them improves the learning curve that the industry points to as a barrier.

The processes needed for the construction students to be equipped with are mentioned in the body of the of the paper and are summarized here. Site logistics, clash detection reports, model based cost estimating, constructability analysis, and visualization are the most important processes construction students should be taught. In addition, they should be taught and rehears on information management, which is the major role of the GCs. This could be broken down into information access management, coordination session plan, determining parties to include, file/format coordination (interoperability and exchange of the different formats), etc.

Information documentation is the process the school can teach the students to equip them with a cutting edge knowledge upon entering the industry. It puts them in a step ahead of the current status of the industry in the area it lags behind.

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Appendix A

Section One: Demographic data of the company

1. Company Name
2. What are (is) the primary type of projects that your company delivers? (select all that apply)

Residential | Commercial | Buildings | Office | Civil/Infrastructure | Industrial | Retail | Others

3. What are your company's primary contractual roles? (select all that apply)

General Contractor | Sub-Contractor | Consultant | Construction Manager | Design-Build | Others

4. Total volume of contract per year (Annual revenue)
5. Geographical spread of the company (Please list states for domestic work, and countries for International work).
6. Number of employees

Section Two: Position of the Interviewee

7. Your position in the company
8. How exposed are you to BIM in your position?
9. How long have you been working with or in the areas related to BIM?
10. What are your work experiences in the industry/academia generally (positions, years)?
11. What is your education background?

Section Three: Company's Exposure to BIM and Its Experience with BIM

12. For how many years has your company implemented BIM?
13. Please specify for the areas you use BIM, which one you implement In-House, Out-Source them, or do not implement them.

4D scheduling	Performance Optimization	Model based estimating	Productivity Optimization	Environmental analysis	Safety	Alternative development
Constructability	Visualization	Database information management	Sustainability	Cost control	Facility management	Site planning

14. Which software packages do you use in each area? And what are the processes for implementing each area?

4D scheduling	Performance Optimization	Model based estimating	Productivity Optimization	Environmental analysis	Safety	Alternative development
Constructability	Visualization	Database information management	Sustainability	Cost control	Facility management	Site planning

15. What are the barriers of implementing BIM in the areas you are using BIM now?
16 What are the barriers of implementing BIM in the areas you have not yet used BIM?
17 How many employees specialize in BIM?
18. How do your employees learn about BIM (select all that apply)
19. Do you have a BIM committee (a group who steers the BIM activities of the company)? If you have one, please explain positions of the members of the committee, along with how many members they are. If you have employees who are semi-involved with BIM, please explain what their primary job function is.
20. Do you have a dedicated BIM department that handles/supports all BIM requests in your company or do you require/plan to have all your employees to become BIM capable?

Section Four: Expectations from Students upon Hiring

21. Please rank the areas of BIM knowledge that you think is most important.

Model specification | Model validation | Model access management | Model version control | Interoperability

22. Which BIM skills are you looking for when you consider students for hiring? Please specify if you expect those skills immediately (1), in the near future(2), or in the far future(3)

4D scheduling	Performance Optimization	Model based estimating	Productivity Optimization	Environmental analysis	Safety	Alternative development
Constructability	Visualization	Database information management	Sustainability	Cost control	Facility management	Site planning

23. How do you evaluate the BIM knowledge of the current applicants of your company? (select all that apply)

Perform a test | recommendation letters on BIM skills | Rely on students' resume | Ask technical questions | Other assessment methods

24. What is your primary expectation regarding BIM knowledge from your current/future employees?

Conceptual knowledge and understanding of BIM tools and processes | Proficient skills with BIM software | Both

25. Which specific software packages do you expect your job applicant to know at the time of applying for the job?

Appendix B

Answering to the following questions, please keep in mind that we are considering these five issues:

I. understanding strategies for effective use of BIM
II. the nature of owner-driven BIM requirements
III. the difference between parametric design and BIM from a constructor's viewpoint
IV. collaborative opportunities with BIM-enabled collaborators

1. Creating Information

1.1. What type of information you create?
1.2. What type of information is required by owners?
1.3. Which tools you use for creating information?

2. Modeling Information

2.1. What type of information do you model?
2.2. Do you construct your own models or reconstruct from other models or do both? (Please be specific)
2.3. Which tools you use for modeling?
2.4. Do you use parametric modeling tools? If yes, for what purpose?

3. Analyzing information

3.1. What type of information do you share and analyze?
3.2. How do you analyze information and how you use it (if possible, specify your input, analysis, and output)? For example, computable information such as cost and quantities, and how you share to inform decision making.
3.3. Which tools do you use for it? How does BIM help?

4. Managing Information

4.1. What are the roles and needs for "managing information"?
4.2. What are the tasks for managing information and how do you specify information requirements?
4.3. How do you facilitate "collaboration" via information management?
4.4. Who are your primary 'collaborators'?
4.5. Which tools you use for it? and how does BIM help?
4.6. How do you share Model/information with contractors, subcontractors, suppliers, and other downstream participants?
4.7. How do you share Model/Information with owner, architects/engineers, and/or other upstream participants?

5. Documenting Information

5.1. What type of information do you document (if any)?
5.2. How BIM helps documentation (if any)?
5.3. Which tools you use for it?