Role, Function, and Competency Requirements for a Successful BIM Implementation

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Introduction

Building Information Modeling (BIM) presents itself with huge opportunities and challenges for the construction industry. In the present BIM is the expression of innovation in the construction industry and it includes new technologies, processes, policies, affects industry’s deliverables and most importantly redefines construction roles. BIM concepts and tools are encouraging revolutionary and evolutionary change through all scales, completely changing the construction landscape as we know it (Succar & Kassem, 2015). The origin of BIM can be pinpointed in the 1960s with the emergence of its concepts during the early days of computing. Later, during the 70s and 80s decades the first modeling programs were created but it still wasn’t until the year 2000 when Revit was created and a real shift towards BIM implementation started to take place. BIM adoption across the industry had been very slow in exception for the past decade, where the industry realizes the incredible value of BIM due to technology and implementation improvements. To illustrate the rapid adoption, one could look at the implementation of BIM in North America where survey results show that BIM adoption by contractors increased from 28% in 2007 to 71% in 2012. Another indicator of BIM’s widespread adoption is the tremendous efforts governments are doing to promote its use, as is the case of the United Kingdom, who has the most ambitious BIM implementation program and demands the use of BIM in public sector constructions. Today, BIM implementation is led by countries and companies around the world and the BIM market is expected to grow to $6.5 billion by 2020 (Smith, 2014).

BIM’s accelerated adoption in the last decade is no coincidence and is mainly related with the fact that construction projects are becoming more complex and difficult to manage than ever before. In accordance to this change information and communication technology in the form of BIM has emerged as a solution to the problem. One benefit of using BIM is the ability to better organize a project’s schedule and budget by using an integrated 5D BIM model that immediately updates both the schedule and budget when any design change takes place. BIM is also useful for hiring and controlling subcontractors because it enables the project manager to have a handle on clash detection and coordination (Bryde, Broquetas, & Volm, 2013). A third benefit derived from the implementation of BIM is the possibility to eliminate delays by having access to early information about missed design solutions and possible arising problems (Migilinskas, Popov, Juocevicius, & Ustinovichius, 2013). As a final example, BIM enables a project’s constructability, understood as the review of construction logic from beginning to end during the preconstruction phase to identify potential roadblocks, constraints, and issues, to be evaluated thus decreasing the uncertainty associated to any said project (Hardin & McCool, 2015). These and countless more benefits serve as BIM’s drivers of implementation and are responsible for its rapid adoption through the industry.

Even though BIM adoption has drastically increased in the last decade, BIM still faces challenges that prevent it from becoming and industry’s must. These challenges may be divided in to two main categories: technical and managerial. The issues regarding the managerial category cluster around the implementation and use of BIM and tend to circle back to the need of construction professionals to adapt their roles and provide more sophisticated services (Smith, 2014). For example, to optimize BIM performance companies and vendors will have to lessen the curve of
BIM trainees. Another example of the shift in roles that needs to take place in order to successfully implement BIM is the need to contractually define responsibilities regarding the control of data entry into the model, update of the model’s data to ensure its accuracy, review of BIM data, and respond for errors in the model (Azhar, 2011).

Keeping this in mind the implementation route for BIM in companies of the construction sector is not yet well defined. Thus far, it’s not clear whether a new role must be defined in the companies or if the existing workforce could acquire new capabilities that enable them to undertake the challenge. This decision may prove itself crucial to the success or failure of a project and the adoption of BIM and new technologies in construction industries. It is precisely that question that this paper aims to answer, should companies train their current work force or hire new BIM specialized works in order to achieve a successful BIM implementation?
Methodology

To answer the question posed in the introduction it was important to begin by analyzing the evolution of BIM, its adoption around the world and the main drivers of implementation. Then, an in-depth research about the necessary BIM related roles for a successful BIM implementation was conducted, where each role was associated with its functions and capabilities. Furthermore, a similar investigation was realized for traditional construction roles and they were similarly associated with their functions and capabilities. Later, the most common BIM uses in the industry were identified and the needed competencies to carry them out as well. Then, the competencies needed for the two types of roles and the BIM uses were cross-referenced to evaluate if it was possible to implement BIM using traditional roles or if hiring BIM specialists was needed. Finally, the investigation was taken to the professional world using a case study to evaluate the results.
Traditional Construction Roles

The construction phase of construction projects is of major importance and plays a vital role in defining the outcome of the project. This phase is usually carried out by one person or organization appointed to take responsibility for the building and supplying of the necessary materials for the project according to the documented design. In order to successfully undertake this job, the constructor must have qualified staff working both on and off site. Among the wide variety of staff there are a few key players that have special importance. These key players are the project manager, construction manager and site manager. Additionally, the site inspector, usually employed by the owner of the project, is of special importance to ensure the construction’s success (Hughes & Murdoch, 2001).

Project Manager

The project manager’s main responsibility is to ensure the overall success of the project within the constraints of cost, schedule, quality and safety requirements (Edum-Fotwe & McCaffer, 2000). The person conducting this role is employed by the constructor and is responsible for the constructor’s input to the project. The project manager is also responsible for the creation and revision of the project execution plan (Hughes & Murdoch, 2001). Also, he must be in control of the project and use the pertinent tools to do so. Additionally, they must establish and maintain information resources to ensure efficient communication in the project. In order to successfully perform this role, the project manager must have a number of competencies. It is of vital importance for the project manager to be skilled and knowledgeable about construction practices (Liu, Van Nederveen, & Hertogh, 2016). Furthermore, they must be able to coordinate the work and activity of other and have excellent communication and leadership skills.

Construction Manager

The construction manager is the person appointed by the construction company to manage and oversee construction operations in the project (Hughes & Murdoch, 2001). The main responsibility of the construction manager is to coordinate the activities within the project with the various actors to ensure the correct development of the project. Additionally, he must monitor and control the progress of the project and be able to handle unexpected situations effectively. He must also ensure that those involved in the project can accomplish their responsibilities. Furthermore, the construction manager must set achievable and effective goals to ensure the project’s success within its constraints. To undertake this functions and responsibilities the construction manager must possess the following set of competencies. It is of vital importance for the construction manager to be skilled and knowledgeable about construction practices. He must also be able to coordinate the work and activities of others as well as manage personnel resources. Finally, he must have
outstanding leadership, teamwork, communication, and critical and analytical thinking skills (Jabar, Ismail, Aziz, & Janipha, 2013a).

Site Manager

The site manager is the person employed by the constructor responsible for coordinating the work on site (Hughes & Murdoch, 2001). This is the person who has ultimate responsibility for the project even though they have no direct control over the work force (Sutherland & Davidson, 1993). They are involved in the company’s strategic decisions and the day to day on site construction, thus making it the most important middle management role in the construction industry. Site managers must also deal with conflicting parties such as management, subcontractors, the work force, the client, etc. To correctly perform the job site managers must have the capability to complete practical and administrative tasks. Finally, they must also possess conflict resolution, teamwork and communication skills (Styhre & Josephson, 2006).

Site Inspector

The site inspector is one of the most important roles running a project (Harris, 2016). This is the person or film responsible of supervising that the construction follows the contract documentation. Site inspectors must perform site visits and be informed about and attend important project meetings (Hughes & Murdoch, 2001). To ensure success in performing this job the site inspector must be skilled and knowledgeable about construction practices. Finally, they must also have great communication and teamwork skills.

Table 1. Traditional Construction Roles Summary

<table>
<thead>
<tr>
<th>Role</th>
<th>Functions</th>
<th>Competencies</th>
<th>Reference</th>
</tr>
</thead>
</table>
| Project Manager | • Deliver the project within the constraints of cost, schedule, quality and safety  
                   • Control the project  
                   • Establish and maintain information resources | • Skilled and knowledgeable about construction practices  
                   • Communication  
                   • Leadership  
                   • Coordinating the work and activities of others | (Edum-Fotwe & McCaffer, 2000)  
                   (Liu et al., 2016)  
                   (Mäki & Kerosuo, 2015)  
                   (Hughes & Murdoch, 2001) |
<table>
<thead>
<tr>
<th>Role</th>
<th>Responsibilities</th>
<th>Key Skills and Competencies</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Construction Manager</td>
<td>• Coordinate activities within the project&lt;br&gt;• Monitor and control the progress of the project&lt;br&gt;• Handle unexpected situations effectively&lt;br&gt;• Manage those involved in the project&lt;br&gt;• Set achievable and effective goals</td>
<td>• Teamwork&lt;br&gt;• Leadership&lt;br&gt;• Communication&lt;br&gt;• Skilled and knowledgeable about construction practices&lt;br&gt;• Coordinating the work and activities of others&lt;br&gt;• Management of personnel resources&lt;br&gt;• Critical and analytical thinking</td>
<td>(Jabar, Ismail, Aziz, &amp; Janipha, 2013b)&lt;br&gt;(Hughes &amp; Murdoch, 2001)</td>
</tr>
<tr>
<td>Site Manager</td>
<td>• Coordinate the work on site&lt;br&gt;• Has ultimate responsibility for the project&lt;br&gt;• Deal with conflicting parties</td>
<td>• Ability to perform practical and administrative tasks&lt;br&gt;• Conflict resolution skills&lt;br&gt;• Teamwork&lt;br&gt;• Communication</td>
<td>(Hughes &amp; Murdoch, 2001)</td>
</tr>
<tr>
<td>Site Inspector</td>
<td>• Supervise that construction follows contract documents&lt;br&gt;• Perform site visits&lt;br&gt;• Be informed of and attend important project meetings</td>
<td>• Skilled and knowledgeable about construction practices&lt;br&gt;• Teamwork&lt;br&gt;• Communication</td>
<td>(Harris, 2016)&lt;br&gt;(Hughes &amp; Murdoch, 2001)</td>
</tr>
</tbody>
</table>
BIM Roles

The emergence of BIM as a tool for improving, systematizing and optimizing project management in all the stages of construction, represents challenges and changes for the actual industry. One of the biggest discussions revolves around the adjustments that need to be performed on the project action roles and the new competencies that they should develop. Many authors have reviewed this issue, and the main dilemma is that there is not a clear-cut definition of the new actors that BIM requires. For instance, in an investigation executed by academics of the University of Auckland, 36 documents from different countries and entities including guides, guidelines, handbooks, manuals, standards and protocols (Davies, Wilkinson, & Mcmeel, 2017). The investigation divided the roles on Project Roles and Organizational Roles which were in turn divided in two types each. Organizational roles being understood as those native to the business itself and project roles referring to jobs exclusive to each project the company is undertaking. The categories will be presented in the following illustration:

![Figure 1. BIM Role Definitions](image)

**BIM Manager (Project)**

The project level BIM manager’s main responsibility is coordinating the team and the production and use of the model (Maria Bernardete Barison, 2010) this is accomplished through the
development and delivery of the BEP and establishing the BIM protocols for the project. The person undertaking this role may be the lead designer, main contractor or a third-party entity hired by the client. Additional functions of the BIM manager may include quality assurance, maintaining oversight over the BIM implementation, guide the collaborative process between the many actors of a project, lead the coordination activity, organizing BIM project meetings, and managing project records (Davies et al., 2017). In order to successfully play out the role of project level BIM manager the person executing it must master the following foundational and technical competencies. The BIM manager must have outstanding communication, leadership, and teamwork skills that enable him to coordinate BIM’s implementation on a project-wide scale. Another foundational skill is the ability to think both critically and analytically to understand and apply BIM concepts and tackle complex problems. On the other hand, a competent BIM Manager must also possess technical capabilities mainly concerning the ability to use various BIM software and tools (M B Barison & Santos, 2011). Furthermore, a BIM project manager must have the ability to manage personnel resources and coordinate the work and activities of others (Uhm, Lee, & Jeon, 2017).

BIM Coordinator

The BIM coordinator is a project level player, which means that their works is constricted within the boundaries of a single project. The persons realizing this job may be a third-party entity or from the construction or design team. The BIM coordinator acts as a support role for the BIM manager (project) and is responsible for technical issues regarding BIM (Liu et al., 2016). Coordinators represent each discipline within the project’s framework and are responsible for their respective models. They must ensure that their models meet the BIM and quality standards defined for the project and follow exchange protocols. Under the leadership of the BIM project manager, who leads the coordination activity, each BIM coordinator is responsible for the coordination and management of their discipline’s model and ensuring any necessary changes are made (Davies et al., 2017). To undertake these functions and responsibilities BIM coordinators must have the following competencies. BIM coordinators must excel in communication and teamwork skills since they are responsible for interdisciplinary communication, information exchange and model coordination and clash detection. They must also be skilled in writing, technology design, quality control analysis, and organizing planning and prioritizing activities (Uhm et al., 2017).

BIM Manager (Organizational)

The organizational level BIM manager plays an important part at the company level rather than the project level. This role isn’t discussed as much as the BIM project manager role but is just as important in successfully implementing BIM. The BIM organizational manager is responsible for training the modeling and coordination staff and is responsible for hardware and software issues (Davies et al., 2017). To perform these functions BIM organizational managers must have the
following competencies. They must know how to effectively train and teach others, in this case the modelers and coordinators. The person undertaking this role must also be capable to manage BIM software and tools and perform administrative activities.

BIM Modeler

The BIM modeler is an organizational role and its main function is to create, develop, and extract documentation from the BIM model (Maria Bernardete Barison, 2010). They are also responsible for the models created and need to keep a relationship with BIM software vendors. It is important to note that even though the extracted documentation from the BIM model belongs to a particular project, how the goal is achieved, in other words how the model is modeled, is an organizational decision (Davies et al., 2017). In order to successfully carry out their job BIM modelers must have the following competencies. BIM modelers must have a thorough understanding of the design process, since the functions of drawing, designing, specifying, sizing, etc. all converge on this role. Finally, BIM modelers must be experts in managing BIM software and tools in order to correctly develop BIM models.

Table 2. BIM Roles Summary

<table>
<thead>
<tr>
<th>Role</th>
<th>Functions</th>
<th>Competencies</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>BIM Manager (Project)</td>
<td>• Develop and deliver the BEP&lt;br&gt;• Establish BIM protocols for the project&lt;br&gt;• Quality assurance&lt;br&gt;• Maintain oversight over BIM responsibilities and deliverables&lt;br&gt;• Guide the collaborative process&lt;br&gt;• Lead the coordination activity&lt;br&gt;• Organize BIM project meetings&lt;br&gt;• Managing project records</td>
<td>• Communication&lt;br&gt;• Leadership&lt;br&gt;• Teamwork&lt;br&gt;• Critical and analytical thinking&lt;br&gt;• Manage BIM software and tools&lt;br&gt;• Coordinating the work and activities of others&lt;br&gt;• Management of personnel resources</td>
<td>(M B Barison &amp; Santos, 2011)&lt;br&gt;(Maria Bernardete Barison, 2010)&lt;br&gt;(Davies et al., 2017)&lt;br&gt;(Uhm et al., 2017)</td>
</tr>
<tr>
<td>BIM Coordinator</td>
<td>• Represent each discipline within</td>
<td>• Writing</td>
<td>(Liu et al., 2016)&lt;br&gt;(Davies et al., 2017)</td>
</tr>
<tr>
<td>Role</td>
<td>Responsibilities</td>
<td>Skills</td>
<td>References</td>
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<td>---------------------------</td>
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</tr>
</tbody>
</table>
| BIM Manager (Organizational) | - Responsible for training  
- Responsible for hardware and software issues | - Training and teaching others  
- Performing administrative activities  
- Manage BIM software and tools | (Davies et al., 2017) |
| BIM Modeler               | - Develop the BIM model  
- Takes responsibility for the BIM model  
- Relationships with software vendors | - Knowledge of the design process  
- Manage BIM software and tools | (Maria Bernardete Barison, 2010)  
(Davies et al., 2017) |
BIM Uses in Construction

According to the investigation realized in Requirements for a BIM execution plan (BEP): a proposal for application in Colombia (Ramírez-Sáenz, Gómez-Sánchez, Ponz-Tienda, Romero-Cortés, & Gutierrez-Bucheli, 2018) only eight out of twenty BEPs contemplate BIM uses when defining the project’s scope. Defining BIM uses in a project’s BEP is extremely because only then will a decision about who will be responsible for each of the uses can be made. Once BIM uses are defined it is possible to look at the proposed work force for the project and evaluate if it meets the needs for successfully implementing BIM or whether it is necessary to capacitate or introduce new actors into the group. From the evaluated BEPs seven main BIM uses can be identified for the construction phase. These uses have been associated with competencies that the executor must possess for its correct application.

The first BIM use is existing conditions modeling. This is a process where a 3D model of the existing conditions for a site is developed. This may include the whole site, facilities on a site, or a specific area within a facility. Once the team has the model valuable information may be extracted from it. This may be useful for documenting existing buildings for historical use, provide documentation of environment future uses, enhance existing conditions documentation, provide local information, assist in future modelling and coordination and may be used for visualization purposes (Pennsylvania State University, 2010).

Secondly, cost estimation is a process where accurate quantity take-off generated from a BIM model allows for cost estimation. This information may be used for the estimation of the cost of all construction materials and their installation (Department of Veteran Affairs, 2010). This practice has the potential to save time, money and avoid leaving the budget constraints (Pennsylvania State University, 2010).

4D modeling is a process in which the dimension of time is added to 3D BIM models (U.S. Army Corps of Engineers, 2009). This may be used to effectively plan the construction sequence and prepare for on-site space requirements. The use of process sequencing assists decision making and the comprehension of construction projects (Department of Veteran Affairs, 2010). Finally, phase planning is also a powerful visualization and communication tool that can lead to a better understanding of the project and be used for marketing and publicity purposes (Pennsylvania State University, 2010).

Additionally, 3D coordination or clash detection is a process where all major interferences between building components are detected and resolved before actual construction (Department of Veteran Affairs, 2010). The potential value of 3D coordination is that it enables the coordination of the construction project through a model, reduces and ideally eliminates field conflicts, increases productivity while reducing costs and construction times and permits more accurate as built drawings (Pennsylvania State University, 2010).

Site utilization planning is a process in which a 4D BIM model is used to geographically represent permanent and temporary facilities on site by using the construction schedule. This enables site management functions such as visualized planning and resources to be analyzed both spatially and
temporarily. With site utilization planning it is possible to generate site usage layouts, identify space and time conflicts, select a construction scheme according to the project’s specifications, and update site organization and space usage as construction progresses (Pennsylvania State University, 2010).

Furthermore, 3D control and planning are processes that uses the BIM model to layout the building assemblies and produce lift drawings used during on site construction. By using BIM for this activity, it is possible to decrease the layout error and language barriers while increasing the communication between office and on site personnel (Pennsylvania State University, 2010).

Finally, record modeling is a process where a 3D model contains an accurate depiction of a facility’s physical conditions and environment. Additionally, the record model also has information linking prebuild specifications to as built specifications, allowing the owner to monitor the project. Record modeling is extremely helpful as it aids in future modeling and 3d design for renovation, provides documentation for future uses, may reduce project delivery times, risks, costs, and lawsuits and assists in the operation and maintenance phase of the building (Pennsylvania State University, 2010).

Table 3. BIM Uses Summary

<table>
<thead>
<tr>
<th>Uses</th>
<th>Competencies</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Existing Conditions</td>
<td>• Manage BIM software and tools</td>
<td>(Pennsylvania State University, 2010)</td>
</tr>
<tr>
<td>Modeling</td>
<td>• Knowledge of BIM authoring tools</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Knowledge of conventional surveying tools and equipment</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Ability to determine what level of detail will add value to the project</td>
<td></td>
</tr>
<tr>
<td>Cost Estimation</td>
<td>• Manage BIM software and tools</td>
<td>(Pennsylvania State University, 2010)</td>
</tr>
<tr>
<td>(Quantity Take-Off)</td>
<td>• Ability to define design modeling procedures which yield accurate quantity</td>
<td>(Department of Veteran Affairs, 2010)</td>
</tr>
<tr>
<td></td>
<td>take-off information</td>
<td></td>
</tr>
<tr>
<td>4D Modeling</td>
<td>• Skilled and knowledgeable about construction practices</td>
<td>(Pennsylvania State University, 2010)</td>
</tr>
<tr>
<td></td>
<td>• Manage BIM software and tools</td>
<td>(U.S. Army Corps of Engineers, 2009)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(Department of Veteran Affairs, 2010)</td>
</tr>
</tbody>
</table>
| 3D Coordination                      | • Manage BIM software and tools  
|                                      | • Coordinating the work and activities of others | (Pennsylvania State University, 2010)  
|                                      |                                            | (Department of Veteran Affairs, 2010) |
| Site Utilization Planning            | • Manage BIM software and tools  
|                                      | • Skilled and knowledgeable about construction practices | (Pennsylvania State University, 2010) |
| 3D Control and Planning              | • Manage BIM software and tools | (Pennsylvania State University, 2010) |
| Record Modeling                      | • Manage BIM software and tools  
|                                      | • Knowledge of the operation process  
|                                      | • Communication                  | (Pennsylvania State University, 2010) |
Conclusions

Companies may take many approaches regarding the implementation of BIM in their projects, but it is here that the key to success or failure lies. After conducting meticulous analysis and research about BIM in the construction sector we can answer the question posed in the introduction: should companies train their current work force or hire new BIM specialized works in order to achieve a successful BIM implementation?

The decision of training current employees opposed to hiring specialized BIM professionals depends solely on the size of the company and complexity of the projects it undertakes. As shown above, the capabilities needed to successfully execute BIM roles and the functions these accomplish are fairly like those already being carried out by traditional construction workers. Keeping this in mind, if the company in question is small and the project it is developing isn’t complex, it is feasible that with proper training current workers may acquire the capabilities necessary to carry out the functions related to BIM roles and uses. On the other hand, keeping in mind that bigger companies come with a much bigger workload and that a project’s complexity is directly proportional to the complexity of its tasks it may be beneficial to include BIM specialists to ensure success. In these cases, thanks to the scenario, and even though the functions and capabilities needed to execute BIM roles and uses haven’t changed, it is wise to include experienced professionals because of the added cost and impact of mistakes and misunderstandings. In conclusion, for an intricate sector such as construction and the evolving nature of BIM, there is no general rule of thumb as to when is it acceptable to train the current workforce to undertake BIM roles and perform BIM uses or when is it wiser to bring on board new specialized professionals. Each project and company is unique and consequently the decision requires specific analysis keeping in mind the size and complexity of the company and project in question.
References


Hughes, W., & Murdoch, J. (2001). Roles in construction projects: Analysis & Terminology. JCT.


Mäki, T., & Kerosuo, H. (2015). Site managers’ daily work and the uses of building information


