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Construction Site Communication Study Using the RAM Management System for BIM Adaptation

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ABSTRACT

The UK's construction industry is witnessing an annual increase in costs due to a lack of communication between the different organizational operators on the construction site that often leads to construction defects. Meanwhile, a cost-reduction strategy plan using BIM has become a fundamental requirement for the government, aiming to keep costs under control. To facilitate BIM adoption in the industry, the BIM strategy was introduced in four phases, with each stage entailing a number of criteria. The industry has seen a global reaction to the Level 2 BIM program and a significant cost saving of 840M in 2013/14 in Europe. However, the industry is unable to match the level 3 BIM, where a collaborative model file server is required as a common sharable platform to achieve efficient communication. This study contributes toward formulating a communication framework in the UK industry to understand communication issues and manage defects. A survey was targeted at construction industry practitioners and academics, with a total number of 328 participants.

KEYWORDS

Building Information Modelling, Communication Tool, Communication Tool Assignment Matrix, Organization Breakdown Structure, Responsibility Assignment Matrix, Work Breakdown Structure

INTRODUCTION

The construction industry is considered to be a key sector of the UK economy. 57% of construction budgets is wasted or becomes non-added value, as estimated by the Construction Institution (McNell, 2008). Over 20 billion per year in the UK is wasted on construction defects, much of which is caused by communication failure between the organizations operating on the construction site (Ernest, 2004). The government started a BIM implementation strategy that consists of 4 levels. In 2016, level 2 BIM compliance became compulsory in the public sector. This step has led to strong collaboration between the government and the industry to reduce costs further. BIM implementation has shown that an additional global 804M was achieved in 2013/14 in France (compulsory in 2017), Germany (compulsory in 2020) and other EU nations, as recorded by the Cabinet Office (Modelling & Plan, 2015).

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The majority of communication tools used on-site display building information as 2D drawings, (e.g. plans, sections, site plans) which unfortunately often proves to be ineffective and can lead to construction errors, as only experienced and well-trained organizational personnel are able to use them to communicate effectively on construction sites (Wang, 2006). However, the upcoming BIM level 3 raises the complexity level, requiring the integration of a multidisciplinary model using a web based environment in a centralized server instead of local servers. However, a similar system of a web based environment BIM server model has not been proposed until now (Gu & London, 2010).

Building construction is a complex set of tasks that involves a number of different parties and many activities that need to be organized to perform together at the same time. Regardless of the project size, construction companies find it beyond their capabilities to perform all construction activities without interacting with a number of organizations, including architects, engineers, consultants, contractors, clients, etc. In addition, a wide range of data needs to be dealt with, ranging from architectural data, structure systems, mechanical services and other factors, that increases the complexity even further (Steel et al., 2009).

Typically, 2D drawings and other types of documents are the most commonly used medium for communicating and sharing information on construction sites. Because of construction's need for frequent information updates, companies try to find a solution to improving communications with other departments, such as using software tools to define the design model details. Although software tools do help companies to organize and manage complex data, designs are still frequently rendered as 2D drawings when they need to be communicated to other collaborators on-site (Howard & Penttilä, 2006).

2D drawings are essential for any project to succeed as a communication tool. Their importance is not only in helping to describe the design project, but they can also serve as information records to identify miscommunications easily in the case of a design issue or construction defect occurring on-site. 3D models are often used to provide additional information compared to the 2D versions. In the case of architecture and design practices, 3D models tend to be used to share knowledge, such as about the building materials employed on the building façade, to create a virtual affect and so convince the clients about the design. In contrast, these types of materials were intentionally selected for presentation purposes only and were not meant for construction site use (Steel et al., 2009).

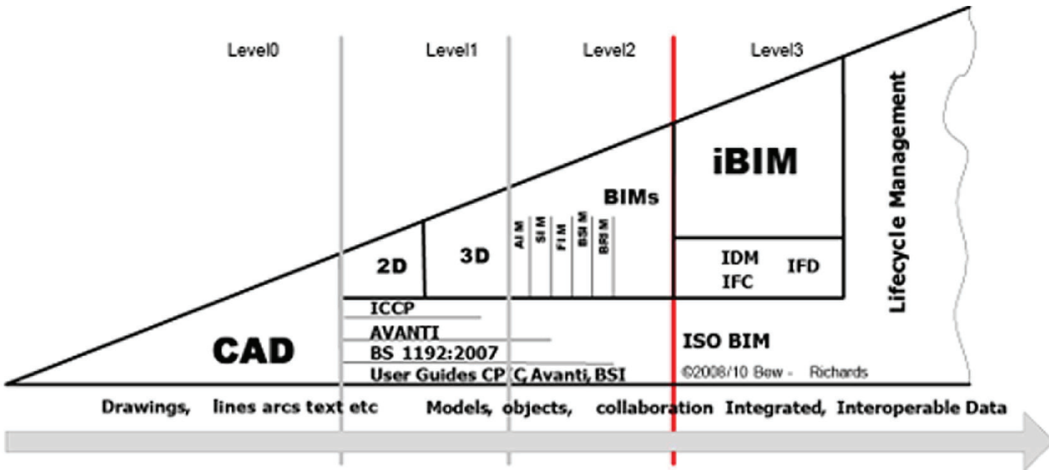
Communicating information in this complex environment, such as architectural materials, can easily lead to miscommunication if this information is used on-site. The only solution is to perform multiple data inspections to ensure that the right information has been delivered to the correct place (Steel et al., 2009).

Building Information Modelling Current Status

The UK construction industry is facing an overlapping issue, characterized by the project specifications, project nature, project life duration and unavailability of standardization in the product process. All of these challenges have made the industry more competitive than ever before, as well as lowering the profits to a minimum and raising costs (Charalambous et al., 2013). To adapt to all of these challenges, a BIM implementation model has been developed by the UK Department of Business Innovations and Skills (BIS), defined in four different levels, starting from level 0 up to level 3, to facilitate BIM adaptation in the construction sector. Building information modeling is a methodology for interdependent networks to manage the essential building data in a digital format throughout the project lifecycle (Howard & Penttilä, 2006). As an emerging management tool, it is considered to be useful for increasing efficiency, as lower costs improve collaboration in the design and process (CITB 2014). However, based on recent studies (People et al., 2012), it has been found that 64% of construction companies are still at level 1 of BIM implementation, with the exception of a few companies such as Arup that are experiencing the advantages of level 2 (Figure 1).

The introduction of BIM level 2 in 2016 addresses the above issues. A significant realization of BIM's value has started to emerge and a BIM framework adaptation has become a necessity for

Figure 1. BIM implementation strategy



all construction companies (McNell, 2008). However, the main changes are yet to appear with the introduction of BIM level 3. As an extended strategy plan, level 3 is expected to change the industry, requiring the re-planning of the construction process and the mindset within the industry itself. The biggest challenge associated with implementing BIM level 3 is the use of a collaborative model server and an online collaborative platform to operate the central model (Modelling & Plan, 2015).

Construction Site Communication Limitations

The communication limitations on construction sites are due to two factors. The first factor is related to the formal and informal organization of the construction process' communication tools, with formal communication such as 2D drawings and written data, and informal information support such as BIM and 3D laser scans (Giel et al., 2010).

The second factor is related to the personnel themselves, where the human factor plays a major role and effective teamwork is required to facilitate the construction process. The failure to maintain this connection causes stakeholders to lose interest in improving communication, or could lead to recrimination between the organization's members, which would cause a loss of trust and communication restrictions, resulting in even more defects and further costs (Hoezen et al., 2006).

The impact of these two factors can be seen clearly in some cases of construction defects. In addition, construction defects can be caused by the use of inappropriate communication tools or by a lack of communication within the groups themselves (Hoezen et al., 2006).

For these reasons, it is important to establish a clear communication framework study that addresses the communication practices' weaknesses in order to assign communication responsibilities in terms of the communication tools, construction phases and organization team members involved on the construction site. This will contribute toward improving the communication, as each collaborator will use the appropriate communication tool to exchange information.

As communication is important for the design phase and the construction site as well, the extended use of BIM at the construction site is recommended to improve the communication between different stockholders, which will help to reduce the construction defects and costs as a result. The strategy of adopting BIM for the construction site requires substantial changes to be made to the existing communication practices. While part of the team integrates BIM into the early design stage, other team members who perform the actual work in the construction phase are unable to benefit from BIM (Tobergte & Curtis, 2013). Crucial information updates are not being communicated effectively, as the use of active data is considered to be a luxury on the construction site. Instead, teams operating on-site have to use conventional 2D drawings to communicate and to understand the complex construction tasks (Hooper-Greenhill, 1999).

Therefore, the research aims to develop the existing Responsibility Assignment Matrix (RAM), which is a project management tool used to define who is responsible for the individual work formed in a matrix table (Nevison & John, 2013), by assigning the appropriate communication tools to the on-site personnel, while addressing these research questions:

1. What are the most effective communication tools used on construction sites?
2. Which grouping personnel/stakeholders are the most active on-site in terms of communication?

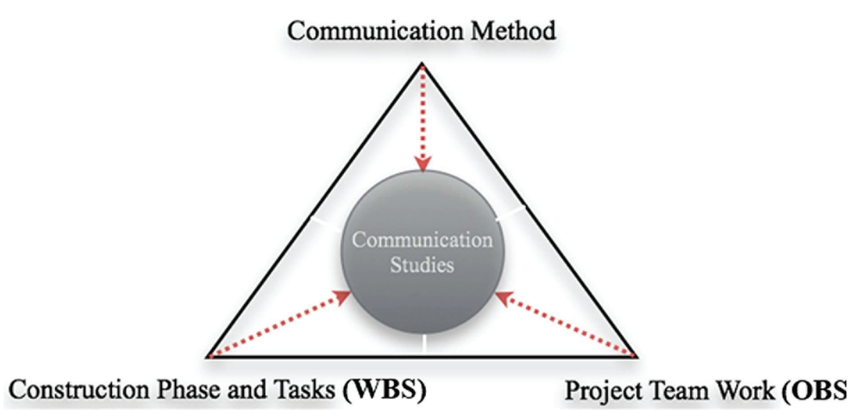
Answering these two questions generally will result to a better understanding of how the communication works on construction site, mostly for all types of construction projects in the UK. To the study under control, the study will discuss the communication on the construction site only, and not the information translation from BIM to another format.

Research Method

The study uses a Responsibility Assignment Matrix (RAM), which is a project management tool (Carstens et al., 2013). It starts by identifying the project's tasks and phases, and then deciding the personnel groups who will carry out the work. These are identified by a system called Work Breakdown Structure or WBS (Brotherton et al., 2008). On the other hand, Organization Breakdown Structure or OBS will help to identify the personnel groups involved on a construction site (Kanabar, 2013). Crossing these two data outputs (Figure 2), the WBS with the OBS, will result in the Responsibility Assignment Matrix or RAM (Energy, 2003). The WBS is responsible for demonstrating how the project components are related and helps to schedule the different construction processes (Devi & Reddy 2012). The OBS, on the other hand, aims to identify the working groups or personnel groups involved in construction operations. Both WBS and OBS are used as input information for the Responsibility Assignment Matrix (RAM), that will be called the Communication Tool Assignment 2 or CTA2 framework in this research. This will represent the communication tool used by all personnel groups in the construction phases throughout the project life-cycle. As a result, the framework will help to improve communication, as every single detail is important.

In order to obtain data on the WBS and OBS, the study uses a qualitative survey that was distributed in the UK among 328 participants who are considered to be involved either in construction

Figure 2. Communication studies diagram



industry practice or in academia. The study managed to receive 48 responses that helped in building the communication framework.

Adapting the Work Breakdown Structure (WBS) for the Communication Study Framework

Construction management uses WBS to break down projects into a number of individual phases. Each phase can be subdivided into small tasks. All of these subdivisions and phases are related and connected together to achieve the final project (Brotherton et al., 2008). This system will help to simplify and facilitate the planning for different interrelated construction phases (Figure 3). Since the study is intended to be implemented for all types of construction projects in the UK, the study had to identify common construction phases across the industry. As a result, a number of construction phases have been selected, namely: Site Preparations, Foundation, Structure, Building Envelop, Interior Construction, Doors/Windows Installation, Electrical Installation, HVAC system, Building Services Installation and Finishing and decoration, respectively (Khalil & Abdul, 2006).

Adapting Organization Breakdown Structure (OBS) for the Communication Framework Study

The second stage after using the WBS is to use the OBS to develop knowledge of a communication framework in relation to the personnel groups operating at the construction site (Golany & Avraham, 2001). The organizations' selection has to fit a wider range of construction projects in the UK. The research will use OBS to identify the personnel or organizational groups who will be carrying out the construction tasks identified earlier in the WBS (Figure 4). This information is important for understanding and organizing the communication structure as well as highlighting any areas for possible improvement (Cpm, 2006).

Figure 3. The work breakdown structure

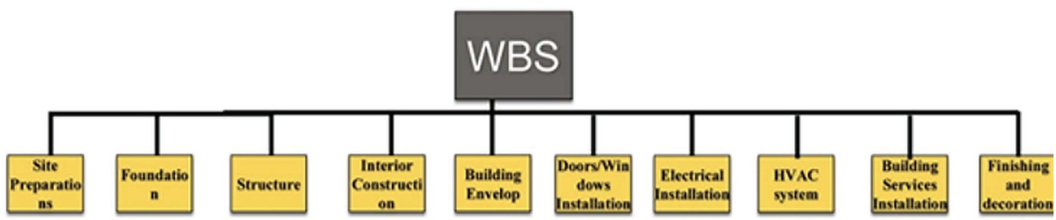
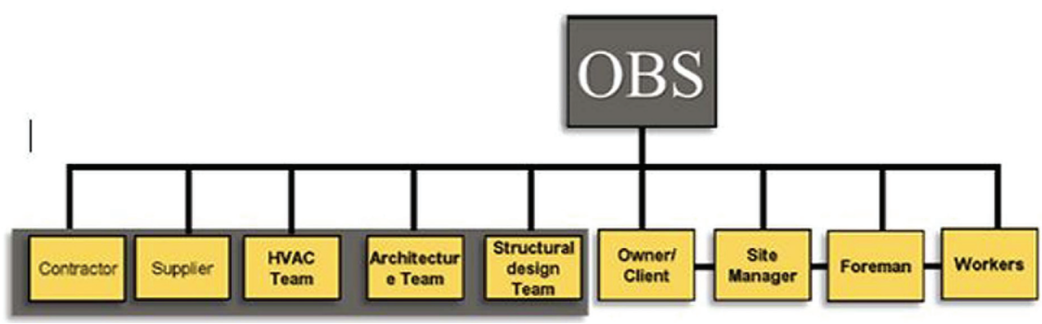


Figure 4. The organizational breakdown structure



The study identified nine main working groups on the construction site, since the research is focused on teams operating on construction sites only. These groups are as follows: Client/Owner, Design Team, Structural Design Team, HVAC Team, Task Manager/Foreman, Architecture, Site Manager, Workers and Project Manager (Khalil & Abdul, 2006).

Communication Tool Assignment Matrix

A RAM is a matrix table that lists both the WBS tasks and OBS groups (Nevison & John, 2013). The research used a modified RAM framework to meet the construction communication study's needs. In this study, the RAM was used to assign communication tools for the personnel groups operating on-site. In this context, it will be called the Communication Tool Assignment Matrix (CTA2). Generally, project managers use RAM to ensure that the construction phases identified by the WBS have the correct organization group from the OBS to assign the communication tool to it. For this reason, the RAM matrix is used to assign the communication tool to the right organization groups (Golany & Shtub, 2001). The RAM in this study and in this context, will help us to understand where to use each communication tool, which group needs to be supported and how to improve collaboration on the construction site.

RESEARCH FINDINGS

Communication Framework Structure

The chart was created to populate two parts of the data per cell. Each cell was divided horizontally into two parts. The upper part accommodates data from the communication tool used in practice, while the lower part is for the recommended communication tool that helps to improve communication (Figure 5). For research purposes, three types of communication tools were selected for the upper part of the cells, including communication by 2D drawings, on-site meetings and the use of text documents. The lower part, in contrast, has two additional types of communication tools: direct instructions and phone calls.

Communication Tool Assignment Matrix Modifications

As a contribution to the study, the participants suggested modifying some aspects of the framework. This can be summarized into two points: the communication responsibilities of sharing and the addition of other types of organizations. In response to the first point, the study Had to choose one of two different options in order to build up the organizational structure. The first option was the horizontal organizational structure whereas the second option was the vertical organizational structure. From the survey data, the study will be following the experts' recommendation as they suggested that client should be involved with the construction site themselves and they need to communicate with others on-site instead of being isolated. That basically means to select the first type of structure of the horizontal organizational structure as seen in Figure 6. In addition, the second request made by the participants was to add another two organizations to the study including the organization of the contractors and suppliers.

The resulting communication framework, seen in Figure 7, will be used to identify the appropriate medium to facilitate the communication during the construction phase. The following charts illustrates the communication medium used by organizations in relation to each construction phase. Figure 7, is to show the overall communication framework in the final format. However, the data density was an issue and another method of data presentation is required. To solve this issue and to facilitate the use of the communication framework, the study has divided the Figure 7 into four different sections, each comes with a key plan as it shown in Figure 8, Figure 9, Figure 10, Figure 11.

Figure 5. How the chart merges the two phases' data into one chart

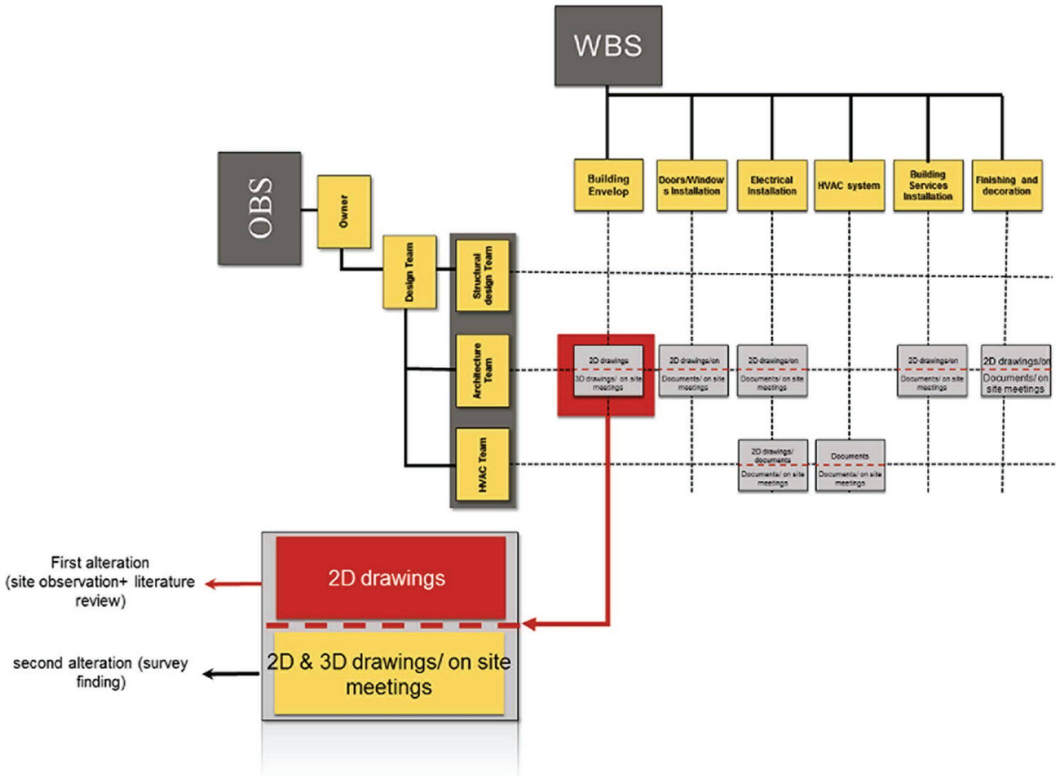
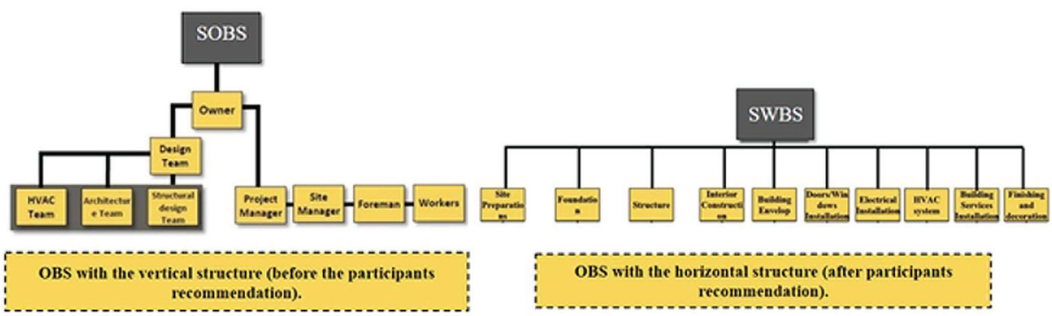


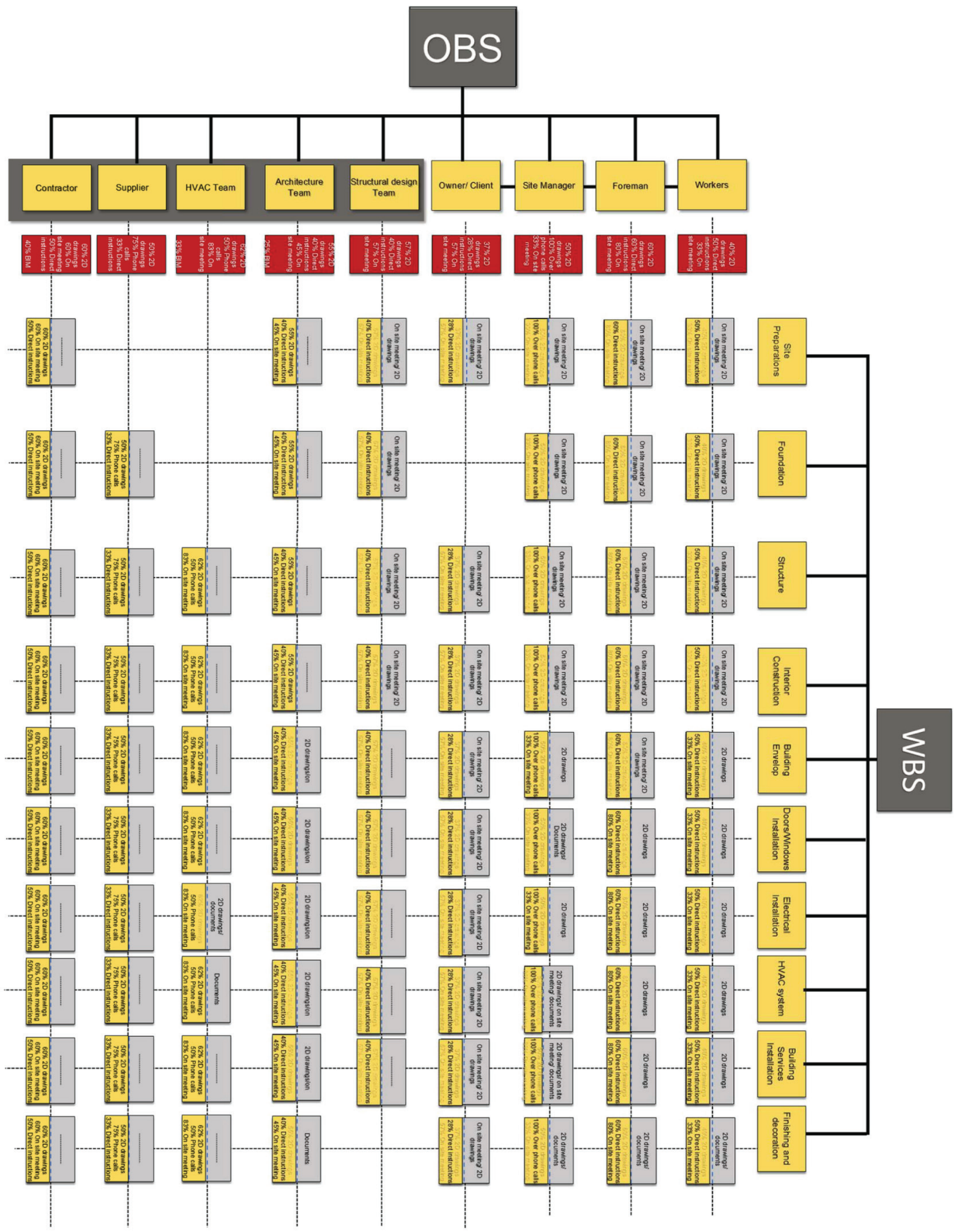
Figure 6. Organization comparison between horizontal and vertical structure



Usage of the Communication Framework

To use the framework, users must first select the organization they would like to know what type of communication tool they use as listed in Figure 4. Second, users again need to identify the construction phase they want to know the communication tool used on by the selected organization. They need to move to Figure 3 to select the corresponded construction phase. Third, is to intersect the column of the selected organization with the row of the construction phase. Finlay, the intersection function will result to a single cell of data showing the type of communication tool used by the selected organization in relation to the construction phase Figure 7, Figure 8, Figure 9, Figure 10, Figure 11.

Figure 7. The CTA showing the communication types used by each organization on each construction phase



CTA: Communication Tool Assignment Matrix Findings

Based on the number of communication tools used throughout the 10 construction phases, 2D drawings score the highest rate of usage of 86% compared to the other types of communication. On-site meetings came in the second place, with 75%. In contrast, using written documents appeared to be the least effective communication tool and its usage was limited to the usage of suppliers and site managers in specific phases such as the decoration and finishing phases. On the other hand, suppliers have shown the highest rate of ability in using the different types of the communication tools. Apart from

Figure 8. Section 1 of the communication framework

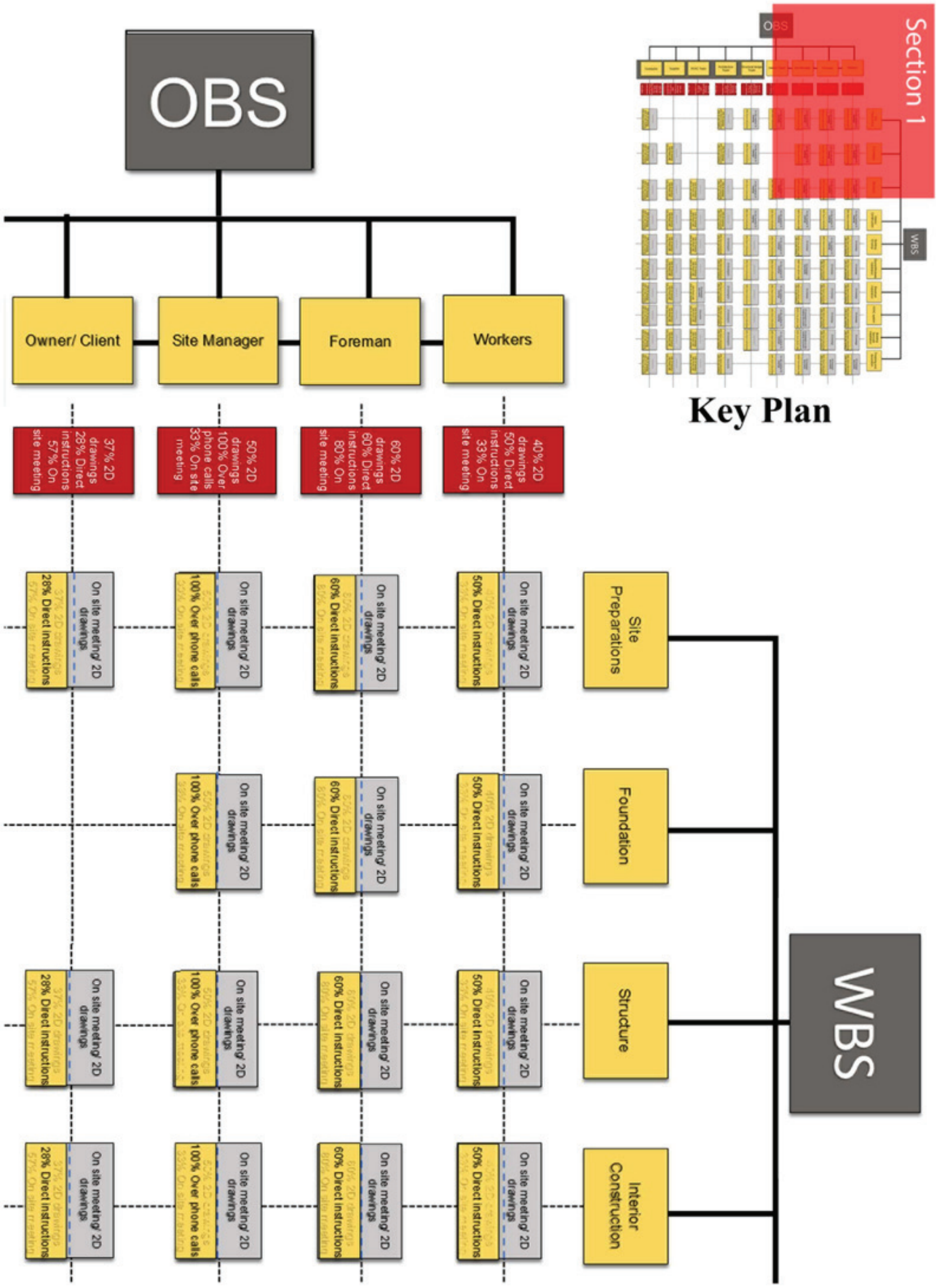
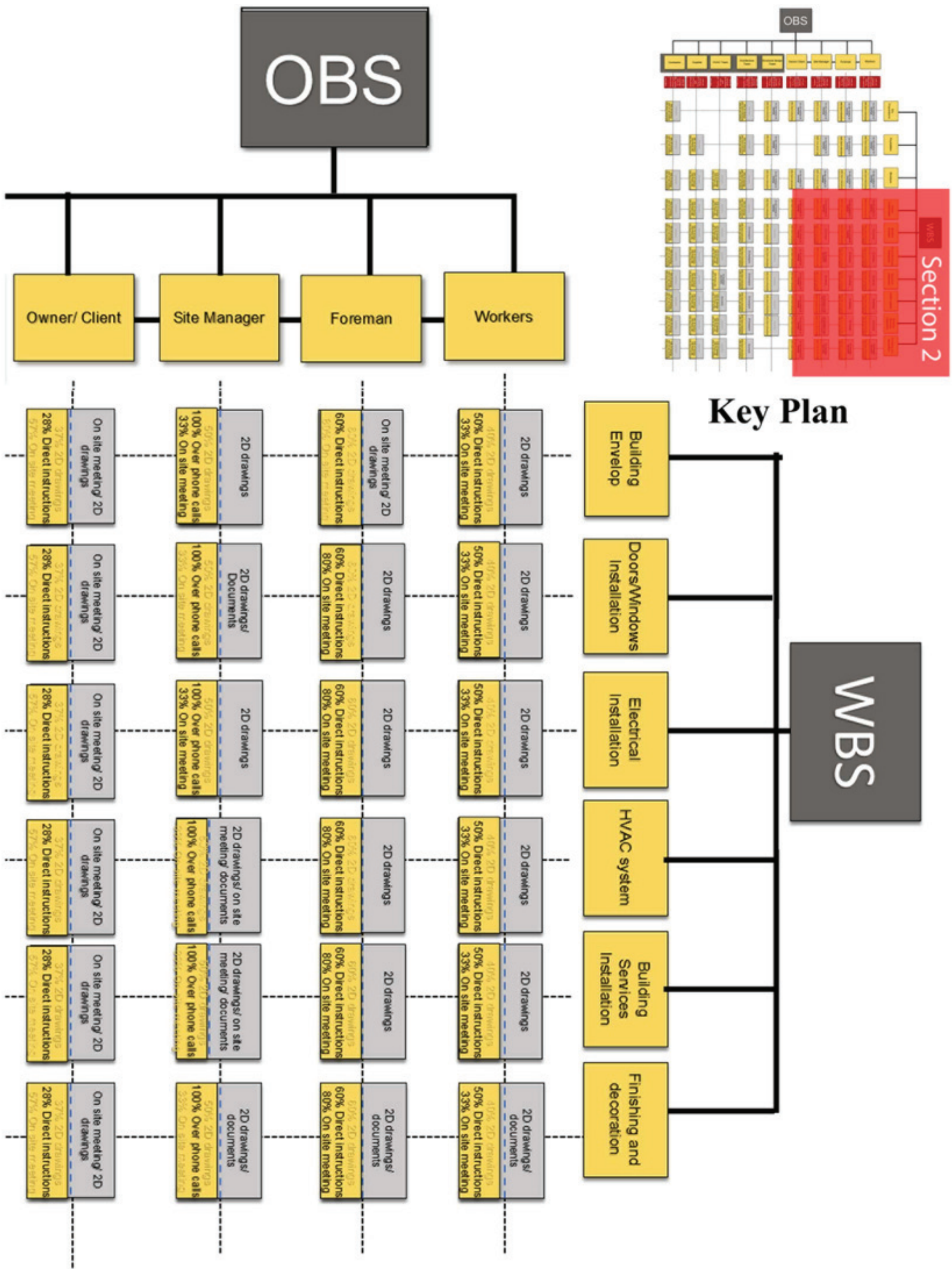


Figure 9. Section 2 of the communication framework

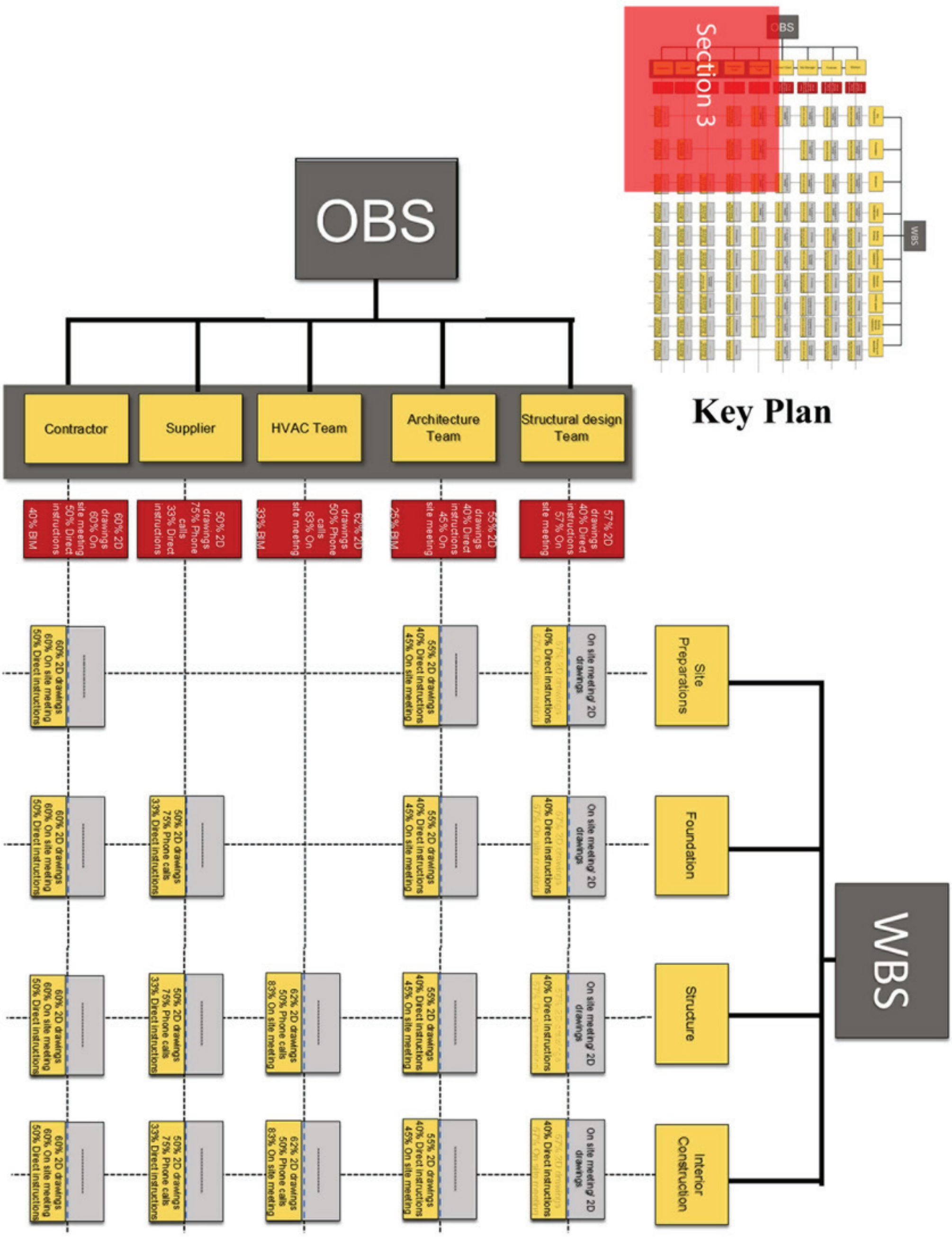


the tool of on-site meeting, supplier have used all types of the communication tools with different percentages (Figure 12).

CONCLUSION

The study was formed to answer two major questions. Identifying the most active organizations on-site, and knowing the communication tools used on construction site. Resulting to a communication

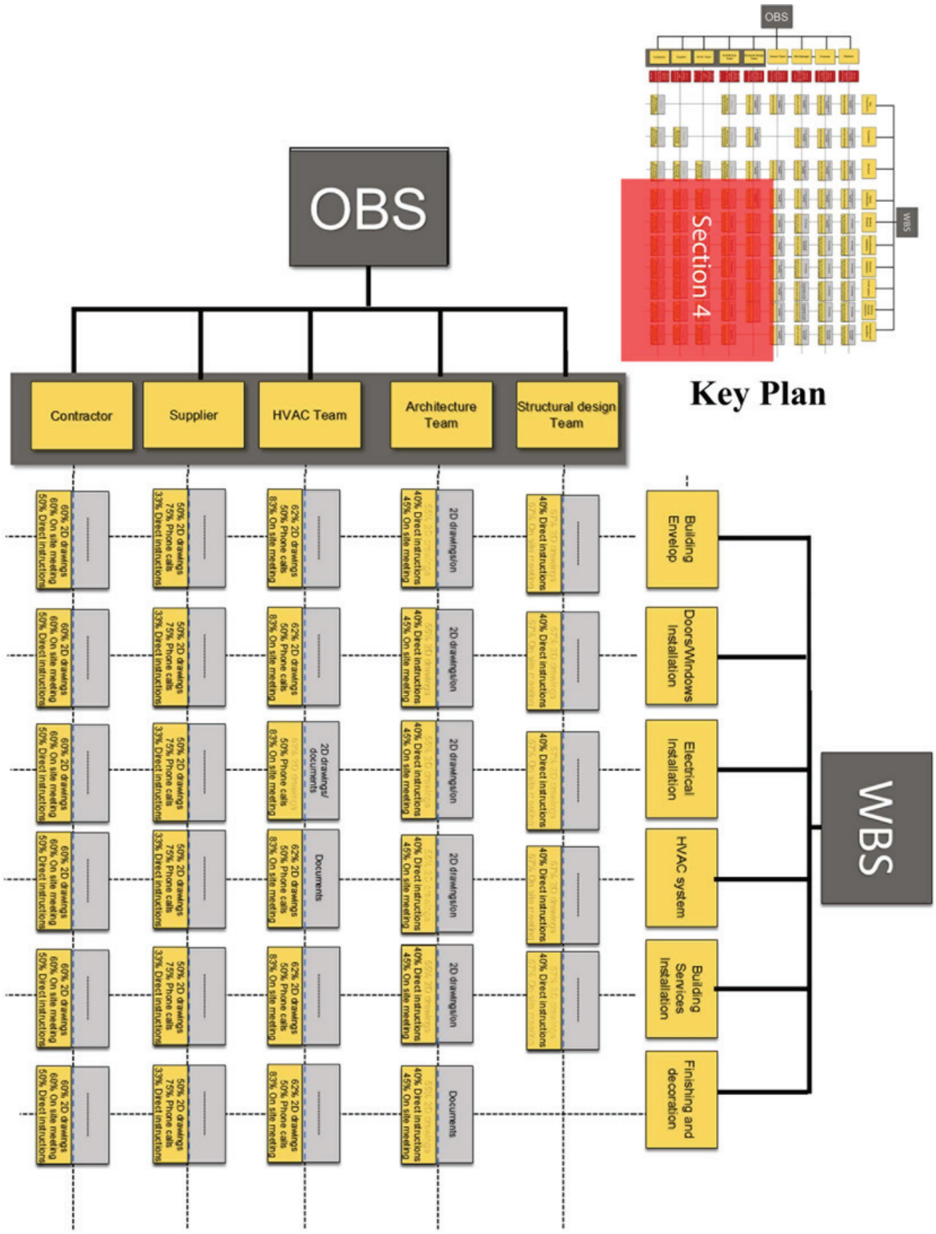
Figure 10. Section 3 of the communication framework



framework describing the communication on the construction site that can be implemented for all type of construction projects in the UK.

In relation to organizations' involvement in construction site communication, it was determined that suppliers are the most active organization on-site. They used all types of communication tool available, except for the tool of conducting meetings on-site. The study shows that suppliers are better adapted to communicating through text documents, giving workers direct instructions and

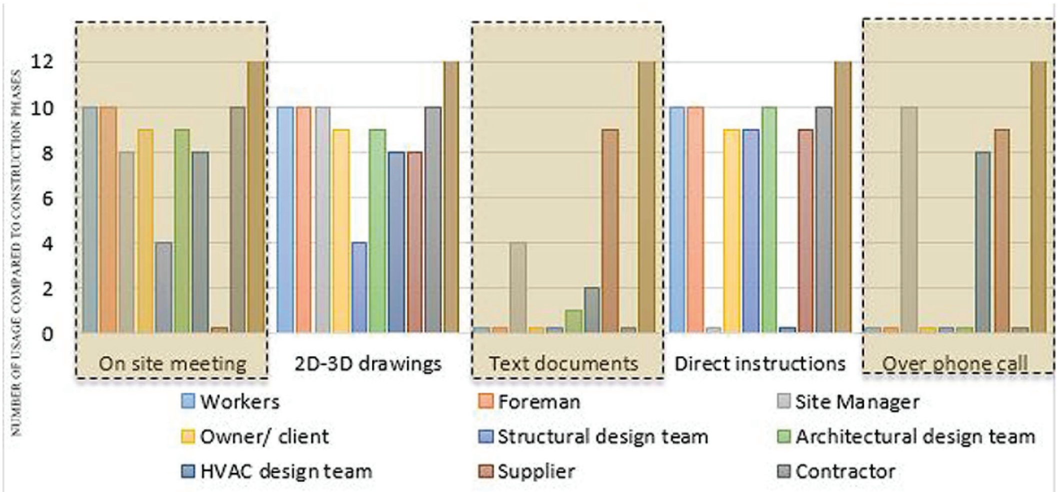
Figure 11. Section 4 of the communication framework



communicating by phone, without being present on-site. Their ability to communicate through 2D/3D drawings is lower than the other types of communication tools, but it still acceptable. Contractors and foreman groups came second, as both show an outstanding capability to communicate via 2D/3D drawings, on-site meetings and understanding direct instructions.

On the other hand, drawings, in 2D and 3D format, was the widely-used communication tool, as answering the second question. Most organizations employ this type of communication during some stages of the construction process to share data and communicate with other organizations. Structure designers are the group least likely to use the 2D/3D drawings, which could potentially limit their

Figure 12. The number of communication tools used to support on site construction inspection



ability to communicate and may lead to construction defects. A future recommendation would be to support the structural design team to them with additional communication tools in the future. However, that will rise numbers of question that need to be answered. First, which organization is better to support? Is it better to support the structural organization who have less ability of communication ability as the study has shown? How that may improve the communication overall? Or is it better to support the supplier organization? And will that improve the communication? Finally, is to compare the result of the two approaches.

A future research plan is to select the structure organization, as the lowest organization using 2D/3D drawings on-site, and support them with BIM. The study will examine the use of Augmented Reality (AR) to provide a direct access to BIM data for the structural organization and knowing how far the combination of BIM and AR may improve the communication on construction site.

REFERENCES

Brotherton, S. A., Fried, R. T., & Norman, E. S. (2008). Applying the Work Breakdown Structure to the Project Management Lifecycle. In *PMI Global Congress Proceedings*.

Carstens, D.S., Richardson, G.L. & Smith, R.B. (2013). Project Management Tools and Techniques - A Practical Guide.

Charalambous, G., Thorpe, T., Demian, P., Yeomans, S. G., Doughty, N., & Peters, C. (2013). Collaborative BIM in the cloud and the communication tools to support it. In *Proceedings of the 30th CIB W78 International Conference*.

CITB. (2014). Skills and Training in the Construction Industry 2014.

Cpm, I. G. (2006). *Project Management Guideline*. Project Planning Phase.

Devi, T. R., & Reddy, V. S. (2012). *Work Breakdown Structure of the Project*. International Journal of Engineering Research and Applications.

Energy, U. S. D. (2003). *Work breakdown structure. Project Management Practices*. Work Breakdown Structure.

Ernest, L. (2004). BRE guidance on construction site communication construction documentation Drawing s.

Giel, B., Issa, R. R. A., & Olbina, S. (2010). *Return on investment analysis of building information modeling in construction*. Computing in Civil and Building Engineering.

Golany, B. & Avraham, S. (2001). Introduction: Division of Between the Project Work Breakdown Structure and Types of Work Breakdown Structure.

Golany, B., & Shtub, A. (2001). Work Breakdown Structure. In Handbook of Industrial Engineering: Technology and Operations Management.

Gu, N., & London, K. (2010). Understanding and facilitating BIM adoption in the AEC industry. *Automation in Construction*, *19*(8), 988–999. doi:10.1016/j.autcon.2010.09.002

Hoezen, M.E.L., Reymen, I.M.M.J. & Dewulf, G.P.M.R. (2006). The problem of communication in construction.

Hooper-Greenhill, E. (1999). Communication in Theory and Practice. In The Educational Role of the Museum.

Howard, R. & Penttilä, H. (2006). Describing the Changes in Architectural Information Free-Form Architectural Expression.

Kanabar, V. (2013). Organizational structure Job Descriptions.

Khalil, M. & Abdul, B.I.N. (2006). Construction planning and scheduling.

McNell, D. (2008). *Building Information Modeling*. InfoComm.

Modelling, B.I. & Plan, S. (2015). Digital Built Britain Level 3 Building Information Modelling - Strategic Plan.

Nevison, J. & John, M. (2013). aWP_RespAssignmentMatrix.

Steel, J., Drogemuller, R. & Toth, B. (2009). Model Interoperability in Building Information Modelling.

Tobergte, D. R., & Curtis, S. (2013). A Framework for Integrating Change Management with Building Information Modeling. *Journal of Chemical Information and Modeling*.

Wang, X. (2006). Using Augmented Reality to Plan Virtual Construction Worksite. *Advanced Robotics*.

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