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BIM adoption and implementation within a mechanical contracting firm

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Abstract: This paper presents the preliminary findings of an on-going research project which aims to study the adoption and implementation of building information modeling (BIM) within a small or medium enterprise (SME) working in the Mechanical contracting field. The objectives of the research are to: document the BIM adoption and implementation process for a specialty contractor in the AEC industry; evaluate the impact of this transformational process within the organization and across it's project network; determine avenues of development for productivity gains using BIM and other IT tools. The paper focuses on three determinant axis of BIM deployment within a SME: (a.) Driving BIM adoption throughout the organization; (b.) Driving BIM implementation at the project network level from the organizational perspective, and.(c) assessment. The paper concludes by presenting and discussing a series of factors which have been identified as having an influence on the BIM adoption and implementation process at the speciality contractor level.

1 Introduction

The Architecture, Engineering and Construction (AEC) industry is characterized by the vast amount of Small or Medium Enterprises (SME) which form its supply chain. These SMEs work in various fields and disciplines and come together to create temporary project networks. They will interact throughout a project's lifecycle and exchange data, information and knowledge, with the common over-arching objective of delivering a product, meeting specific requirements commissioned by a client. Much has been said about the effectiveness and efficiency of this process, or lack thereof, and several avenues of research have been developed addressing the issues inherent to the AEC industry. Amidst these developments, the past decade has seen the emergence of Building Information Modeling (BIM), as a tool, a technology and a process, which is disrupting the current state of practice by pushing for the redefinition of interactions and processes throughout the industry. The aim of this paper is to present the preliminary findings of an on-going research project which is studying the BIM adoption and implementation process within a SME working in the mechanical contracting field. The paper focuses on three determinant axis of BIM deployment within a SME: (a) Driving BIM adoption throughout the organization; (b) Driving BIM implementation at the project network level from the organizational perspective and (c) performance assessment. An initial review of the literature indicates that these three axis, while being heavily interrelated, are often enquired into separately. It is found that in order to fully understand the BIM adoption and implementation process, these three axis must be considered together. This research project attempts to bridge this gap by studying the BIM adoption and implementation process from an organizational and project network perspective and assessing the process across these two axis. This study is unique in that it provides insight into the transformational process across the entire organizational supply chain, from office to field. Preliminary findings suggest that contextual and environmental factors will modulate the BIM adoption and implementation process by dictating offer and demand. Organizational factors, such as management support and user buy-in, will be determinant in the depth and breadth of this process. Assessing the impact of this transformation requires that project data collection strategies be formalized at the source. It has become apparent that strategic planning at the organizational level is key to the success of the BIM adoption and implementation process.

2 Motivation

2.1 Building Information Modeling

A Building Information Model is defined as "[...] a digital representation of physical and functional characteristics of a facility. As such it serves as a shared knowledge resource for information about a facility forming a reliable basis for decisions during its lifecycle from inception onward (NIST, 2007) "Building Information Modeling is defined as "[...] a technology and associated set of processes to produce, communicate, and analyze building models." (Eastman et al., 2011) BIM is thus conceptualized to be both a technology and a process, which enables the digital construction of a building, or prototyping, prior to its physical construction. "A basic premise of BIM is collaboration by different stakeholders at different phases of the lifecycle of a facility to insert, extract, update, or modify information in the BIM to support and reflect the roles of that stakeholder." (Eastman et al., 2011) While technology is driving the "BIM revolution", it alone is not sufficient to induce the re-configuration of practice within the AEC industry needed to fully harness the potential benefits of BIM (Mihindu and Arayici, 2008). This re-configuration must happen at multiple levels. Hence, organizations must re-configure their business practices in order to successfully implement BIM, while project networks must adapt and align their project delivery processes to maximise the benefits of these emerging tools and technologies. (Taylor and Bernstein, 2009).

Many enquiries into BIM adoption and implementation have been conducted over the past decade (eg. Bernstein and Pittman, 2004) These enquiries have determined barriers, benefits as well as factors which affect the adoption and implementation process from multiple perspectives. In addition, Some authors have looked into BIM implementation at specific stages, be it programming (Manning and Messner, 2008), design development (Ku et al., 2008) or construction documents (Leicht and Messner, 2008), while others have looked at the implementation process for specific actors within the project network. For example, Arayici et al. (2011) looked into the BIM adoption process within a SME working in the architecture domain. They determined inhibitors and strategies to facilitate the process. However, they did not delve into the effects of the BIM implementation process at the project network level. Kaner et al. (2008) looked into the BIM adoption and implementation process for 2 structural engineering firms designing with pre-cast concrete. The enquiry is at the organizational level and discusses the motivation and issues surrounding this process. While this paper offers great insight into the procedural ramifications of BIM adoption and implementation within engineering firms, the enquiry is limited to self-performed work of pre-cast concrete design and very little is discussed at the project network level. Staub-French and Khanzode (2007) provide a detailed approach to implementing both 3D and 4D modeling and coordination in a project network from a technological, organizational and procedural perspective. They go on to discuss the impact of this implementation on project performance and finally relate the benefits that come from the implementation of BIM in a project setting. However, the adoption process at the organizational level isn't discussed. Khanzode (2010) goes on to present his Integrated, Virtual Design and Construction and Lean (IVL) method for coordination of MEP systems. The author presents the results of 4 case studies where either Virtual Design and Construction (VDC) or Lean methods (or a combination of both) was implemented for MEP coordination. The results are compelling in that the author provides empirical evidence of the significant benefits to be found in both increased productivity and reduction of waste. Here again, the implementation process is discussed at the project network level and little is said about the implications of the adoption and implementation process at the organizational level.

It becomes possible to view a trend in the literature whereby, BIM adoption and implementation has been discussed either at the organizational level or at the project network level; the crucial interface between both has been sparsely documented. A notable exception is Dossick and Neff (2010) who discuss the effects of BIM implementation on collaboration within project networks, specifically at the MEP coordination level. The authors find that project team members are faced with conflicting obligations, to personal scope, to project, and to their organization, due to a tightly coupled technological environment, induced by the use of BIM, within a mis-aligned, badly structured (termed "loosely coupled") organizational environment. Hence, there is a need for a better alignment at the organizational level to overcome these issues of project network structure which can limit the effectiveness of BIM deployment with the project network. While this paper discusses the aforementioned issues, there is little attempt to enquire into how these issues could be resolved. It also focuses on a specific point in the supply chain, MEP coordination. The conclusions of this paper do point towards important factors to be taken into account at the BIM implementation stage. In essence, from an industry perspective, it can be recognized that BIM adoption and implementation has been largely carried out on an ad-hoc basis within organizations, relying on specific projects to further the process. It seems as though there is a lack of over-arching, strategic approach to BIM adoption and implementation within organizations which could possibly lead to sub-par performance.

2.2 Adoption and Implementation factors

As previously stated, many academic enquiries have been aimed at determining specific factors that drive or inhibit the adoption and implementation of BIM and on a larger scale IT in the AEC industry. Mitropoulos and Tatum (2000) identify four forces that drive innovation at the organizational level: competitive advantage, process problems, technological opportunity, and institutional requirements. The authors find that diffusion of innovation is a function of these four drivers rather than that of the technology itself. They also find that innovative behaviour is driven by industry conditions and organizational factors. Nikas et al. (2007) investigate drivers and antecedents that affect the adoption of collaboration technologies in the AEC industry. The authors make the distinction between drivers, internal, external factors and perceived benefits that drive the decision to adopt a new technology, and antecedents, the prerequisite resources required to adopt this new technology. While Nikas et al's enquiry was at the organizational level, Taylor (2007) identifies a series of antecedents that affect the implementation of 3D CAD at the project network level. In this enquiry, antecedants are regarded more as variables rather than pre-existing conditions. The author goes on to develop a framework for 3D CAD implementation in design and construction networks. This framework relates the antecedents previously identified within the interorganizational interfaces created by the project network. These are identified as the technology interface, the organizational interface, the work interface and the regulative interface. Change management is identified as an intraorganizational antecedant. Stewart et al. (2004) identify barriers and coping strategies to IT implementation within the Australian AEC industry. These barriers and coping strategies are identified at the industry level, organization level and at the project level. The main take-away from this study is the perceived top-down effect of these factors from the industry level to the project level, thereby confirming the importance of the environment on the diffusion of innovation. Finally, Lehtinen (2012) identifies seven structurally relevant factors in BIM implementation. These barriers are (1) management support, (2) coordination and control, (3) learning and experience, (4) technology management, (5) communication, (6) motivation and (7) defining roles. These factors are identified within the context of vertical integration and it's effect on diffusion of systemic innovation. They are relevant at multiple levels and scales of BIM adoption and implementation.

2.3 Performance measurement and assessment

The need for performance measurements is three-fold: First, measurement is required for consistent evaluation of performance. Second, measurement is required for improvement. Third, measurement is required for comparison to others in the same field (benchmarking) (Succar et al., 2012). In parallel, acquisition and diffusion of performance related data will make the "business case for BIM" and eliminate some uncertainty in light of the considerable investments required on the part of individual organizations to adopt and implement BIM. Furthermore, performance is closely related to maturity, ie. the maturity level of an organization or a project network will influence the performance of the project. There is therefore a need to measure and assess both maturity and project performance. However, the operationalization of performance measurement is still lacking a solid foundation. As reported by Sebastian and van Berlo (2010) the " (...) various existing BIM maturity assessment tools are not yet sufficiently 'mature' to serve as a standard benchmarking tool that is objective (i.e. perform qualitative and quantitative analyses), comprehensive (i.e. evaluates the model, modelling process and organization) and collective (i.e. commonly accepted in the construction industry)." (Sebastian and van Berlo, 2010) In other words, while data is being gathered on the use of BIM and the business case is being made, efforts to collect performance data are not uniform and replicable, ie. no acceptable model is universally accepted for the measurement of performance which may hinder objective data collection on a project scale. Typically, measurement is based on the 'three traditional indicators of performance' (Mohsini and

Davidson, 1992), which are Cost, Schedule and Quality. In addition, many authors have looked into measuring performance within BIM environments (eg. Suermann, 2009) Succar et al. (2012) propose 5 components for the measurement of BIM performance. Coates et al. (2010) and Kunz and Fischer (2012) propose several KPIs to evaluate the BIM implementation process. Finally, Khanzode et al. (2008) specified and used a series of metrics in their evaluation of the Camino Medical Healthcare project to further showcase the benefits of implementing VDC in a project setting. Thus, while BIM is being adopted on a massive scale, and benefits of its implementation are being felt and somewhat measured, there still lacks a tangible framework that aims to validate and assess the overall impact of the process at the project network and organizational level.

3 Research methodology

This research project is part of a larger, over-arching research project which involves three pilot projects where BIM has been adopted within different organizations and implemented within several project network. These pilot projects concern different actors within the project network and different stages in the project lifecycle. Thus, each pilot project sets out to document the BIM adoption and implementation process for a given point in the supply chain during the project lifecycle and assess how this process is affecting project outcome.

This particular project aims to study the BIM adoption and implementation process within a SME working in the mechanical contracting field. The project will study this process from both the organizational and project network perspective. The objectives of the research are the following:

- To document the BIM adoption and implementation process for a specialty contractor in the AEC industry from an organizational and project network perspective;
- To evaluate the impact of this transformational process within the organization and across it's project network;
- To determine avenues of development for productivity gains using BIM and other IT tools

The research subject is a Vancouver, BC based mechanical contractor specializing in the commercial and institutional construction sectors (hereby called the firm). Founded in 2004, the focus of the firm has been design/build and design/assist projects in the Greater Vancouver area. The firm is made up of 50 employees, of whom 13 are office personnel (project managers, coordinators, estimators as well as administrative staff) and 37 are site personnel (superintendents, foremen, journeymen). Since their foundation, they have completed over 50 projects ranging from $100k to $12M.

The research project employs a mixed-method longitudinal approach divided into 4 distinct stages much akin to the action-research process. These stages are: (1) Benchmarking the current state of the organization, (2) Defining the desired state and metrics to evaluate the BIM implementation process and its impact, (3) Deployment and documenting of the BIM implementation process, and (4) Data analysis and feedback. Qualitative data has been collected through semi-structured interviews, in-situ observations, participation in project meetings and intra-firm meetings and through informal discussions. The interviews took place over the period of a week where top management personnel as well as project managers and the BIM manager were interviewed. Interviews lasted between 1h00 and 1h30 and were directed at gaining insight into the functioning of the firm, the BIM adoption process and how the firm was going about with the transition towards BIM. Follow-up interviews are scheduled in the near future to discuss and document the evolution of the BIM implementation process. Quantitative data such as cost data, time sheets, models, plans and other project specific documents were supplied by the firm. This data was analyzed to review the quantitative impact on productivity. Validation is being ensured through triangulation of multiple data sources across project settings. Moreover, specific performance metrics for impact assessment have been determined and are being measured across multiple projects to ensure generalizability of findings.

4 Driving BIM adoption throughout the organization

The initial decision to transition towards BIM came from the two founding principals of the firm. Seeing

BIM as a way to “get ahead of the curve” and “gain a distinct competitive advantage over other mechanical contractors” the firm decided to invest in these new technologies. Along with a project manager for the firm, the top management founded a committee to study the adoption and implementation of BIM technologies and processes. The committee set clear objectives and goals and dictated the deployment plan. Strategically speaking, the adoption of BIM fit into the overall desire to streamline the self-performed work of the firm as well as create interference models with which they could coordinate their sub-trades and fabricators. This over-arching strategy considered three key elements: (1) Increase visibility and market-share within the mechanical contracting domain (2) Focus on design-build and design-assist type projects and (3) increase quality and productivity through modeling and pre-fabrication.

Prior to the adoption of BIM, the only drafting that was performed by the firm was weld maps and the occasional as-built drawings at construction close-out. Therefore no drafting or modeling infrastructure really existed within the firm which means that no standards, library, etc. were in place. The firm was embarking on this endeavour with a blank slate when it comes to creating digital media. A hardware infrastructure was already in place within the office and the personnel were mainly trained on project management software. It is important to note, that due to the relatively small size of the firm, there was no IT department to rely upon and that the committee relied on employees initiatives. The move to BIM prompted the firm to hire a BIM manager that would look into the overall BIM implementation process as well as the strategic turn towards IT. It is the BIM manager who was mandated to perform the evaluation of different BIM software and make recommendations. This decision was a pivotal one due to subsequent issues with software choice such as training, interoperability and suitability. After more than a year of evaluation, the firm made a decision of implementing a specific software platform (hereby the modeling software) as the firm standard. In order to overcome the severe limitations of the modeling software in respect to fabrication level detailing, a second piece of software (hereby the detailing software) was introduced in late 2012. This software platform is geared towards fabrication and contains a 3rd party library of elements, which is managed externally. The introduction of a second piece of BIM software does introduce its set of issues, such as limited interoperability with the modeling software and introducing and/or reconfiguring workflows. Naturally, the issues with hiring and training personnel capable of working with these tools also represent a major hurdle in the implementation of this piece of software.

In terms of personnel and training, the firm’s short and mid term goals are to train two to three more project managers/coordinators on the modeling and detailing software platforms. In terms of field personnel, the aim of the firm is to educate and inform their personnel on the essence of BIM, the possibilities it introduces and the way it will affect their work. Thus, while field personnel are not being trained to use the modeling/computer based tools, they are being informed on what the technology and the shift in processes means for them. The interviewees stated that as a whole, the firm has displayed enthusiasm at the prospect of working with BIM and being a leader in that field. The firm has been reinforcing their commitment to BIM and attempting to maintain enthusiasm and buy-in from all of their personnel by involving them in the overall adoption process. However, as the firm moves towards other avenues such as pre-fabrication and use of robotic stations and tablets, the adoption process will shift from the office to the field. Again, the strategy is to implement these technologies on a small scale and slowly train the personnel to use them. The main issue though will be to determine who will be trained and at what time.

5 Driving BIM implementation throughout the project life-cycle

The BIM implementation process is an evolutionary one whereby capabilities are incrementally developed as projects move forward and new technologies or tools are introduced. The firm uses each project as “triggers” to develop a skill set, implement a new technology or process or invest in other capabilities in parallel to BIM, such as pre-fabrication or laser scanning. See table 1 for an outline of BIM implementation process through project execution. The main issue with this project-based implementation is to maintain the alignment between the expectations towards BIM, the intent with the process and it’s execution. Setting a clear vision in line with an over-arching organizational strategy is seen as paramount for a successful implementation process. The project based evolution was set along two concurrent project streams: Project stream #1: District energy projects including fabrication and installation of Energy Transfer Stations (ETS) and Project stream #2: Traditional building mechanical systems including HVAC, fire protection, plumbing, etc.

Table 1 – Outline of BIM implementation process through project

		Description of BIM deployment	Capability evolution	Barriers	Benefits
Project #1	**Large institutional district energy project**	- Modeled 8 Energy Transfer Stations - Clash detection with existing mechanical elements within rooms - Intuitively established the first version communication protocole between the field and the office for fabrication drawings	-Developed modeling capabilities -Developed laser scanning capabilities -Developed some on-site "pre-fabrication" capabilities	- Pilot project - No previous in-house modeling capability - Traditional D-B-B project so little interaction with design professionals	- Minimized loss due to upstream conflict resolution - Rapid resolution of issues due to easy visualization - Project "would of almost been impossible without BIM" (2506201201)
Project #2	**2 storey wood-frame institutional (health-care) building**	- Used BIM to model all areas with most potential for conflict (shafts, ceiling spaces, etc.) - Decided to model all building services (HVAC, Fire Protection, Plumbing, Electrical, etc.) to perform clash detection - Design-Build role	- Personnel now more capable with BIM tools - Communication of layout, assemblies and sequences to other disciplines for coordination - Model lacking meta-data, used primarily for visualization purposes	- BIM deployed in a lonely setting - Contractual set-up not geared towards collaborative work and use of BIM - Coordination issues with design professionals, notably Architects due to entrenched ideals - Not all specialty contractors on board with the use of BIM	- Allows the firm more leadership in the project network - Deployment of BIM in a design-build role = more input at the design stage - Proved beyond a doubt that certain structural elements had to be redisigned for the mechanical systems to work prior to construction
Project #3	**Medium size municipal district energy project**	-Modeling 4 Energy Transfer Stations - Communcation protocol to get information to field is being refined	- Building on experience acquired during Project #1 - Pre-fabrication capabilities are being streamlined - Developing an expertise in the field - Experimenting with tablets in the field	- Traditional D-B-B project so little interaction with design professionals	- Modeling and fabrication of Energy Transfer Stations is becoming streamlined - Publicized benefits of BIM starting to be obtained
Project #4	**Renovation of a large commercial building**	- First deployment of BIM in a collaborative setting - Design-Assist role - Use BIM to model all areas with most potential for conflict (shafts, ceiling spaces, etc.)	- Acquireing laser scanner and further developping laser scanning cpabilities - Building on the expertise of project #2 - Developping capacity to collaborate through BIM within project network - Implementing Robotic Stations and Tablets in the field	- Need to hire additional staff who have to be trained - Lack of experience in a collabortive setting - Need to align standards with others in the project network	- Benefits expected to align with publicized benefits (fewer RFIs, better cost control, high quality work, etc.)

5.1 Project stream #1: District energy projects including fabrication and installation of Energy Transfer Stations (ETS)

Project stream #1 consists in the fabrication, installation and retrofit of district energy systems. Most of this work is done within existing buildings and has to contend with very limited space. While this is a

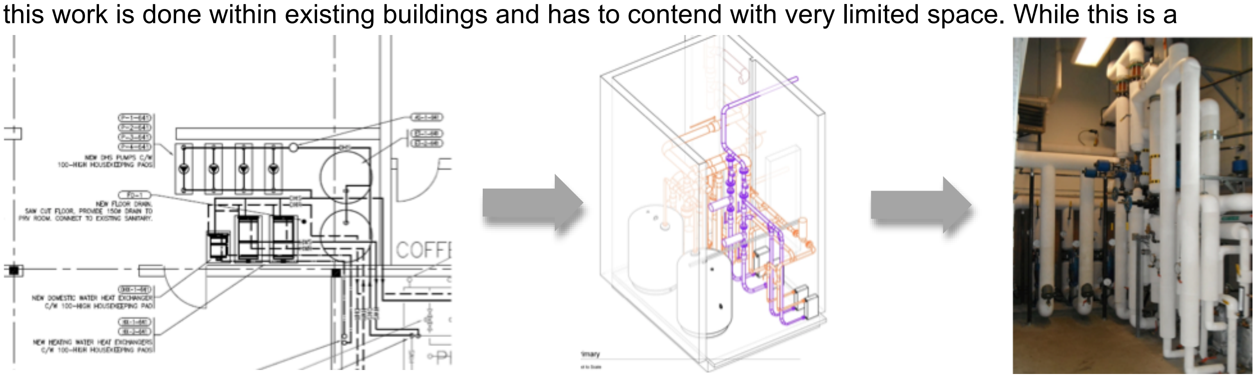

Fig. 1 – From 2D to reality

challenge, this also offers the opportunity to perform a laser scan of the space and model the ETS and the pipe runs prior to fabrication and installation, thus greatly reducing rework in the field. To date, the firm has been creating the models from 2D contractual drawings submitted by the consulting firms (fig. 1), and inserting and validating them within the scanned model (fig. 2). The firm are currently implementing the detailing software within this stream in order to pre-fabricate most of the elements off-site.

The firm often acts as prime contractor in this stream which offers a distinct advantage in that it has much more control on the whole construction process. In addition, the type of project lends itself to a 'lonely' setting, whereas the amount of information and modeling required is limited to the work performed by the firm which requires more adjustment at the organizational level than at the project network level. The most important adjustment is ensuring that the information produced in the office get to the field and distributed to the field workers in an efficient manner. Where traditionally, the site foreman would have dissected and dispatched the various pieces of the contractual drawings to specific workers through face-to-face discussion and the use of hand sketches, now the information is being produced in the office. The project team thus have to establish a communication protocol through which plans are analyzed, models built and validated and finally documentation produced and distributed.

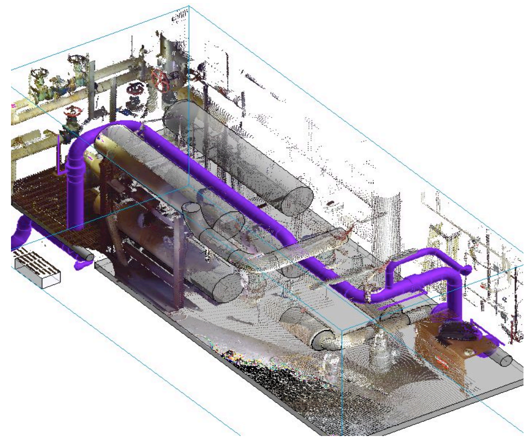

Fig. 2 – Design validation though laser scanning

5.2 Project stream #2: Traditional building mechanical systems

Project stream #2 consists in the traditional project execution at the mechanical contractor level. Typically under the responsibility of the firm in this type of project setting are the sheet metal contractor, the fire protection contractor, pipe insulation and refrigeration contractor while plumbing, HVAC piping and equipment installation are self-performed work. This project stream will be procured through various routes, mainly traditional design-bid-build and design-assist/design-build. To date, the firm has experienced little involvement from the project network at the modeling level. Project coordination is still done through 2D drawings, with the exception of certain consultant firms who have produced the odd BIM model.

The major difficulty faced in this project setting is the general reluctance by project teams to move towards BIM. The firm thus has to work in a lonely setting, developing their own model and holding all their sub-contractors accountable to that model. This is possible due to the contractual set-up with these sub-contractors. However, the firm has also modeled elements which are outside their scope of work, such as cable trays. During project #2, when presented with the model, the electrical contractor refused to comply with the installation strategy set-forth by the firm which caused serious problems as ceiling space was at a premium for this project. The lack of control over other disciplines could be viewed as a lack of contractual control and/or a basic lack of good faith. Even through a more integrative delivery method, there are still no provisions in the contract that prevented siloed work and individualistic attitudes. In the case of project #2, while BIM was beneficial to a certain extent, it is possible to see that the contractual considerations were not providing the necessary environment for collaboration.

In terms of benefits for both project streams, constructability review, design validation and visualization are the most prominent. For example, in project #2, ceiling space was at a premium, so much so that once the initial model was created by the firm, they noticed that many services indicated in the 2D drawings produced by the consultants would simply not fit. Therefore, they had to redesign certain elements and when that did not work out, they ultimately asked the design team to consider modifying certain non-mechanical elements to suit. The design team, presented with the irrefutable visual evidence that the current structure and mechanical scheme could not work together, re-designed the problematic areas to offer the clearance required. This was done during the design stage and was possible due to the firm's modeling effort as well as their involvement at the design stage. The impact of this is difficult to quantify, but needless to say, had the issue not been raised during the design stage, the entire project could have been compromised. Another unquantifiable benefit revealed by this project is the added influence of the firm within the project team. By taking leadership of the project, the firm has offered increased value to the client as well as to the general contractor by mitigating costly issues upstream. For SMEs, being able to offer a quality service and product is indispensable for continued success.

6 Discussion

Throughout this research project, several factors have been identified as having an impact on the organizational BIM adoption and implementation process. While many factors align themselves with those discussed previously (eg. Mitropulos and Tatum, 2000; Lehtinen, 2012) others have emerged which are specific to the reality of the sub-contractor.

Management support and User buy-in

The firm's management played an integral part in the successful adoption of BIM through total support of the process. It was thus easier for the personnel involved to identify and allocate the necessary resources for the adoption and implementation process as there was tremendous buy-in from the decision makers. The vision for BIM within the firm came from them and was broadcasted to the firm's employees. There was a clear message throughout the firm that BIM was the way forward. In contrast, top management delegated alot of the decision making to the personnel that would be using BIM, notably choosing the software packages and exploring other avenues such as robotic stations and laser scanning. This has for effect that users are empowered and integrated into the overall BIM deployment process.

Context will modulate the rate of diffusion

The business context has largely influenced the rate of BIM implementation within the firm. The role of the firm in the supply chain dictates that they have little influence on the formation of the project network which will influence the deployment of BIM. In parallel, the procurement method will have the same effect. To date, the firm has only been capable of deploying BIM in a 'lonely' setting where all modeling work was performed in-house, limiting the potential impact of BIM. While the firm is actively seeking projects which will deploy a more collaborative BIM setting, there seems to be an overall lack of such projects being commissioned either because clients and owners are going the more traditional route or because of legal and procurement barriers that hinder the flow of information across the supply chain (ie. projects being designed in BIM but being tendered in 2D, paper–based sets). Therefore, the possibility of furthering the BIM implementation process has been limited by the actual opportunity to implement BIM, which leads to the "triggered" implementation process.

Agility is key

Business agility is becoming synonymous with diffusion of innovation (eg. Baskerville et al., 2005). The organization's preparedness to deploy BIM will be influenced by the personnel that is available at the required time, their level of expertise and their capacity to execute the project requirements. Therefore the organization must demonstrate incredible agility to navigate and choose which projects to get involved in and to what extent, least they become overwhelmed and cannot meet demand. To date, the firm has not been faced with this challenge due to a restrained demand for BIM, however, in the near future, and with the firm's growing expertise and reputation, this question of preparedness and agility will become an issue.

Getting BIM to the Field: Modifying work and information flows

At the forefront of the procedural ramifications of BIM implementation for a speciality contractor is the redefinition of information and workflows between office and field personnel. As previously stated, project execution was traditionally resolved in the field leading to the know inadequacies of the AEC industry. The introduction of BIM has shifted this execution and resolution to the office. While information is now becoming much more precise and reliable, the expertise of the field workers is lacking in the resolution process. Therefore a communication protocol to transfer and diffuse information is a must in order to encourage some feedback flows between the office personnel and the field personnel, notably the BIM coordinator and the site foremen. In order to put this protocol in place, there must be a clear understanding of what information is needed downstream and how the information must be presented. The firm is developing this protocol through experimentation, however a more formal approach would undoubtedly yield better results.

Coordination and control

Lehtinen (2012) discusses the pros and cons of vertical integration (VI) on the factors influencing BIM implementation, namely coordination and control of the process. He determines that a distinct advantage of VI is the easier management of changing liability and contractual issues whereby a vertically integrated firm will have no need to negotiate contracts for the work it performs itself. It will also offer more stable relationships. While in the case of a mechanical contractor, vertical integration of the entire supply chain pertaining to its scope of work (ie, design and construction of mechanical systems) is a possibility, for SMEs it may be a far-fetched reality. However, it would be interesting to look into the level of integration which could be achieved reasonably such as including either the electrical scope of work or offering consulting services. An alternative to this is to review the contractual set-ups between speciality contractors to address the issues of authority and responsibility.

Measuring performance

The assessment process is characterized by the need for a rigorous data collection method. Clear and consistent metrics must be targeted with a particular understanding of what the analysis of the collected data will yield. The firm has a history of tracking cost components and maintaining a cost database which is used for estimating. A centralized project management software has been implemented, which can create detailed reports of a variety of information pertaining to specific data sets. The firm thus displays the foundations upon which to build an efficient benchmarking and performance assessment process. While it is still on-going, certain recommendations can be made in order to facilitate the process. First, like any implementation effort, there must be support from the top management and buy-in from the users. The goals and objective of this performance measurement must be communicated to all the employees in order to ensure their buy-in, as the collection of data will be performed by them. Secondly, the correct data must be captured. Issues like vague cost codes and time sheets, incorrect data entry, etc. must be addressed by modifying what is captured and how it is captured. Lastly, as illustrated by the projects studied, the targeted metrics can vary in their degree of subjectivity along a scale whose poles range from perceived impacts defined through qualitative metrics to measured impact defined through quantitative metrics. The depth and breadth of data collection will also vary due to the targeted level of evaluation. At the project level, the breadth of data collection will be more substantial as many data points will be collected at a unique point in time (or over a short period). On the other hand, at the organizational level, data collection will happen over a longer period of time for a chosen number of metrics. Across this scale, the method in which data is collected will vary from more anecdotal evidence through feedback and perceptions to hard evidence from precise data points collected through various means such as time sheets, project logs and cost reports. Regardless of the type of metric used, it’s evaluation can be useful to further the business case for BIM throughout the firm, which can help in anchoring buy-in for BIM.

7 Conclusion

This paper has presented the preliminary results of an on-going research project aimed at studying the adoption and implementation of BIM within a SME working in the mechanical contracting field. This study distinguishes itself due to the fact that it looks into the impact of the implementation process at both the organizational level and at the project network level from the perspective of a speciality contractor in the AEC industry. As this research project is on-going, data is still being collected, however, initial analysis points towards a series of factors that will impact the adoption and implementation process. Several of these factors reflect findings covered in other works while others have been sparsely reported on. Further work will be done to refine these factors and a round of follow up interviews is slated in order to validate some of the findings. Also, additional work is set to be done on formalizing the performance measurement piece and implementing it in a real-world setting. Findings will be reported in a follow-up paper.

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