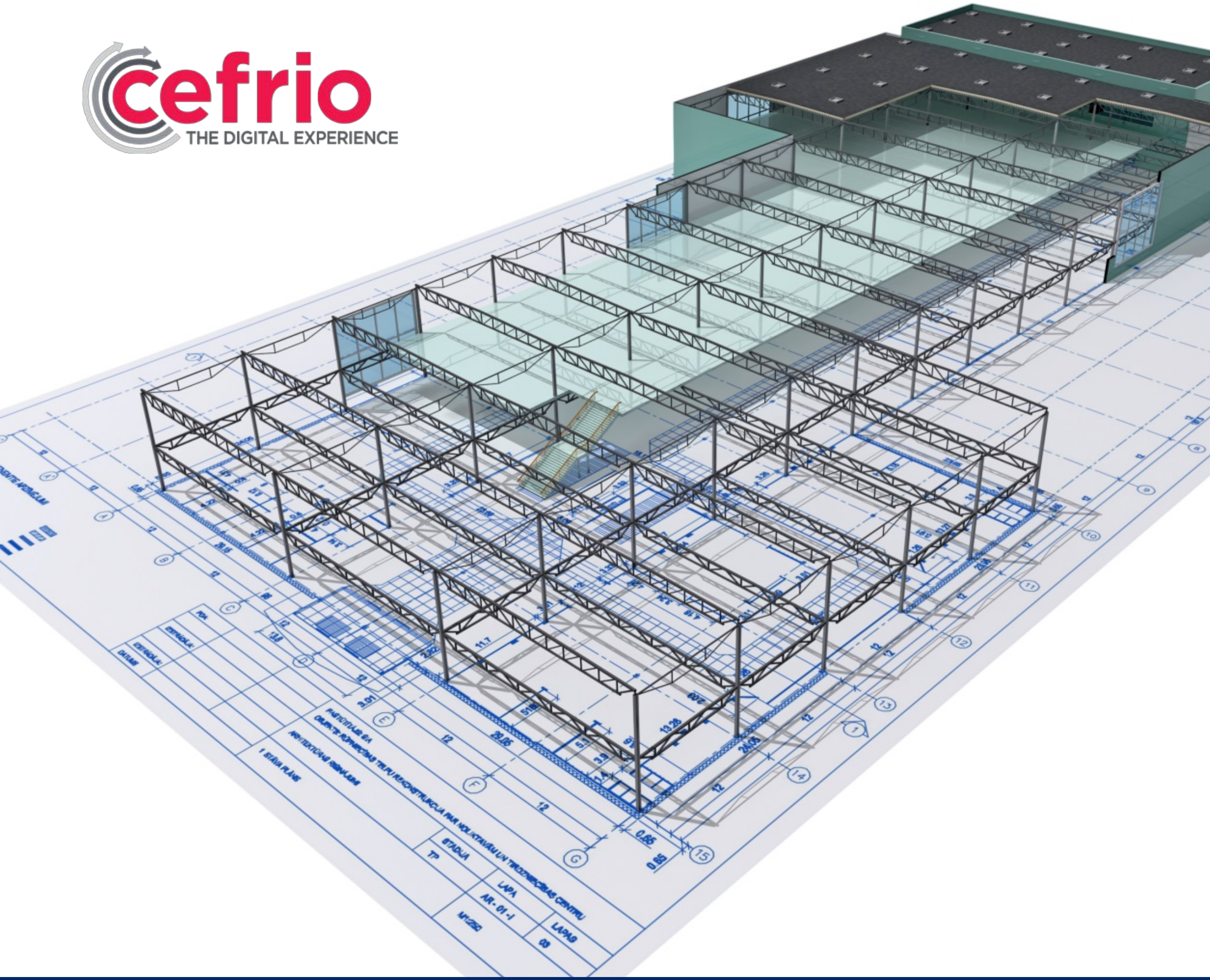

THE INEVITABLE SHIFT TOWARDS BUILDING INFORMATION MODELLING (BIM) IN CANADA'S CONSTRUCTION SECTOR: A THREE-PROJECT SUMMARY

RESEARCH SUMMARY & HIGHLIGHTS

WITH THE PARTICIPATION OF

Conseil national de recherches Canada
National Research Council Canada

Programme d'aide à la recherche industrielle
Industrial Research Assistance Program

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SUMMARY

This report presents the culmination of a multi-phased research project undertaken in 2011, which set out to determine avenues to improve the efficiency and productivity of the Canadian construction industry through the use of Information Technologies (IT), namely **Building Information Modeling (BIM)**. More specifically, this report presents the findings of the fourth and final phase of this research project, which focused on the operationalization of three pilot projects (two in Quebec, and one in British Columbia) that were identified to cover different angles of BIM integration with a focus on improving productivity of Small or Medium Enterprises (SMEs) in the Canadian construction industry.

In addition, the project supported the launch of a larger program of experimentation to validate and generalize frameworks and guidelines for use by SMEs looking to integrate BIM within their organizations. In parallel, the aim was to mobilize various actors in the industry and educate them on the importance and advantages of these new technologies and how they can help in maintaining their competiveness in a changing market.

The general research goals and objectives were to:

> Develop a framework for the adoption and implementation of BIM within an SME in the Architecture, Engineering and Construction (AEC) sector;

> Establish benchmarks for the BIM adoption and implementation process;

> Establish productivity measures for the company to evaluate the effectiveness of these tools and processes.

Lastly, throughout the projects risk management was a core issue. Although there are tools and guidelines available to help large AEC firms integrate BIM, the margin for error is much smaller for SMEs, given that they do not have the financial and human resources found in larger firms to manage the large-scale BIM integration process. The development of BIM frameworks and guidelines tailored to the needs of SMEs should therefore remain a concern for NRC-IRAP.

5 MAIN RESEARCH FINDINGS

1. SMEs do not have the luxury that large firms have in terms of financial margins and dedicated IT departments for BIM implementation. Therefore, it is even more important for SMEs to be deliberate and thorough in developing an organizational strategy to implement BIM.

2. It is critical for all firms getting started with BIM to develop a BIM implementation strategy using a top-down and bottom-up approach so that management and field personnel are equally committed and empowered, and to ensure that the short-term and long-term goals, implementation plan, and resource requirements are developed with full input from all necessary personnel;

3. The SMEs studied reported many benefits from BIM including, increased opportunity to offer additional services and added value to clients; increased quality of communication and information flow; and increased visualization, coordination and validation capabilities.

4. The SMEs studied also reported many challenges, including procurement modes that limit supply chain integration; the low maturity of some project team members; the difficulty in assessing and evaluating the impact of the BIM adoption and implementation.

5. Certain aspects of BIM implementation may be easier for smaller firms (fewer than 50 employees), which can be more nimble in making the necessary organizational changes required when compared to larger firms that have to deal with a more rigid functional structure.

A BIM implantation guide for SMES has been developed based on the research findings and can be found on page 14.

RESEARCH CONTEXT

RESEARCH STRUCTURE

This research project comprised four phases:

1. BIM-related technologies were identified as the most promising avenues for the improvement of productivity in the construction industry based on a thorough review of the literature.

2. Interviews were conducted with early adopters (clients, design professionals and contractors) of IT and BIM, first to discover possible gaps between existing practices and the literature, second to identify directions of emerging practices in the Canadian industry, third to assess discrepancies in the level of BIM adoption between the Canadian and American industries, and finally to articulate pilot projects that may help to address these gaps.

3. The experimental program was developed to study BIM adoption within the industry. Three pilot projects were identified to cover different aspects of BIM for improving productivity in construction. Two were conducted in Quebec, and one in British Columbia.

4. The three pilot projects identified during phase III were carried out.

Research activities conducted as part of the first three phases allowed researchers to:

> Highlight and validate BIM tools and technologies that are seen as being the most promising in terms of improving the productivity of the construction industry;

> Establish gaps between existing practices and those proposed in the literature on the use of BIM technologies in the construction industry;

> Determine emerging practices in the Canadian construction industry, such as Integrated Supply Chain (ISC), Integrated Project Delivery (IPD), and Lean Construction. Combining these practices with BIM can offer the best context of its use. These approaches encourage collaboration, integration, and full use information technologies.

> Determine the extent of use of innovative technologies other than BIM (mobile computing, document management, etc).

> Evaluate the gaps of different stakeholders in terms of BIM adoption between the Canadian and U.S. industries;

> Define the objectives of work and BIM dimensions that will be selected for the experimentation program;

> Define roles, responsibilities and commitments of partners and developers of each experimentation field;

> Develop a protocol for the three pilot projects; this included establishing processes, budgets, and timing; roles and governance; and deliverables.

THREE EXPERIMENTATION PROJECTS

Pilot Project I

Project objective:

To study BIM implementation in the field by a property developer.

Project description:

This experimentation project studied BIM adoption and implementation for a multi-residential property developer on a specific construction project. The breakthroughs concerning information and communication technologies (ICTs) were minor in this sector, which is mainly comprised of SMEs. The contractor was approached because of his specialization in developing and marketing a new building erection technology, the "Upbrella construction system."

Pilot Project II

Project objective:

To study BIM adoption and implementation within an architecture firm that specializes in high-energy performance projects.

Project description:

This experimentation project compared a project that integrated BIM with a project delivered in the traditional fashion. The firm chosen looked to BIM as a collaborative inter-disciplinary platform and saw it as an opportunity to stand out from its competitors by improving the precision of construction documents, thereby possibly reducing its operating costs.

Pilot Project III

Project objective:

To study BIM adoption and implementation within a speciality contracting firm.

Project description:

This experimentation project studied the BIM adoption and implementation process within a mechanical contracting firm. The resulting organizational changes in terms of both internal functioning and interaction with the project's supply chain were observed and documented. The impact of BIM on project performance was also studied.

OVERVIEW OF CANADIAN SMES

The Canadian Architecture, Engineering and Construction (AEC) industry is characterized by the vast amount of SMEs, which form its supply chain. These SMEs, working in various fields and disciplines, come together to create temporary project teams and form the backbone of the Canadian construction industry. In effect, of the 128,650 employers in the construction industry alone, 99.9% of those are considered SMEs (less than 500 employees) with the majority of firms (60.5%) counting less than 5 employees[1]. While past research has set out to enquire and explain this phenomenon, noting the challenges and the benefits of such a reality, it remains that SMEs in the Canadian construction sector have to contend with increasing pressure from multiple sources, such as increasing global competition and internal economic pressures.

A study by Industry Canada has found that between 2002 and 2011, labour productivity for the Canadian construction sector has decreased 0.7% per year on average, while labor productivity for the Canadian Economy has increased 1.7% per year over the same period[2]. The most recent statistics from Industry Canada indicate that between 2008 and 2012, labor productivity for the Construction sector has increased 2.7% per year on average, while labor productivity for the Canadian Economy has increased 1.2% per year[3]. While this latest statistic is promising, it remains that SMEs in the Canadian construction industry are faced with multiple challenges that, if not properly addressed, can pose a serious threat to their existence. Therefore, there is a need for these SMEs to find ways to further increase their productivity, offer value added services, and set themselves apart from the competition in order to strive and contribute to the Canadian economy.

BIM: A FACTOR OF INNOVATION

The term 'Building Information Modeling (BIM)' has come to mean different things to different people. We view BIM as both a product and a process. We define BIM in a way that is consistent with the National BIM Standard (NBIMS), which defines a Building Information Model 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 life-cycle from inception onward." (NIBS 2007)*

BIM can also be defined as a process – the process of Building Information Modeling. From this perspective, BIM can be defined as:

> *"a new approach to design, construction, and facility management...BIM is not a thing or a type of software but a human activity that ultimately involves broad process changes in construction." (BIM Handbook – Eastman et. al., 2008)*

> *"a process focused on the development, use and transfer of a digital information model of a building project to improve the design, construction and operations of a project or portfolio of facilities." (PSU Computer Integrated Construction Program 2010)*

BIM provides a shared representation of the facility design that facilitates collaboration and information sharing across the various project stakeholders, i.e., architects, engineers, contractors, managers, and owners.

However, BIM technologies are also seen as disruptive, i.e., technological innovations which are dramatically transforming the ways in which AEC activities are carried out. Specifically, certain tasks are being eliminated while others are appearing, distribution of work is being reviewed, and roles and responsibilities are changing. Therefore, SMEs looking to adopt and implement these technologies have to modify their current practices and redefine their workflows to suit the new realities imposed by BIM and take full advantage of their potential for adding value to the project delivery process. In addition, each individual organization evolving within the AEC industry will be impacted in varying ways, in function of their position, role and responsibility within the industry's supply chain. Thus, the nature and extent of this reconfiguration will depend highly on the firm's position within the project supply chain.

[1] Industry Canada (CIS), Establishments Construction, (Consulted 05 March 2014) https://www.ic.gc.ca/app/scr/sbms/sbb/cis/establishments.html?code=23&lang=eng

[2] Industry Canada (CIS), Labour Productivity Construction, (Consulted 20 August 2012) http://www.ic.gc.ca/cis-sic/cis-sic.nsf/IDE/cis-sic23proe.html (page no longer available)

[3] Industry Canada (CIS), Labour Productivity Construction, (Consulted 05 March 2014) https://www.ic.gc.ca/app/scr/sbms/sbb/cis/labourProductivity.html?code=23&lang=eng

THE CANADIAN CONSTRUCTION SECTOR'S SLOW RATE OF BIM ADOPTION

During Phases I and II of the research project, important gaps were observed between the Canadian and American construction industries. The main gap noted was that the overall level of use of BIM tools on projects was systematically lower in the Canadian industry than in the American industry. Other gaps noted pertained to the actual use of BIM tools, such as analysis, and the level of training of employees. Gaps were also observed between companies operating locally and on an international scale. These gaps can be explained by the fact that since 2007, BIM has been a requirement for most American public projects. The core issue in Canada is the fact that the majority of clients, public agencies in particular, with the exception of Infrastructure Alberta, are reluctant to require the use of BIM. This is seen as a serious barrier to BIM adoption, as confirmed by the survey conducted in Phase II with early adopters and innovators in the Canadian construction industry. The following highlights some of these barriers that were noted in the survey carried out back in 2011[4].

- Individuals are resistant to change;
- The limited use of BIM across the project life-cycle, which negates the value of BIM.
- Professionals are still working in silos, and there is a lack of communication and coordination between disciplines;
- Market demand of BIM plays a major role in its adoption and implementation within an organization. To date, clients are not seeing the advantages and benefits of BIM and therefor are not requiring it;
- There are some misunderstandings about what BIM is – a technology, a process, or a specific piece of software. This lack of clarity makes it more difficult to establish BIM protocols and processes, and use it integrated way.
- Inexperienced firms pose a major obstacle to full BIM implementation within the project team;
- Implementation problems: insufficient methods, uneven training quality and allotted time;
- Delays in training qualified staff;
- Organizations are having difficulty justifying training costs since the use of BIM is not being required consistently across projects, and personnel often have to be retrained. ;

Testimonials

"[…] the client often does not see the added value. He says 'I pay more for nothing.' […]." (Manufacturer, pg. 61)

"[…] The best way for a technology to be accepted is when the client imposes it, because that is not negotiable. The client has an important role to play here, because if it is based on a voluntary basis, it will be much more difficult than if it is imposed by the client." (IT Director, pg.22-23)

"[…] The owner did not see the value because they knew that it might cost them more money, as an added service, because that is probably how it was presented to the designers. So they said no, we do not want it." (Contractor, pg.61)

"It is the lack of personnel who have BIM experience... That is the biggest problem… […]." (Architect, pg 59)

Source: Forgues, Daniel and Sheryl Staub-French. (2011). *Improving Efficiency and Productivity in the Construction Sector Through the Use of Information Technologies.*

[4] Forgues, Daniel and Sheryl Staub-French. *Improving Efficiency and Productivity in the Construction Sector Through the Use of Information Technologies,* September 2011, pp. 45-46, 53-54.

SUMMARY OF KEY FINDINGS AND LESSONS LEARNED

The intent for aligning three distinct pilot projects was to widen the scope of enquiry to include a substantial portion of the project supply chain. This allowed a more considerable depth of enquiry at the organizational level while maintaining a project supply chain perspective. The common denominator in all three projects was the fact that all three subjects were SMEs, with less than 50 employees, who were looking into adopting and implementing BIM.

From these projects, significant observations were made, some which were highly contextual and others which were very similar across the pilot projects. The key findings below represent the observations made throughout the research project and their relationship to the findings, which stood out across all three pilot projects.

KEY BENEFITS TO BIM ADOPTION AND IMPLEMENTATION

Highlights

While the benefits of BIM adoption and implementation accrued by each SME were highly contextual and specific to their role in the project supply chain, some benefits are consistent across all three perspectives:

- Increased opportunity to offer additional services and added value to clients;
- Increased quality of communication and information flow;
- Increased visualization, coordination and validation capabilities.
- BIM is a considerable Marketing tool for SMEs, BIM adoption increases the opportunities of an SMEs selection for a given project.

The specific benefits of each experimentation project were also identified.

BIM facilitated the following benefits for the property developer (Pilot Project I):

- The development of a clash detection process of three consecutive phases: pre-detection “modeling”; detection “selecting and management”; post-detection “following and updating resources and knowledge”;
- The demonstration of communication and coordination problems in the management of projects in the residential construction sector and how New Information and Communication Technologies (NICTs) can help resolve them;
- The development of productivity measures and processes for production control, which have been based on “Lean Construction” approach to optimize the workflows.

BIM facilitated the following benefits for the architecture-engineering firm (Pilot Project II):

- Increased the value proposition for potential clients;
- Optimized the inter-disciplinary workflows within the organization leading to increased synergy between these disciplines.
- Improved the design processes through continuous feedback loops between operations and design (design for operation).
- Identified the shared critical path between disciplines in order to facilitate technical coordination during design development.

BIM facilitated the following benefits for the specialty contractor (Pilot Project III):

- Used as a marketing tool which resulted in an increase in requests for proposals and invitations to bid on larger projects;
- Allowed the specialty contractor to take a leadership role within the supply chain;
- Increase in overall client satisfaction through better conformance to original project scope and intent;
- Increase in personnel productivity;
- Increase in budget conformance;
- Increase in information accuracy;
- Increase in prefabrication efficiency.

Testimonials

"(A) digital model facilitates the communication of design." (Contractor, pg. 62)

"BIM can facilitate (the work process), if everybody is willing to play by the same rules." (Contractor, pg. 66)

"Leveraging BIM meant spending more time on the front end; workload is shifting to earlier in the process […]. However, you should be spending less time at the end of the project." (Architect, p. 55-56)

Source: Forgues, Daniel and Sheryl Staub-French. (2011). *Improving Efficiency and Productivity in the Construction Sector Through the Use of Information Technologies.*

KEY CHALLENGES TO THE BIM ADOPTION AND IMPLEMENTATION PROCESS

Highlights

Contrary to the benefits, the key challenges faced by the SMEs in their BIM adoption and implementation process were much more consistent across the supply chain. Namely, those key challenges were:

- The project context, including the delivery mode, past relationships of project team members and the type and complexity of the project, greatly impacted the extent to which BIM was implemented;
- Full implementation of BIM within the project teams studied, namely the co-development and consistent use of the BIM throughout the project lifecycle, was seriously hindered by the siloed and fragmented nature of the construction industry (ie. many small companies forming the project supply chain);
- The consistently low maturity of project team members with regards to BIM across the different project contexts limited the extent of BIM implementation, since the organizations participating in the project didn't have the capacity to develop, maintain and use the BIM consistently across a project's lifecycle.
- Assessing and evaluating the impact of the BIM adoption and implementation process was a challenge across all three projects, due to the absence of performance assessment strategies and clear metrics.

Researchers did nevertheless identify the specific challenges of each experimentation project.

The main challenges encountered by the property developer (Pilot Project I) in their adoption process were:

- Delays in authorization of funds for the project, and the withdrawal of funding in the support for the Upbrella portion of the project;
- Roles and responsibilities in this specific project wasn't well defined due to the inexperience of the property developer as a promoter;

- Lack of collaboration between professionals (architects, mechanical engineer) was observed, as well as a lack of respect for production deadlines for project documentation (slow preparation and approval of shop drawings).

The main challenges encountered by the architecture-engineering firm (Pilot Project II) in their adoption process were:

- The use of BIM as a collaborative design tool required engineering consultants to actively participate in the schematic design and design development stages of a project rather than the current tendency to limit their participation to certain specific stages;
- Continuous knowledge creation and process improvement was lacking which hindered the efficient implementation of BIM as a collaborative platform. This is seen as being in part due to the fragmented, one-off, project based nature of the construction industry, which hinders the creation of long-term relationships;
- The professional responsibility from consulting engineers must be encouraged to ensure technical coordination with other disciplines, such as architecture, to improve the quality of construction documents;
- Sufficient knowledge was lacking on the part of the clients and owners about BIM to define and validate internal requirements and to evaluate the minimum expertise level needed by selected firms to adequately fulfill these requirements.

The main challenges encountered by the specialty contractor (Pilot Project III) in their adoption process were:

- The various project environments, defined by the delivery mode, the types of contracts and the past history with project stakeholders, played a clear part in defining the extent to which BIM was implemented.
- Inconsistencies in the project team members approaches to BIM, such as varying expectations, intentions and commitment towards the use of BIM, influenced its implementation across the supply chain.
- Lack of control and influence on the project delivery method resulted in a reactionary approach to BIM implementation at the project level.
- Hiring and maintaining personnel with adequate modeling and model coordination capabilities.
- Choosing the appropriate software suite and managing the technology (versioning, adoption of new technology, etc.);
- Being able to understand the extent of the impact of BIM and related processes across the organization;
- Evaluating the return-on-investment (ROI) at the organizational level and the project level to justify the considerable investments needed to adopt and implement BIM successfully.

Testimonials

“The challenge has been: getting involved sooner in the design process and the use of BIM, towards the specific goal.” (Contractor, pg. 66)

“People will naturally resist change, but creating interest and success stories can help in influencing people on the use of BIM. There is a need for getting over the hump of fear by giving training.” (Contractor, pg. 60)

“Instead of keeping it too wide, I think that we should work more at the individual level to develop these BIM skills. […] I think there's attention to the capabilities of the individual. We are moving in this direction […].” (Architect, pg. 63)

Source: Forgues, Daniel and Sheryl Staub-French. (2011). *Improving Efficiency and Productivity in the Construction Sector Through the Use of Information Technologies.*

KEY LESSONS LEARNED

Highlights

The lessons learned were again highly contextual. However, it was possible to generalize some of the key lessons learned:

- Establishing a strategic approach at the organizational level is a critical success factor for BIM implementation
- Contractual relationships, a client's level of knowledge about BIM, and an organization's levels of maturity all play a key role in the quality or speed of BIM adoption and its related benefits.
- BIM adoption needs alignment (i.e. establish common ground) at the organizational, procedural and technological levels between organizations looking to collaborate in a BIM environment.

The specific lessons learned from each experimentation project were also documented.

The main lessons learned from the property developer (Pilot Project I) perspective were:

- BIM implementation requests the elaboration of a business strategy and a BIM Execution Plan, and the hiring of a BIM coordinator prior to launching a project.
- The contractual documents for any project have to include a Concept of Operations that documents a production control methods and approaches.
- BIM implementation and performance measurement is better to be accompanied by a Construction Management procurement approach than the traditional Design-Bid-Build approach.

The main lessons learned from the architecture-engineering firm's (Pilot Project II) perspective were:

- Interoperability issues, especially for SMEs, should be address at the organizational level, and not only at the technological level.
- The required level of development of the architectural design requires a better alignment with the information needed to perform energy analysis.
- Operations and maintenance of electro-mechanical systems within buildings need to be considered by consulting engineers when developing their design.

The main lessons learned from the specialty contractor's (Pilot Project III) perspective were:

- The importance of establishing the suitability of BIM within the organization, essentially asking the question: Is BIM 'right' for the organization?
- The importance of a consistent and coherent organizational strategy in the BIM adoption and implementation process, to align the business strategy with the BIM adoption process and to target investments;
- The opportunity for a specialty contractor to minimize disruptions caused by the BIM adoption process by isolating this process from the rest of his business activities on a pilot project;
- The necessity to strike a balance between a top-down and bottom-up adoption approach to the BIM adoption process meaning an equal distribution of responsibilities between top management and employees and the creation of a steering committee with sufficient decisional power to empower users;
- The importance of an agile approach (ie. the organization be able to quickly react to change and adapt themselves to evolving conditions) to the organizational BIM implementation process;
- The importance of including all employees concerned with the transformation at the organizational level in the adoption and implementation process;
- The importance of establishing clear uses and requirements for the model;
- The need to assess and evaluate the impact of BIM, and to develop the necessary data collection procedure.

CONCLUSIONS

BIM is a disruptive technology at both the organizational and project supply chain level. As indicated in the McGraw-Hill surveys (2009-2012), organizations in the US that are advanced BIM users consider that successful BIM adoption and implementation requires drastic changes in the way in which work is organized internally. Typical large AEC firms have adopted a highly fragmented and hierarchical functional structure in which work is divided in work packages and tasks divided among different levels of specialists, thus the expression of "working in silos." Firms that have fully deployed BIM seem to have a much flatter structure and the boundaries between specialties are much less apparent. Changing the organization of work in a large firm is a painful and costly process.

Due to their lower "organizational inertia," the transformation of workflows and structure might be easier in ways to achieve in firms with less than 50 employees (which represent the majority of firms in the Canadian construction industry) as it was observed in two of the pilot projects. Furthermore, these organizations consider that the successful use of BIM is a paradigm shift in the nature of the relationships between the members of the project network. This was confirmed during our Phase II interviews. Representatives from organizations that are advanced BIM users argue that all the firms involved in a project, and more importantly, the client or the developer, need to have achieved an adequate level of proficiency in the use of BIM to ensure the successful implementation of BIM throughout the project.

RISKS ASSOCIATED WITH BIM FOR SMES

Early results show that, even if it might be easier for SMEs to adapt their practices to leverage BIM benefits, it is quite a risky undertaking that needs to be carefully planned and managed. Risks must be identified and addressed since heavy investments are required in BIM infrastructure and training, and because there may be a loss of productivity in the short term, which compounds issues in a market where profit margins are already slim. These results also demonstrate that trying to establish the benefits of BIM by calculating percentage of gains in productivity may be misguided.

BIM ADOPTION AND IMPLEMENTATION AT THE ORGANIZATIONAL LEVEL

One of the core problems identified during interviews conducted in Phase II regarding the adoption of IT in construction was the lack of alignment between BIM implementation and the business strategy as well as the lack of an IT strategy. Previous interviews done with representatives in large AEC firms in Phase II showed that in larger organizations, BIM is usually introduced at the project level, due to specific contract requirements. Upper management often sees the full deployment of BIM within the firm as a risk, since, currently, few clients are requiring BIM, and this requirement is mainly limited to large projects. In SMEs, decision makers can be much closer to the field. They usually can see the potential benefits of BIM and the opportunity to gain a competitive advantage in deploying BIM related technologies throughout the firm. They can also be more agile to reorganize the work and evolve their business structure than in larger firms, exceptions occurring.

Therefore, as previously mentioned, having a strategic approach to BIM implementation at the organizational level is seen as a critical success factor. The two contractors (Pilot Project II and III) had a clear vision for the deployment of BIM that was aligned with the firms' business goals. This was not the case with Pilot Project I which, while it is not the sole factor for the failure to deploy BIM successfully for the project, had a strong negative impact. A preliminary list of risks to take into account is presented in the key recommendations.

BIM ADOPTION AND IMPLEMENTATION AT THE SUPPLY CHAIN LEVEL

The major issue in the BIM implementation process in Pilot Project I is the lack of alignment between firms' project supply chain in mastering BIM-related technologies. The main obstacle was that none of the firms involved in the project were using BIM and some of them did not even know what BIM was. They also had no obligation to use it. Even if the organization saw the potential of BIM through past research work with our group, they did not have the in-house resources to develop proper BIM requirements, include them in their contracts, or provide an incentive for the use of BIM. The only incentive and main justification for the research project – using BIM to determine the best course of action for conducting the work with the Upbrella technology – was lost when the funding for this part of the project was lost. Discrepancies between firms' skill level in BIM-related technologies was also an issue with Pilot Project II, when the firm was often the only sub-trade using BIM or when BIM was not required for the project.

In pilot project II, the strategic use of BIM was observed as a leverage to obtain contracts from private clients. First, the organization did not only consider that it had considerably increased its efficiency and productivity for delivering the concept and preliminary design (cutting the effort by 2/3), but it also drastically improved the company's opportunity to obtain private contracts through a much faster and convincing information production process for decision making. Moreover, the firm plans to expand into a new market for optimization of the building operation through better design. Using data from buildings they have designed and commissioned, they can evaluate the impact of design decisions that can be improved in future projects with the same client or others, introducing the ability of continuous improvements in design performance.

Second, the firm participating in the second experimentation project, realizing from a previous Engage research project with our group that major gains could be achieved by rethinking the organization of work and processes around the potential offered by BIM, have integrated mechanical and electrical engineers in their team. They are also proposing in their marketing strategy, new project delivery approaches to their client in which BIM is the cornerstone to important cost and schedule reduction.

For Pilot Project III, the extent of benefits accrued fluctuated drastically depending of the organization's role in the supply chain. The organization used BIM as a selling factor to position itself at a more profitable and influential position in the supply chain. The firm from Pilot Project I had to deal with a sector of the industry (residential construction in Quebec) that proved to be ignorant about BIM and somewhat immature in the management of the design and the construction process. This is a specific case, and should not be generalized to the whole Canadian industry. Changes in practices in this context can only be achieved by detailing all BIM requirements and workflows in the contracts.

MEASURING THE PERFORMANCE AND THE IMPACT OF TECHNOLOGY

One of the key conditions outlined in Phase II for firms and supply chains to improve their processes/practices is through benchmarking, a core tool for process reengineering and continuous improvement. The issue in construction is that work is not organized around processes, but work packages whose size and content will vary from project to project. Therefore methods used in other industries, such as activity-based costing, are difficult to apply. Approaches ideally have to be devised for each context. Generic metrics could only be defined after analysis of an adequate sample of projects.

While the two organizations successful in their BIM adoption and implementation process recognize a positive impact of BIM on productivity or efficiency, they highlight the difficulty of benchmarking the impact of BIM on projects without a proper set of metrics agreed to at the onset of a project. Extrapolations are often required since information on the benchmarked traditional projects was not organized for such analysis.

For the firms in Pilot Project II and III, the approach was to use data from a project realized by the firm that was similar in size and type before BIM as a benchmark. The firm in Pilot Project I was more complex, since the aim was to measure the impact of BIM and Upbrella technologies on the performance of the supply chain. Since the project used as a basis for the experimentation project was their first, the benchmark had to use the first four floors to measure the productivity for conventional construction then measure productivity improvement on the two last floors that were going to be built using the Upbrella system. Unfortunately, data collected for the first floors had limited success since the work in such projects appeared not to be coordinated. Researchers associated with the project therefore had to subsequently adopt a technique derived from value stream mapping (VSM), based on the Toyota production method philosophy.

BIM IMPLEMENTATION GUIDE FOR SMES

Below is a series of action-oriented recommendations for SMEs wishing to adopt and implement BIM within their organization based on the findings from the three pilot projects. The recommendations are developed across 8 steps that are essential in the adoption and implementation process (Figure 1). These recommendations compliment the guidelines being developed which are based on international guidelines.

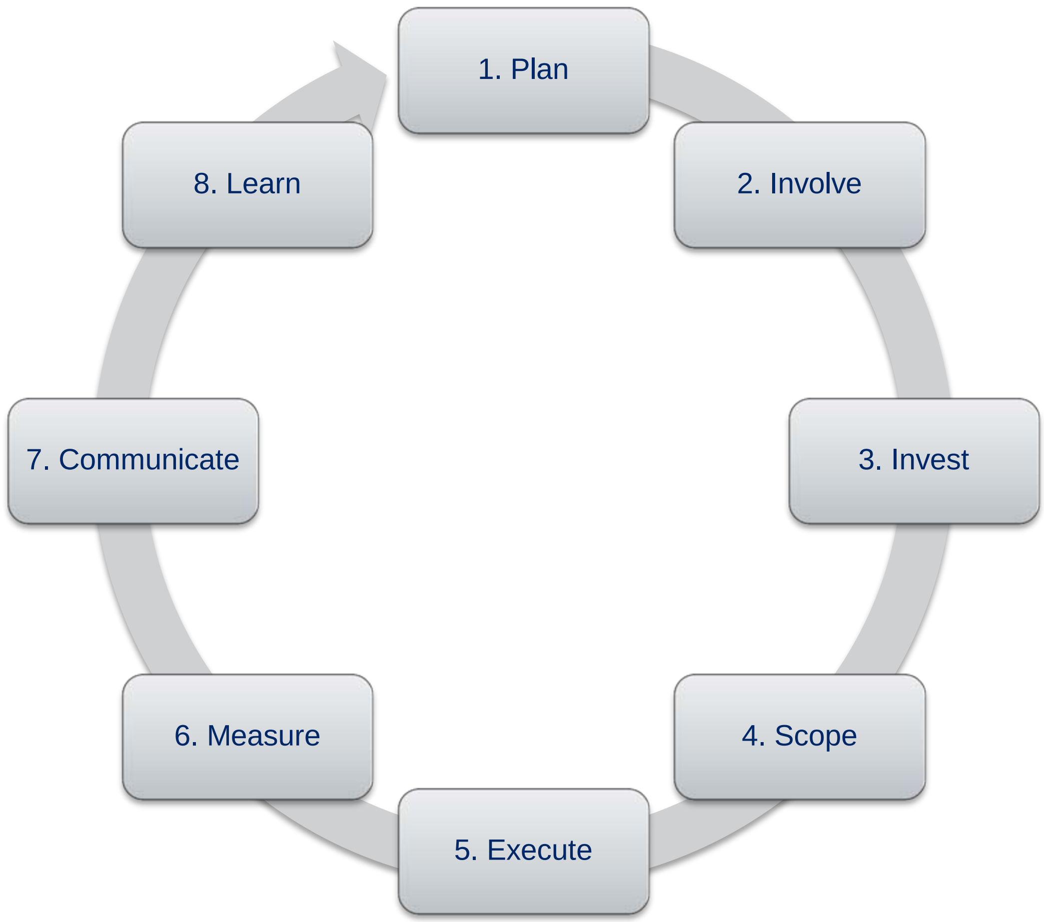

Figure 1 – Iterative Steps for BIM Adoption and Implementation

1. Plan the strategy

a. The upper management is responsible for setting the overall vision for BIM within the organization: The personnel should be engaged and empowered throughout the process.

b. Outline a clear strategy for BIM and how it can be implemented to help the organization fulfill its business plan.

c. Identify short-term and long-term goals and objectives of the overall strategy:

   i. Short-term goals: focus around initial investments in training, hardware, software and piloting a project

   ii. Long-term goals: focus around maintaining the infrastructure in place as well as developing BIM capabilities and relationships with other organizations to consistently leverage BIM.

d. Identify what the desired end-state of BIM should be within the organization and map out how to get there

   i. Set a timeframe and fix milestones for implementation

   ii. Fix priorities where BIM can help the organization improve their product and/or service.

e. Identify the value proposition for BIM according to discipline – As an organization, where can BIM be leveraged to improve the business processes? Identify, assess and manage risks associated to the BIM adoption and implementation process before starting. Key risks include:

   i. Financial risks such as investments required for hardware, software and training of personnel as well as upkeep of infrastructure

   ii. Operational risks such as staffing and ensuring the right level of commitment to the BIM effort within the organization.

   iii. Risk of overextending the scope of BIM implementation

   iv. Project level risks such as mismanagement of time spent on BIM-related activities that do not offer any benefit to the organization or project.

2. Involve the appropriate people

a. Establish the core team: identify the BIM leaders within the organization that have the capability and the willingness to spearhead the implementation process.

b. Hire or identify a BIM champion with past experience with BIM, preferably from within the organization.

c. Set up BIM Committee, where upper management and employees can meet to discuss the BIM adoption and implementation process.

d. Empower personnel to take initiative and make decisions regarding BIM use by giving them sufficient decisional power.

e. Identify clear roles and responsibilities for personnel involved in the adoption process.

f. Seek to involve key personnel from many different backgrounds to extend the scope of BIM adoption:

   i. For Design firms, involve technicians and draft personnel as well as senior personnel.

   ii. For Construction firms, involve field personnel as well as office personnel.

3. Invest in the effort

a. Commit sufficient financial resources to the BIM implementation process.

b. Hire and/or incentivize key personnel who will be instrumental in the BIM implementation process

c. Train personnel and maintaining their capabilities through continuous education.

d. Invest in an adequate infrastructure to support the use of BIM, such as adequate hardware and networking capabilities.

e. Identify and choose the appropriate technology to suit the organization's needs.

   i. Identify how the technology will be used: will the organization be authoring and creating models or simply viewing them? What will the output of the software be used for (visualization, coordination, fabrication, etc.)?

   ii. Identify who in the organization will be using the technology.

4. **Scope the extent of BIM implementation.** Identify the different technologies, which are susceptible to be used by other project team members and identify possible interoperability issues.

a. Identify a pilot project:

   i. Determine which project would be most suitable for a pilot project (this can depend on many factors including, timeframe, project complexity, resource availability, etc.).

   ii. Determine the extent and scope of BIM to be implemented in the pilot project by selecting a specific area of focus or a certain system to model as a first step.

   iii. Target areas where BIM can rapidly make a difference in the organization's scope of work, identify the "low hanging fruit" and stick to that in the beginning.

   iv. Determine the expected benefits of BIM in this project.

   v. Carry out the pilot project and ensure continuous feedback from the personnel involved in the pilot project.

   vi. Capture the experiences gained by the project team. Identify the strengths and the weaknesses encountered during the project.

   vii. Stay committed to the adoption and implementation process throughout the pilot project.

b. On subsequent project(s):

   i. Set clear expectations for the use and development of the model.

   ii. Identify a project team's level of capability with BIM and set expectations that are consistent with those capabilities.

   iii. Identify BIM deliverables and milestones.

   iv. Identify the expected benefits of BIM.

   v. Capture experiences and encourage feedback to develop knowledge.

c. Develop a Project Execution Plan with the project team.

   i. Refer to pre-established guidelines such as the Penn State Project Execution Planning Guide[5]

[5] http://bim.psu.edu/

   ii. At a minimum, a good project execution plan should set out the uses for BIM on the project, the responsibilities, the milestones for deliverables and the infrastructure to be deployed;

   iii. Other items, such as file formats and data exchange procedures, BIM standards may also be important to identify;

   iv. Address how to best use and benefit from the various models throughout the project lifecycle.

d. Seek integration at the project level: The most notable benefits of BIM were achieved when project teams worked in a more integrated manner, sharing the models and communicating freely.

5. Execute the process

a. Commit to the BIM implementation effort at the project level:

   i. Assign adequate resources for BIM to the project, such as a dedicated BIM coordinator.

   ii. Stay committed throughout the project. Return on investment may not be possible in the first project(s).

b. In the event of limited BIM use by the project team, focus and restrain the BIM effort to fulfill the organizations scope of work - Full BIM may not be attainable nor necessary.

c. Develop the model strategically throughout the project.

   i. Consider how the model(s) can be transferred and re-used efficiently between phases and for all stakeholders.

   ii. Set conventions and standards upfront.

6. Measure progress

a. Assess the BIM adoption and implementation process by validating if goals and objectives are being met at the set milestones.

b. Set up performance assessment within the organization to:

   i. Check the advancement of the BIM implementation effort.

   ii. Encourage progress to fulfill the goals and objectives set-out by the upper management and develop new capabilities.

   iii. Confirm priorities and maintain targets.

   iv. Track the capability and maturity of the organization and individual employees by, among others, identifying who has gained experience on which projects and how many projects the organization has delivered using BIM.

   v. Measure return on investment by evaluating the quantifiable benefits of BIM.

c. Engage the technical and field personnel by seeking feedback from them with regards to how BIM is being received at the operational level.

7. Communicate progress

a. Communicate “quick wins” and benefits obtained through BIM to garner enthusiasm throughout the organization

b. Leverage past experience to market the organization’s skills and BIM capabilities to obtain new business and forge new relationships

c. When marketing the organization’s BIM capabilities, take care in not overpromising on the organizations capabilities.

d. Establish modeling standards and best practices that will allow the organization to leverage the model as much as possible. Communicate those standards to other members of the project team to minimize re-work on the model.

8. Learn from experience

a. Establish a continuous feedback loop between the project and the organization to capture knowledge and build on past experience;

b. Learn to identify opportunities to develop additional BIM capabilities by recognizing project environment that are conducive to BIM.

c. Develop a knowledge base within the organization to capture and diffuse lessons learned.

d. Implement the lessons learned and knowledge gained from past project to reassess, adapt and redesign the implementation process (step 1) to suit the ever-changing realities of the organization’s business context and strategies.

The 8 steps presented above are aimed at helping SMEs in planning their BIM adoption and implementation process at both the organizational level and the project level. BIM adoption and implementation is cyclical; it is a continuous and expansive process. While the cycle presented in Figure 1 attempts to be as generic as possible, organizations should adapt the process to their specific discipline or area of expertise. This adaption process will impact the scope of BIM implementation, how BIM is used, the expectations towards BIM and the level of return, which can be achieved.

RESEARCH LIMITATIONS AND FUTURE WORK

The aim of the fourth and final phase of the project was to identify, through three pilot projects, the challenges and rewards of implementing BIM in SMEs in various real-world contexts. It was an exploratory research project, and as such, the ability to generalize across these projects is limited. This type of research nonetheless provides rich information on the specifics of implementing BIM within an SME across the project supply chain in different contexts.

The main limitation of this research project was the relatively short timeframe for data collection. While the timeline allowed an in-depth look into the organization through the benchmarking process, many of the projects on which the organizations themselves were involved in were at various stages of completion, which therefore limited the extent of hard data that was collected.

While the focus of the research project was at the SME level, the findings were generated by three different organizations working in different fields that do not represent the entire spectrum of the construction supply chain. In addition, the research project was carried out in two provinces, and more precisely in two major cities (Montreal and Vancouver). As was put forth in the key findings section, the context plays a major role in determining the extent of diffusion of innovation; therefore it is difficult to generalize findings across the entire country because the level of new technology adoption will vary from region to region.

Lastly, while considerable access was granted to the participating organizations, this was not always the case with other members of the project supply chain on various projects. Therefore, the perspectives presented are of the organizations alone and the way in which the adoption and implementation of BIM impacted their personal environment.

Future work should look into the contextual aspect of BIM adoption and implementation across the country. Other markets should be researched in order to determine trends and gather more data to increase generalizability at the national scale. Also, the depth of enquiry should be extended into the measurable benefits of BIM from the organizational perspective across various contexts.

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