BIM: Business Transformation through Building Information Modeling

Prepared for

The Precast/Prestressed Concrete Institute (PCI)

Prepared by

IKERD

People | Building | Clarity

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1 Executive Summary

BIM: Business Transformation through Building Information Modeling (BIM) is an industry report focused on the impact of BIM technology, specifically on the use of digital data for the Precast/Prestressed Concrete industry. The Precast / Prestressed Concrete Institute (PCI) funded this report and its findings under the direction of their BIM Fast Team.

This document will provide an outline of why precast industry leaders and firm owners should choose to expand BIM capabilities within their organizations. The report will present information on the investment required to start down a BIM path, methods for integrating BIM in the business, and process improvement ideas that have proven to increase efficiency, reduce defects, and decrease the cost of doing business. The document intends to aid business leaders in developing a company vision and justify the investment in BIM.

Major concepts addressed in this report concern an understanding of how the utilization of BIM affects the industry. A clear possible conclusion is that precast firms must adopt BIM to maintain relevance as a viable precast company. Failure to adopt efficient methods will cause a firm's business to decline, and the result is that they will no longer be relevant in the marketplace as their BIM-enabled competitors gain their market share. A 2015 survey shows the need for change where 90% of the industry say they will need BIM by the year 2020 to meet and satisfy their clients' demands. The precast/prestressed concrete industry is already behind other industries in the use of BIM generated data in operations, and customers perceive other construction materials as more technologically advanced.

The precast/prestressed concrete industry must decide if it wants to follow the manufacturing trend of improving productivity or the construction trend of declining productivity. In a Stanford study by Dr. Paul Teicholz, changes have been well documented in manufacturing and construction labor productivity. Research over a 48-year time period showed there has been a linear trend totaling over -15% loss in US construction productivity after adjusting for inflations (-0.32% per year decline). However, over the same time US manufacturing industries have improved a total of almost 150% in productivity (+3.06% per year) after adjusting for inflation. Much of the manufacturing improvements have been attributed to effective implementation and business process transformation with technology. Precast/prestressed concrete could benefit greatly from the adoption of manufacturing techniques that improve efficiency and productivity, but a shift in mindset is required for this to happen. Precast companies have reached a crossroad and must choose which path to take: productivity or stagnation.

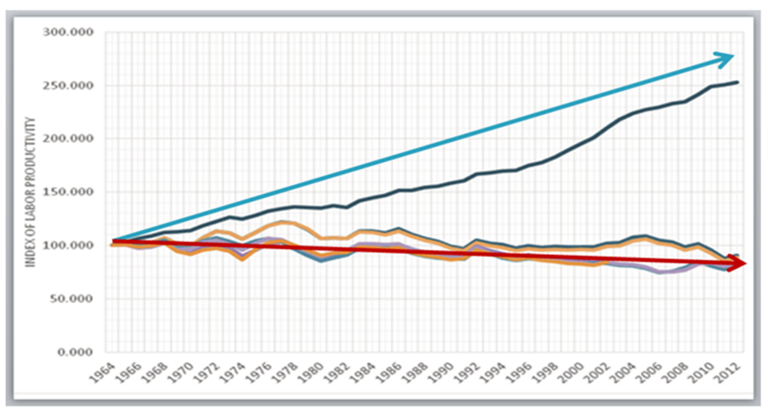

Image above is from Dr. Teicholz at Stanford University research titled Labor-Productivity Declines in the Construction Industry. It illustrates the decline in construction productivity over the last 50 years versus the productivity of all other non-farm labor industries in the US. The total decline in construction productivity has been more than 15% down while manufacturing productivity has increased by 150%. The precast industry must choose if it will follow the productivity trends of construction down or improve along the trends of all other US manufactures.

The construction industry is well aware of the trends in increased manufacturing versus decreased onsite efficiencies. As such, more prefabrication processes have been integrated in construction and more modular construction processes will be adopted in the future. The precast industry is uniquely positioned to take advantage of those trends, but only if they are technologically advanced to support participation with the decision makers in affecting the design and construction processes. A Smart Market Report published by McGraw-Hill Construction in 2011 titled *Prefabrication and Modularization: Increasing Productivity in the Construction Industry* documents a study by NIST and others and reports that 77% of contractors believe that BIM would allow them to use prefabrication on larger, more complex projects in the future.

The sections discussed in this report are the following:

1. Business Transformation: Integrating BIM into the industry requires a change of the business model, developing a vision for company-wide improvement.
2. Investment: Deciding how much time, effort, and money to invest in BIM is dependent on the goals and benefits a company seeks.
3. Return on Investment: Quantifying ROI for BIM integration is reviewed from several perspectives that include both quantitative and subjective considerations.
4. Industry Status: Information has been gathered through an extensive and variety of sources. These include but are not limited to interviews with industry leaders, surveys PCI conducted in 2012 and 2015, and tours of numerous Precast/Prestressed Concrete operations.
5. Legal Implications: BIM is potentially affecting every aspect of the internal operation for plants on projects that require this emerging technology.

Determining whether to adopt BIM is a critical core decision as the precast industry looks towards 2020. The decision will affect how companies win business, earn profit, serve their clients, reduce errors, attract new talent, and increase market share (or at least maintain it). Ultimately, the decision may determine whether a business will survive.

2 Precast Business Model

To reap the benefits of BIM, a total transformation of the business model is required. Impossible? Hardly! The challenge is developing a new vision of the business and then executing changes. Business transformation is a process that many companies and organizations attempt. However, even with the best planning, many change efforts may falter at some point during the extended time that it takes to enact lasting transformation.[1] To continue through the transformation process without stalling, BIM cannot be viewed as a drafting tool. It must be viewed as intelligence to be integrated across an enterprise. This does not start with a drafting department that has a new tool. It starts with a vision of data management that should influence every department in the company. Beyond this, the vision must include the desired end result to drive development of protocols for front end data input. The transformation must begin with the end goals in mind.

Consider the amount of data that is required to execute a precast concrete project and to manage a precast concrete business. Much of that data is generated manually, then input and transferred between departments multiple times; thus, it has a reasonable probability of incurring errors. Inefficiencies in data generation and handling slow down processes resulting in defects and unnecessary costs and waste. If Building Information Modeling (BIM) can be recognized within a precast operation as an information management tool, as it was developed to be, rather than just 3D drawings, then the benefits can be improved processes, reduced defects, enhanced performance, and dramatically improved business results.

A strategic challenge is presenting itself to the precast industry in the form of BIM. Even as effort toward change begins, the industry must build momentum or quickly lose what little forward push there is to start. If business-as-usual is good enough for the majority of the industry, then any urgency associated with new processes focused on using BIM as the core of data management will quickly be lost. To generate forward movement, the buzz phrase “paradigm shift” needs to be replaced by “disruptive innovation”. Integration of BIM in the operation of an enterprise cannot simply be a shift in focus. Instead, this technology must be considered a new strategic direction to change the business. Every step in the business process is considered a candidate for improvement through using intelligent transfer of data rather than traditional analog methods of documenting data. An estimate can be created from a sales drawing. During project execution, the estimate can be checked against actual costs to update estimating standards of procedures and to best manage the project. Decisions on the most efficient production scheduling can be made. Whether internal or external, material orders can be generated without human manual data input errors.

Whatever the company’s goals, BIM adoption will require changes; wherever data exchanges are identified, information will have to be organized and integrated for the most efficient use. At the same time, the degree of integration can be tailored to the company goals allowing partial integration, gradual integration, or complete integration. These changes will no doubt be disruptive, but a detailed execution plan should lessen the effect, while also maximizing and expediting the return benefits later.

Why face change and disruption? As previously stated, productivity in construction has declined for a number of years, while productivity in manufacturing has improved. The precast industry must identify with manufacturing to encourage innovation and growth. The opportunity has arrived for the majority of precast manufacturers to innovate and adapt to a new normal. Technology

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[1] John P. Kotter, *Leading Change: Why Transformation Efforts Fail* (Harvard Business Review, March-April 1995).

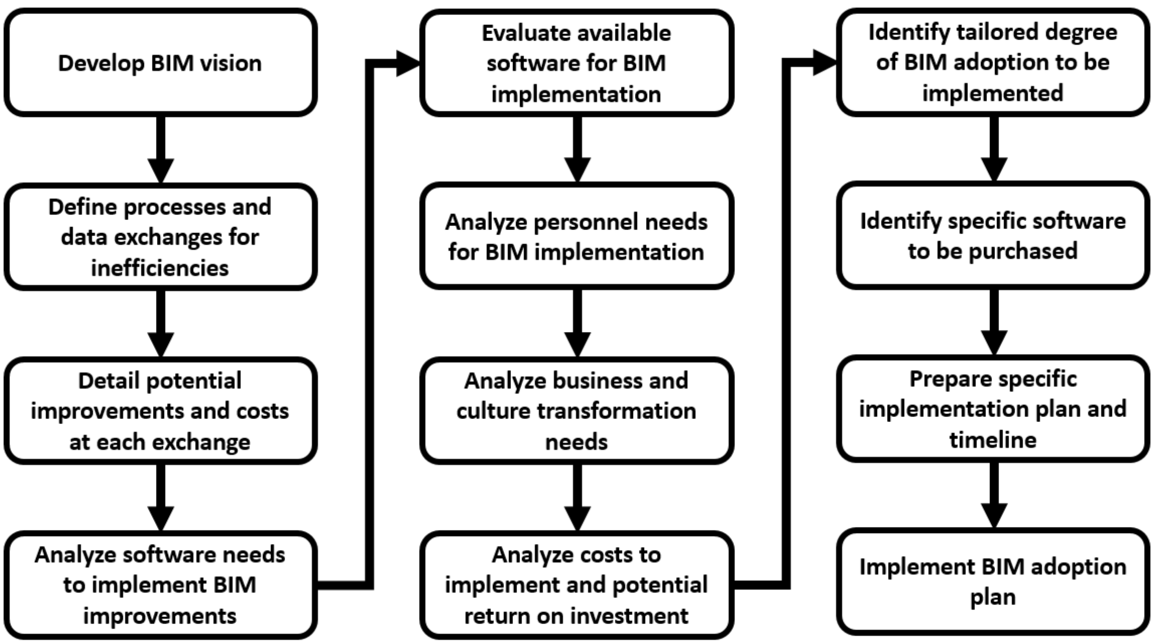
now exists that allows for the precast industry to adapt to these changes while also improving productivity, lowering costs, and reducing defects. The time has come.

To create a vision for BIM integration, all business processes—from sales through project completion—must be considered. (See Section 4.2 for a detailed look at the possibilities.) There will be a cost for implementation associated with this change effort. Each company will need to develop their budgets for the implementation that is right for their organization. However, regardless of the level of implementation, every company can realize some level of return on investment for their efforts in BIM. The vision developed should take advantage of as many opportunities as the as a company's cash flow will allow. This document is prepared in a way that presents the available opportunities in BIM while allowing for a selective adoption approach for each company to create a customized integration plan. Guidance on the costs of implementation can be found in Section 3.

2.1 BIM Implementation Flowchart

The image below gives a general outline for the way to develop a BIM implementation strategy. The first step is to identify the company's goals with improvement of information transfer. By analyzing processes within a plant to find inefficiencies and outline potential costs and improvements, each company can better understand the investments—in capital, software, personnel, or time—that could streamline production and lead to higher efficiencies. A generic process map is presented in Appendix A: Sample Plant Process Map; it quickly illustrates activities in the manufacturing process where data control can improve productivity.

After a plan is developed and prepared, implementation time will vary based on the degree of BIM integration to be undertaken. Outlining the timeline for BIM implementation for each process will enhance the understanding of the commitment required to make the transition to BIM and lay out the path for BIM to become an integrated part of the company.



3 Investment

The matter of investing in BIM is dependent on a number of variables. As seen in the flowchart in the last section, there are many steps along the path to BIM implementation and each of these can be different for different firms. Once each firm decides to move forward with BIM, there are investments of time and money. An implementation plan requires an evaluation of the desired end results of BIM integration to drive the standards and data protocols to be developed.

3.1 Evaluation Phase

The following examples outline items to be considered in the evaluation phase of BIM that will require employee training, time, money, etc. Investment requirements may overlap and be used for more than one item. Proper evaluation of BIM goals will aid in developing an action plan of investments. The following list can be considered as items over the initial evaluation phase that may take 1 to 3 months or more.

1. Commitment to applying, assessing, and managing BIM technology:
   a. Management meetings, discussions, and examination.
   b. Allow 5 man-days as a minimum
2. Assessment of departments for the potential improvement opportunities applying BIM, creating goals that are measurable, attainable, realistic, and timely, and develop an Action Plan:
   a. Develop companywide process map to evaluate where a BIM enabled workflow applies
   b. Allow 10 man-days as minimum
3. Evaluate available BIM software with regard to satisfying BIM workflow goals:
   a. Allow 10 man-days as a minimum
4. Review existing computer hardware and IT assessment of network capabilities with regards to BIM Software requirements:
   a. Network assessments include both Local Area Network (LAN) & wireless Wide Area Network (WAN) for multi-location companies and those using outside modeling sources.
   b. Allow 3 man-days as a minimum

3.2 Implementation Phase

The following examples outline items to be considered in the implementation phase of BIM that will also require employee training, time, money, etc. Investment requirements may overlap and be used for more than one item. Evaluation of BIM goals will aid in developing an action plan of investments. The following list can be considered as items over the initial implementation phase that may be considered to be 9 to 18 months or more in duration. It is realistic to consider this phase may be as much as 1.5% of the firm’s annual revenue or more for initial implementation.

1. Purchase BIM software and hardware:
   a. $5,000 to $30,000 per station for purchase with maintenance as an additional cost in subsequent years.
      or
      $3,000-$10,000 per station per year as a lease with maintenance included.
   b. Annual software maintenance 15%-30% of purchase price.

   c. Note: it is important that firms review the purchase vs. lease options from their software providers. A current trend in the industry is moving towards software as a service for a monthly lease per user. This can greatly lower the barriers to entry for some plant business models.
   d. $2,000 to $4,000 for hardware, such as computers and related devices.
   e. Additional network and related IT expenses may be required; reference the IT section below.
2. Basic Software Training:
   a. Allow as a minimum 10 man-days per employee.
   b. Software trainer fee is an additional 10%-30% of the software purchase price per employee. This is negotiable if arranged and purchased jointly with the software.
   c. Note: it is important that firms find training resources that understand the BIM needs of the precast concrete industry from a holistic perspective.
3. Development of **internal** required BIM standards and drawings using the new software, set up customized company specific modelling protocols and procedures:
   a. Will vary depending on complexity of work undertaken by the manufacturer.
   b. Allow 30-90 man-days.
4. Development of **external** required BIM standards and drawings using the new software, set up customized company specific modelling protocols and procedures:
   a. Will vary depending on complexity of work undertaken by the manufacturer.
   b. Note: Protocol must be considered for plant's operational BIM requirements when interfacing with outside consultants. Clear standards and guidelines for model creation by external engineers and modelers is essential for reliable information extraction in BIM. This consideration is especially important for smaller PC manufacturers who use a high percentage of multiple external consultants for their BIM creation.
   c. Allow 10-60 man-days.
5. Advanced Software Training:
   a. Will vary depending on complexity of work undertaken by the manufacturer. Allow as a minimum 5 man-days per employee.
   b. Software trainer fee is additional.
6. On the Job Training utilizing BIM software can be thought of as a cost to project. This would be represented by initially requiring more time to generate drawings and format information deliverables similar to the company's traditional pre-BIM format:
   a. Cost inefficiencies will occur due to use of the new technology. Increased man-hours and increased schedule can be expected.
   b. Man-days will vary depending on complexity of work and the abilities of the personnel. (Initial BIM implementation using new software could take substantially longer and require many more man-hours compared to traditional drafting methods. Personnel will be inefficient as they learn the new software and new BIM workflow.)
   c. It is strongly advised that a smaller, simpler project with a reasonable schedule be chosen to be the manufacturers first full BIM project.
   d. Note that there is no clear evidence showing which employees grasp the new technology best. Sometimes it the most experienced worker, sometimes it is not. As with most things, it usually comes down to each individual's attitude and acceptance of the change.

7. Information Technology (IT) expenses are notable and widely varied in BIM implementation due to company size and available utilities.
    a. Network infrastructure for sharing of models and other data.
    b. Hardware, such as computers and monitors.
    c. Software for BIM models, data storage, and plant operations.
    d. Training in software and hardware maintenance.
    e. IT personnel or outside help if needed for IT operations.

3.2.1 Specific Implementation Examples

1. Utilizing BIM workflows for estimating and sales:
    a. Train personnel to create estimating and sales models.
    b. Develop the required reports and cost estimates from the digital data.
    c. It is possible more than one software tool will be required for sales. For example, the right choice for fabrication-level modeling and quantity take-offs may not be the same as for renderings.
2. Utilizing BIM workflows for scheduling, production planning, and reporting:
    a. Train personnel to utilize BIM data for scheduling and production planning.
    b. Develop the required reports and information from the digital data.
3. Utilizing BIM workflows in material tracking, purchasing, and Enterprise Resource Planning (ERP) integration, i.e. Radio-Frequency Identification (RFID) or barcodes technology, and using BIM data for product identification tags:
    a. Train personnel to utilize BIM data within the company’s ERP software.
    b. Purchase new ERP software if desired.
    c. Purchase new bar code or RFID equipment if desired.
4. Utilizing BIM workflows in digital automatic rebar bending/cutting technology:
    a. Train personnel to create digital rebar bending files.
    b. Develop the required files from the digital BIM data.
    c. Purchase automatic rebar bending equipment or outsource digital files to external rebar suppliers using this technology.
5. Utilizing BIM workflows in digital steel hardware fabrication technology:
    a. Train personnel to create digital steel hardware fabrication files.
    b. Develop the required files from the digital BIM data.
    c. Purchase CNC equipment or outsource digital files to external steel suppliers using this technology.
    d. Purchase software to interface with fabrication equipment.
6. Utilizing BIM workflows with CNC formwork fabrication:
    a. Train personnel to create digital CNC files.
    b. Develop the required files from the digital BIM data.
    c. Purchase CNC equipment or outsource digital files to external steel suppliers using this technology.
    d. Purchase software to interface with fabrication equipment.
7. Utilizing BIM data to integrate laser projection for casting:
    a. Train personnel to use laser projection equipment and read laser-projected layouts.
    b. Purchase laser projection equipment.
    c. Develop the required files for projection from the digital BIM data.
8. Utilizing BIM data for changes in workflow within the plant, utilizing tablets and monitors instead of paper or paper drawings, create specific work instructions from BIM data and model, as well as utilizing BIM data with QC and other functions including the batch plant:
    a. Train personnel to use new technology.
    b. Purchase software, monitors and tablets for production and QC personnel.
9. Utilizing BIM workflows with digital surveying and erection sequencing:
    a. Train personnel to utilize the digital data for digital surveying on site.
    b. Train personnel to use BIM model for erection planning and sequencing.
    c. Purchase digital surveying equipment.

10. Utilizing BIM throughout the company:
    a. Train personnel to utilize the BIM model in all departments, and change workflow and processes to accommodate use of BIM data.
    b. Purchase new software and hardware as required for other personnel using BIM technology.

3.3 Investment Summary

The size of the company, the volume of production, and the goals of the company affect how much a firm should invest in BIM in order to benefit from its capabilities. On a basic level the size of a company can be small, medium, or large with the intent to grow in revenue, production, employees, or a combination of some or all of those factors. Research and analysis of the status of a firm can determine the size of a company as small, medium, or large. The company can therefore determine how to move forward with BIM capabilities. The amount of equipment such as BIM creation stations, BIM review stations, tablets, and software will be based on various factors.

The quantifying investment depends on the following factors:

1) Firm's commitment to business transformation with BIM
2) Size of firm
3) Product mix (architectural, structural, plank, bridge)
4) If they use in-house or 3rd party consultants for BIM. This is similar to what they may have historically done with CAD and engineering calculations (in-house versus third party consultants).

An example of size and volume analysis is shown in Appendix B: Investment Cost Models. The following is a summary of sample conceptual investment table for a rough order of magnitude for BIM investment for the given firm sizes. For some firms, BIM implementation costs may go to third party consultants to aid in the initial change to BIM for development of standards and data protocols.

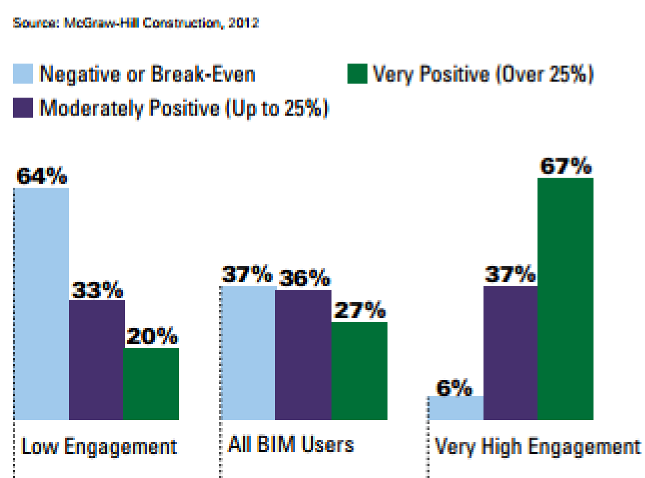
Example Size Revenue ($M)	First Year Implementation	Subsequent Years Minimum Investment
$10 or Less	1.5% - 3.0%	0.75% - 2.0%
$10 - $30	1.0% - 3.0%	0.5% - 2.0%
$30 +	1.0% - 2.0%	0.5% - 1.5%

4 Return on Investment

Calculating the return on investment for BIM within individual companies or across an industry is a challenging task. However, understanding the economic value of such a drastic change is vital to making decisions about BIM adoption and implementation. ROI analysis can provide valuable insight into the way individual companies can adopt BIM and use it most effectively, but there are complications because ROI calculations cannot easily quantify the value of intangible factors. For example, time saved by avoiding clashes or additional client relationships formed because of BIM use are difficult elements to measure, yet they are an integral factor in arriving at reasonable ROI figures.

On the tangible side of ROI analysis, when quantifying ROI there are three main types of BIM investment: initial startup costs for technology adoption, costs to adapt BIM practices to specific projects, and long-term costs for comprehensive business transformations.[2] Initial costs include purchasing software, training personnel in a new system, upgrading hardware, and setting up BIM software in a manner tailored for the company. Costs to adapt BIM to specific projects and firms range from improving internal communication and sharing of models to adding specialized personnel, such as IT, to accommodate the processes of the firm. Long-term costs can be the most intangible; however, these can include developing standards or customizing software and training for growth and competence in BIM. While initial costs are often extensive because of purchasing new software and the time and cost of training personnel, it is noteworthy that a McGraw-Hill study found that as firms implement BIM more fully the ROI for BIM increases with the additional engagement.[3]

BIM ROI for Users by Level of Engagement[4]



Many benefits of implementing BIM are not quantified as easily. A 2012 McGraw-Hill study found that within BIM users of all types, nearly 50% said that a long-term benefit of BIM was obtaining and keeping repeat business. BIM adoption and proficiency can attract new customers by

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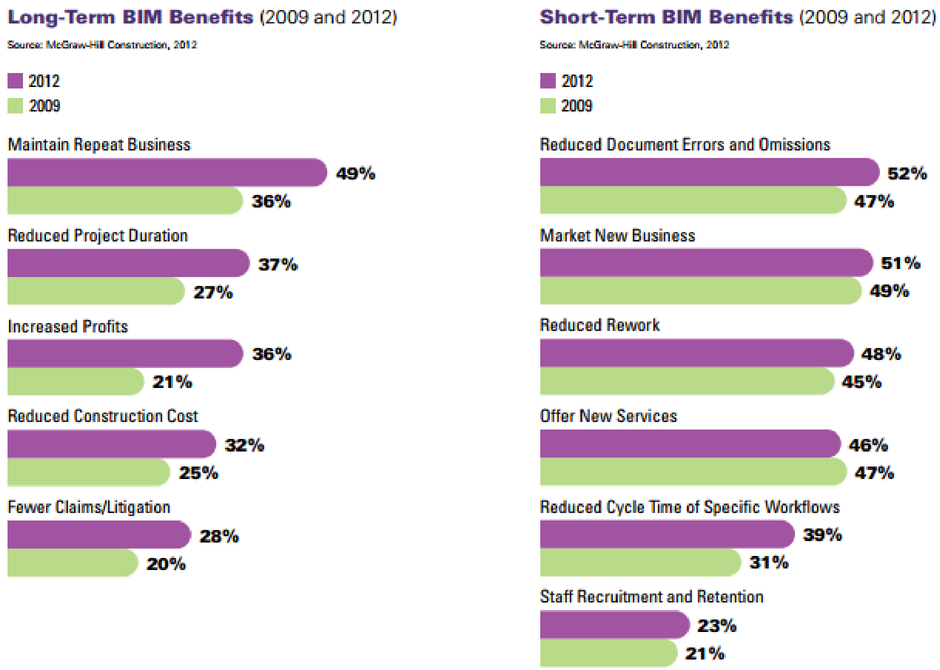
[2] Erin Hoffer, Measuring the Value of BIM: Achieving Strategic ROI, (Autodesk: 2014).
[3] The Business Value of BIM in North America: Multi-Year Trend Analysis and User Ratings (2007–2012), (McGraw-Hill Construction, 2012).
[4] The Business Value of BIM in North America: Multi-Year Trend Analysis and User Ratings (2007–2012), 24.

enticing owners or contractors who are technology minded and want to work with precasters who are on the forefront of the adoption curve. The same study found that 52% of BIM users said that a short-term benefit of BIM is reduced document errors and omissions.[5] Fixing problems virtually in a model long before construction even begins can prevent rework of drawings or product and it can save time and money throughout a project. Other short and long-term benefits of BIM that BIM users identified are shown in the image below.

Long-Term and Short-Term BIM Benefits[6]



But how are problems which are prevented and never happened quantifiable for ROI analysis? Here lies the difficulty in finding reasonable ROI for BIM adoption. Although intangible benefits may not have readily associated dollar figures, team time savings, cost avoidance from clashes, schedule compression, and better estimates based on model data are positive trends for any company.[7] Analyzing completed projects with losses due to preventable errors can be an indicator of potential savings with BIM and clash detection. In Autodesk's ROI eBook for BIM, one architecture firm VP noted, "It wasn't really a financial decision…This is where everything is going. If we're going to keep up and remain competitive, we're going to have to go there."[8] In the end, BIM adoption may not be only about ROI in dollars, but also ROI in relationships and staying competitive in the market. Surviving in the industry is 100% return on investment.

[5] The Business Value of BIM in North America: Multi-Year Trend Analysis and User Ratings (2007–2012).
[6] The Business Value of BIM in North America: Multi-Year Trend Analysis and User Ratings (2007–2012), 18.
[7] Understanding the ROI of BIM, (Vico Software: 2016), http://www.vicosoftware.com/0/understanding-the-roi-of-bim/tabid/86011/.
[8] Hoffer, Measuring the Value of BIM: Achieving Strategic ROI.

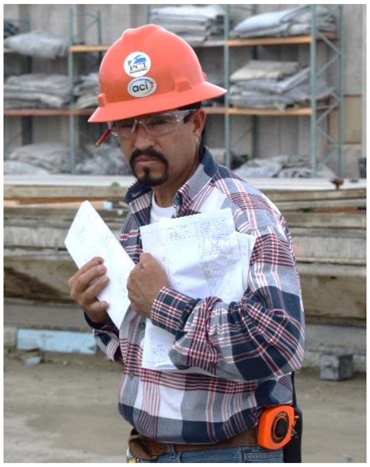
4.1 Why BIM Matters to the Precast Concrete Workflow

Return on investment is based on how a BIM workflow can improve a company's productivity through the use of many new concepts developed using new technology and data exchanges. The following work processes are many of the areas with opportunity for improvement by directly accessing data created by BIM tools.

1. Concept drawing to sell the product
2. Detail drawings
3. Submittal / Approval process
4. Material Procurement
5. Inventory
6. IFC files
7. Material orders
8. Billing
9. Cost accounting
10. Batching
11. Driving the laser layout
12. Formwork
13. Casting
14. Reinforcing steel / Rebar bending
15. Embed layouts
16. QC on piece and mix
17. QC tracking
18. Repairs
19. Testing / Inspections
20. Finishing
21. Storing / Yarding
22. Trade coordination
23. Shipping
24. Truck sequencing
25. Erection sequencing
26. Crane location and sequencing
27. Engineering
28. Erection
29. Embed verification in the field
30. As-builts

Throughout the process of creating a precast piece, there are multitudes of steps and data exchanges that happen to lead up to the moment depicted below. As an example, prior to placing an embed in location on a production piece, modeling, purchasing, forming, casting, and more must occur correctly and on schedule. BIM can be used to streamline each process and data exchange to increase productivity and efficiency. If BIM is used, the result is a precisely placed embed that can be located with lasers instead of a measuring tape, and a piece that has been tracked and logged every step of the way.

4.2 Opportunities to Improve Efficiency



The following examples are current activities and tasks in the precast/prestressed concrete industry that are completed in a manner that normally uses analog information sharing. Using a Building Information Modeling (BIM) enabled workflow for these examples could improve the overall process of precast concrete manufacturing. This would help move these plants forward into a digital method of sharing data for greater plant efficiency.

4.2.1 Enterprise Resource Planning (ERP) Integration

Different sized plants used various levels of sophistication in ERP systems. ERP systems are used to track estimates versus actual data in inventory, accounts receivable, accounts payable, scheduling, and report results to management.

Current inefficiencies:

- Manually entered, handwritten reports
- Data errors from manual entry
- Limited real-time data
- Inventory inaccuracies

BIM benefits:

- Automated loading of project data to the ERP system
- Real-time information for making management decisions
- Reduce data errors
- Piece level cost reporting
- Graphical visualization of ERP data: cost, scheduling, etc.
- Timely and accurate invoicing

4.2.2 Construction Plans

In the precast / prestressed industry, the company's internal team is relying on paper to make their casting forms and place accessories, and they need to check against the project's construction drawings. Often their paper copies could be out of date. In a BIM enabled workflow, productivity could benefit from using current digital drawings on screen and on mobile tablets. A BIM environment allows personnel in the office and in the plant to have the same up-to-date models and information.

Current inefficiencies:

- Incorrect plans/drawings
- Plans without change orders or new updates
- Plans/drawings without all changes reflecting coordination with other trades

Current processes: companies can spend several man-hours addressing these issues every day. In a future state, this can be reduced as much as 25-90% of the current amount of time.

BIM benefits:

- The model contains real-time information for up-to-date production and fabrication deliverables.
- Better visualization for both an unskilled workforce and seasoned veterans
- More clarity
- Mentoring tool

4.2.3 Materials Tracking

Today, material inventory information is tracked manually in multiple isolated spreadsheets. In a BIM workflow, materials quantities are generated automatically from the 3D model and would be tracked in one database. Managers can then see if the amount of materials on hand are sufficient for the projects coming up for production, and this would then help in planning for ordering of materials and yard storage. Doing so would also allow direct comparison to budget information and real-time inventory information that is updated automatically as product is fabricated.

Current inefficiencies:

- Not enough mix material
- Unknown amounts of the types of mix material
- Inability to track how much material is used over time
- Not enough embed stock or other materials
- Fabrication and galvanizing information not with the embed plans/drawings
- Manual embed plate ordering
- Manual embed plate fabrication
- Not knowing how much reinforcing material is needed for a given pour or day
- Time spent calculating the linear feet of prestressing tendons needed
- Time spent calculating the number of post-tensioning tendons needed

Current processes: lack of materials has the potential for significant losses in production in a precast operation and companies stand to lose multiple man-days as a consequence of running out of materials. In a future state, time lost can be reduced as much as 75-90% of the current amount of time.

BIM benefits:

- Reduce lost production days due to poor material management
- Lean material management with just-in-time delivery
- Reduce waste
- Prioritization of reinforcing and embed fabrication
- Open inventory management with vendor sourcing (integrated databases)
- Vendor collaboration for inventory management with proactive vendor delivery
- Avoid over-ordering of materials
- Internal material tracking, such as pigment, aggregates, cementitious materials, embeds, inserts, rebar, strand, formwork, brick, insulation, formliner, wythe connectors, etc.
- More informed purchasing
- More accurate billing

4.2.4 Materials Fabrication

4.2.4.1 Embeds: Fabrication and Finish

Currently, this is an area where a lot of re-entry of data and repetition of labor is occurring; these parts are created by the steel fabricator from shop drawings, then shipped to the galvanizer, then returned to the precast plant when they come back from the galvanizer. Labor costs are incurred to sort the parts at the steel fabricator, again at the galvanizer, and finally again at the precast plant. In a BIM workflow, these parts could be tracked and grouped together in assigned “kits”. With pre-kitted embeds and other parts, each party involved from fabricator to plant knows which parts are grouped together and can more efficiently handle parts based on their grouping and project.

Current inefficiencies:

- Parts shipped to third-party fabricators or galvanizers not grouped or sorted
- Parts not grouped by project, making finding parts more time consuming
- Manual measurements with tape measures
- Language barriers, literacy, and experience of the workforce
- Excess or insufficient material ordered
- Reentry of information in the procurement and accounting processes
- Paper-based assignments of mill certificates
- Lost time searching for the correct piece in piles of inventory

Current processes: manual measurements and reading plans/drawings from paper can cause inaccuracies in piece layouts, which can cause delays and rework later in the life of the piece. Reentry of information, incorrect amounts of materials, and even workforce experience can also be factors that negatively affect the productivity in embed fabrication. In a future state, time lost can be reduced as much as 75% of the current amount of time.

BIM benefits:

- Accurate materials for fabrication
- Automated digital fabrication data to in-house or third-party fabricators
- Digitally driven fabrication equipment: shear, punch, welder, plasma cutter, bandsaw, CNC tooling, robotics, etc.
- Lean, just-in-time fabrication
- Kitting during fabrication
- Optimized use of materials for fabrication (includes automated tracking of material nesting and drop)
- Automated digital linking of mill certificates to production pieces
- Better visualization of end product before fabrication

4.2.4.2 Reinforcing: Fabrication & Installation

Time loss in workflows through a plant for reinforcing bars would include paper drawings of the design, details, fabrication, and installation. In a BIM enabled workflow, information could be tracked throughout the entire process in one working model.

BIM systems could also aid in proper installation – positioning and type of reinforcement – through the use of BIM review stations for viewing plans/drawings or laser projection systems for precise placement.

Current inefficiencies:

- Manual measurements with tape measures
- Language barriers, literacy, and experience of the workforce
- Excess or insufficient material ordered
- Reentry of information in the procurement and accounting processes
- Paper-based assignments of mill certificates
- Multiple tooling changeovers between bar sizes

Current processes: manual measurements and reading plans/drawings from paper can cause inaccuracies in piece layouts, which can cause delays and rework later in the life of the piece. Reentry of information, incorrect amounts of materials, and even workforce experience can also be factors that negatively impact the productivity in reinforcement fabrication. In a future state, time lost can be reduced as much as 75% of the current amount of time.

BIM benefits:

- Accurate materials for fabrication
- Automated digital fabrication data to in-house or third-party fabricators
- Digitally driven fabrication equipment: shear, bender, threader, bandsaw, robotics, etc.
- Lean, just-in-time fabrication
- Kitting during fabrication
- Optimized use of materials for fabrication and tooling (includes automated tracking of material nesting and drop)
- Better visualization of end product before fabrication

4.2.5 Formwork Creation and Tracking

Currently, paper drawings are printed and used for manual formwork creation. In a BIM workflow, digital models and files of form plans/drawings could be sent to a CNC router to create precise forms. Drawings could also be displayed on screens and digital workstations throughout the shop. In a BIM system, the location of forms in the plant can be tracked by assigning identification numbers. Additionally, the maintenance on multi-use or standard forms can be tracked to aid in compliance with quality control and measurement tolerances.

Current inefficiencies:

- Insufficient material for the formwork on the project
- Poor scheduling of shop hours for formwork
- Part fabrication (Manual vs. CNC router)
- Complex formwork requiring highly skilled laborers
- Manual measurements with tape measures
- Language barriers, literacy, and experience of the workforce

Current processes: manual measurements and reading plans from paper can cause inaccuracies in formwork creation, which can cause delays as casting must wait on forms to be created. Reentry of information, incorrect amounts of materials, and even workforce experience can also be factors which negatively impact the productivity in form fabrication. In a future state, time lost can be reduced as much as 75-90% of the current amount of time.

BIM benefits:

- Automatic parts list generation
- Reduced man-hours
- Laser projection of product geometry
- Reduction in moldwork cost and moldwork changeover cost
- Build more complicated molds
- Utilize less skilled workforce
- 3D-printed mold fabrication
- CNC mold fabrication from model data
- Robotic formwork installation
- Programmable matter

4.2.6 Casting

Today, project information and plant maps are often manually updated and tracked with paper reports. Using a BIM workflow, information of casting locations could be tracked and be uniform throughout the plant. Screens on the plant floor (instead of paper drawings at each station) could give an up-to-date status of which stations are being used for what parts and what stage of the casting process each station is currently in. In a BIM system, pre-pour and post-pour inspection sheets could also be completed on a tablet and automatically recorded to eliminate the need for reentry and aid in ease of access if the information is needed later. These inspections can then be a tool for continuous improvement as trends and issues are tracked digitally and easily accessed in real time.

Additionally, new technologies are now available to increase accuracy on the casting beds. Laser layout equipment allows workers to use handheld tablets to cycle through form, embed, and other critical piece placement layouts. Lasers project the exact locations of each part, greatly reducing errors that result from hand-measured placement read from paper drawings. Handheld technology such as tablets can also be useful for checking piece locations in the yard, opening part plans/drawings and models while on a job site, and much more.

Current inefficiencies:

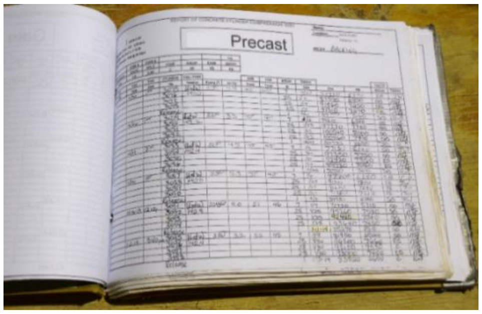
- Not having the correct formwork or embeds (or having to track down the correct formwork or embeds) for a casting
- Plans/drawings that are not up-to-date with embed locations
- Manually recorded quality control information from checks
- Time spent gathering inspection information for a casting
- Time spent gathering materials for a casting
- Manual tracking of production quantities and man-hours

Current processes: pieces that are incorrectly cast can cause multiple man-hours of time spent later on rework, repairs, or recasting. Pieces that are not kitted can cause delays when considering that these must be found before the piece is done. In a future state, time lost can be reduced as much as 75-90% of the current amount of time.

BIM benefits:

- Reduced errors caused by outdated information
- Reduced defects
- Reduction in interference issues
- Faster manufacturing sequences
- Optimized utilization of casting surfaces
- Reduced downtime thru use of kitting material delivery to the bed
- Coordination with batching and concrete delivery
- Real-time tracking of material costs against budget
- Real-time tracking of material quantities
- Planning and reporting for batch plant

4.2.7 Quality Control and Testing Records



Current methods of maintaining testing records are often manual entries using paper archival. In a BIM workflow, equipment could automatically log results from sieve tests and cylinder break test to be directly archived into a database. This reduces the amount of reentry needed and lowers any human error that could occur in logging or reentering test results. The data from test specimens could also be linked to the model and specific pieces in the model for easy access if needed.

Current inefficiencies:

- Manual entry of QC data
- Records kept on paper which are difficult to search
- Procedures and tests must be manually completed
- Project information manually recorded
- Mix performance data over time is not easily accessible
- Data for an element is not easily accessible if there is an issue
- Manually entered pre and post-pour inspection QC data
- Verifying QC Process for PCI Certification
- Auditing cost

Current processes: manually entering testing and quality control data can cost multiple man-hours of reentering or searching if the data is needed at a later time. It can also be difficult to track trends, such as mix performance if the data is in an analog format. In a future state, time lost can be reduced as much as 75-90% of the current amount of time.

BIM benefits:

- Readily searchable quality control records
- Trends of performance for mixes can be historically tracked
- Avoiding data reentry and paper records
- Consolidated real-time data for project testing requirements and associated results
- Drive robotics for post-pour inspections
- Real-time quality control for pre and post pour checks
- Recording prestress forces and elongations with piece data
- Real-time health monitoring
- Remote access to audit quality control records

4.2.8 Defect Reduction, Repairs, and Rework

Currently, pieces needing rework or repair are tracked manually and any logs are updated occasionally by hand. Digital tracking of the repair status of each piece in real-time and assignments to employees can accelerate the repair process by providing up-to-date status, locations, and time stamps for any piece being repaired.

Current inefficiencies:

- Manual records of which pieces need rework
- Manual records of where damaged pieces are stored
- Scheduling of rework to ensure on-time shipping
- Scheduling bed space for recasting
- Paper drawings of details for repair or recasting
- Materials ordering for repairs
- Manual records for repair inspections
- Product shipped without the needed repairs

Current processes: manual records of which pieces need repair are not updated in real-time, this can cause multiple man-hour delays and issues as pieces must be found in the yard, moved, repaired, moved again to storage, and each step recorded. In a future state, time lost can be reduced as much as 75-90% of the current amount of time.

BIM benefits:

- Better repair documentation
- Better tracking of repair status
- Prioritization of repairs
- Repairs finished on time
- More accurate as-built information
- Better plant management of defect tracking
- Accurate cost accounting of rework
- Coordination of interfacing pieces and trades to reduce rework by modifying non-manufactured pieces
- Less costly rework completed in the yard instead of in the field

4.2.9 Finished Product Tracking

Today, tracking finished products from the storage yard to the site is typically a manual process done with handwritten numbers and references. In a digitally enabled workflow, there could be model-based tracking which links the digital model to tracking systems, such as bar codes or other scanning systems, in order to digitally log piece locations in the yard and create a real-time layout of what is being stored in the yard.



In a BIM enabled workflow, straddle lift crane drivers could more easily find panels in the yard because location and movement of pieces could be available in a single digital log. Inventory could be tracked and logged digitally to track logistics, element parts, trends, shipping status and other key information related to the elements.

Current inefficiencies:

- The required piece cannot be found.
- The required piece is on the bottom of the stack.
- Manual records of elements to be cured and yarded
- Inefficient space usage in the yard
- Pieces to be shipped are inaccessible
- Confirmation of piece repair status prior to shipment

Current processes: companies spend multiple man-hours on each project trying to find pieces in the storage yard or rearranging stacks for access to the required piece. In a future state, time lost can be reduced as much as 75% of the current amount of time.

BIM benefits:

- Preplanned yard placement
- More efficient use of space in the yard
- Faster storage process
- Pieces are not lost and are readily accessible
- Faster load out procedures
- Reduced rehandling of pieces and subsequent reduction in damage

4.2.10 Labor and Assignments Tracking

In a BIM enabled workflow, an RFID or barcode tag system could track each employees' time, location, and tasks. An employee census can be taken in real time, to find what stations are being worked in and which may be under-staffed. Labor data can also be tied back to model elements if digital logs of assignments and locations are used.

Today, project information and plant maps are often manually updated and tracked with paper reports. Using a BIM workflow, workers can be assigned to jobs and tracked to understand the flow of labor through the plant and the real-time labor needs for the work load.

In many plants, tools and other assets are tracked manually with written systems. In a BIM workflow, tools, assignments, work teams, and more can be tracked in digital databases. Using these databases can provide additional benefits of understanding patterns within a plant and finding areas or processes which can be streamlined and work more efficiently.

Current inefficiencies:

- Scheduling labor for pieces and projects
- Scheduling projects within the plant and pour sequences
- Excessive overtime
- Reworking labor and pour schedules if erection sequences change
- Tracking tools and assets

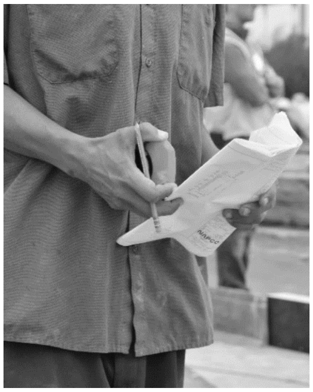
Current processes: manual databases for scheduling and sequencing can cause lost time in rescheduling and reassigning labor and tasks. In a future state, time lost can be reduced as much as 50% of the current amount of time.

BIM benefits:

- Better information for traditional metrics (per yard, per sq. ft, etc.)
- More accurate estimates on future projects
- Real time tracking of labor costs against budget
- Improved resource leveling
- Management of overtime

4.2.11 Field Coordination

Laser scanning can be used to confirm the field layout of embeds and verify the location of adjoining structure. Embeds in precast concrete pieces have to align with other embeds or anchor rods designed and installed by other subcontractors for curtain wall, structural steel, cast-in place concrete, and others. The adjoining structure must be installed within tolerance to avoid clashes and allow bearings and attachments to perform properly.



Using laser scanning equipment, installed structure and embeds are located in 3D space and can be compared to the models created for precast pieces. If misplaced structure, embeds, crooked anchor rods, or other potential problems are corrected prior to being discovered on site, this will eliminate crane and crew downtime saving money and keeping projects on schedule.

Current inefficiencies:

- Inaccurate or not up-to-date drawings of as-builts for embeds in the casting and structure
- Inaccurate embed placement
- Foundation size inaccuracies
- Installation delays due to inaccurate information
- Inefficient kitting of job site embeds
- Manual field measurements and documentation
- Manual load lists
- Lack of sufficient time for field layout and evaluation of existing conditions driven by shortened construction schedules
- Rough sketches of deviant existing conditions produced by field labor and faxed to engineering at the 11th hour requesting alternate fix designs and revised hardware

Current processes: inaccurate or incomplete drawings can lead to confusion and mistakes in field placement of embeds. Notable delays in erection can occur if embeds are incorrect and rework or recasting must be done to fix the error. In a future state, time lost can be reduced as much as 25-50% of the current amount of time.

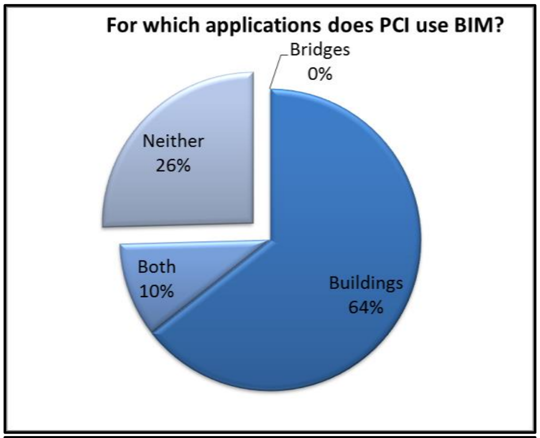
BIM benefits:

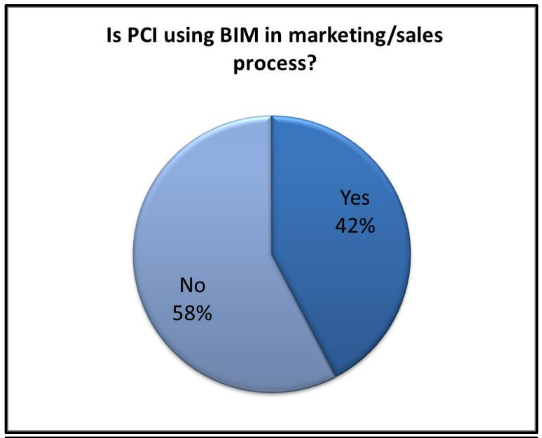
- Laser scanning integration with the model
- Total Station integration with the model
- Earlier identification and modification for field errors
- Reduced field crew downtime

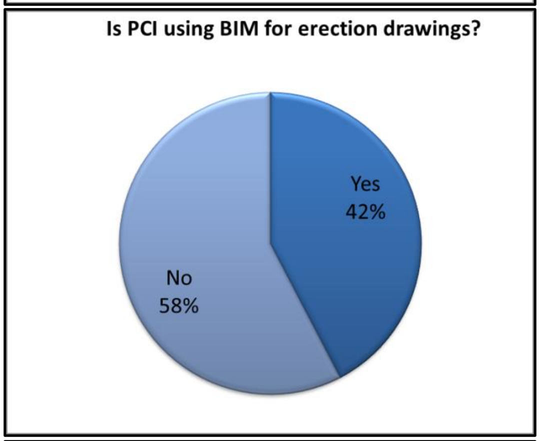
- Accurate tracking of piece placement
- Automatically generated load lists
- Production planning related to changes in erection sequence
- Accurate crane plan integration
- Graphical representation of erection in 4D
- Safer worksites due to more accurate pick plans
- Safer worksites due to more accurate and clearer brace plans
- Ability to install more complicated products accurately

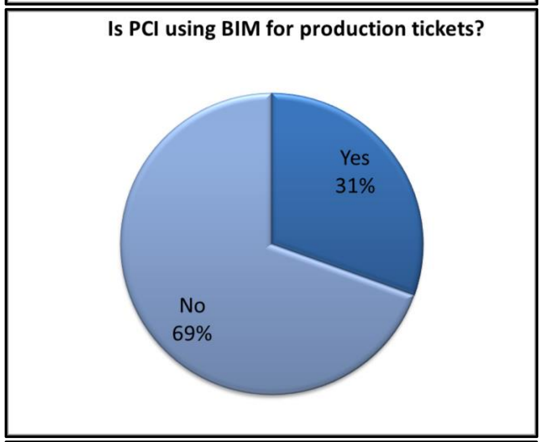
5 Industry Status

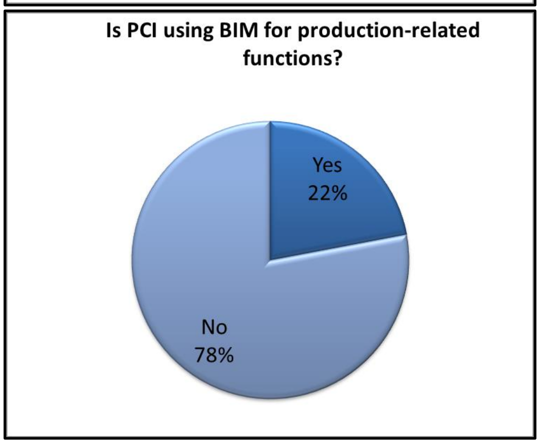
The PCI BIM Committee conducted an industry survey in 2012 to get a sense of the extent of BIM use within the precast/prestressed industry and the applications of use. There were 59 responses to the survey and the results were summarized as shown in the following charts. As a point of reference, McGraw Hill conducted a survey of General Contractors regarding BIM. One question asked the contractors to rate trades on proficiency. In the US, 62% of contractors rated the steel industry in the top three trades in BIM proficiency. Only 13% rated the concrete and masonry industry in the top three in proficiency. This clearly indicates that the perception is that concrete trades lag seriously behind the steel industry in BIM skills.

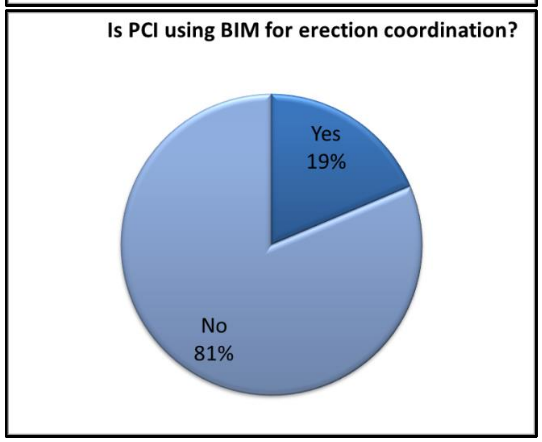


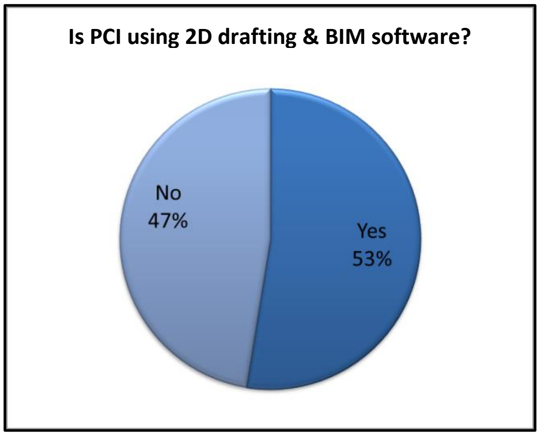


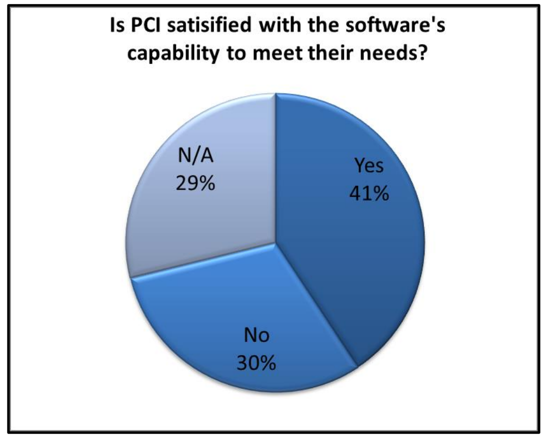




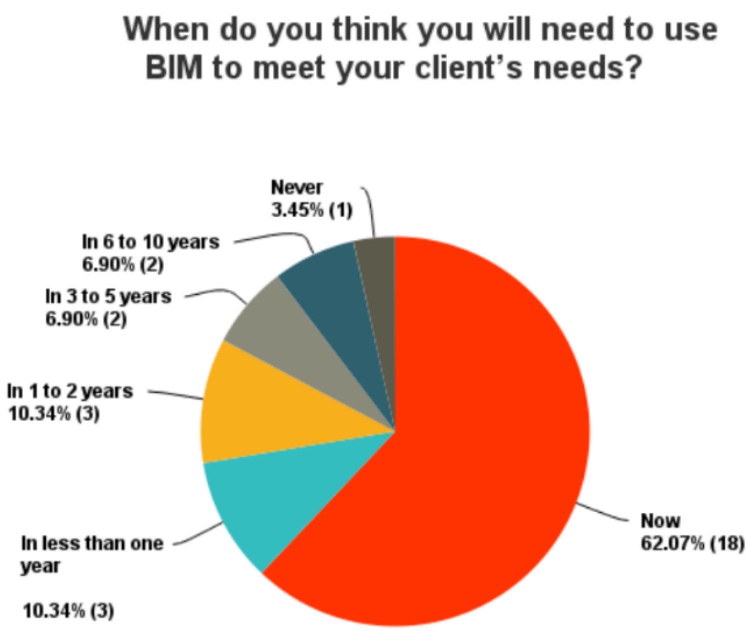








In a survey conducted by PCI in 2015, twenty-nine respondents answered the question: "When do you think you will need to use BIM to meet your client's needs?" Over 50% of the respondents answered NOW. Only one person answered Never. The need for BIM to meet clients' needs has grown in the precast industry and predicted to continue growing as per the opinion of those in the precast concrete industry themselves.



6 Building Information Modeling Key Trends

This section of the report provides background on some key trends that precast concrete contractors should be aware of when considering moving into BIM. These trends and their related organizations will be referenced in later sections of the report. This section is provided for readers who may benefit from a review of the trend and organization or who may be new to the topic of BIM altogether and value a short introduction. The items addressed in this section are:

6.1 BIM Forum

The BIM Forum is a national organization for leaders in the construction industry aimed at facilitating the adoption and implementation of BIM. By developing best practices for virtual design and construction, the BIM Forum provides resources and information to enable businesses to make the most out of BIM technology.

Every year, BIM Forum's conferences give the opportunity to learn about ways that others in the industry are using BIM to improve their efficiency and productivity. There are general contractors who will want all trades they work with to send personnel from their organizations to attend this event and take the opportunity to extend their vision of BIM implementation. There is an opportunity for the precast industry to lead here through adoption of new technologies. Many members of PCI, such as Clark Pacific and EnCon United, have presented at this conference previously.

More information about BIM Forum and the conferences can be found at http://bimforum.org.

6.2 BIM Forum Level of Development (LOD)

Clearly defined contract scopes save time for professionals in the construction industry and increase profit. Building Information Modeling (BIM) can improve scope clarity if addressed proactively, or it can compound the difficulties in achieving clarity if ignored. The construction industry has reached a point where the use of BIM is not self-explanatory: it could be used to create 2D shop drawings, coordinate trades, or estimate cost. When BIM came into existence, the industry originally lacked a vocabulary for communicating the Level of Development (LOD) between parties. The BIM Forum™ *Level of Development* (LOD) *Specification 2015* (http://bimforum.org/LOD/) is an industry-changing reference that enables construction professionals to clarify their scope with BIM, providing the solution to the problem of vague BIM scope definition.

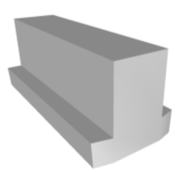
Before the LOD Specification, many model element authors were unaware of expectations upon entering a project. The LOD Specification is simply a collection of definitions describing input and information requirements with graphic/model examples of the different levels of development for building elements. This provides a clear, common vocabulary for use between parties on a project team. The simplicity of this specification is illustrated in the graphics on the following page.

The Level of Development (LOD) Specification is used nationally to specify the degree to which an element is modeled. LOD definitions in terms of model elements are below:

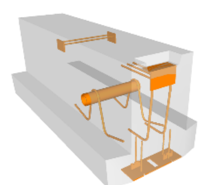
- **LOD 100**: The Model Element may be graphically represented in the Model with a symbol or other generic representation, but does not satisfy the requirements for LOD 200. Information related to the Model Element (i.e. cost per square foot, tonnage of HVAC, etc.) can be derived from other Model Elements.
- **LOD 200**: The Model Element is graphically represented within the Model as a generic system, object, or assembly with approximate quantities, size, shape, location, and orientation. Non-graphic information may also be attached to the Model Element.
- **LOD 300**: The Model Element is graphically represented within the Model as a specific system, object or assembly in terms of quantity, size, shape, location, and orientation. Non-graphic information may also be attached to the Model Element.
- **LOD 350**: The Model Element is graphically represented within the Model as a *specific* system, object, or assembly in terms of quantity, size, shape, orientation, and interfaces with other building systems. Non-graphic information may also be attached to the Model Element.
- **LOD 400**: The Model Element is graphically represented within the Model as a specific system, object or assembly in terms of size, shape, location, quantity, and orientation with detailing, fabrication, assembly, and installation information. Non-graphic information may also be attached to the Model Element.

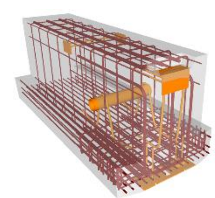
It is important to note that there is no LOD of an entire model; the model is a mixture of different elements within different LOD.


LOD 100


LOD 200


LOD 300


LOD 350


LOD 400

Examples of precast elements are shown in the progression from LOD 100 through 400 in the figures above. The LOD to which an element is modeled depends on the BIM expertise of the company, the parameters of the job, and the project team. Some companies, if they are new to BIM, may only provide the basic structural ideas and work with a third-party structural BIM consultant for more detailed modeling. Some jobs may only require LOD 200 for general coordination, while other may require LOD 400 for fabrication purposes. Different team members may also require different LOD: an estimator may be able to work with lower LOD for initial takeoffs, while the shop and plant crews will need higher LOD for precision in piece fabrication. Additionally, an expanded explanation of the program and sample BIM Execution Plan are provided in Appendix C: 2015 BIM Forum Level of Development Specification Introduction & Precast Concrete Elements of this report.

More information about LOD and the full LOD Specification can be found at http://bimforum.org/lod/.

6.3 Associated General Contractors Certificate of Management in BIM

There are also certifications in the construction industry that provide training and accreditation for managers from all trades in BIM practices and concepts. The Associated General Contractors' (AGC) Certificate of Management in BIM (CM-BIM) is an assessment-based, four-part course that aims to provide understanding in BIM adoption, practices, and process transformation for management in the construction industry. The CM-BIM is a widely recognized program and many general contractors will want all companies they work with to have project managers with this credential on their BIM projects. Having this credential shows a general knowledge of BIM and assures contractors that the trades they are working with have a shared terminology and understanding for BIM practices on a project.

More information about AGC's CM-BIM course can be found at https://www.agc.org/learn/education-training/building-information-modeling/cm-bim.

6.4 Certificate of Management in Lean Construction

Another credential offered by the AGC is the Certificate of Management – Lean Construction (CM-LEAN). The CM-LEAN provides an understanding of the concepts and application of Lean Construction and shows professionals how to change their companies toward lean practices and techniques which aim to increase efficiency and value while minimizing costs.

General contractors will want the companies they work with to have project managers with this credential on their BIM projects. Having this credential shows a general knowledge of lean practices and assures contractors that the trades they are working with share their terminology, values, and goals on a project.

More information about AGC's CM-LEAN course can be found at https://www.agc.org/learn/education-training/lean-construction/certificate-management-lean-construction.

6.5 Certificate of Development in BIM (CD-BIM.com) & BIM Execution Plans

The Certificate of Development in BIM (CD-BIM) is a credential for those professionals developing BIM models. The CD-BIM provides basic understanding of what BIM is and how it is used in construction projects. General contractors will want trade modelers in the companies they work with to have the CD-BIM as this denotes that they have general knowledge and core competency in standard modeling practices and understand the basics of the processes in BIM projects. Additionally, an expanded explanation of the program and sample BIM Execution Plan are provided in Appendix D: Certificate of Development in BIM & BIM Execution Plan of this report.

More information about the CD-BIM course can be found at http://cd-bim.com/content/about-cd-bim.

6.6 USIBD and Laser Scan Confirmation

The U.S. Institute of Building Documentation (USIBD) promotes and facilitates standardized practices and guidelines for the creation of accurate drawings and models in the construction and design industries. One method of ensuring that construction and erection plans have been followed correctly is the use of laser scanning—a type of reality capture—to confirm as-built geometry. Laser surveying to confirm embed and part placement was previously discussed in this report.

7 Legal Implications

This document has primarily addressed integrating BIM processes into precast manufacturing; however, there are contractual implications that companies need to be aware of in BIM projects in addition to considering improved productivity as discussed in this report. Generally, companies need to know what they are getting into when signing a contract on a project required BIM.

BIM can potentially affect every aspect of the internal operation for plants on projects that require this emerging technology. Methods for contracting on a project using BIM need to be considered by companies, including relating BIM contract language to their other project contracts. This will include legal risk consideration that precast manufacturers need to be aware of related to the model Level of Development (LOD) they are asked to deliver.

Precast companies also need to consider the different types of models and explore how different project delivery types can influence the extent to which BIM is used. Finally, the key roles of all team members in BIM on the project need to be examined, including how these team members champion BIM with others to maximize the benefits of modeling technology on the project, as well as the risk that can result when they do not. Building on this knowledge, the companies can then explore concepts of liability exposure and standards of care that arise from using BIM.

Contractual implications that arise with the use of BIM can happen when there are not clearly defined digital data protocols for the creation of various elements in the BIM model. It is important to consider the coordination and reliance of information contributed by team members or project players as these need to be clearly defined. A contract needs to outline the extent to which the information contributed can be relied on to ensure the quality and reliability of information on any given project.

In summary, the rewards of BIM far outweigh any perceived legal risks associated with it. For companies to succeed, they need to review their particular projects, clients, and contracts with BIM before committing their firms to delivery models.

8 Conclusion

The precast/prestressed industry has an important opportunity now to step forward and use the technology and data management tools provided by BIM to increase productivity and efficiency. Precast industry leaders and firm owners should choose to expand BIM capabilities within their organizations because firms that make the change to adopt BIM workflows will be able to maintain relevance as viable precast companies. Failure to adopt efficient methods will cause a firm's business to decline, and the result is that they will no longer be relevant in the marketplace as their BIM-enabled competitors gain their market share.

Precast companies of all sizes will face the choice to change their current practices and adopt BIM or stay stagnant and continue with the same processes as they have always used. The integration of BIM with precast operations must focus on all data exchanges and processes, instead of focusing on 2D drawings. Wherever data exchanges are identified, information will have to be organized and integrated for the most efficient use. The degree of integration can be tailored to the company goals allowing partial integration, gradual integration, or complete integration of BIM processes with the current plant needs and outputs. These changes will be disruptive, but the assistance and resources of experienced BIM consultants or industry partners can aid in the transition by preparing detailed execution plans, evaluating processes and data exchanges to be streamlined, and training personnel in new practices, software, and technology. The commitment of a precast firm to the BIM changes will mediate any problems, while also maximizing and expediting the return benefits later.

Champions of BIM tools and business practices are also needed to move the BIM implementation to the next level. Precast companies need to decide whether they want to continue to follow the long-time trend of decreasing construction productivity or the positive trend of increasing manufacturing productivity, which has been attributed in no small part to effective implementation and business process transformation with technology. The precast/prestressed concrete industry can benefit greatly from the adoption of manufacturing techniques that improve efficiency and productivity, but a shift in mindset is required for this to happen. The precast industry has reached a crossroad and must choose which path to take; productivity or stagnation, and BIM can provide the tools needed for progress.

9 Acknowledgements

PCI is an organization dedicated to fostering greater understanding and use of precast and prestressed concrete. The PCI BIM Fast Team develops and reports information on the business application of BIM for precast concrete structures, while helping the precast industry understand the practical business applications of the latest technology.

PCI BIM Fast Team

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David Figurski	Rocky Mountain Prestress
Kim Hammon	Clark Pacific
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Appendix

Appendix A: Sample Plant Process Map

Appendix B: Investment Cost Models

Appendix C: 2015 BIM Forum Level of Development Specification Introduction & Precast Concrete Elements

Appendix D: Certificate of Development in BIM & BIM Execution Plan

Appendix E: Software Applications

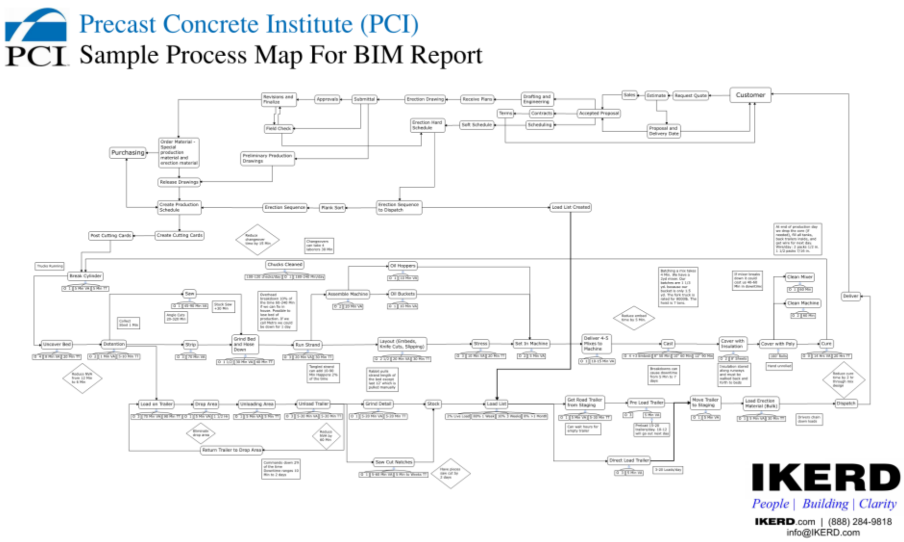
Appendix F: Documents Referenced

Appendix A: Sample Plant Process Map

The following are two sample process maps of a precast concrete production plant. The first map is a hollow core production plant. The second map is an architectural map. Full-sized samples of the maps can be found at:

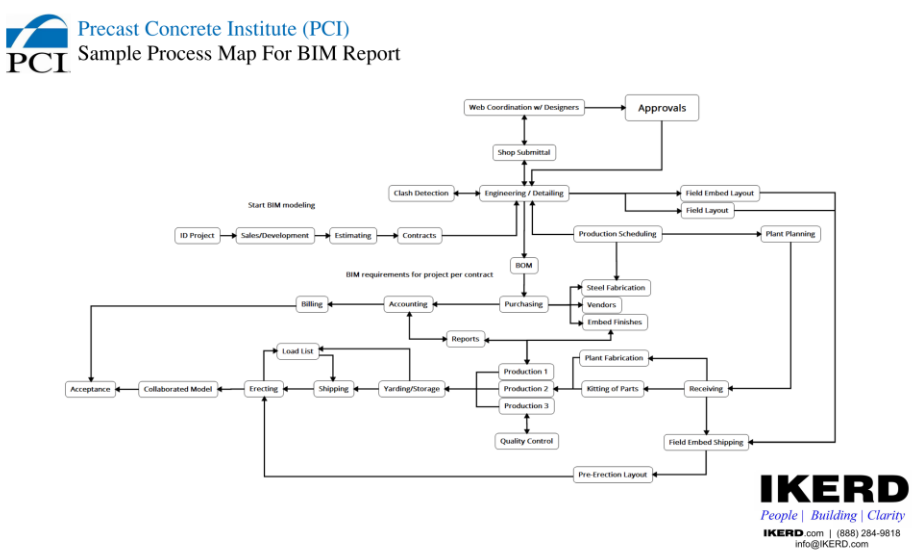
https://www.pci.org/Members_Only/Business_Resources/

1. Hollow core process map



This image is a thumbnail of the full-sized, readable version that can be found on the PCI website.

2. Architectural precast process map



This image is a thumbnail of the full-sized, readable version that can be found on the PCI website.

Appendix B: Investment Cost Models

The following are three hypothetical budgets for three sample precast companies with the common investment examples for BIM implementation costs shown. Actual implementation costs will vary depending on a large number of factors, including—but not limited to—a firm's goals and particular plant needs and capabilities. The following table is for instructional purposes only and does not represent any actual implementation budget. However, a firm can anticipate investing more than 1.5% of their annual revenue during the first 9 to 18 months of implementation.

Example Sample Budgets for 3 Hypothetical Precast Companies

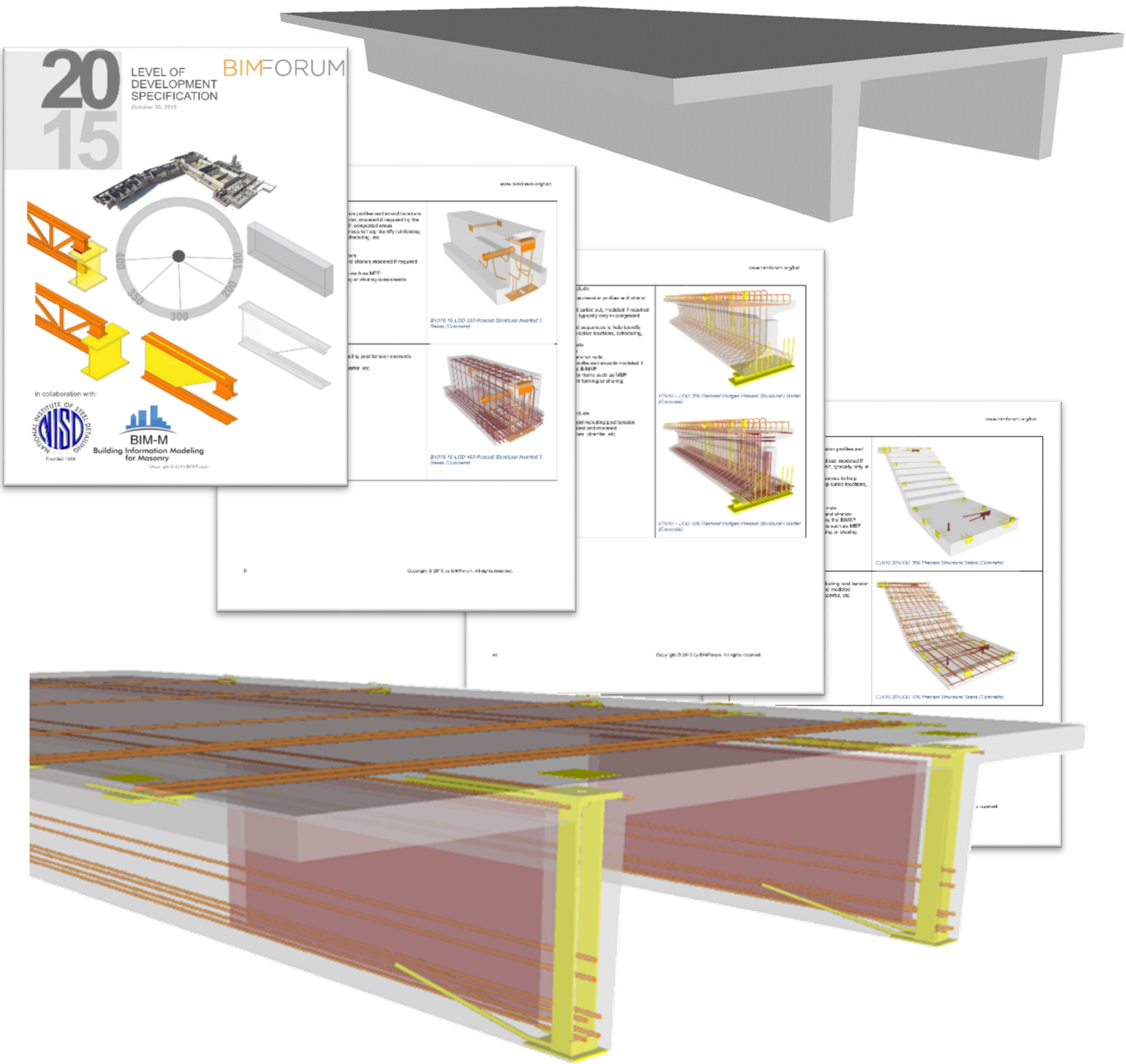
B	C	D	E	F	G	H	I
Precast Company Catigory		Small		Mid		Large	
Annual Revenue Range	$M	$5		$15		$60	
Employees, Number of Full Time Equivilents (#)	#	50		125		250	
Concrete Volume per Pour Day	Cubic Yards (YD	36		100		340	
Concrete Pour Days Per Year	Days	175		175		175	
Concrete Volume per Year	1000x YD	6.3		17.5		59.5	
Rev / yd	$/yd	$800		$850		$1,000	
Annual Revenue Calcualted from Concrete Volumes		$5,040,000		$14,875,000		$59,500,000	
rev $/person	$/person /yr	$100,800		$119,000		$238,000	
Company Facility Land Size	Acres	20		45		60	
Estimators on Staff	#	1		2		6	
				Invetments			
	$/EA (below)	# of Seats (below)		# of Seats (below)		# of Seats (below)	
BIM CREATION STATION	$ 25,000	1	$ 25,000	3	$ 75,000	12	$ 300,000
BIM REVIEW STATION	$ 4,000	3	$ 12,000	6	$ 24,000	12	$ 48,000
TABLETS	$ 700	10	$ 7,000	20	$ 14,000	50	$ 35,000
PDF SOFTWARE	$ 300	10	$ 3,000	20	$ 6,000	50	$ 15,000
IT infistructure, Sever Upgrades, etc.	Varies by size	1	$ 10,000	1	$ 30,000	1	$ 60,000
Total BIM Hardware & Software:			**$ 57,000**		**$ 149,000**		**$ 458,000**
Training - BIM Creation\managment	$ 9,000	1	$ 9,000	3	$ 27,000	18	$ 162,000
Operation BIM Training per person x staff team	$ 3,000	10	$ 30,000	30	$ 90,000	50	$ 150,000
Total BIM Training Budget:			***$ 39,000***		***$ 117,000***		***$ 312,000***
Total BIM Invetment:			***$ 96,000***		***$ 266,000***		***$ 770,000***
BIM Investment as Percentage of Rev =			**1.905%**		**1.788%**		**1.294%**

Appendix C: 2015 BIM Forum Level of Development Specification Introduction & Precast Concrete Elements

The BIM Forum is collaborating with PCI to improve the specification of precast element vocabulary. The LOD Specification is intended to be used in conjunction with BIM Execution Plans to provide clarity for all parties involved in a project.

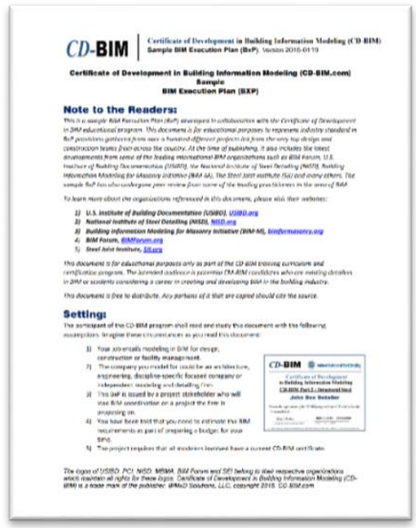
Access to the BIMForum LOD excerpt of Precast/Prestressed concrete elements can be found at https://www.pci.org/Members_Only/Business_Resources/

More information about LOD and the full LOD Specification can be found at http://bimforum.org/lod/.



Appendix D: Certificate of Development in BIM & BIM Execution Plan

An important aspect of any BIM project is a solid BIM execution plan. A valuable aspect of the CD-BIM.com program is that it provided a free sample BxP that is used as reference in the program's reference exam questions. To download a copy of the BxP, you simply need to register for a free account on www.CD-BIM.com/BXP and then access the download PDF file. The following is from the CD-BIM.com website.


CD-BIM | Certificate of Development in Building Information Modeling (CD-BIM)
Sample BIM Execution Plan (BxP). Version 2016-0119

Certificate of Development in Building Information Modeling (CD-BIM.com)
Sample
BIM Execution Plan (BXP)

Note to the Readers:

To learn more about the organizations referenced in this document, please visit their websites:

1) U.S. Institute of Building Documentation (USIBD), USIBD.org
2) National Institute of Steel Detailing (NISD), NISD.org
3) Building Information Modeling for Masonry Initiative (BIM-M), bimformasonry.org
4) BIM Forum, BIMForum.org
5) Steel Joist Institute, SJI.org

This document is free to distribute. Any portions of it that are copied should cite the source.

Setting:

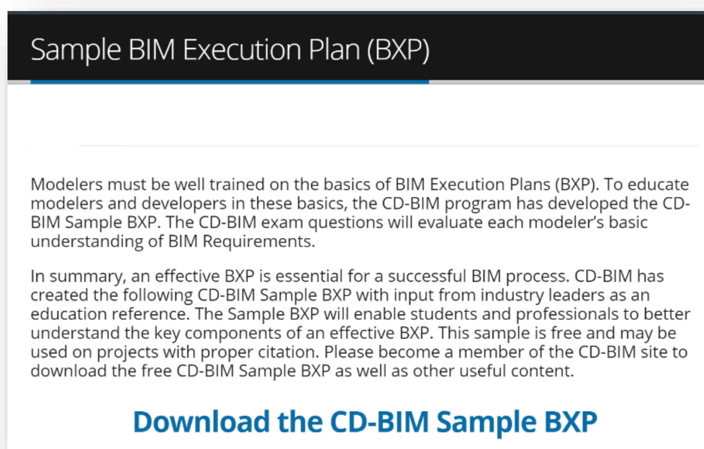
The participant of the CD-BIM program shall read and study this document with the following assumptions. Imagine these circumstances as you read this document:

1) Your job entails modeling in BIM for design, construction or facility management.
4) You have been told that you need to estimate the BIM requirements as part of preparing a budget for your time.
5) The project requires that all modelers involved have a current CD-BIM certificate.

Modelers must be well trained on the basics of BIM Execution Plans (BXP). To educate modelers and detailers in these basics, the CD-BIM program has developed the CD-BIM Sample BXP. The CD-BIM exam questions will evaluate each modeler's basic understanding of BIM Requirements.

"It is no secret that Building Information Modeling (BIM) has become an essential part of the built environment. The Certificate of Development - Building Information Modeling is an assessment based certificate credential that establishes the knowledge and understanding of concepts to BIM and detailing practices that is important for all BIM teams to know. CD-BIM has been designed to prepare entry level technicians as well as highly experienced construction professionals in BIM with a common understanding of core concepts. Some of these topics include who the stake holders are in the process, what is the BIM Execution plan, how do coordination meetings function and many other key concepts.

In summary, an effective BXP is essential for a successful BIM process. CD-BIM has created the following CD-BIM Sample BXP with input from industry leaders as an education reference. The Sample BXP will enable students and professionals to better understand the key components of an effective BXP. This sample is free and may be used on projects with proper citation. Please become a member of the CD-BIM site to download the free CD-BIM Sample BXP as well as other useful content."



The CD-BIM Sample BIM Execution Plan can also be found at https://www.pci.org/Members_Only/Business_Resources/

Appendix E: Software Applications

As the transition to BIM workflows begins, each company will need a detailed plan that identifies processes that will transition to software-run data exchanges. Many uses of BIM are discussed previously in this document, and the list of potential BIM software applications to achieve those possibilities includes the following:

Authoring Applications:

1. Autodesk Revit Structure w/ Edge Precast (edgeforrevit.com)
2. Nemetschek/ GRAPHISOFT ArchiCAD
3. StructureWorks, LLC
4. Trimble Tekla Structures
5. IDAT BDS-Precast

Model Federation Software:

1. Autodesk Navisworks Manage
2. Bentley Project Navigator
3. Trimble Tekla BIMsight

Product Management and Enterprise Resource Planning (ERP) Systems:

1. Betsy (http://www.betsy.de/products.php)
2. Concrete Vision (http://www.vproinc.com/)
3. Ebos (http://www.ebos.org/en/about-ebosr)

Appendix F: Documents Referenced

The following documents were utilized for relevant information in the making of this document:

1. *Reasons for BIM*, David Figurski (Rocky Mountain Prestress).
2. *Investment Outline*, Wayne Kassian (Kassian Dyck & Associates).
3. PCI BIM Committee Industry Survey (2012)
4. *BIMForum 2015 Level of Specification* (LOD), http://bimforum.org/lod.
5. *Labor-Productivity Declines in the Construction Industry: Causes and Remedies (Another Look)*, Dr. Paul Teicholz, (AEC bytes: 2013), http://www.aecbytes.com/viewpoint/2013/issue_67.html
6. *Leading Change: Why Transformation Efforts Fail*, John P. Kotter, (Harvard Business Review, March-April 1995).
7. *Measuring the Value of BIM: Achieving Strategic ROI*, Erin Hoffer, (Autodesk: 2014).
8. *The Business Value of BIM in North America: Multi-Year Trend Analysis and User Ratings (2007–2012)*, (McGraw-Hill Construction, 2012).
9. *Understanding the ROI of BIM*, (Vico Software: 2016), http://www.vicosoftware.com/0/understanding-the-roi-of-bim/tabid/86011/.