The State of Wisconsin
Department of Administration
Division of State Facilities

Building Information Modeling

A report on the current state of BIM technologies and recommendations for implementation.

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Preface

Building Information Model or BIM: *A digital representation of the 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."* National Institute of Standards and Technology)

Every journey begins with a step. To successfully make a journey, preparation is required. Since October 2006 the Department of Administration, Division of State Facilities has been in preparation to begin this journey into Building Information Modeling for the betterment of capital asset and capital project programs serving the agencies, and citizens of Wisconsin. The journey begins July 1, 2009 with the implementation of the first segment of DSF BIM Guidelines and Standards.

BIM is not new technology. BIM has been in development and use by other industry sectors beginning as early as the 1950s. As the applications continue to evolve with developing computing and digital information technology, BIM is now entering the capital asset industry including planning, design, construction, and operations – encompassing the life cycle of the faculty.

This findings report is made available by the Wisconsin Department of Administration to provide a glimpse into the trends, benefits, and complexities of the BIM technology that determined these initial guidelines and standards. These findings form the base and set the course of the implementation strategy in the next few years. Because of the highly fragmented segments that make up the planning, design construction and operations sectors and the rapid changes and development of digital technology, future modification to this implementation strategy is certain. However, the core content of the implementation strategy is based on fundamental concepts that are unlikely to change.

The support and encouragement from the Division's leadership and use of resources in the preparation of this BIM implementation is appreciated. The vision of Tab Tabrizi, Chief State Engineer and Director of the Bureau of Architecture and Engineering to establish BIM standards and guidelines set the implementation strategy in motion. The vigilance of Dave Haley, Chief State Architect and Bureau Deputy Director in recognizing that BIM is a tool to enable not substitute the talent, skills and abilities of competent people gave balance to the requirements. The education, counseling and advice from our consultant, Kevin Connolly, Connolly Architects Inc., Milwaukee gave clear insight to construction industry perspective.

This findings report has resulted in the published DSF BIM Guidelines and Standards.
When taking a journey, it is always best to have a guide. The direction and explanation of BIM applications are provided as guidelines. The results and outcomes listed are expected to achieve substantially uniform usage as a standard for BIM applications.

The promise of this parametric digital technology and information exchange between applications and users: to reduce waste, reduce costs, improve certainty of outcome, and optimize performance of facility planning, design, construction, and operations may one day be achieved. Even if only a portion of the promise is realized in the future, benefits can be realized today with this implementation. The journey begins.

Bill Napier
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Executive Summary

National studies have, over the last five years, documented long-term declines in construction productivity., These studies suggest that the reuse of facility information and responding to owner demand for greater certainty of outcomes are necessary to correcting this decline. Observing similar needs and trends, The Division of State Facilities (DSF) is actively participating in a number of national organizations and doing research into new technologies and practices. Building Information Modeling is one of the core technologies that is showing promise in the Architecture/Engineering (A/E) and Construction industries.

A Building Information Model is a digital representation of physical and functional characteristics of a facility. Building Information Model*ing* is the practice of producing, communicating and analyzing building models. All contracting methodologies can use BIM to improve outcomes..

BIM technology and practice are evolving on many fronts throughout the country. In Wisconsin concurrent development is occurring in DSF, A/E, and Construction Industries.

DSF is leading by example by acquiring knowledge and sustaining commitment towards technologies that interface with evolving BIM applications. Areas of work include:

- Facility Documentation and Assessment
- Capital Facility Planning
- Project Communications and Collaboration
- Geographical Information Systems
- Facility management
- Long term data (asset) management

RECOMMENDATION: DSF should establish a collaborative, cross agency/A/EC industry advisory group to monitor progress on BIM and to develop goals and strategies for BIM process transformation.

The organizing and presentation of this information to achieve a clear picture of the status and trends of the technology is difficult. To provide structure to the findings the report addresses the principal groups working in capital development programs throughout the world: Owners/Operators, Designers (Architects, Engineers), and Constructors. Bracketing these groups is the Introduction and Long Term Vision of BIM for DSF.

Owners/Operators seek reduced costs, ready access to existing information, improved decision making, higher productivity, higher building performance, and greater certainty of project outcomes. At Federal level the leading agencies include GSA, USCOE, US Coast Guard, Veterans Administration. The DSF is collaborating with these and other state agencies through networks in the buildingSMART alliance, FIATECH, and related BIM initiative organizations. At the local level, DSF continues to work with representatives from the liaison committee and related BIM focused groups including AIA, ACEC, AGC, ABC, etc. DSF continues to expand BIM implementation strategies and related technologies for State of Wisconsin agencies beyond the Department of Military Affairs and University of Wisconsin System Administration.

It has become evident the transition of the technology in the long term will assist the Owners/Operators throughout the life cycle of assets to operate and maintain facilities, effectively manage entire asset portfolios on and enterprise wide basis, identify strategic planning needs, and execute design and construction using best practice delivery methods.

Designers: The Architecture and Engineering Professionals are using BIM to varying degrees throughout the design process. Most advanced uses are in the areas of design visualization and the creation of construction documents for architectural and structural design. Mechanical, electrical and civil engineering professionals and the software that supports them, are not advanced to the same level. However 3D software currently being used by many of these engineers will interface with BIM technology and there are positive indicators that these professionals are adapting BIM as well.

Integrated energy analysis, design quality checking and quantity take-off/estimating using BIM data, is being used by some architects and engineers to aid in early design decisions and better collaboration. BIM shifts the A/E's work effort, as more time is used during early design but less effort is required for construction documents, as a result of the technology.

Constructors: The Construction Industry is implementing BIM technologies as well. Its early uses of models focus on constructability, productivity, schedule and cost control. Recommendations for the contractors will be the subject of a later report.

A long term vision coupled with mid-term goals are needed to advance the use of BIM for the State of Wisconsin capital asset and project program. The long term is about achieving access to information, higher productivity and greater certainty of outcomes. Immediate goals include continual evaluation of fundamental process changes to take full advantage of all the opportunities BIM has to offer. At the core of this technology transformation in the construction industry is the use of digital parametric technology and the exchange of digital data across all platforms and among all principal groups (AECOO). These findings have formed the implementation strategy and the content of the first incremental BIM Guidelines and Standards.

RECOMMENDATION: Create a standard set of requirements and guidelines for BIM implementation on State projects. The initial requirements should be conservative and recognize the evolving nature of this technology.

1.0 Introduction

The purpose of this report is to establish a common understanding of BIM technology, describe part of the industry efforts worldwide to apply BIM technology, and form the basis of DSF BIM Guidelines and Standards and BIM Implementation Strategy. The report examines current use of BIM by Owners in areas of interest to Wisconsin and DSF; by Architects and Engineers; and by Contractors. Within each section are recommendations that relate to the topic discussed. These recommendations take a fundamental approach to BIM implementation framed by the following parameters:

- BIM Guidelines and Standards must work within the Design-Bid-Build delivery process. This does not preclude adapting these with other project delivery methods as DSF recognizes the value of alternative delivery approaches to construction.

- The guidelines focus is on the services of Architects and Engineers as described in the DSF *A/E Policy and Procedure Manual*.

- The requirements of the guidelines are intended to be within the capability of the technology and achievable skills of the professional disciplines. The standards and procedures required are not cutting edge technologies needing unusual investment or otherwise difficult to achieve on the part of the A/E.

- The initial guidelines are not intended to dictate a firm's modeling standards or workflow.

- The BIM Guidelines and Standards are software neutral and encourage use of open standards for interoperability.

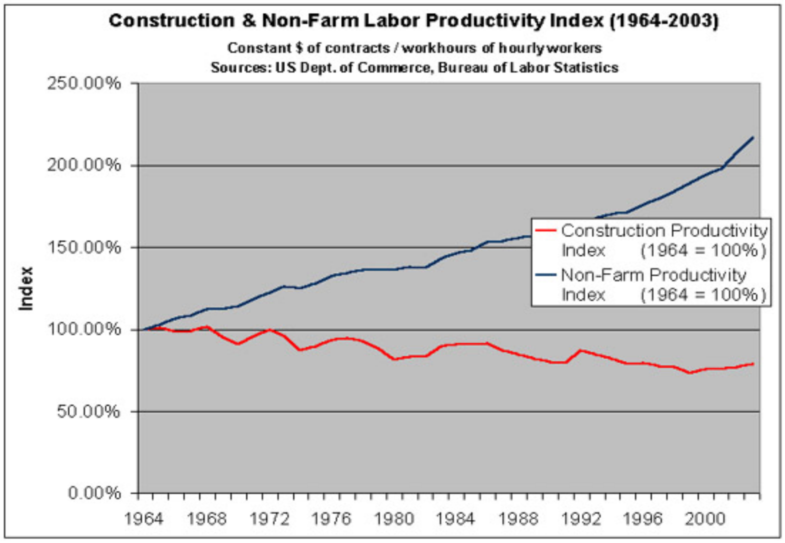
The following sections describe what is causing the changes in the capital facilities industry, an overview of Building Information Modeling (BIM) and why most of the A/E industry is ready for this change.

1.1. Driving Forces of Change

There are three overarching forces changing the capital facilities industry today: Productivity decline, advancing technology and lifecycle perspective.

1.1.1. The Recognition of Productivity Decline

In 2004, the Center for Integrated Facility Engineering at Stanford University conducted research on construction industry labor productivity. (CIFE Stanford, 2007) The study found that productivity in non-farm industry sectors has risen dramatically in the last forty years except for the construction industry which actually declined 10%. This is a result of many factors including industry segmentation and increased project complexities. This report suggests that traditional practices and technologies have contributed unnecessary waste and errors.



As the number of design and construction sub-specialties increase there is a growing problem of common data definition, data exchange policies and software interoperability. A recent study done by the National Institute of Standards and Technology showed $15.8 billion wasted yearly as a result of inadequate information flow, redundancy, and incompatibility between systems. (National Institute of Standards and Technology, 2004) And in a 2007 report, McGraw Hill drilled further down and stated that on average, 3.1% of every project can be attributed to the costs of lack of software interoperability. (McGraw Hill Smart Market Report on Interoperability, 2007)

In February, 2007 DSF presented a report to the Construction Industry Institute (CII) entitled "CONSTRUCTION CONTRACT CHANGE ORDERS Internal Benchmarking and Comparative Functional Benchmarking" . It identified spending of $20 million per year on change orders. Of this 75% is due to changes in scope and 17% due to unforeseen conditions, and 8% design oversight. Over half the changes were major changes (exceeding $250,000 each). With $500 million in construction expenditures each year, a significant portion of the change orders should be avoided using BIM technology.

Other industries have taken advantage of technology to improve productivity. However, *"the capital projects industry greatly lags other sectors in exploiting technological advances. It is characterized by vast disparities in business practices and levels of technology application. It is fragmented, with great divergence in tools and technologies from company to company and across its supply chains."* (FIATECH, 2009)

1.1.2.<u>Technology Advances: The Promise of Greater Certainty:</u>
Achieved service, sales and production goals, building performance, return on investment, cost and schedule control, maintainability, legal, functional, visually appealing and others are objectives that are at the top of every facility owners mind at the start of the project. They are also the source of uncertainty.

Though BIM is not the panacea, early uses of the technology and methods have shown that better decision making information is available much earlier, improving understanding and giving greater certainty of outcomes to all team members. Some of the factors that contribute to BIM's ability to improve certainty include:

- Use of pre-design BIM tools improves project planning, coordination of program, cost and schedule projections, and clearly communicates of intent to the design team. (Onuma Planning Systems) (Trelligence)
- Easy to produce 2D, 3D and 4D visualization of any aspect of the design to improve understanding and the quantity and quality of decision making at all design stages.
- Better assurance of program compliance through ongoing analysis of the building model against owner requirements. (Solibri)
- Integrated energy, sustainability and daylighting analysis tools allow better early decisions resulting in higher performance buildings and increased long-term value. (Ecotect) (Graphisoft)
- Better cost control from the beginning of projects through early comparative estimates and feedback during design. (Beck Technology)
- Higher quality bid and construction documents through improved communication and coordination between A/E disciplines with the use of BIM checking tools. (Solibri) (Autodesk Navisworks)
- Higher quality bid and construction documents as a result of drawing views being extracted from models made up of non-redundant elements that maintain precise geometry and relationships. (Graphisoft) (Bentley Systems) (Autodesk Revit) (Digital Project)

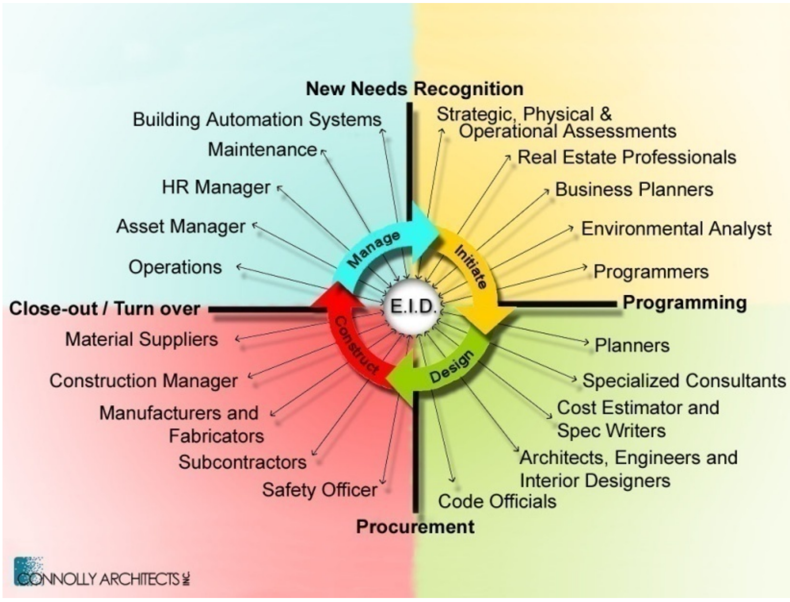
1.1.3. Repurposing and Reuse of Information: A Lifecycle Perspective

Facility owners have recognized that information can be leveraged like any other asset. The manual and piecemeal collection and entry of capital asset information is expensive, time consuming and error prone. Maintaining and retrieving accurate and relevant information is not uniform and consumes resources. BIM changes this situation. Properly structured, BIM allows owners to create an “Enterprise Information Database” (EID) that becomes the repository for information as it is developed over the lifecycle of the facility. BIM formats assist in automated populating data points for facility management systems, serve as asset management tools, and provide information for future evaluation and planning.

Regardless of capital asset portfolio complexity or size of the capital project the continuous project lifecycle includes these elements:

1. Operating / Facility Management
    - Usually the longest duration, highest risk phase in terms of costs
    - Ongoing maintenance and repair to maintain the asset value and service use
2. Planning
    - Usually the shortest duration, highest risk in terms of costs to find information or making decisions with missing information
    - During operations of facility, over time, needs change and new demands are placed on space and obsolete systems impact cost of operations
    - Evaluation of existing facility to repurpose all or part, or remove from asset portfolio inventory
3. Designing
    - Validation of Owner and capital asset requirements
    - Develop solutions reconciling scope, costs, schedule, quality and host of other criteria
4. Construction
    - Procurement of goods and services
    - Execution of the solution

The lifecycle illustration below shows process flow and provides context for information exchanges generated and shared by all phases.



In order for owners to best capitalize on the data that is generated in the BIM process, there must be repeatable standards. One organization that is setting such standards for data definitions and exchange policies is the Construction Operations Building Information Exchange. (COBIE) The objective is to capture the data as it is being created in a consistent format by the owner, designer, constructor, commissioning agent so that the data is then available to the owner. COBIE is also developing effective and efficient methods for the handoff of information between these parties in order to eliminate waste and errors in the process and create an additive approach to information development. BIM authoring tools can export data in COBIE compliant format.

1.2. Building Information Modeling

1.2.1. What is BIM?

"A Building Information Model is 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." (National Institute of Standards and Technology, 2004)In this definition BIM is a noun. The models are characterized by intelligent representations of building elements and components; that include data to describe how they behave (analysis); in a consistent, non-redundant and coordinated way. They are developed using various software packages.

Another definition exists that defines BIM as a verb: *"Building Information Modeling … is a modeling technology and associated set of processes to produce, communicate and analyze building models."* (Eastman, BIM Handbook, 2008, p. 13) However, BIM is not a project delivery method. The "associated set of processes" is applicable to all types of contracting methods to improve outcomes.

A BIM is typically started with and then maintained in a BIM Authoring program. The National Institute of Building Sciences defines BIM authoring tools as: *Tools that generate original information and digital representations or intelligent virtual models.* (National Institute of Standards and Technology, 2004) The original models or portions created in the authoring program can be exported and used in BIM analysis, checking, viewing, reporting and other programs, which are typically independent programs. Results from these programs are incorporated back into the originally authored file.

RECOMMENDATION: Require A/E to create and maintain their BIM in a DSF approved BIM authoring tool.

1.2.2 Parametric Objects

The concept of parametric objects is central to BIM. By defining the rules (parameters) that affect an object, the object can reconfigure to respond. In general, anything that can be described and documented can become a parametric object. A single parametric object contains rules that describe multiple options.

As an example, a user can select 'window type-double hung' from a pull-down list of parameters. Immediately the generic window object will reconfigure itself into a Double Hung Window, with all double hung window characteristics. The same pull-down menu would also allow the window to become a casement window, an awning window or a fixed window.

Parametric objects can mimic real-world behaviors and attributes. A parametric model is aware of the characteristics of components and the interactions between them. It maintains consistent relationships between elements as the model is manipulated. For example, in a parametric building model, if the pitch of the roof is changed, the walls automatically follow the revised roofline. Or, place the window in a wall and the wall knows how to accept the window.

The individual objects and the model as a whole have rules for viewing in a non-redundant way. A floor plan, elevation, section and even the 3D image is a view of the same object or set of objects. Similarly data can be extracted such as a window schedule. If the window height is changed in elevation view, it is automatically changed on the schedule.

1.2.3 What BIM (noun or verb) is not

- A software trade name
- A contracting method
- Models that contains only 3D data with no attributes or parametric properties
- Models that are composed of multiple 2D CAD files
- Models that allow changes in one view that are not automatically reflected in other views
- Complete… BIM is an evolving technology, but clear advantages are occurring now.

1.3. Interoperability

The long-term benefits from BIM revolve around data that can be 'grown' over time to include a virtual description of a facility and all relevant information about the facility and its surroundings. To achieve these benefits the data must be consistent and repeatable. Large numbers of people and systems work together to produce and maintain this data. For that reason, the data and systems that people use must be interoperable.

Interoperability is the ability to exchange data between diverse platforms and applications, allowing multiple types of experts to contribute to the project. There are two fundamental aspects of interoperability: technology and business process.

1.3.1 Business Process

Research and development efforts are occurring in various organizations to understand who needs what information, when, and how will it be exchanged within and across business organizations. A few of the many efforts underway include:

- The Open Geospatial Consortium (OGC), an international organization that is developing publicly available interface specifications to support interoperable solutions that "geo-enable" data used in the Web, GIS and BIM.
- The Construction Operations Building Information Exchange (COBIE) is working to capture and exchange building information relevant to facility managers.
- The Open Standards Consortium for Real Estate (OSCRE) focuses on data exchange within the real estate business process.
- The International Code Council (ICC) is developing data and rule definitions to automate code compliance checking.
- The Association of General Contractors (AGC) continues its development of exchange specifications for transactional data now commonly exchanged as paper documents, such as agreements, change orders, and submittals.
- The primary organization working on interoperability is buildingSMART International (formerly the International Alliance for Interoperability) with 13 chapters worldwide. It is a non-profit alliance of building industry participants including: architects, engineers, contractors, building owners and facility managers, building project manufacturers, software vendors, information providers, government agencies, research labs and universities. Its goal is to develop a universal standard for information sharing and interoperability of intelligent digital building models. Their major product is the IFC. In the US, buildingSMART is organized under the National Institute of Building Sciences.

In the last five years the quality and quantity of systems that meet interoperability standards has increased dramatically. As an example, energy analysis from model data is now a relatively easy task, due to interoperability. Five years ago this was not true. As these data exchange specifications advance the quality of software interoperability will increase.

1.3.2 Technology

There is a number of exchange formats used today to achieve varying degrees of interoperability. *Proprietary file exchange* formats such as DXF, and DWG have been successfully used in the past to exchange geometric and alphanumeric data. *Proprietary direct links*, which are custom programs that use the application program interface (API) language of the host program, can be very robust and often seamless to the user.

There are also a number of *Open Standard formats*. Extensible Markup Language, XML, is an open standard for transfer of alphanumeric data. Though the standard is open the applications are written by software companies or organizations. The application has a specific purpose and use group. A/EcXML, gbXML, agcXML and ebXML are examples used today.

Industry Foundation Class (IFC) is another open standard exchange format. It is the only format that can exchange 3D geometric object properties, organizational relations, object attributes, alphanumeric, and other BIM data. (CIS/2 is a similar open standard focused on structural model exchange) IFC data model is the only broad based object model exchange method and will likely become the international standard for building data exchange within the construction industry. (Eastman, BIM Handbook, 2008, p. 68)

1.3.2 Key Issues

Any definition of software interoperability must include the ability to have free and reliable access to data, across any application, in perpetuity. Currently problems exist to varying degrees with all the alternatives above.

The data initially generated by any product is proprietary to that product. Direct links through APIs or open standards transfers through xmls work well as long as both parties actively maintain their interfaces. If a business redirects its strategies, changes alliances or goes out of business the data may no longer be exchangeable.

Versioning and upgrading is a continuing issue. A proprietary exchange format must be upgraded to work with each software package it interfaces with. This issue escalates exponentially as each of these companies' must upgrade their products with those of others. Many times the upgrade does not occur causing potential business process changes on the part of the user.

IFC standards must also be upgraded over time. However if the proprietary software is IFC compliant, it only needs the one interface upgrade to the latest IFC version. In theory, if all software can interpret the IFC data model, the upgrade issue is minimized.

It is likely that future building model servers will increasingly rely on IFC as it is the only comprehensive exchange capability for construction. (Eastman, BIM Handbook, 2008, p. 88) These long term building model repositories will maintain data integrity, versioning, management, coordination between multiple applications and more. However Eastman adds that current neutral formats are inadequate to recreate the BIM files completely. Currently any neutral exchange format must be augmented by the native BIM files.

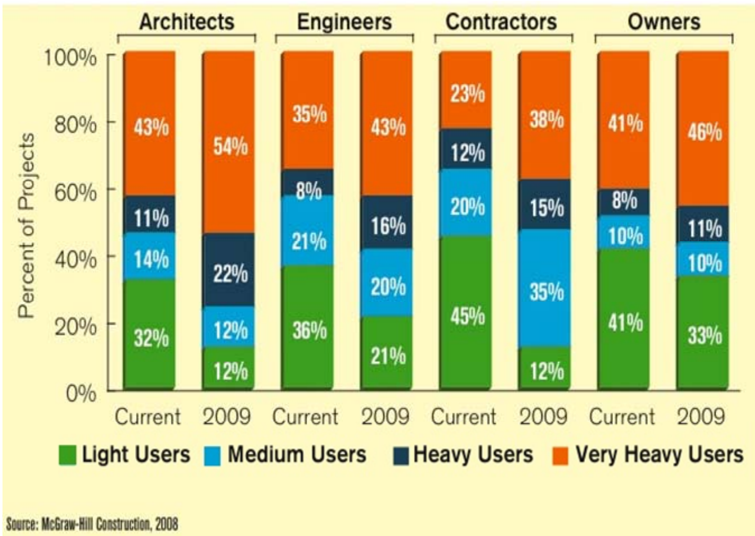
RECOMMENDATION: DSF should continue its open standards policies for data exchange. Require A/E to us BIM authoring tools complying with the current version of IFC per BuildingSMARTAlliance. (Building Smart Alliance)

1.4. BIM Maturity in Various AECOO Industries

The use of BIM (both as a software and process) is maturing faster in some sectors of the capital projects industry than others. Architects and engineers are currently the most experienced in its use (McGraw Hill Smart Market Report on BIM, 2009) Much of the A/E world has been quick to recognize the value of BIM and many in the last three to five years have become acquainted with the possibilities.. However, the software available to engineers, other that structural, is just now becoming mature and is generally used only by the earliest of adopters.

In April 2008 DSF surveyed one dozen "pilot project" AE firms that were voluntarily using BIM on State projects. The results were similar though extended use beyond basic modeling was uncommon. Anecdotal evidence since this survey suggests extended use for scheduling, energy analysis, conflict checking and cost comparisons are occurring.

RECOMMENDATION: Require Architects and structural engineers to use BIM. Require M, E, P, FP and Civil engineers to work and submit 3D files.



2.0 The Owner/Operator

This section focuses on various DSF initiatives, current and potential, where building information modeling can have a positive impact. In order to move to BIM and the benefits from BIM, DSF must address the following fronts. Recommendations in this section apply to DSF with additional references to A/E requirement sections.

2.1 Facility Documentation and Assessment

Documenting and assessing existing facilities using BIM models can help DSF better manage the full life cycle cost of building ownership. BIM data allows for future capital facility planning and budgeting process using more consistent and verified data.

Enterprise clients such as the United States Coast Guard manage and maintain their facilities and infrastructure systems using BIM based systems. They use BIM to link their facilities to their mission execution. The result has been improved building life cycle management and better allocation of resources. (Bevins, 2005) (Eastman, BIM Handbook, 2008, p. 339)

As additions or alterations occur, and are modeled, the State begins to receive similar benefits. BIM offers multiple ways to incrementally link State facilities to the budgeting and management processes to improve annual budgets and increase transparency. Formal methods to connecting existing facility data to business decision making systems through use of BIM will happen in future releases of this document.

> *RECOMMENDATION: DSF should develop a guideline that identifies what kinds of information need to be collected and how it is to be formatted for BIM documentation and internal assessment.*

2.2 Capital Facility Planning

The Capital Facility Planning process can be optimized using building information modeling processes. Various BIM based planning tools exist to corroborate program, budget and schedule assumptions. One such system, the Onuma Planning System (Onuma Planning Systems) assists an owner in collecting program information and helps make broadscope assumptions like first costs, operating costs, and schedules. From this basic information an owner can do high level testing of site utilization, energy use, cost scenarios and more. Set up properly, a preliminary architect-ready model can be exported and included as part of the project statement. D-Profiler (Beck Technology) is another similar planning tool.

> *RECOMMENDATION: Consider, evaluate and apply tools to improve the planning process.*

2.3 Design Assessment

State Agencies and DSF expend personnel resources manually reviewing A/E work against DSF standards and Agency program requirements. The current submittal and review requirements include the distribution of paper and electronic (PDF) documents. Submissions are reviewed independently by staff engineers and the project manager. Comments are entered into the WISBuild website for review and response by A/E. Since there is no direct linkage between the submission and WISBuild, there can be inconsistencies between reviews and confusion as to where on the drawings the comments apply.

Currently larger projects have a formal peer design review at end of “schematic design” phase. At the end of “design development” phase the project manager relies on the design report for confirmation of program adherence, construction costs, energy and daylighting reporting and other design validations. Rarely is a detailed review of the design solution done. DSF Engineering does a cursory review of systems against DSF standards. At end of “construction documents” phase engineering checks the various disciplines for compliance with DSF standards. The project manger checks overall document coordination and in particular division one of the specifications.

> *RECOMMENDATION: DSF should develop an electronic method of document review that directly connects review comments to the plans and specifications submitted by the A/E. DSF should also develop tools that allow staff to validate the accuracy and completeness of submittals.*

BIM offers new ways to assess the designs at each phase of the process. BIM checking tools can be configured to automate many of the review items mandated by DSF. BIM checking tools can also review beyond DSF standards and requirements.. 3D visualization and tabulation tools exist within the authoring programs. Questions like, “what does this look like?” or, “what is my efficiency ratio?” can be answered quickly.

External analysis and automatic checking tools exist to electronically confirm many of the things now done manually. A model can be compared against many pre-established “rules”. Circulation patterns, adjacency of spaces, simple building code checks, building elements occupying the same space (collisions), and more can be verified. These model-checking tools are not yet common among A/E with the exception of collision checking in some larger firms.

Accuracy and completeness of models will become important as DSF moves toward a BIM based system. These models will become the permanent archive of facility data and must therefore be accurate. Checking tools exist to check the integrity of the model itself. The format of deliverables and standards required within the files can be checked against DSF requirements. The model can be “commissioned” to test if it has been built and works as intended. These technologies are available but not yet in mainstream use.

> *RECOMMENDATION: DSF should monitor development and applications of automatic document and model checking software as availability and reliability increase.*

2.4 Project Communications and Collaboration

Communication is essential to integrated processes. Without tools that simplify communication and allow the DSF and State Agencies to make timely decisions, it is difficult to minimize errors and keep everyone in the loop. A collaborative approach to project communications will be the best way to minimize problems. In an integrated process, it is the only way.

DSF currently uses WISBuild and email for most digital project communications. WISBuild’s use is limited to construction related requests for information, change order tracking and some review communications. It is not a collaboration site. Email has been shown to be difficult to manage. A number of worldwide studies have shown that email does not serve the interests of collaborative project teams adequately. Various project teams may be using other collaborative tools provided by the A/E's.

RECOMMENDATION: Continue to incorporate a file transfer methods into future versions of WISBuild for electronic transfer of required pdf's. Continue research into project collaboration tools.

2.5 Geographical Information Systems GIS

The worlds of geographers, engineers, architects, planners, facility maintenance and capital asset managers are converging. Maps aren't just maps – they are data rich information systems. Buildings are no longer only a geometric shape on a piece of paper but rather symbols or shapes containing information about the building structure, use and site. They are BIM. Building information models, BIM, should be geo-referenced to allow data sharing between both worlds and facilitate record retrieval over long periods of time. Buildings change names, shapes, functions, addresses, agencies and institutions, but they rarely change geographic locations.

This convergence has enormous implications for our future as custodians of the built environment. With this bridge into GIS, BIM can become part of geospatial applications. Both BIM and GIS can then share information and integrate that information in context for emergency preparedness and other infrastructure assessment needs. (Jernigan, 2008)

DSF is working with the Geographic Information Office (GIO) at the State of Wisconsin to integrate Geographic Information System (GIS) technology into our business practices. The GIO is currently running ESRI ARCGIS Server 9.3. This is a web-based system allowing users to access only the information for their security group – similar to WisBuild.

ARCGIS is able to access and interface with information and files stored in IBM DB2, IBM Informix, Oracle, Microsoft Access, Microsoft SQL Server, and PostgreSQL, and database applications such as WisBuild and WALMS, document management software such as Sharepoint, CADD software such as AutoCAD and a variety of utility modeling software. GIS can serve as the portal to access, store, analyze and view the BIM for building assets, as well as the information for the non-building assets owned or leased by the State of Wisconsin.

The long range goal is for A/E's BIM models to interact with the State's ESRI ARCGIS so that the data in the BIM can be displayed, referenced and reused both publicly and for internal use in programming, design, capital and business planning.

RECOMMENDATION: Continue building GIS systems that can link to BIM. Consider use of OGC standards.

2.6 Facility Management

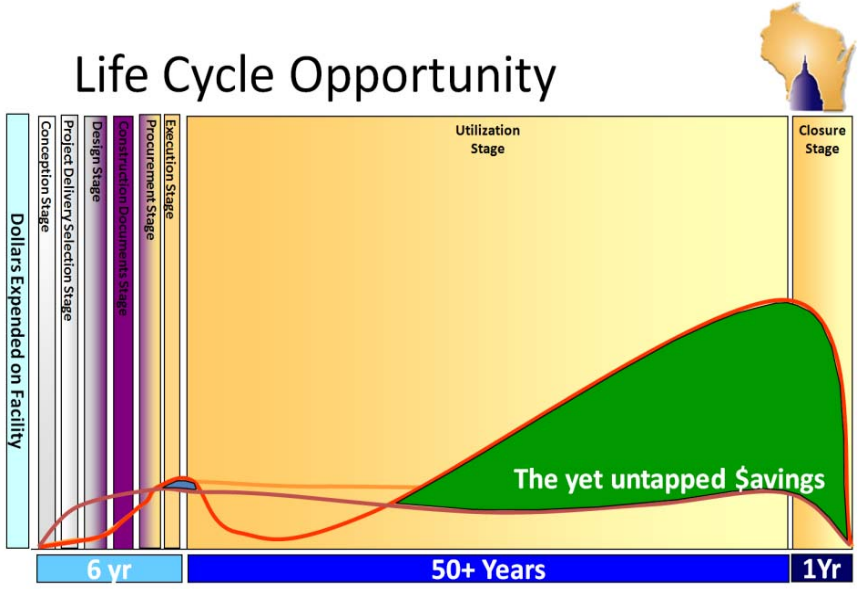
The State of Wisconsin has shifted management strategies from individual project assets to a comprehensive portfolio encompassing all of the capital assets. Facility Management of these assets is critical to maintain services and be stewards of the public works.

Handoff from construction into facility startup includes the many and diverse documentation and data making up the record documents including Operation and Maintenance Manuals and Commissioning Reports.

Reporting of building performance is ongoing especially with respect to energy use. These are useful when evaluating facilities and systems for replacement, modification or decommissioning. The core of data is the CMMS, for automated processing and tracking of routine services, repair and maintenance. This can provide data for feedback for building performance.

Data collection now includes necessary items for building inventory, risk management, and emergency response. The data points, exchange, and uniform standards is needed to meet objective of portfolio management.

The chart below illustrates the potential cost savings, or risk if information is not obtained and effective decisions are not made regarding life of asset. The top line shows normal trend in asset management: build it, don't put any money in it, wait till it breaks, then replace it. The bottom line shows an integrated portfolio practice allocating funds early for quality maintenance and repair so as to avoid or defer the costly replacement.



RECOMMENDATION: Continue development of Facility Management Systems. Develop data definitions, collection and exchange policies. Consider COBIE as a model.

2.7 Long Term Data (asset) Management

The BIM process relies on accessible and consistent archives of project information that are added to over time. From these archives, much of the data needed for projects, operations and planning of facilities can be extracted, in lieu of reproducing the information every time work must be done on a facility.

Any system for organizing this BIM data must allow consistent and safe ways to store and find the information users need, when they need it. This data must be shareable, in a consistent and repeatable way. In a paper-based system, management of information created libraries. In the current CAD-based system, document and file management systems have evolved. In the BIM world, the databases that make up the various documents and reports is what will need to be managed. The systems likely to be used for this function are called model servers.

Model servers are designed to store, validate, update and manage *data*, in lieu of storing *files*. This data is not proprietary. For this reason, model servers are software independent. They do not rely on the user having the correct version of software to use the data. Any software capable of working with the structured data (IFC) contained in the model server will suffice.

Today, such model servers are beginning to become commercially available, but much work and testing is still needed. (Jorgensen & al, 2008)

> *RECOMMENDATION: Develop a long term data asset management plan. Continue to monitor IFC model server technology.*

3.0 The Designers (A/E)

The following is an informational assessment on the state of major technologies sectors and practices in the architecture and engineering disciplines. It distinguishes what is mainstream, what is emerging and what can be reasonably expected of the A/E today.

3.1. BIM Technologies

Various BIM technology sectors exist and are being used with differing degrees of success.

3.1.1. Existing Facility Assessment and Documentation

BIM is an appropriate tool to collect and document both geometry and information. The data collected can be as simple as a "BIMBlob" with data attached, or a fully developed model with full information including a conditions report. Onuma Inc (Onuma Planning Systems) and A/EC Infosystems (AEC Infosystems) have developed an award winning approach to collecting building data for the US Coast Guard. (Eastman, BIM Handbook, 2008, p. 339)

RECOMMENDATION: Require the A/E to model the existing conditions for all alterations and additions projects. The extent of modeling and information to be included should be determined based on project needs.

3.1.2. Programming and Planning Technologies

Tools exist that capture space requirements including shape, size, vertical and horizontal adjacencies. These numerical requirements automatically convert to spatial blocks for planning and stacking studies. Many of these programs link to BIM authoring software for immediate translation to walls and floors. MS Visio Space Planner, Trelligence and Onuma Planning Systems are three such programs.

Few architectural firms are using these tools at this time. Further these may be more appropriate for the agencies to use for project planning.

RECOMMENDATION: Encourage A/E use of BIM planning tools such as ones mentioned above.

3.1.3. Schematic Design Technologies

In the early concept stage there are many sketching tools being used by architects: Form-Z, Rhino, Sketch-up and Maxon to name a few. These help architects quickly study and communicate design options and have great visual output. These tools however are not BIM tools. They do not carry object types, parametrics or properties (other than geometry and color) and they are not interoperable with other bim applications.

If a firm is using BIM, then at some point the concept design is "re-modeled" with their BIM authoring software.

RECOMMENDATION: Require A/E to provide a BIM authored model by the end of 10% phase.

Early analysis tools exist to do comparative energy use and construction cost studies. They are not as accurate as the detailed analysis generated later in the process for more complete models and should be used to help inform major early decisions, rather than to make final design decisions. In addition, design validation against a space program can be done from data automatically reported from the model and compared to the programming data. This report may be a simple spreadsheet or one of the more sophisticated planning programs described above.

RECOMMENDATION: Require A/E use comparative construction costs and energy analysis tools and use and space validation methods directly from the model or compatible digital tools.

Various sustainable design practices can be enhanced thru the use of BIM. Daylighting, sun control, site use, natural ventilation, space zoning, photovoltaics, passive solar collection, vegetation systems and others can be optimized using BIM.

RECOMMENDATION: Encourage A/E to use BIM as much as practical to strengthen the sustainability aspects of their design solutions in the

3.1.4. Design Development Technologies

BIM Authoring: Projects using BIM technology and processes are developed to a significantly higher level in the Design Development stage than a non-BIM process. This adds value and confidence to the design solutions. Later construction documentation phases require less revision and build upon early decisions. This *front-loading* of the process requires strong teamwork and collaboration to capture the high value BIM brings to the process.

Currently each discipline authors their model in their own software. Models are periodically brought together for coordination and document production. BIM authoring for architectural and structural are the furthest along in development and are being widely used.

BIM authoring software for building systems (MEP) is not as well developed. Reports and interviews show that HVAC modeling is improving but not in mainstream use. Plumbing and Electrical are further behind HVAC. However many of the MEP software applications being used for the last ten or more year can generate 3D information as well as automatically schedule information from these 3D elements. Using IFC or other data transfer methods this data can be imported to BIM authoring tools and or conflict checking programs.

Civil BIM Authoring software is also lagging and not widely used. However similar to MEP, 3D files are being created and can be imported to BIM files.

RECOMMENDATION: Require Architects and Structural Engineers to continue model development into Preliminary Design using their respective BIM models, maintaining all parametric links within their respective software. Deliverables for this phase of work should remain the same as specified in the DSF A/E Policy and Procedure Manual.

RECOMMENDATION: Require MEP and civil Engineers to provide 3-dimensional information for coordination and document production. Encourage use of BIM. Deliverables for this phase of work should remain the same as specified in the DSF A/E Policy and Procedure Manual.

RECOMMENDATION: Require A/E to geo-reference site plans and building models to Wisconsin's datum.

Analysis/Simulation software reuse the data created and embedded in the model to achieve improved understanding of predicted results and provide higher level decision making information, i.e. energy, structural, acoustics, air flow, and daylighting. Engineers have been using a variety of similar programs for years. Current versions and new products now work directly with BIM though import/export files or, through a direct link for more efficiency and accuracy because of the non-redundant data transfer.

RECOMMENDATION: Require A/E to use energy modeling and checking software for compliance with DSF standards. Encourage A/E to use other BIM analysis tools.

Checking software is emerging as a valuable tool. Navisworks and Solibri are two such programs. The programs run a predetermined set of rules and can check for conflicts between systems like structure and ductwork. They can also check for adherence to space programs, and soon will do early code checks. Some software can check the integrity of the model for things like correct modeling techniques, adherence to standard and IFC compliance. These programs are not yet widely used by architects and engineers. Although adoption of these tools will be an added cost of doing business they are of high value to the owner.

RECOMMENDATION: Require A/E to use checking software for conflicts between all major disciplines.

RECOMMENDATION: A/E is currently required to confirm the Preliminary Design with original program for compliance with space and efficiency ratios. Require A/E to do this automatically thru the BIM authoring tool or thru a checking tool.

Quantity take-off software that the A/E will typically use is embedded in the BIM authoring tool. Quantities can be extracted and exported to a unit cost database or spreadsheet. These quantity take offs can assist in doing incremental value engineering throughout the design process. They should not be substituted for other aspects of estimating such as climate, project complexity, economic conditions, site restrictions and other less tangible factors the software cannot report on.

RECOMMENDATION: Encourage A/E to use the quantity features of their program to the fullest extent.

3.1.5. Construction Document Technologies

In BIM practice, the Design/Development model(s) is the completed design. In a design/bid/build delivery method, all that remains is to extract the reports needed to communicate the design intent to the bidders.

Construction drawing generation is a powerful capability of BIM. A single model representation of the design allows for automatic production of most of the drawings and schedules, currently required by DSF, in an accurate and consistent way. We say "most of the drawings" because once a view is extracted from the model it will need additional noting, dimensioning and other "linework" to complete the description of what is being depicted. The front-end loaded aspects of the Design/Development phase is now balanced with a construction document process that takes less resources.

As with the Design/Development models, current practice among A/E to extract drawings from a combination of models or a model with 2 dimensional backgrounds. Some MEP engineers are combining their 2D drawings with 2D extractions from the architect's model. At present time there are many "work around" combinations being tried for firms at varying levels of BIM competency. However, the reality of a single parametric model among all disciplines is not possible at this time.

RECOMMENDATION: Require architects and structural engineers to extract all plans, sections, elevations, schedules directly from their respective models. Deliverables should be the same as required in the DSF A/E Policy and Procedure Manual.

RECOMMENDATION: Require MEP engineers to produce all plans, sections, elevations, details, schedules directly from their respective 3D files or models. These files must be the same 3D files used to coordinate with architectural and structural design/development drawings. Encourage MEP engineers to use BIM to the fullest extent possible. Deliverables should be the same as required in Section 5 of the DSF A/E Policy and Procedure Manual.

Specifications technology has progressed from simple word processing master files to sophisticated data base driven systems. Some programs can link to BIM files in a one-to-one relationship. If a brick object is placed in the model its corresponding spec data shows up in the specifications. However there are other spec sections that apply to this brick and multiple other objects and thus cannot make this one-to-one link. Sections like general conditions do not yet properly correspond to a BIM. This technology is changing rapidly and not developed for mainstream use. No recommendations for BIM use related to specifications are recommended at this time.

3.2. Project collaboration

The A/E industry is made up of various disciplines and specialties. Rarely, if ever, does one firm provide all the needed services for the completion of a project. Team members are interdependent on each other for knowledge and decisions to move the project forward. The degree to which decisions are made in a properly informed and timely manner determine the success of the project.

The notion of Lean Design principals is analogous to that of Lean Construction principals (Lean Construction Institute). Where Lean Construction seeks to eliminate construction time and material waste, Lean Design seeks to reduce decision time and unnecessary design iterations. Traditional decision making consists of some kind of request for information being made then waiting for an answer. During that wait which could last hours to weeks, that piece of the project is on hold and other parts continue creating a gap in information flow and accumulated knowledge.

Most decisions required collaboration to arrive at a decision to move forward. Regularly scheduled traditional team meetings address these. But the issues need to be anticipated and well understood for these meetings to be productive. Multiplying the decisions and discussion needed by the number of team members and then again by the complexity of the project and you begin to get a sense of current inefficiencies, especially in light of current available technologies.

At the opposite end of this spectrum is a suggested future where collaboration between technologies provides almost instantaneous analysis and information. For example adding a window would parametrically result in a revised energy calculation, construction cost, schedule adjustment and others that the team leader then makes an informed decision on. Formal development of higher levels of collaboration both for technology and humans are needed to take advantage of BIM capabilities.

The current state of project collaboration can be categorized as follows

3.2.1. File Sharing

Document management systems exist for all team members to access. These can be in-house systems or intranets, out of house extranets, FTP sites and web based sharing site. Versioning, file check out procedures and other controls help manage the information. DSF's WISBUILD is a file sharing site.

3.2.2. Reviewing

Reviewing is a one-way collaboration method that has existed for years. However, today technology is used to allow for clearer definition of intent, timely turn around and efficient documentation. PDF's, IFC, DWF and 3D PDF's can display 2D and 3D information. They are easy to generate out of the BIM authoring tools, compact for transmission and can be used for "redlined" markups.

3.2.3. Project Communications

These sites, typically "rented" online, have tools and systems for use by the distributed team. It is the virtual office. They include calendars, task assignment tracking, message board, time tracking, write board, file sharing and markups, and chat systems. Many include a document management system and all have simple yet robust permissions and security systems in place. These sites help with collaboration and documentation, but are not true collaborative tools.

3.2.4. Collaboration

Collaboration synergies exist when two or more people work simultaneously on a problem. Project network sites, subsets of social network sites, give all team members "live" access to activities and questions that are occurring throughout the day. Chat boxes, internet phone systems and video web meeting sites remain live thru out the day for impromptu meetings.

3.2.5. Electronic collaboration

One-way electronic collaboration is achieved by a manual export to an analysis tool. The results are reported such as daylighting levels. If a change in the model is needed it is done manually then re-checked as needed. Checking, evaluation and most analysis tools work this way.

Two-way electronic collaboration occurs with an export out an analysis being done then the resulting change made to the model. The designer then makes the final acceptance of the suggested change. This kind of collaboration is only occurring in some structural BIM applications at this time.

RECOMMENDATION: Encourage A/E to use project collaboration tools to the fullest extent possible.

RECOMMENDATION: Require A/E to make all submittals electronically, including 3D information where applicable. This should be sent electronically to a document management site. DSF should use these files for checking and markup purposes.

3.3. Model Quality Assurance

Model quality assurance is about adherence to standards. A standard exists to clarify expectations for outcomes, allow for maximum collaboration and interoperability and ensure future usability of the data. Unfortunately, few industry standards exist at this time. The National Building Information Modeling Standards administered through the National Institute of Building Sciences has established a work plan and vision for the development of BIM standards. (Building Smart Alliance) .

3.3.1. <u>Quality Concepts</u>

Industry standards and best practices are in the early stages of development. However, early adopters of BIM in Wisconsin are developing standards and practices base on what works best for them. Though developed independently most of these modeling concepts are in alignment with industry trends and the early (and future) written quality standards such as the National BIM Standards. Quality practices observed include:

- Firm change management plans for phasing in use of BIM authoring software.
- Development and use of element and component objects that embed the best practices of the firm.
- Maintain parametric linkage within the model. Extract 2d views from this models
- Use of correct object definitions for modeling: i.e. use a table object for a table – do not "fudge it" with slab commands. It may *look right* but will not *be right* for scheduling, analysis or interoperability with other software.
- Efficient and accurate modeling practices i.e. object overlap, correct closures of walls, etc. Again it needs to *look right* and *be right*.
- Adherence to the A/E's own and DSF standards.
- Use of industry accepted, or DSF defined, nomenclature for objects and spaces
- Use of viewing, checking, and standard output file formats as needed, i.e. pdf, dwf, etc.
- Use of open standards and IFC compliance for file transfers
- Creation and use of BIM planning procedures.
- Where intelligent objects are not available, modeling items as "concept objects"

RECOMMENDATION: Encourage A/E to use the quality guidelines above.

RECOMMENDATION: A/E is expected to have adequate internal checks in place for quality control. Encourage A/E to use automatic model quality checking tools to confirm compliance with their own standards.

3.3.2. <u>Future Uses of the A/E BIM</u>

Currently there are many unanswered questions regarding the purpose of model beyond its initially intended use as a communication instrument to constructors.

As DSF and the State of Wisconsin is currently structured for project delivery, there is no opportunity for contractor collaboration before bidding. Therefore no model transfer pre-

planning is being done (modeling protocols, standards, responsibilities etc). There are currently no requirements to turn the model over to the constructors
.

Currently DSF requires the A/E to create 2-dimensional record drawings based on submitted information deemed reliable from the contractor. This information may or may not be entered into the model by the A/E. If true as-built models are going to be relied upon for future use, only the contractor can guarantee their accuracy as they are the ones who know exactly what went into the construction.

Currently 2-dimensional record drawings are relied upon as reference drawings. The Standard of Care today requires A/E and constructors to confirm and recreate what is needed to inform the next project. BIM Model quality expectations and standards of care are currently undefined.

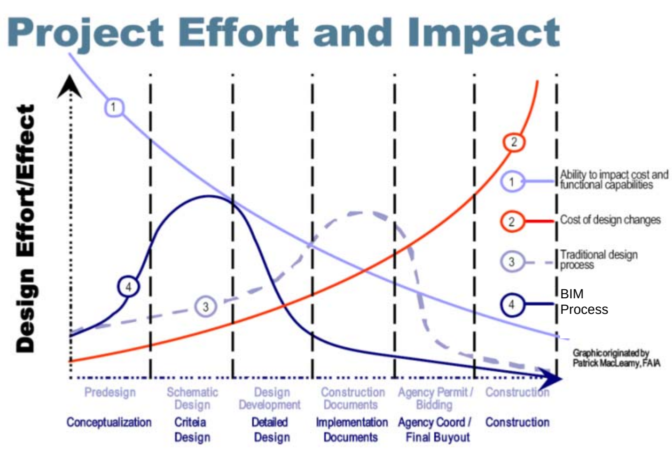
There is the perception of higher quality information contained in a BIM compared to a 2-dimensional file. In fact, the two as produced by the A/E with a 2D deliverable requirement only are identical. Both offer the opportunity to include incorrect or mistaken information. Both require professional knowledge and an understanding of construction and project requirements. Without proper software training and understanding, an owner, facility manager, contractor or others can create documents that are inaccurate and create high liability for all team members in either method.

Without definitions of what the model will be used for, and without information standards BIM models are likely to be filed away, just like 2D documents. Models must be planned so that they allow for long-term uses, or they have little long-term value.

RECOMMENDATION: Encourage A/E to submit models to DSF as part of the deliverables at this time. Begin planning for the long-term use and application of BIM.

3.4. Work Effort Shift

Building Information Model based technology creates new business and practice processes and opportunities within the architecture, engineering, construction and operations (A/ECOO) community. These changes necessitate the reallocation of the work effort during the design process. Through the focused application of BIM technology, the designer provides the owner better decision making information, much earlier in the design process. As the work effort curve shifts earlier in the process the ability to make high quality decision increases and the need for costly changes later in the process is reduced.



"Collaboration, Integrated Information and the Project Lifecycle in Building Design, Construction and Operation", The Construction Users Roundtable, August 2004

Utilizing BIM technologies allows for early program validation, design concept visualizations, energy optimization, comparable cost models and more. The A/E team can have a fully validated project completed by DSF's peer review.

The Division's Preliminary Design deliverable milestone represents the Design Development Drawings. In days of pencil and/or electronic drafting this corresponded to 35% of the work effort. However with BIM this may represent a higher portion of the total project work effort, depending on the capabilities of the A/E team.

This work effort vs deliverable ratio "rebalances" itself by the end of the Final Design phase or DSF's 100% review milestone. This leaves the remaining, 25% of the fee for bidding and construction administration services. This work effort reallocation is not simply a shift in fees which may seem to benefit the A/E. Rather it is a new ability to provide a preliminary design with more certainty in design, cost, schedule and energy outcomes.

A restructuring of fee allocation should be considered in recognition of these changing work efforts. Any restructuring should be based on A/E's BIM capabilities, scope of the project and adherence to work effort descriptions. The following chart compares DSF project phases with alternative project phase naming conventions proposed by the American Institute of Architects. (The American Institute of Architects, 2007)

DSF Project Phases	***Alternative Project Phases***	***Description of A/E BIM work effort***	***Traditional work effort***	***BIM work effort***
Pre-design *(agency work but confirmed by A/E during pre-contract phase)*	Conceptualization	Confirms program, budget and schedule at a high level	0	0
Peer review	Criteria Design	Defines the optimum design solution meeting program, budget and schedule.	10% 10% total	15% 15% total
Preliminary Design	Detailed Design	Facility design is fully developed, coordinated and validated. Cost and Schedule established with high level of precision.	25% 35% total	30% 45% total
Final Design (100% review)	Implementation Documents: Review	Detailed design is fully annotated and graphically clarified for accurate bidding, scheduling and construction purposes.	40% 75% total	30% 75% total
Bid set	Implementation Documents: Bidding	Above plus inclusion of review into model(s)	In above	In above
Bidding	Buyout	Clarify document intent	5% 80% total	5% 80% total
Construction Issue	Implementation Documents: Construction	Above plus inclusion of addendum into model(s)	In above	In above
Construction	Construction	Maintain Implementation model(s)	20% 100%	20% 100%
Closeout	Closeout	Record documents, change orders and other appropriate close-out submittals incorporated into the model(s)	In above	In above

RECOMMENDATION:
A/E firms will have differing levels of expertise and, State projects will have differing levels of services required. DSF should consider Peer Review and Preliminary Design fee allocation for BIM work effort. DSF should take the necessary steps to affect the needed changes in procedures, policies, administrative rules or laws.

4.0 The Constructors

The following is an overview of the use of BIM in the construction industry. Though the recommendations of this report are for the Architect and Engineer, it is important to understand that BIM does not stop at contract award, regardless of delivery method. Further integration of the design and construction industries will improve the BIM process and overall project quality.

4.1. Virtual Construction

Some contractors are creating a BIM incorporating selected portions of structure, architecture, mechanical, electrical and plumbing components. In A/EC partnering situations the A/E design development model is handed over to the contractor for further development. These models are then used for "clash detection" (same as described in section 3.1.3) that identify hard clashes, such as a duct with a beam, and soft clashed, such as a wall with a mechanical access door swing.

The advantage the contractor has over the architect is that they can use the actual products being proposed for installation verses the designers' which are typically a performance based BIM element.

4.2. Construction Analysis and Planning

Traditional scheduling methods are labor intensive and difficult for the lay person to understand their meaning. BIM construction planning tools go beyond the typical scheduling chart and include direct links to the design model to capture spatial information. This allows better communication and understanding of the schedule and how it impacts site logistics.

"4D" models, which refer to 3D models with the dimension of time added, allow schedulers to visually plan and communicate activities in the context of time and space. BIM components are linked to scheduling programs to create animated 4D movies. And because they are linked if a change is made to the schedule the 4D model can be automatically updated.

Analysis tools combine BIM elements and construction method information to optimize activity sequencing. Incorporating spatial and productivity information reveal time-space conflicts on the job site before the real problem occurs. (Eastman, BIM Handbook, 2008, p. 224)

4.3. Cost and Schedule Management

BIM software can provide visual and information links to manage the construction process. Cost and schedule management using the same estimates and schedule described above, procurement purchasing and and safety planning are a few applications being used. Enterprise resource planning (ERP) software, common in other industries, is starting to be adopted by general contractors. ERP integrates and automates the construction management processes. (Directions Magazine)

4.4. Offsite Fabrication

BIM can provide sub-contractors the ability to export spatial information, specifications, and delivery requirements directly from the model. Structural steel and sheet metal fabricators have been using direct fabrication from their own models for some time and are well positioned to take advantage of BIM. (Eastman, BIM Handbook, 2008, p. 236)

Other trades such as precast and aluminum curtain walls are also beginning to take advantage of BIM tools.

4.5. Onsite Construction

BIM supports quality control during construction. Techniques are being used from simple visual inspections that manually compare construction to the model, to laser scanning that export directly to the model for construction verification. Other sophisticated techniques that are evolving using information directly from the BIM include machine-guidance, GPS and Radio Frequency Identification tags for component tracking. (Eastman, BIM Handbook, 2008, p. 238)

5.0 The Long Term Vision

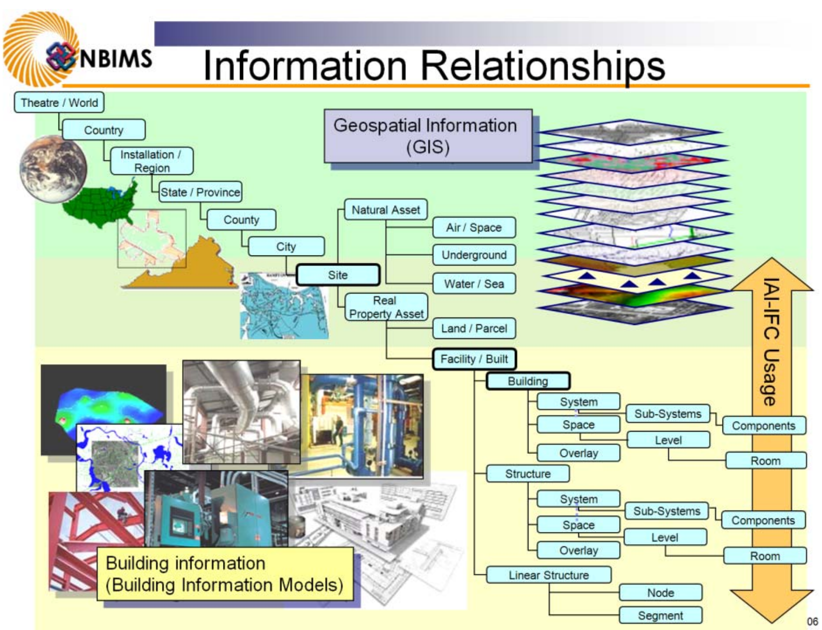
Since 1851 Wisconsin's motto "Forward" has reflected the State's continuous drive to be a national leader. The not-so-small step toward BIM adoption is one few other states have taken. A clear look into the future and how to get there continues this initiative…FORWARD..

Advances in BIM, both the technology and the process, are leading to new business practices for Owners, Designers and Contractors. These changes are in turn leading to further development of the technologies. However, BIM is not developing in a vacuum. Its progress is being influenced by developments in the Internet, software and hardware technologies, societal changes, capital facility organizations and other less predictable forces.

We can reasonably predict here the industry will be in five years…; much further out we cannot. Mid-term goals coupled with a guiding long-term vision that is adaptive and flexible is required.

5.1. The long-term vision

The long term vision is foremost about easy and reliable access to *Information*. A GIS/BIM cross-linked platform with open access at varying security levels becomes the basis for many other things. This platform offers everything from high level GIS information to agency project planners, land planners, first responders and others, to detailed BIM information to facility managers, A/E's, and constructors. The platform bridges the gap between world-scale data, where GIS excels and highly detailed, granular data where BIM excels.



The long-term vision is also about *Productivity*. Greater efficiencies can be achieved from within DSF, across all agencies, and among the A/E and the Constructors. Captured intelligence, optimized communications, ongoing work process analysis and change, alternative delivery methods, globalization of A/E services and construction products and more will allow for higher quality outputs at all levels.

Finally, the long-term vision is about *Greater Certainty*. Use of new technologies and practices in the future will improve the quality of information. The vision is for accurate project planning; full transparency and confidence in design decisions and the construction process; optimized facility design; and accurate measurements of all the project's goals during the facilities use.

5.2. Mid-term Goals

Progression to BIM is not like the change to CAD twenty-five years ago. BIM requires a paradigm shift in how we work to a more holistic and collaborative approach to facility development and operation. Fundamental process changes will be needed to take full advantage of all the opportunities BIM has to offer.

Contracting methods, process analysis and change, data definitions, new roles and responsibilities, new kinds of expertise, and integrated design, construction, and management are some of the issues that will need to be addressed in the near future.

In order for Wisconsin and all its facility stakeholders to progress into the future, commitments will be needed at all levels. State laws, rules, procedures and A/E contracts will need to be evaluated and changed where needed. Adequate funding for technology development and process change must be provided. And, continuous two-way communications between all involved will help make this transition itself a collaborative process.

> *RECOMMENDATION: DSF should establish a collaborative, cross agency/A/EC industry work group to develop goals and strategies for BIM process transformation.*

5.3. Implementation Strategy

The task of implementation by the State of Wisconsin is an enormous responsibility. DSF has sought out expertise in the field of BIM and related technologies and collaborative integrated design and project teams. DSF leadership has taken the position of being an industry leader staying away from the bleeding edge while recognizing this is an ongoing industry change, not unique to public work or Wisconsin.

This findings report provides recommendations for progressive sequential implementation beginning with the A/E design phases and form a baseline of understanding with those involved in DSF capital projects. The fragmentation of the building industry is also observed within the State of Wisconsin building program. This fragmentation is found in processes, rules, use of information, exchange of information and the various business cultures among the organizations. As the A/Es contributed to development of these standards, the constructors, facility management and operations, and capital planning representatives will be engaged in developing implementation for respective sectors.

The following timelines for implementation are proposed. The A/E is the first group in the guideline release as they are first to gather or create information and create a solution using digital technology. To determine what contractor digital submittals and database exchanges are needed, Facility Management and Operations must determine their needs within their capacity of resources for maintaining the information as an asset. The next findings report should evaluate the existing Facility Management data management and reconcile with emerging best practices in the industry. The finding topics may include what information is needed and in what format by the facility operators; how should this information be captured during design and construction;

how should the project requirements be defined for a successful completion. Project planning and project delivery make up the last major industry segments.

RECOMMENDATION: To provide structure for continued deployment of DSF BIM Guidelines and Standards, the following implementation sequence is proposed

July 1, 2009	*Issue initial set of A/E BIM Guidelines and Standards*
January 1, 2010	*State Agency Facility Management / Operations (data points)*
July 1, 2010:	*Contractor Submittals into State Agency Facility Management*
January 1, 2011	*Agency Project Planning*
July 1, 2011	*Alternative delivery methods*

RECOMMENDATION: Establish means to capture feedback in a public forum so all can benefit from sharing information with each guideline deployment.

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Glossary of Terms

2D—Analogous to painting or hand drafting. The architect's equivalent to word-processing. 2D computer graphics deal primarily with geometric entities (points, lines, planes, etc.). Blueprints, construction documents and anything output (or drawn on) paper are 2D.

3D—Analogous to sculpture. Prior to computers, architects manually constructed perspectives and physical (cardboard, Foamcore, balsa) models to represent a project's design concepts. Today computers have automated concept visualization. These 3D graphics can be exported to rapid prototyping systems to create physical models. 3D computer graphics rely on much of the same programming as 2D computer graphics.

3.5D—3D with the addition of limited object technology (minimal object intelligence and not integrating NCS or IFCS) or, 3D with implied movement (Ken Burns effects, trees blown by wind, moving people, etc.). This is definitely not BIM, no matter what you are told.

4D—Building Information Model with the addition of time (virtual building model with scheduling).

5D—Building Information Model with time and construction information additions (virtual building model with cost and project management).

A/EcXML—Architecture/Engineering/Construction-oriented Extensible Markup Language. Internet-oriented data structure for representing information used in BIM.

CAD Object—These objects are symbols and 3D representations that are static (line work with little or no intelligence). These objects are "instance-based," i.e., each use requires a new "instance" of the object, tailored to the specific situation. This approach requires a significant library of objects (i.e., one object for each size of window, another for each type of window and another for window detail). This approach results in significant storage and file size requirements to store repetitive and unconnected information.

GDL—Geometric Description Language. A scriptable language for programming intelligent objects using a fraction of memory of other modeled objects. A GDL object can store 3D information (geometry, appearance, surface, material, quantity, construction, etc.), 2D information (plan representation, minimal space requirements, labels, etc.), and property information (serial numbers, price, dealer information, URL, and any other kind of database information). Multiple instances of the same object but with different appearance, material, size, etc. are kept together in one object. GDL is especially important as the Internet emerges as the best communication platform for the building industry.

Georeference—Refers to exactly locating something in the virtual world, via coordinate systems. Georeferenced buildings are tied to established coordinate systems such that they can be rapidly located in their proper place and time. Latitude, longitude, and elevation are three of the possible coordinate systems for referencing a location. Georeferencing allows for high-level studies of relationships, causes, and effects in a real-world context.

IAI—International Alliance for Interoperability. Subset of the International Standards Organization (ISO), charged with developing standards for standardizing how software represents data.

IDM—Information Delivery Manual is a document-mapping building processes, identifying results and describing actions required within process.

IFCs—Industry Foundation Classes. IFCs define how “things” such as structure, doors, walls, and fans (as well as abstract concepts such as space, organization, information exchange, and process) should be described so that different software packages can use the same information.

Integrated Practice—Uses early contribution of knowledge through utilization of new technologies, allowing architects to realize their highest potentials as designers and collaborators while expanding the value they provide throughout the project life cycle

Integration—The introduction of working practices, methods and behaviors that create a culture in which individuals and organizations are able to work together efficiently and effectively.

Intelligent Object—These Building Components can behave smart, i.e., they can adapt to changing conditions. The user can easily customize them through an interface. These objects are “rules-based,” i.e., they incorporate rules that define how the object adapts to other objects, database calls, and user input parameters. Because of the “rules base,” each object can represent an entire subset of an entity, i.e., one window object can represent an manufacturer's entire window line and can generate all 2D, 3D, details, finishes, shapes, and profiles. This results in significant decreases in the space required to store the equivalent information and results in very small files.

Model Server—Model servers allow centralized storage of IFC information models allowing them to be accessed and modified via the Internet. Model servers are a critical element in the long-term management of building information that will be hosted, added to, and manipulated by a large audience over a building’s life cycle. The IFC-based model server is a virtual building archive, is possibly the most innovative technical approach to the future of BIM.

Multi-file approach—Multi-file systems use loosely coupled collections of drawings, each representing a portion of the complete model. These drawings are connected through various mechanisms to generate additional views of the building, reports, and schedules. Issues include the complexity of managing this loosely coupled collection of drawings and the opportunity for errors if the user manipulates the individual files outside the drawing management capabilities.

NBIMS—National BIM Standard. Standard for how information is presented via BIM, currently under development with the cooperation of the AIA, CSI, and NIBS. The National CAD Standard will become a subset of NBIMS upon completion.

NCS—National CAD Standard. Graphic standard for how information is presented via CAD systems, developed with the cooperation of the AIA, CSI, and NIBS.

NIBS—National Institute of Building Sciences. Organization supporting NCS and the IAI in the United States.

Object Oriented—A computer program may be seen as a collection of programs (objects) that act on each other. Each object can receive messages, process data, and send messages to other objects. Objects can be viewed as independent little machines or actors with a distinct role or responsibility.

Parametric—Objects that reflect real-world behaviors and attributes. A parametric model is aware of the characteristics of components and the interactions between them. It maintains consistent relationships between elements as the model is manipulated. For example, in a parametric building model, if the pitch of the roof is changed, the walls automatically follow the revised roofline.

Prototype—A working model used to test design concepts, impacts, and ideas quickly prior, to physical implementation. Integral part of a system design process created to reduce risks and costs. Can be developed incrementally so that each prototype is influenced by previous prototypes to resolve deficiencies, refine the design or increase understanding. When a prototype is developed to a level that meets project goals, it is ready for construction.

Single model approach—Revolves around a single, logical, consistent database for all information associated with the building. The building design is represented in a single virtual building that captures everything known about the asset. From this database, all project visualizations, analysis and management information can be extracted.

Value network—The Value Network adds an extra dimension to the concept of Value Chains. Value networks represent the complexity, collaboration, and interrelationships of today's organizations and environment. Value Chains are linear and Value Networks are three-dimensional.

Writeboard—Collaborative Web-based text development system that allows for editing, version control and change comparisons.

Definitions are compiled from a variety of sources including: Wikipedia, technology vendors, NIST, NBIMS, and others.

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Bibliography

AEC Infosystems. (n.d.). *http://www.aecinfosystems.com/*.

AGC. (n.d.). *http://www.agc.org/cs/industry_topics/technology/agc_xml*.

Autodesk Navisworks
http://usa.autodesk.com/adsk/servlet/index?siteID=123112&id=10571060.

Autodesk Revit. *http://usa.autodesk.com/adsk/servlet/index?id=3781831&siteID=123112*.

Beck Technology. (n.d.). *http://www.beck-technology.com/*.

Bentley Systems. (n.d.). *http://www.bentley.com/en-US/Solutions/Buildings/*.

Bevins, R. (2005). *http://www.building-connections.info/news/3%20Bob%20Bevins.pdf*.

Building Smart Alliance. (n.d.). *http://www.buildingsmartalliance.org/*.

Building Smart Alliance. (n.d.). *http://www.buildingsmartalliance.org/nbims/*.

CIFE Stanford. (2007). *http://cife.stanford.edu/index.html*.

COBIE. (n.d.). *http://www.wbdg.org/resources/cobie.php*.

Digital Project. (n.d.). *http://www.gehrytechnologies.com/*.

Directions Magazine.
http://www.directionsmag.com/companies/SoftTech_Engineers_Private_Limited_The_Leading_CAD_Company/products/OPTICON_ERP_for_Construction_Industry/

Eastman, C. (2009, March 9). (K. J. Connolly, Interviewer)

Eastman, C. (2008). *BIM Handbook.* Wiley.

Ecotect. (n.d.). *http://www.ecotect.com/*.

FIATECH. (2009). *http://fiatech.org/tech-roadmap/overview.html?start=1*.

Graphisoft. (n.d.). *http://www.graphisoft.com/products/archicad-solutions/analysis.html*.

Graphisoft. (n.d.). *http://www.graphisoft.com/products/virtual_building/*.

ICC. (n.d.). *http://www.iccsafe.org/SMARTcodes/index.html*.

Jernigan, F. (2008). *Big Bim Little Bim.* 4Site Press.

Jorgensen, K. A., & al, e. (2008). *http://vbn.aau.dk/fbspretrieve/14804119/ReportIfcModelServer-Final.pdf*.

Lean Construction Institute. (n.d.). *http://www.leanconstruction.org/*.

McGraw Hill Smart Market Report on BIM. (2009). *http://construction.ecnext.com/coms2/analytics*.

McGraw Hill Smart Market Report on Interoperability. (2007). *http://www.aia.org/about/initiatives/AIAS078440*.

National Instutute of Standards and Technology. (2004). *http://www.bfrl.nist.gov/oae/publications/gcrs/04867.pdf*.

OGC. (n.d.). *http://www.opengeospatial.org*.

Onuma Planning Systems. (n.d.). *http://onuma.com/products/*.

OSCRE. (n.d.). *http://web.pisces.co.uk/oscre/default.aspx*.

Solibri. (n.d.). *www.solibri.com*.

The American Institute of Architects. (2007). *Integrated Project Delivery: A Guide.* www.aia.org/ip.

The National Institute of Building Sciences . (n.d.).

Trelligence. (n.d.). *http://www.trelligence.com/*.

Whole Building Design Guide. (n.d.). *http://www.wbdg.org/*.