buildingSMART alliance
Open Geospatial Consortium, Inc.

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Summary of the Architecture, Engineering, Construction, Owner Operator Phase 1 (AECOO-1) Joint Testbed

buildingSMART alliance™ (bSa) and The Open Geospatial Consortium, Inc. (OGC®)

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Preface

The Architecture, Engineering, Construction, Owner Operator, Phase 1 (AECOO-1) Testbed developed and implemented methods to streamline communications between parties in the conceptual design phase to get an early understanding of the tradeoffs between construction cost and energy efficiency. To that end, the project developed the interoperability components required for these analyses in collaborative team settings. These were Information Delivery Manuals (IDMs) for quantity takeoffs and energy analysis business processes, and used these to define Model View Definitions (MVDs)—standards-based subsets of Industry Foundation Classes (IFCs). AECOO-1 was conducted in response the felt need that overall productivity loss and fragmentation in the capital facilities development industries is no longer tolerable. All stakeholders need to practice the best way they know, and practice profitably; software interoperability problems must not hold them back. Non-interoperable software and data is cause for loss of competition across the market.

The AECOO-1 Testbed was jointly led by the buildingSMART alliance™ (bSa) and The Open Geospatial Consortium, Inc. (OGC®). The Testbed was conducted using the OGC Interoperability Program Policy and Procedures for a Testbed initiative. All results of this Testbed have been submitted to bSa for consideration as candidate specifications and best practices under the National Building Information Model Standard (NBIMS) Rules of Governance.

Should bSa and other AEC-related standards bodies adopt the results of AECOO-1 as approved standards via their respective consensus processes, then software providers will be positioned to provide products and services that employ these specifications to their users to streamline communications and information exchanges and lower risks and costs between project participants during the conceptual design phase of capital projects.

The Sponsors of the AECOO-1 Testbed were:

Architecture Firms: HOK, Burt Hill and Ellerbe Becket
General Contractors: Webcor and Gilbane
Government Agencies: US General Services Administration and Statsbygg (Norway)
Trade Associations: American Institute of Architects and Large Firm Roundtable

The main outcomes of AECOO-1 were:

- **Application of the interoperability Testbed process** to the AECOO community was accomplished through coordination of ten sponsoring organizations. The Sponsors and four affiliated standards organizations developed and issued a Request for Quotation/Call for Participation (RFQ/CFP) released in May of 2008.
- **Twenty-seven organizations participated in some aspect of AECOO-1**, including Sponsors and affiliated standards organizations.
- **Two Information Delivery Manuals** for Energy Analysis and Quantity Takeoff were developed, based on the AIA Integrated Project Delivery Process.
- **Two Model View Definitions** for Energy Analysis and Quantity Takeoff were developed, based on the AIA Integrated Project Delivery Process

- **Two demonstrations** that iterate through a series of changes to a “test building” highlighting energy cost reduction (building performance) and building materials’ quantity and cost. The demonstrations used a number of different software products that interchanged IFC information using existing commercial off-the-shelf software.

The use of the methods and processes developed in AECOO-1 facilitate earlier understanding of the tradeoffs between construction quantities take off, cost, and energy efficiency. The process for design change, energy evaluation, and change approval were shown to reduce timeframes from weeks to hours.

Chapters 1 through 5 detail the background for and work completed over the life of the Testbed. In Chapter 6 of the Report, we present an analysis of the work accomplished and discuss lessons learned. In addition we put forward six recommendations for future progress. Supporting these recommendations are two Annexes. Annex A delves more distinctly into the means for closing communication gaps along the AEC lifecycle.

In late 2009 the American Institute of Architects, one of the sponsors of AECOO-1 issued a position request on interoperability related to project delivery. The request suggests interoperability in the AEC market is best accomplished using professional, public and private-sector adoption of open standards. The results of the AECOO-1 Testbed are to be seen as a partial contribution in meeting AIA’s position statement. The full position statement is made part of this Summary Report and can be found in Annex B.

For more information, contact Louis Hecht (lhecht@opengeospatial.org) or Raj Singh (rsingh@opengeospatial.org) of the OGC and/or David Morris (david_morris@emcorgroup.com) of the buildingSMART alliance.

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Summary of Architecture, Engineering, Construction, Owner, Operator Testbed 1 (AECOO-1)

The buildingSMART alliance (bSa)[1] (a Council of the National Institute of Building Sciences) and the Open Geospatial Consortium (OGC)[2] conducted a Testbed, based on OGC's Interoperability Program (IP) to develop candidate specifications and best practices to meet sponsor requirements. The AECOO-1 Testbed looked at streamlining communications and information exchanges between project participants during the criteria design phase to get an understanding of the tradeoffs between construction quantity take off, cost and energy efficiency.

The OGC Interoperability Program is a global, hands-on and collaborative prototyping program for rapid development of proven candidate specifications. In this Testbed, international technology developers and providers and sponsors teamed together to solve specific AECOO interoperability problems posed by the initiative's sponsoring organizations. Testbeds and other Interoperability Program modes of interaction between users and developers are designed to encourage rapid development, testing, validation and adoption of open, consensus-based standards.

Engagement of multiple standards organizations and professional associations in a common Testbed activity also helps to address increasingly challenging standards issues that could not be solved by one organization alone.

1 Overview

The AECOO-1 Testbed began in July 2008 and was formally completed on May 26, 2009. Prior to Testbed execution was a concept development effort as well as a published Request for Technology (RFT) that provided interested parties an opportunity to comment on proposed Testbed requirements prior to releasing the AECOO-1 Testbed's Request for Quotation/Call for Participation.

There were 2 primary focus areas for AECOO-1 Testbed activity.

First, was to provide a demonstrable and operational set of processes and procedures for bSa take up - to advance their mission to develop an implementable National Building Information Standard (NBIMS). In this Testbed, bSa and OGC were not only focusing on specific operational issues for how to do standards, but also to demonstrate and transfer operational processes and

[1] This council provides industry-wide, public and private leadership and support for the development, standardization, and integration of building information modeling technologies to provide for full automation of the entire lifecycle of buildings. The alliance, in association with the American Institute of Architects and the Construction Specifications Institute, develops and publishes the consensus-based United States National CAD Standard®. The alliance also sustains the consensus-based National BIM Standard. The alliance coordinates projects establishing best business practices, enterprise architecture, education transformation, research and development throughout the industry. The alliance acts as the North American chapter of buildingSMART International a consortium of 30 countries with like goals. See http://www.buildingsmartalliance.org/

[2] The Open Geospatial Consortium, Inc.® (OGC) is a non-profit, international, voluntary consensus standards organization that is leading the development of standards for geospatial and location based services. See http://www.opengeospatial.org/

procedures for bSa to use as the members move forward in advancing requirements identified in the National Building Information Standard, Part 1, Version 1 issued in late 2007. The specific processes and procedures that were designed as part of this Testbed involved developing a standards based approach for Information Delivery Manuals, as well as for the companion document for Model View Definitions. In implementing these processes, bSa and OGC used general guidance documented throughout Chapter 5 of the NBIMS (December 7, 2007)[3], combined with procedures and processes for Testbeds within OGC's Interoperability Program (see http://www.opengeospatial.org/ogc/policies/ippp).

The second focus area was to apply these processes so that bSa may establish it's direction about using rapid standards development processes to foster faster, better and cheaper information exchanges and best practices during collaborative work inside the NBIMS program, and that can readily transferred to project teams using NBIMS-based software. With this in mind we applied these processes and procedures to advance interoperability for three areas of business and technical interest by the sponsors:

- Building Performance and Energy Analysis
- Quantity Takeoffs for Cost Estimation
- Requests for Information (Communications Project Delivery and Decision Support).

The first two technical areas of interest participants received sponsor funding. The final area of interest was only briefly explored with in-kind participation only, and was largely dealt with inside demonstration planning and preparation. Within this context of the work undertaken, the Integrated Project Delivery Process (as designed by the American Institute of Architects (AIA)) was used as the business cycle platform for information exchange.

1.1 Organizations in AECOO-1

1.1.1 Sponsoring Organizations

The Sponsors of the AECOO-1 Testbed are:

- **Architecture Firms:** HOK, Burt Hill and Ellerbe Becket
- **General Contractors:** Webcor and Gilbane
- **Government Agencies:** US General Services Administration and Statsbygg (Norway)
  Trade Associations: American Institute of Architects and Large Firm Roundtable

Testbed Alliance Partners[4] for AECOO-1 are:

- BuildingSmart International

[3] The National Building Information Model Standard, Part 1, Version is available at: http://www.wbdg.org/bim/nbims.php. The vision for NBIMS is "an improved planning, design, construction, operation, and maintenance process using a standardized machine-readable information model for each facility, new or old, which contains all appropriate information created or gathered about that facility in a format useable by all throughout its lifecycle." The organization, philosophies, policies, plans, and working methods that comprise the NBIMS Initiative and the products of the Committee will be the National BIM Standard (NBIM Standard), which includes classifications, guides, recommended practices, and specifications.

[4] Alliance Partners are organizations that contribute resources and relevant documents towards advancement of Testbed goals and have reciprocal standards roles across the community.

- US National Institute of Standards (NIST)
- Associated General Contractors of America
- International Code Council
- Construction Specification Institute

1.1.2 AECOO-1 Interoperability Program (IP) Team

The IP Team is an engineering and management team to oversee and coordinate OGC Interoperability Initiatives. The IP Team facilitates architectural discussions, synopsizes technology threads, and supports the specification editorial process. The IP Team for the AECOO-1 Testbed was comprised of OGC staff and representatives from bSa member organizations. The AECOO-1 Team was as follows:

- Interoperability Program Executive Director: George Percivall, OGC
- Initiative Director: Raj Singh, OGC
- Thread Architects and Consultants
  - Energy Performance and Building Analysis: Benjamin Welle, Stanford Center for Integrated Facility Engineering
  - Quantity Takeoff and Costing: Thomas Wiggins, Faithful and Gould, Inc.
  - Communications Project Delivery and Decision Support – Raj Singh, OGC
- Project Development: Louis Hecht, OGC
- Demo Capture: Greg Buehler, OGC

1.1.3 Complete List of Organizations

The following organizations played one or more roles in AECOO-1 as participants, sponsors and/or observers and were actively involved in contributing to and editing of Testbed deliverables, as well as the demonstrations.

- AGC (Association of General Contractors of America)
- ARBA Studios LC
- ASHRAE (The American Society of Heating, Refrigerating and Air-Conditioning Engineers)
- Bentley Systems
- BuildingSmart International
- CSI (Construction Specification Institute)
- Digital Alchemy
- ICC (International Code Council)
- Eppstein Uhen Architects
- Faithful & Gould
- Granlund
- Graphisoft
- LBNL (Lawrence Berkley National Laboratory)
- Onuma
- OSS Nokalava
- OSCRE (Open Standards Consortium for Real Estate)

- PhiCubed/Sofi Exec
- Nemetschek North America
- NewForma
- NIST (US National Institute of Standards and Technology
- Tokmo Systems
- TU Berlin
- University of Florida, Department of Building Construction

1.2 Schedule

The AECOO-1 Testbed Execution Phase was preceded by a Concept Development Phase that included the release of a Request for Technology (RFT). Responses to the RFT from industry were used by the Sponsors to identify requirements for the RFQ. The overall process of the Testbed is shown in Figure 1. The dates for the various milestones were:

AECOO-1 Concept Development Phase:

• Sponsor Meetings	October 2007 - March 2008
• RFQ development	March 2008 – April 2008
• RFQ response period	May 2008 – June 2008

AECOO-1 Execution Phase*:

• Kickoff Meeting	30 June – 3 July 2008
• Interim Information Delivery Manual (IDM) Deliveries	December 2008
• Final Delivery	January 2009
• Interim Model View Definition (MVD) Deliveries	March 2009
• Final MVD Deliveries	May 2009
• AECOO-1 Demonstration	March 2009
• AECOO-1 2nd Demonstration	May 2009
• Web based Demo Release	June 2009

*After the Kickoff Meeting, design, development and public review of IDMs, testing of AECOO-1 MVDs were conducted in a distributed fashion supported by the collaborative development resources of telecoms, a web portal, web collaboration tools, e-mail and weekly telephone conferences.

Each participant had an agreed to Statement Of Work milestones and deliverables. A limited number of Engineering Reports delivery dates were extended as the inputs needed to complete some work items were not available in a timely manner or other participant time constraints were agreed to.

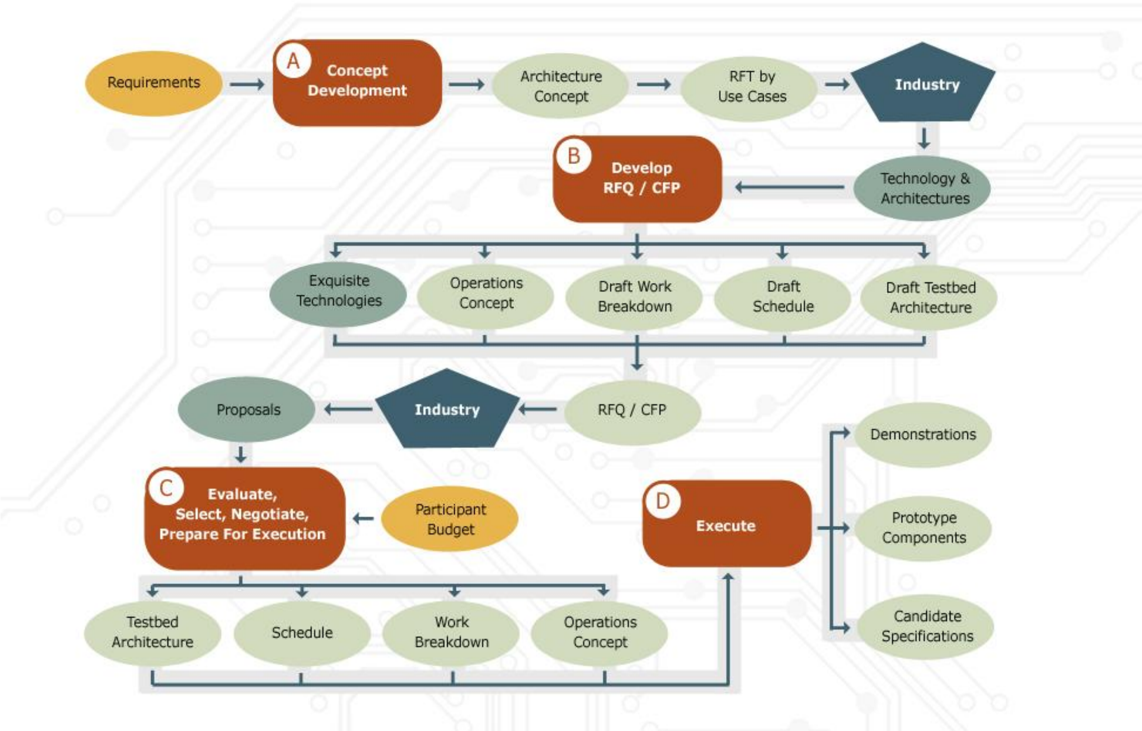

Figure 1 – AECOO-1 Testbed Process

1.3 Testbed Accomplishments

- **Ten** sponsoring organizations defined Testbed requirements for AECOO-1. The sponsors' requirements were first documented in an RFT that was issued in February 2008. OGC received 20 AECOO industry responses and those responses were used as input to develop and publish the Request for Quotation/Call for Participation (RFQ/CFP) documents that were released by the OGC in May of 2008.

- **Four** affiliated standards organizations provided pre RFQ/CFP advice, technical assistance. During the execution of the Testbed they were provided an opportunity for their membership to review interim documents in their various stages of drafting. Many of the four affiliated standards organizations regularly attended weekly conference calls for each technical thread.

- **27** organizations (including Sponsors and affiliated standards organizations) participated in some aspect of AECOO-1. Roles for organizations in AECOO-1 include sponsors, participants and information architects, building architects, cost estimators, application providers and building energy analysts. Additionally, many organizations were observers, as provided for under the OGC's Interoperability Program's Testbed Processes and Procedures.

- Major technical achievements and demonstrations of AECOO-1 results include the following:

- **Energy Analysis Thread:** Information Delivery Manual (IDM) for Building Performance and Energy Analysis (BPEA) [5] was developed and then used for development and implementation of the companion Model View Definition (MVD)[6]. The MVD, based on the IFC standard 2.3 was then implemented in vendor IFC toolboxes within their respective solutions.

  The IDM for Building Performance and Energy Analysis is available at: http://portal.opengeospatial.org/files/?artifact_id=29385

  The MVD for Building Performance and Energy Analysis is available at: http://portal.opengeospatial.org/files/?artifact_id=34060 (for IFC 2.3) and http://portal.opengeospatial.org/files/?artifact_id=34059 (for Generic) http://63.249.21.136/IAI-MVD/reporting/listMVDs.php?SRT=&MVD=BSA-002&DV=2 (online)

  Concept Development, MVD and Implementation Guide for 2nd Level Space Boundaries are available at:

  Space Boundary Concept and Implementation Guideline: http://portal.opengeospatial.org/files/?artifact_id=35079

  Space Boundary MVD: http://portal.opengeospatial.org/files/?artifact_id=29375

- **Quantity Takeoff Thread:** Information Delivery Manual (IDM) for Quantity Takeoff was developed and then used for development and implementation of the companion Model View Definition (MVD). The MVD, based on the IFC standard 2.3 was then implemented in vendor IFC toolboxes within their respective solutions.

  The IDM for Quantity Takeoff is available at: http://portal.opengeospatial.org/files/?artifact_id=32567

  The MVD for Quantity Takeoff is available at: http://portal.opengeospatial.org/files/?artifact_id=34062 (for IFC 2.3) and http://portal.opengeospatial.org/files/?artifact_id=34061 (for Generic) http://63.249.21.136/IAI-MVD/reporting/listMVDs.php?SRT=&MVD=BSA-001&DV=2 (online)

- **Communications Project Delivery and Decision Support** involved development of a series of user scenarios that enabled users and software providers to demonstrate the accomplishments brought forward in the BPEA and QTO threads with a test building**.**

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[5] Information Delivery Manual defines the business processes and information flows for any topical issue involved with the design, construction and operation of a building. IDM specifies the process definition including the context and purpose of the exchange, the originating and consuming actors, and the information created and consumed. An approved IDM standard can become the basis of a contract between two parties for data interchange, thereby, treating information as an asset, enabling BIM-based methods, and regulating the information sharing between project participants.

[6] Model View Definitions provide information to software providers so that they may satisfy business process information flows that are required and defined within one or more IDM's. MVD's are usually designed to be stakeholder specific in regard to information to be exchanged. MVDs collectively aggregate information flows between a sender, a receiver along with a purpose for that particular exchange. MVDs can be generic or specific to a data model such as IFC 2.3.

- **Demonstrations and webcast:** Two demonstrations were completed as part of the Testbed. The demonstration comprised a number of different energy and building performance components of the "test building", the results of energy analysis using EnergyPlus and the effect those changes had on quantity of building materials and cost. The demonstrations used a number of different software vendor products that interchanged IFC information using existing commercial off-the-shelf software to perform the necessary calculations and results. The first demonstration was held in Washington at the National Building Museum in March of 2009. The second demonstration was via a webinar in May of 2009.

An on-line version of the webcast demonstration is available at:
http://www.opengeospatial.org/pub/www/aecoo-1/index.html

Participants in the Demonstration included the following organizations:

- Bentley
- Digital Alchemy
- Faithful and Gould
- Graphisoft
- Lawrence Berkeley National Laboratory
- Nemetschek, NA
- Phi Cubed/Sofi Exec
- Stanford Center for Integrated Facility Engineering
- Tokmo

2 Interoperability in the AEC Market

The AEC market is closely tied to global financial and real property markets. Since 2007 the AEC, real property and financial markets can be described as stressed and in disarray, however this has not impeded prospects for innovation in these large segments of the real economy. In fact, it is quite the opposite as we continue to witness a consistent and overarching characteristic of innovation in these fields of business, **which is that work is increasingly focused on information systems that can work together, or "interoperate"[7].**

Much has been written about the nature of and context for interoperability in the AEC market and many see the fractionated nature of the market to be too large a hurdle to overcome[8]. But

[7] Interoperability can mean different things to different people and communities. I**nteroperability** generally is a property referring to the ability of diverse information systems and organizations to work together (inter-operate). The term as used in this Report is a technical system engineering term as well as social, political, and organizational factors that impact system to system performance. A distinction must be drawn between interoperability and **interoperation**, with the former referring to creating a common fabric of interaction that everyone can connect to equally, and the latter being defined piecewise between particular systems (often through the creation of specific software adapters). It is our experience that it is far easier to do interoperation first, but it is interoperability that builds a real commodity with maximal benefits to the market.

[8] Managing Dynamic Life-Cycle-Dependent Building Objects in a Distributed Computing Environment; Construction Informatics Digital Library http://itc.scix.net/ paper w78-1997-443.

again, when these doubts are parsed far enough we can begin to derive an interoperability quotient, or IQ that technologists and practitioners alike can see from their distinct perspectives – that discrete components and systems, when conjoined with the ability to speak with each other, constructively influences the behavior of other systems and components in that market.

In the AEC market the tiny IQ has for some time increasingly impacted the economic value of information that can be used across the building lifecycle. The AEC market's low IQ indicates innovations that follow conventional norms are destined to underachieve and will continue fostering non-value added economic cost, lost productivity and lessened competitiveness. Information that plays well with other information across different and competing software applications is quickly becoming the new metric for innovation excellence, market take up and revenue growth.

Look no further than the Internet for inspiration about interoperable innovation. The misunderstood genius of the Internet is that interoperability makes "networks of networks" possible. Standards that permit diverse data and applications to mingle creatively explain why the Internet's influence as a multimedia, multifunctional and multidisciplinary environment for innovation remains unsurpassed. Consider "mash-ups" as a model: Google Maps can easily be mixed and mashed with property, seismic or epidemiological data to produce novel applications that might launch a company or an industry. Greater interoperability invites greater innovation – and vice versa. *It is this characteristic that this Testbed and the combined efforts and collaboration between bSa and OGC are addressing.*

Over the last 10 years the concept of merging CAD, data management, requirements for extending the shelf life of information and repurposing previously collected information helped to create what we now know to be Building Information Model (BIM) software. A BIM 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 lifecycle from inception onward.

Many organizations over the past 5 years have jumped on the BIM bandwagon, and to those who did, suddenly realized the extent to which technology, business practice and process are jointly and materially impacted. The business opportunity space and production possibilities curves when employing BIM technologies are naturally pushed out, which implies that to receive the maximum benefit of the technology and new applications, the idea of paving over old cow paths does not suffice. Inherent in this mix of integrated application software and data sharing capabilities is the opportunity for AEC businesses to **not** automate old and outmoded processes, but rather to evaluate and institute processes that increase efficiencies, productivity and add value. If BIM, through its technological advancement facilitates realizing process improvements, then reasonable economic and business judgments can be made about adoption.

BIM technological components help organizations to overhaul their business processes because the overall scope of the technology is broad. Currently BIM can be described **as a product** or **as an intelligent digital representation of data** about a capital facility. BIM authoring tools encompass CAD and are used to create and aggregate information, which, before BIM, were offered as separate software with non-machine interpretable information in a paper-centric process.

2.1 Interoperability Standards in the BIM Marketplace

Users also desire to extend the value proposition of BIM beyond its role as simply a product – to see it and use it *as a mechanism to carry out collaborative processes throughout the lifecycle of the facility***.** This value proposition covers business drivers, automated process capabilities and other network messaging and communications advantages. Currently, the opportunities to use BIM as a collaborative resource are largely dependent on project team members deciding which single vendor software to use for that project, and this decision customarily requires additional investments for transfer technology (along with related financial, training and support costs). Forcing AEC companies to change software on a project-by-project basis, and to continuously invest in new software and training negatively impacts the larger gains that BIM can offer and often means that businesses must continuously change the way in which they operate to accommodate the way that particular software works on a project-by-project basis.

So now the market is increasingly demanding that open information standards be more broadly applied to BIM technologies so that each partner in a project can comfortably adapt their internal processes, so that they can share project information across their chosen software and other partner's chosen and possibly heterogeneous software platform(s), while preserving information sustainability and fidelity across the lifecycle and minimizing their and their client's risk. This demand targets software providers to offer capabilities to exchange information seamlessly.

When BIM (and all its associated data categories and attributes) is successfully standardized across a set of numerous, but commonly defined data and information service levels and shown to work in run time conditions, the full utility of the technology as a collaborative tool and a facility lifecycle management tool can be realized. It involves gaining agreements about well-understood information exchanges, workflows, and procedures at not only the human level, but also the machines human use - where teams use and rely on repeatable, verifiable, transparent, and sustainable information throughout the building lifecycle.

Thus, the basic premise of standards for BIM is to foster collaboration by different stakeholders at different phases of the lifecycle of a facility to insert, extract, update, or modify information in their software of choice and to support and reflect the roles of that stakeholder no matter what provider's software is used by any member in a project team. When BIM software from any provider can be thought of and used as a shared digital representation founded on open standards we then have achieved a level of interoperability like that suggested on page 7.

The National BIM Standard promotes the idea of the market undertaking and defining business requirements for standards that can result in interoperable software across the market. Software interoperability is seamless data exchange at the software level among diverse applications, each of which may have its own internal data structure. Interoperability is achieved by mapping parts of each participating application's internal data structure to a standards-based data model and vice versa. If the employed standards-based data model is open, any application provider can participate in the mapping process and thus become interoperable with any other application provider's offering that participated in the mapping. Interoperability eliminates the costly practice of integrating every application (and version) with every other application (and version).

The NBIM Standard maintains that viable software interoperability in the capital facilities industry requires the acceptance of an open data model and the use of service interfaces contained within provider's software to bring the capabilities of the data model to workflows within the project delivery work cycle. If the data model is accepted as the lingua franca and industry-wide means of communication and can be represented in its appropriate parts along the entire facility lifecycle, then every software application used across the lifecycle can become interoperable.

3 An Architecture for Interoperable Project Delivery

Given the mix of technical and business issues confronting the AEC market and the potential benefits interoperability through standards offers, the goal of AECOO-1 was to develop a process for standards development whereby more efficient sharing of building information between participants in a project team, and between the heterogeneous software products they use can be realized.

In the Concept Development stage of AECOO-1 (development of and comments on the RFT), we found that most of the industry that responded thought information sharing about buildings as an issue that involved transmitting complete information about a building between two design software packages. However, once a discussion on this topic was initiated during the kickoff meetings and later parts of the Testbed execution phase, we found that design-software-to-design-software was the *least* useful information sharing case to address. In the course of a design project, there is little need to share all aspects of the design between project participants. What is more important is to exchange relevant elements of the design between the lead architecture firm or lead general contractor and subcontractors with specific expertise in areas such as lighting, energy usage, building cost, HVAC, circulation, etc.

3.1 Elements of BIM Standards for Interoperability

The design elements needed by these specialists are highly diverse, and so is the software they use to do their jobs. AECOO-1 found that there are few, if any, *standard business practices* addressing fundamental information exchange requirements between the design team and area specialists. Technology cannot provide solutions until the business practices are firmly in place. This is why the information sharing challenge has been so difficult to solve, and many in the industry feel that technology standards efforts have not been as successful as they should. Therefore, in order to make progress on the technology front, AECOO-1 also had to advance the process for developing business information practices associated with sponsor requirements.

The National Building Information Model Standard, Part 1, Version 1 provided us with the concepts of an Information Delivery Manual (IDM), which articulates what building information is required to accomplish a particular specialty analysis (e.g. lighting design, energy performance, materials cost, etc.), and a Model View Definition (MVD), which is the smallest set of Industry Foundation Classes (IFCs) that are needed to express the information requirements of a particular IDM. We found that specialists do their work to varying degrees of specificity depending on how fully developed the building model is at a point in time. In other words, the accuracy of the lighting study, energy analysis, or cost estimate changes as the design evolves.

It is impossible to create software that will work as needed with any building at every stage of design, so our task became one of limiting the degrees of freedom in the design process so that software designers have a reasonable expectation of how much detail and definition they can expect to find in a building at a particular stage of design.

AECOO-1 made two significant contributions in this area. First, we agreed upon a universal definition of project phases, and what level of detail was captured in building design at each project phase[9]. This was a critical first step to characterize what information could be expected to be present—and therefore what types of analyses could be performed—at a particular stage of design. Second, we brought into the discussion the groups responsible for standardizing nomenclature for building materials and other aspects of the design process such as the Construction Specification Institute's OmniClass and Uniformat nomenclatures. Utilizing standard definitions of building materials, sizes, etc., is a prerequisite for creating standardized design interchange files in a standard data model for AEC – Industry Foundation Class (IFC) format. This aspect of standardization will need to occur often within the NBIMS process going forward. It is a conclusion implied in NBIMS Version 1, Part 1 and now verified by work done in AECOO-1.

With our analysis of information flows from the business perspective of the sponsor's requirements complete, we could then apply what was learned to the technology realm. The essential steps taken are graphically depicted in Figure 2. Following the figure we explore in more detail the actual activities that were undertaken.

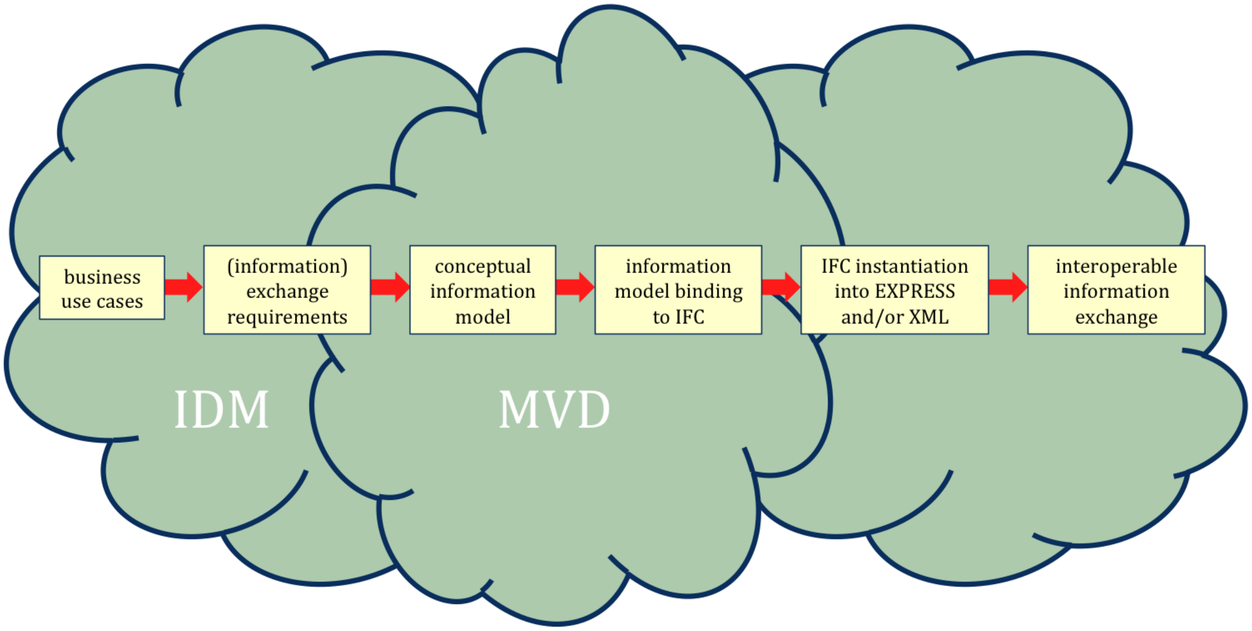

Figure 2 – Interoperable information exchange relies on standardized business processes being codified in IDMs and MVDs

3.2 Interoperability Standards for Business Practices and Design Maturity

There is currently little standardization of the stages of design maturity during a project lifecycle, and therefore it is difficult to develop software that can work generically with any building. Therefore our first task of limiting the degrees of design freedom was to pick a project stage, and

[9] "Organizing the Development of a Building Information Model", Jim Bedrick, November, 2008 (unpublished) and Integrated Project Delivery: A Working Definition, AIA California Council, 2007.

define fully what design information would be present in the IDM for the building model at any stage.

We chose to work at the conceptual design stage, as this is the point in time at which significant changes can still be made to positively impact cost, energy performance, and other key factors that inform final design. This choice resulted in the following definition of early, or conceptual design:

- Level of Detail 200: Approximate geometry[10]

  Design & Coordination (function / form / behavior): Generic elements shown in three dimensions (maximum size, purpose).

  Authorized use for 4D Scheduling: Time-scaled, ordered appearance of detailed assemblies.

  Authorized use for Cost Estimating: Estimated cost based on measurement of generic elements (e.g. generic interior wall).

  Authorized use for Program Compliance: Specific room requirements.

  Authorized use for Environmental (lighting, energy use, air movement Analysis/Simulation): Conceptual design based on geometry and assumed system types.

With this definition in place, we could then begin to define the information requirements for the IDMs that would support our two target business cases, energy performance and materials cost estimation. And then it became a simple matter to create the MVDs (see Figure 3 below) that defined what IFCs were needed to articulate the IDMs. The software vendors could then write code to translate their internal, proprietary building information models into interchangeable IFC models for energy analysis at the conceptual design stage, and materials cost estimation at the early design stage.

For perspective, creating the definition of conceptual design took about 2 project months, and the IDMs took 2-3 project months. The MVD creation took less than 2 weeks, and the actual software development amongst the participating providers took under 2 months.

This underlines strongly the importance of having the industry agree to standardized business practices before we can have any hope of standardized information flows between software packages. This was by far the most important lesson of AECOO-1.

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[10] From “Organizing the Development of a Building Information Model”, Jim Bedrick, November, 2008 (unpublished).

Figure 3 – MVDs relationship to information exchange between heterogeneous software and/or firms

4 AECOO-1 Threads and Work Areas

The development of the AECOO-1 Testbed was organized around the following 3 threads:

- Building Performance and Energy Analysis (BPEA)
- Quantity Takeoff for Cost Estimation (QTO)
- Communications Project Delivery and Decision Support (CPD)

A summary of each thread is provided below.

4.1 IDM For Building Performance and Energy Analysis (BPEA)

Energy analysis is concerned with predicting the usage profile and cost of energy consumption within buildings. Conceptual design phase energy modeling is used to provide the design team with first order of magnitude feedback about the impact of various building configurations on annual energy performance. Conceptual phase energy modeling requires the designer to make assumptions for a wide of range of simulation input if information is not yet available. It takes into account as input data:

- Building geometry including the layout and configuration of spaces,
- Building orientation,
- Building construction including the thermal properties of all construction elements including walls, floors, roofs/ceilings, windows, doors, and shading devices,
- Building usage including functional use,
- Internal loads and schedules for lighting, occupants, and equipment,
- Heating, ventilating, and air conditioning (HVAC) system type and operating characteristics,
- Space conditioning requirements,
- Utility rates, and
- Weather data.

The output results of energy analysis may include:

- Assessment of the space and building energy performance for compliance with regulations and targets,
- Overall estimate of the energy use by space and for the building and an overall estimate of the energy cost,
- Time based simulation of the energy use of the building and time based estimate of utility costs, and
- Lifecycle estimate of the energy use and cost for the building.

For the purposes of this process map, conceptual phase energy analysis is considered to include the assessment of heating and cooling demand within a building during peak periods.

Various types of analyses are within the scope of this process map, including:

- Setting comfort criteria for spaces including minimum and maximum required indoor air temperatures (summer and winter), minimum fresh air requirements,
- Heat loss/gain calculations using well defined analytical methods,
- Energy performance rating system and/or energy code requirement compliance,
- Analysis of energy consumption in meeting the building energy demands, and
- Optimization of energy performance related to equipment or system type and related equipment/system performance characteristics considering lifecycle cost, environmental impact issues, and comfort aspects.

4.1.1 Cyclical Design

Energy analysis is now a critical path workflow throughout the design stages of a project. Two key parts of energy analysis were considered in the Testbed:

4.1.1.1 Conceptual Design

This is the analysis work undertaken during the programming and concept design stage of the project. It is about providing advice on the potential energy performance of a building and its systems to other design roles. The aim of this analysis is to have an impact on the overall building design, determine the feasibility of concepts in an energy context and to establish energy targets. Conceptual analysis may be undertaken in the absence of detailed geometric information about the building layout, though frequently general spatial layout is included during this stage. The designer is more concerned with relative performance values between the design options being considered, rather than absolute performance values. Though assumptions typically must be made at this stage, maintaining consistent assumptions between the options being evaluated allows for relative performance to be evaluated.

4.1.1.2 Detailed Design

This is the analysis work undertaken during the schematic and design development stages of the project and assumes the availability of geometric and building system information for the design. The overall process is the same at each stage of work, the difference being simply about the extent of the information available and the level of certainty that can be applied to the information. These factors impact the analysis methods used, which may range from relatively simple at the earlier design stages to detailed dynamic simulations at the later design stages.

Within this process map, the conceptual design phase for Building Performance and Energy Analysis is shown in Figure 4.

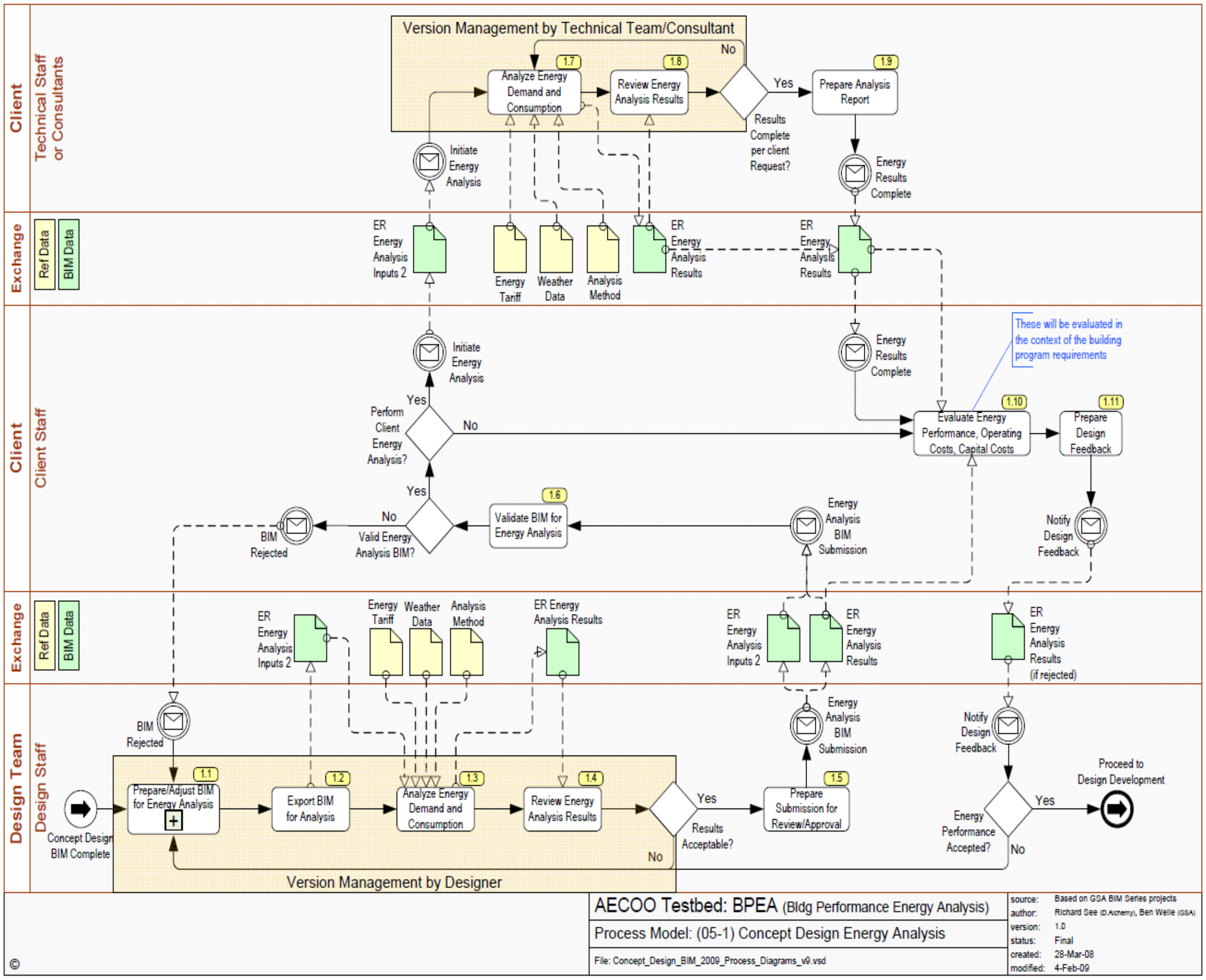

Figure 4 - Concept Design Phase Energy Analysis

4.1.2 IDM BPEA Information Exchanges

For Conceptual Design, the scope of the exchange of information is primarily about spaces with associated energy information and about proposed energy analysis zones. The purpose of the exchange requirement is to support the coordination of energy analysis requirements with general in building zoning and spacing requirements. Information requirements were defined as “required” or “optional”. Data parameters and units of measurement were also defined. Also it was presumed that information exchanges took place between the role of Architect and a Mechanical Engineer and/or Energy Consultant.

The exchange requirement assumes that a building model is available from which relevant geometric information required for energy analysis can be derived. It is anticipated that the building model will provide context information about the project including units to be used, coordinate systems to be adopted and the direction of true north.

The building model will provide specific information about:

- The building, its location, composition, overall shape and orientation
- The shape and location of adjacent buildings to enable shading effects to be determined
- Building stories within the building
- Spatial configuration

Information that is provided by this exchange is to enhance the initial set of building model information including:

- Space type and function identification with type data being obtained from a project space type library (which is in turn derived from an industry space type library). This data will drive assumptions on internal loads, conditioning requirements, etc.
- Building elements construction type data with type data being obtained from a project construction type library (which is in turn derived from a industry construction type library). This data will provide information on the thermal characteristics of the building envelope and internal constructions.
- Space boundaries that define the relation between spaces and building elements and the geometry that describes the space boundary connection.
- Energy targets.
- HVAC zoning, day lighting, and the use of photovoltaics.

For energy simulation and analysis, the scope is about the exchange of information related to energy demand, comfort, and annual energy consumption. The purpose of the exchange requirement is to enable coordination of energy analysis with other design roles based on the results of energy analysis and the ability to comply with set energy targets. The exchange requirement assumes that information about the building has been satisfied.

Information that is provided by this exchange requirement to includes:

- Ventilation requirements,
- Peak thermal loads,
- Energy demand,
- Annual energy consumption,
- Utility rates, and
- Energy costs.

4.1.3 2nd Level Space Boundaries

At the Conceptual Design level of the building process as defined by IPD, the notion of space boundaries[11] plays a role in energy analysis and quantity takeoff for cost estimation. There are defined three levels of space boundaries. The IDM developed in the BPEA Thread accounts for the first level. To provide for a more complete energy analysis and cost estimation, 2nd level space boundaries need to be calculated and work to define this component for conceptual design energy analysis was initiated in the Testbed.

4.1.3.1 Ist Level Space Boundaries

1st level space boundaries are the boundaries of a space defined by the surfaces of building elements bounding this space (physical space boundaries) or by virtual surfaces provided by an adjacent space with no dividing wall. Other characteristics that are part of a 1st level space boundary include:

- 1st level space boundaries do not consider any change of material in the bounding building elements, or different spaces/zones behind a wall or slab (floor or ceiling).
- 1st level space boundaries are differentiated in two ways: virtual or physical and internal or external.
- 1st level space boundaries form a closed shell around the space (so long as the space is completely enclosed) and include overlapping boundaries representing openings (filled or not) in the building elements (see implementers agreement below).
- Implementers' Agreements --

    Connection geometry for 1st level space boundaries may contain arcs (i.e. creating cylindrical surfaces), or polygons (i.e. creating extruded surfaces with orientation changes).

    1st level space boundaries representing building elements (wall, slabs, columns, beams) do not include inner loops to create voids (e.g. for openings). Instead, there are separate 1st level space boundaries representing such openings (with or without contained doors and windows) -- which overlap and are coplanar with the space boundaries representing the host wall, slab, column, or beam.

[11] Space boundaries are virtual objects used to calculate quantities for various forms of analysis related to spaces or rooms in buildings. Analyses that use space boundaries include: Quantity takeoff for Cost Estimating – In early stages of design, many objects have not yet been modeled. In this phase of a project, space boundaries (and other measurements based on the space object) are used to estimate such things as finish materials (i.e. carpeting, tile, paint) and casework. Facilities Management Work Package Estimating – During the operations phase of a building's life cycle, space boundaries can be used to estimate areas for facilities management work packages such as re-painting, carpet cleaning, and cleaning of other building element surfaces. Energy Analysis – that is, estimating the amount of energy that will be used by a building during operation. Space boundaries need to be calculated to capture more accurate energy flow between a space and other spaces or the outside air.

4.1.3.2 2nd Level Space Boundaries

2nd level space boundaries still represent building elements that bound the space, but are more granular in that they are subdivided in any of the following cases:

- Contained openings (with or without fillings like doors and windows)
- Differences in materials and/or material assemblies (e.g. a wainscote or paneling on the lower portion of a wall).
- Differences in spaces or zones on the other side of the building element (or virtual boundary) represented by the space boundary (e.g. two different spaces on the other side of a wall)
- Differentiation between physical / virtual boundaries and internal / external boundaries is the same as for 1st level space boundaries.
- 2nd level space boundaries represent both sides of a heat transfer surface separated by the thickness of the building element. They can be used by thermal analysis software, but require, that the two adjacent surfaces are found and be combined to form a single heat transfer surface. This is required even where the two surfaces are of different length (e.g. non-rectangular wall connections and curved walls). See also 3rd level space boundaries.
- 2nd level space boundaries (including the 3rd level subtype described below) form a closed shell around the space (so long as the space is completely enclosed).
- Implementers' Agreements --

  The connection geometry of 2nd level space boundaries is restricted to planar surfaces only. This means that curved surfaces must be segmented.

  The connection geometry of 2nd level space boundaries of walls/slabs/columns/beams and included openings/doors/windows do not overlap.

4.1.3.3 3rd Level Space Boundaries

3rd level space boundaries are special types of 2nd level space boundaries.

- Type 3a - The most common type occurs where the element behind the boundary is a building element, rather than a space or zone. For example: the end of a wall (wall butt) that divides two spaces on the other side of a wall.
- Type 3b - a second type occurs where path based building elements intersect and overlap.
- Type 3c - The third type occurs at non-orthogonal intersections of building elements where the two sides of the element have different lengths (e.g. angled wall connections). The extra length on one side or the other is defined to be a 3rd level space boundary.
- 3rd level space boundaries are typically ignored in heat transfer calculations for energy analysis because the transfer in these cases is negligible. Identification of such boundaries, as 3rd level, enables energy analysis software to ignore them.
- The combination of 2nd level and 3rd level space boundaries form a closed shell around the space (so long as the space is completely enclosed).
- Similar to 1st and 2nd level space boundaries, 3rd level space boundaries are a differentiation into virtual or physical and internal or external space boundaries.
- Implementers' Agreements --

The connection geometry of 3rd level space boundaries is restricted to planar surfaces only (same as for 2nd level). This means that curved surfaces must be segmented.

The connection geometry of 3rd level space boundaries of walls/slabs/columns/beams and included openings/doors/windows do not overlap (same as for 2nd level).

The Implementation Guide developed as part of this Testbed and completed under further USGSA guidance defines a stepwise approach for calculating space boundaries in buildings. A companion MVD provides software developers the means for implementation in software using IFC structured data.

4.1.4 MVD For Building Performance and Energy Analysis (BPEA)

Two MVD's were constructed for the BPEA IDM: a Generic and a Model View Binding for IFC 2.3 version along with an Implementation Guide.

The Generic Model View presents a collection of diagrams documenting the concepts based on the Exchange Requirements defined in the Information Delivery Manual (IDM). Note that generic concepts are documented and cataloged in the MVD coordination database for reuse across multiple MVDs.

The Model View Binding presents a collection of diagrams documenting how each generic concept will be represented in the IFC 2.3 information model schema to be used for the exchange Binding concepts are documented and cataloged in the MVD coordination database for reuse in multiple MVDs that will use the same schema for exchange for other MVDs using IFC 2.3.

The Implementation Guide provides instructions for programmers about how to implement specific concepts defined in the IDM and includes 3 parts:

- Data instantiation diagrams - These diagrams document the exact information model entities that will be used to represent the concept (e.g. IfcObject) and parameters that must be used (e.g. property values),
- Implementer agreements - Generally, these are agreed limitations to be used in this representation of the concept where the underlying information model schema would allow a broader range of possibilities (e.g. agreement to use 3D facet geometry where the schema would allow for other types of 3D geometry).
- Reference data - in many cases, an MVD will make use of existing industry standards to define value ranges (e.g. classification systems or enumerations defined in a reference standard). If the exchange only allows values from such a reference standard, a URL or information sufficient to access that reference standard will be provided.

4.2 IDM For Quantity Takeoff for Cost Estimation (QTO)

Quantity Take-Off is a precursor to completing a cost estimate to determine whether the design meets the project budget. In the early design (conceptual) design phase, quantities used for estimating are building or elemental level quantities as more detailed design information are not available. For example, the conceptual phase allows:

- Walls and slabs by area,
- Windows by count by size,
- Spaces by area,

- Structural system by facility area,
- Heating system by facility area,
- Cooling system by facility area,

The output of the quantity take-off may be the result of a report produced by the cost estimating application, which shows quantities. Other than a valid IFC file for use by cost estimating applications, the QTO process does not produce any output.

Throughout the estimating process the estimator typically communicates through various media with the design team, and perhaps the owner, to understand the design intent fully providing an appropriate estimate of building costs. Often, this post model output interaction among the various actors / roles is not captured formally. For Communication, Process and Decision (CPD) Making functionality, the BIM must be able to document the actors / roles interacting with the model. The various actors and roles mentioned specifically in the IDM are not indicative of all potential actors / roles at early design stages.

4.2.1 Cyclical Design

The process of outputting a quantity take-off is cyclical to match the design submittal requirements. It supports the cost estimating requirements to verify that the project design is within the established budget. The quantity take-off will have increasing complexity as the design progresses from early concept through final design.

4.2.1.1 Conceptual

This is the analysis work undertaken during the programming and concept design stage of the project. It is about providing advice on the potential construction cost of a building to design roles and the client. The aim of this analysis is to determine the feasibility of concepts in a capital cost context. Conceptual analysis may be undertaken in the absence of detailed geometric information about the building layout, though frequently general spatial layout is included during this stage. Assumptions typically must be made at this stage, maintaining consistent assumptions between the options being evaluated allows for evaluation of relative cost performance.

4.2.1.2 Detailed

This is the analysis work undertaken during the schematic; design development and construction document stages of the project and assumes the availability of geometric and building system information for the design. The overall process is the same at each stage of work, the difference being simply about the extent of the information available and the level of certainty that can be applied to the information. These factors impact the analysis methods used, which may range from relatively simple area and elemental quantities at the earlier design stages to detailed quantity take-off at the later design stages.

Within this process map below, the conceptual design phase of the project is shown. The process map generically refers to the Design Team, Client – Client Staff and Client – Technical Staff or Consultants. For CPD integration, OmniClass Table 33 Disciplines provides a classification for the actors and OmniClass Table 34 Organizational Roles provides a classification for the roles. Any specific project team may require expanding the generic roles shown in process map to define in greater detail the actors and roles of the project.

Figure 5 depicts the Concept Design business processes for Quantity Take-off.

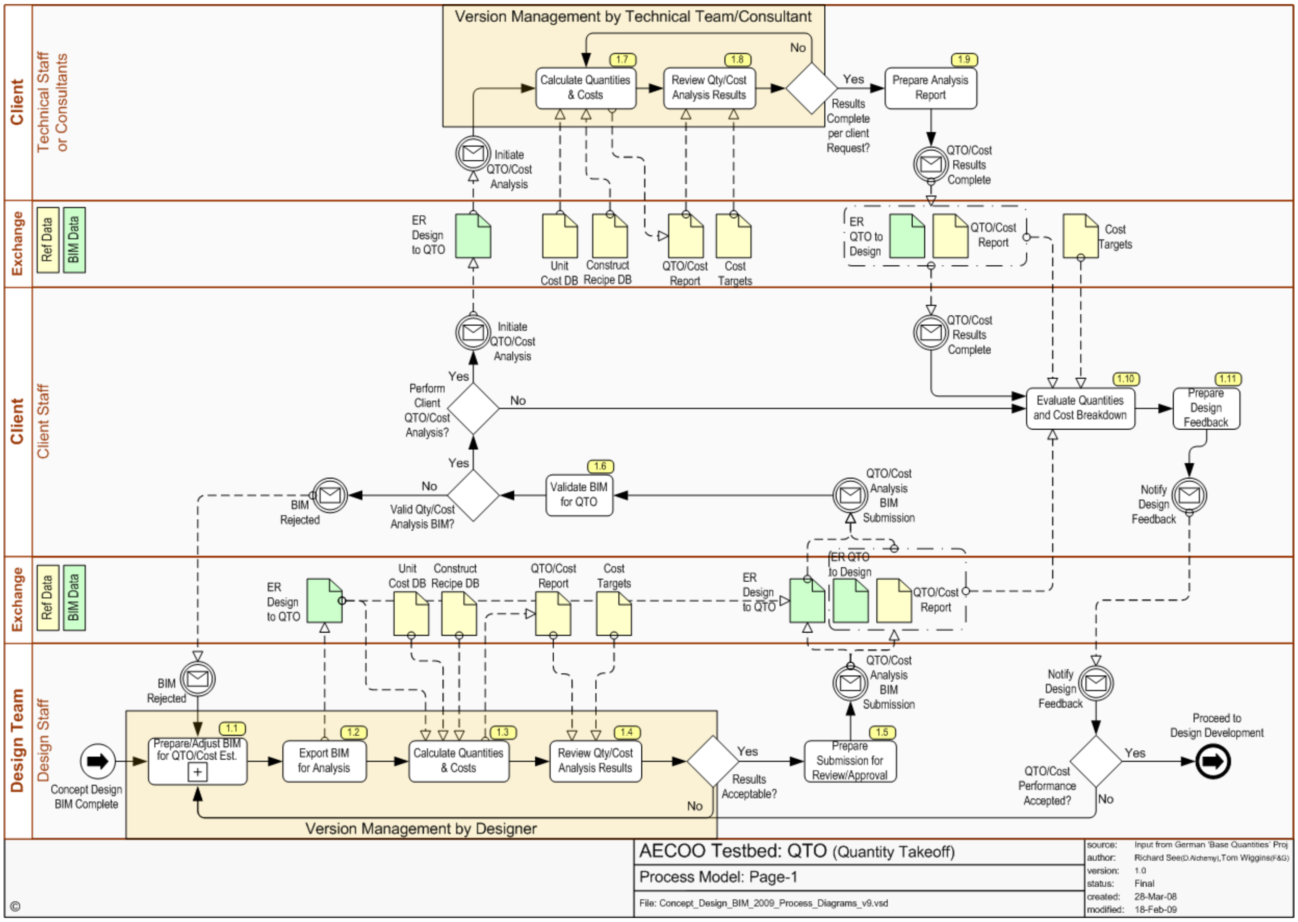

Figure 5 – Concept Design Phase Quantity Take-Off

4.3 MVD for Quantity Takeoff for Cost Estimation

The same procedures as discussed in Section 4.1.4 were applied to the QTO IDM to develop the QTO MVDs – both generic as well as for IFC 2.3.

4.4 Communications Project Delivery and Decision Support (CPD)

This thread involved the development of a series of user scenarios and situations that enabled users and software providers to demonstrate the accomplishments brought forward in the BPEA and QTO threads with a test building. It involved the development of the test building in multiple provider BIMs, a charrate that involved making changes to the building that impact energy performance, quantities and costs.

5 Demonstrations and Webcast

Two demonstrations were completed as part of the AECOO-1 Testbed. The demonstrations comprised a number of different energy and building performance components of the "test building", the results of energy analysis using EnergyPlus and the effect those changes had on quantity of building materials and cost. The demonstrations used a number of different software vendor products that interchanged IFC information using existing commercial off-the-shelf software to perform the necessary calculations and results. The first demonstration was held in Washington at the National Building Museum in March of 2009. The second demonstration was via a webinar in May of 2009.

A streaming webcast of the May 28 AECOO-1 webinar is available for review: http://www.opengeospatial.org/pub/www/aecoo-1/index.html.

The webcast demonstrates results from the AECOO (Architecture, Engineering, Construction, Owner and Operator industry) Phase 1 Testbed.

The demonstrations focus on early design for a new building. The owner of the new building is interested to explore more energy efficient design alternatives and to have the building perform more cost effectively for the next 30 years.

The owner hires a design team composed of architecture firm and a general contractor, mechanical engineer and other professionals to conduct conceptual and early design services with the objective exploring these facets as part of the overall design process. In preliminary scoping meetings with the architect and general contractor team an established working budget was established. The building owner enters into an Integrated Project Delivery (IPD) contract with the architecture firm and general contractor to develop a schematic design package for the building. The architecture firm/general contractor is tasked to evaluate several design alternatives, providing estimates of energy performance, quantities and cost related to those design alternatives. This input will allow the owner to calculate a return-on-investment for the project, and predict long-term building operating costs. Given that this is early design, the schematic design package and work to be undertake is to better understand cost and explore cost in terms of LEED building certification with relative performance options rather than absolute values

The iterative process of design, energy analysis, cost estimation and owner analysis that was used in the demonstration is shown in Figure 6.

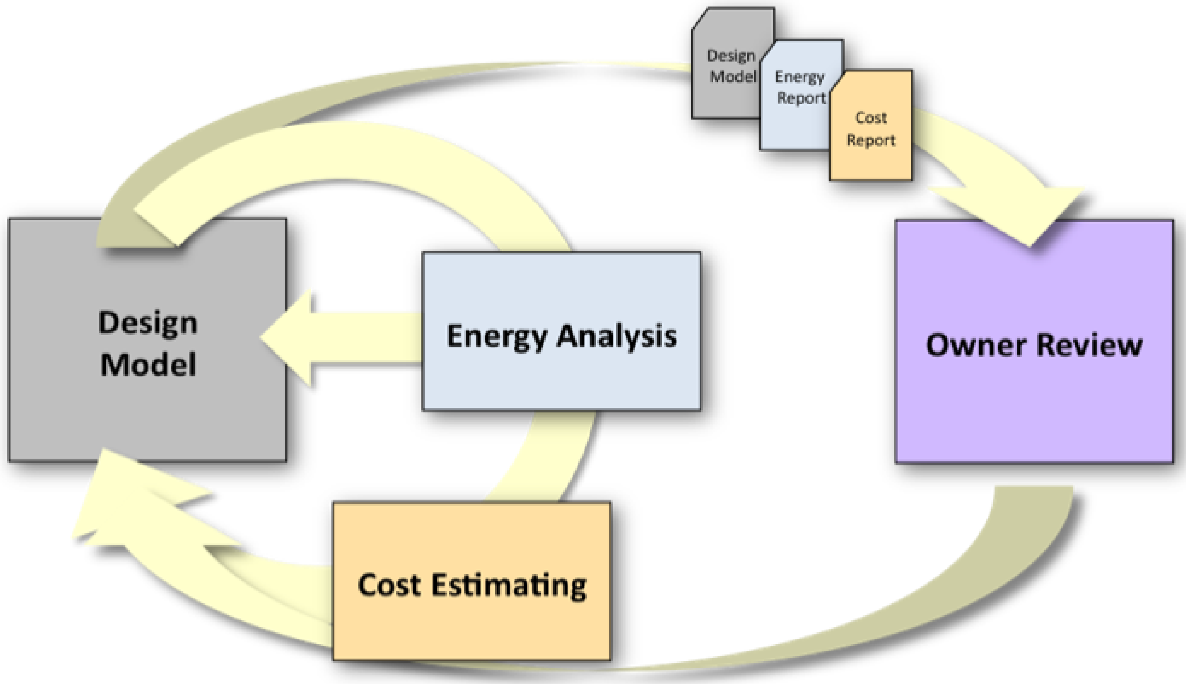

Figure 6 – AECOO-1 Demonstration flow of events

The demonstration highlighted four important conclusions of the Testbed:

- Technology standards for interoperability provide a compelling approach for addressing owners' business requirements for better communication, process management, decision support and performance simulation of design alternatives;
- Integrated Project Delivery (IPD) is realizable with interoperable technologies that enable faster, cheaper, and more effective information processes;
- Project design teams can bring both energy and economic impact analysis upstream (i.e., earlier phases of design) using software that can seamlessly exchange data among different vendors' building information model (BIM) software applications, such as BIM authoring tools, quantity takeoff, value engineering, energy simulation, project and document management, and decision support; and
- Multidisciplinary project teams that work together with data-sharing tools and common information models can indeed achieve better results faster than teams each working in their respective stovepipe application settings.

The exchange of data using IFCs was accomplished as shown in Figure 7.

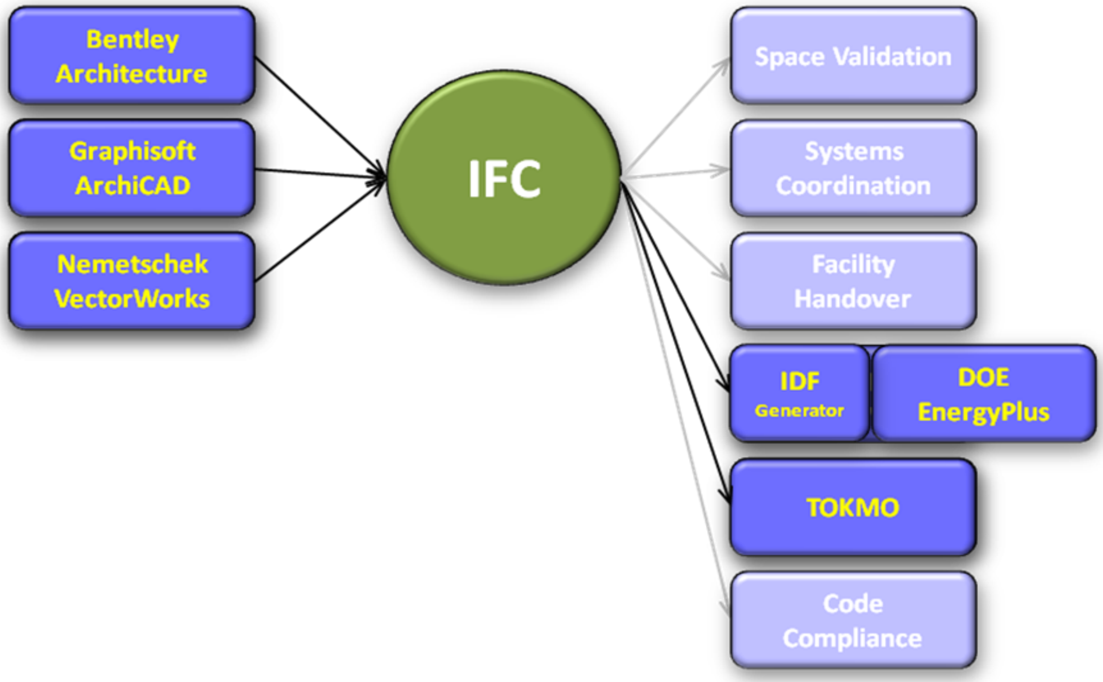

Figure 7 – IFC Data Exchange in Demonstration

The process and software of the demonstrations prove that the following are achievable today:

a) Quantitative cost and performance justification of design decisions early in the design process, resulting from parallel, partially automated and near-real-time cost estimating and building energy performance simulation;

b) Standardized process definition that indentifies tasks and information requirements for all participants and stakeholders, and unambiguously defines all data exchange requirements across the process;

c) Effective electronic information management and dissemination that serves all processes and project participants and stakeholders; and

d) Limited use of Industry Foundation Classes (IFC - ISO Standard 16739).

6 Lessons Learned & Recommendations

AECOO-1 provided bSa and OGC with a Petri dish in which to experiment with proven approaches to standards development that are recognized globally as efficient, capable and targeted and apply them to AEC market requirements. Given we were integrating a Testbed process designed for rapid development of web services standards to the AEC market we draw some conclusions for further discussion and follow-on testing by members of both organizations.

6.1 The Dimensions of BIM – Product, File and Conceptual

The belief that a Building Information Model is a way to organize information over the course of that facility's lifecycle is accepted in the market. The belief that BIM can and should be the single, unifying resource for a project is a key and essential conceptual objective going forward for market efficiency is also accepted, but the idea that a BIM for any single project or portfolio of projects can be explicitly represented by s single data model, file type and/or single vendor software or suite of software packages is unrealistic. The AIA in its recent position statement[12] about interoperability aptly describes today's situation:

> Not all architects (or consultants, contractors, subcontractors, suppliers or owners) use the same software packages for their work, nor should they: each should use the best tool for the job in their particular business enterprise. But industry stakeholders do not work in a vacuum: they must share information in order to complete projects, and the amount of necessary information sharing is increasing at a dramatic pace…
>
> There are many dimensions to the data or information contained in software packages used in the AEC industry today. Begin by considering a building information model: every single object in a model has dozens or hundreds of discrete pieces of associated alphanumeric or geometric data. Multiply that by the hundreds or thousands of objects in the model. Then layer on possible other uses of the data beyond the model, like performance analysis of the design (structural, thermal, lighting, etc.), project management, estimating or facility management software, or sharing of the data between different BIM applications, and so on. Acknowledge that some of the data is time-sensitive and may change over the life of the model. The complexity of ensuring those hundreds of thousands of pieces of data be shared between packages in an accurate, consistent, complete and effective fashion, especially when one acknowledges the proprietary nature of the software packages, is mind-boggling.

The areas of expertise that flow into the design, development, and execution of a building project and/or a portfolio of properties are so diverse and distinctive that the industry must continue to plan for a scenario where firms use the best software for the particular job at hand, whether that job is design, energy utilization, project management, RFI tracking, code compliance, etc.

We now witness products being offered as BIM by individual vendors that offer users an array of one-stop, integrated offerings, often tied together by a proprietary data model(s) to support the full range of requirements identified above.

We also must acknowledge that due, in part to the lack of widely accepted and used application and data interoperability processes that are standardized across the marketplace, vendors and users have developed symbiotic relationships to satisfy business practice.

Finally, we need to acknowledge that a standard information model for building information classes is available. This standard, while still evolving to capture new requirements, has not been seen as an adoptable counter response to current vendor and user relationships and the perceived efficiencies of proprietary data structures. For the most part the standard is treated as more of an exotic framework for information exchange than as market driven best practice. The buildingSMART alliance and the NBIMS project exist to correct these market failures and raise awareness about the negative impacts and costs vendor lock-in creates throughout the market, and undertake necessary at the standards level for the market to gain the confidence and

[12] New Position Statement Request On Interoperability and Project Deliver – Submitted by the Board of Integrated Practice Discussion Group, 2009.

experience the benefits open standards information exchange provides not unlike in other fields such as emergency response, geospatial information, finance and healthcare.

We begin by accepting that BIM is a concept, not a product per se, nor a single file type that can be stored in a database or on a hard drive. The BIM *is* the digital representation of a project. Therefore, it is unreasonable to ever expect the whole BIM to be interoperable, and exchanged between software packages. The BIM is distinctive, and unique to every project.

Recommendation: bSa and allied national and international standards bodies should clarify market confusion regarding the term BIM, and set out in well defined, well coordinated and understandable ways to define the full utility of BIM and BIM-related standards and to shift providers business practices to deliver market driven, standards-based collaboration and facility lifecycle management tools. The next two recommendation define a way forward for achieving this end state.

Recommendation: Standards for BIM exist in piece parts; there is no underlying base that serves as the foundation for information exchange. Architecting (in the information sense) where BIM standards are needed should start with abstract concepts using well-known methods for Reference Architecture and Reference Model[13]. Key assumptions to be defined include resources that are distributed across ownership boundaries, people and systems interactions, security, management and governance. Interactions between people and systems is primarily through exchange of messages with reliability that is appropriate for the intended users and purposes.

Recommendation: The essence of information standards for BIM (and all its associated data categories and attributes) is based on 1) standards bodies organizational structures whose focus are responsibility for elements of the types of architectures listed above; and 2) development of "successful" standardized business practices and modeled information exchanges. (Successful is meant to mean that the practices and exchanges are connected across a set of numerous, but commonly defined data and information service levels and shown to work in run time condition).

6.2 Information Interoperability and Data Exchange Across BIM

Information interoperability needs to occur when two people using different software need to communicate effectively and efficiently. This idea may seem simplistic, but it helps clarify and constrain the problem. A structural steel cost estimator doesn't need the entire BIM to do his/her work. In fact, it would be a waste of money for the cost estimation software vendor to build whole BIM support into their product, and if they did, every time that BIM was delivered to the estimator and brought into the costing software, more money would be wasted carrying around information that had no bearing on the problem at hand.

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[13] See for example: IEEE Recommended Practice for Architectural Description of Software-Intensive Systems, Std IEEE 1471-2000 and OASIS Reference Architecture for Service Oriented Architecture Version 1.0, Public Review Draft 1, 23 April 2008. IEEE 1471 is the short name for a standard formally known as ANSI/IEEE 1471-2000, *Recommended Practice for Architecture Description of Software-Intensive Systems.* Within IEEE parlance, this is a *Recommended Practice*, the least normative of the kinds of IEEE standards. In 2007 this standard was adopted by ISO/IEC JTC1/SC7 as ISO/IEC 42010:2007, *Systems and Software Engineering -- Recommended practice for architectural description of software-intensive systems*. (see: http://www.iso-architecture.org/ieee-1471/ieee-1471-faq.html.

Lesson: What the industry must focus on- if an information architecture framework is agreed to be found necessary and then developed- is creating as part of that architecture an interoperability layer for major processes, or sub-tasks, that are common to every building project, and require information exchange between specialized software packages (whether between firms or within the same firm). The IDM as was constructed for topics in the AECOO-1 Testbed begins to fulfill this role

The interoperability challenge can therefore be described as the ability to extract the smallest, most directly relevant information required to execute a particular task, and share that information in a manner that is understandable by a wide range of users that use a wide range of software packages. This information will come from a BIM, but the BIM is conceptual, and parts of it may (and usually do) reside in a host of different software database and application systems, but the BIM and its conceptual requirements are likely to be needed where combinations of design, project management, and communications management (e.g. email or Microsoft Outlook) software are in constant use.

Lesson: Migrating the requirements of IDM into interoperability standards that can be implemented by providers happens in the MVD. Once an IDM is agreed to the process for bringing those practices and exchanges into the world of software is fairly straight forward.

This interoperability level for BIM information exchange is called a Model View Definition (MVD) level in buildingSMART parlance. MVDs match up with project functions horizontally and vertically in the AEC lifecycle. We do not see a need to make any one provider's BIM package and related offerings interoperable with other providers, except at the point where the MVDs are constructed for purposes of information exchange. When well-devised business practices and processes are articulated in strong Information Delivery Manuals (IDMs) as were developed in this Testbed, good MVDs can be created. And only then can interoperability be expected from software providers.

Testing software providers' implementations of MVDs should be built into the standards development process, and should take place before an MVD is approved. The exchange requirements documented in one or more IDMs and their corresponding MVD may also need to be re-examined during testing.

There are sets of MVDs that persist along the entire lifecycle, such as cost. Cost information is the business of every stakeholder along the lifecycle. However, given the latitude and approaches that cost estimators play at any given point, it may well be more efficient to provide a cost estimator with tools that best enable their individual processes and choices. The issue of messaging about cost information, and the ability to view that information along with supporting attributes in other application's environments is the distinguishing interoperability requirement.

6.3 The BIM Concept Needs a Message-based, Web Services Approach

This Testbed showed what is possible when MVDs are shared between parties using file exchange via project management software, or simply email. The next step is to pass messages that can act as a means for access, display, edit and seamless integration. So, in considering what needs to be accomplished by the market over the coming years are:

1. An agreement on an information architecture that encourages stakeholders to have conversations among and between project team members with messaging.

2. A standards-based means for enabling messages to pass between the systems of application providers in accordance with MVD requirements.

Recommendation: IFC is currently the lingua franca of MVD. Migrating from the file-based nature of IFC to a messaging context about project details, management and coordination is what BIM information architecture is about. With this focus the enormity of the job is brought down several notches in scale.

The market seems ready and willing to embrace an IT message-based architecture for the AEC market that is purpose based, and matches the way people in the market want to work. There is room for a shared vision, which resides in the databases of each provider, and provides any stakeholder the ability to view their concept of those databases depending on their respective expertise and responsibility. Conversations can then happen between organizations and individuals at the MVD level of detail.

6.4 IFC Should Be XML

The market will eventually need to decide whether it wishes to pass files via Express or pass messages via XML. Each requires different skill sets and industry architecture. Maintaining both requires providers to maintain two standards based libraries. Providers currently support both their internal data structure libraries as well as IFC/Express. Currently, IFC is seen as an exotic format for providers to maintain and is not present in their core product offerings. Continuing to rely on Express raises the probability that attribute data needed for information fidelity, using IFC will continue to be marginalized.

The industry is already moving towards the exclusive use of XML for standards. Efforts with good momentum include Green Building XML (gbXML), Automating Equipment Information Exchange (AEX), aecXML, agcXML and Open Building Information Xchange (oBIX). XML encodings such as those listed above are ready made for web services integration to BIM software. Technically speaking, the Express language could be used to pass information in a web services environment, but it is a poor fit and insufficient mainstream market adoption. XML is designed to work with web services, and there is a wealth of mature supporting software and software standards to facilitate the adoption of existing AEC-based XML encodings and schema with existing web services standards to adapt AEC software offerings. Simply put, Express creates an extra cost barrier whose value is questionable at best.

If IFC classes are to become a widely used and accepted industry standard, then the viewpoint of them being seen as exotic will need to end, and that signal can only come from the market. If that signal does appear, then interest and resources from the wider IT industry will be stimulated to address, maintain and further enhance interoperable open data models.

Leadership from the IT industry will also be helpful so that the myriads of attribute data products from groups such as the Construction Specification Institute (e.g., OmniClass) can be rapidly built out for software adoption using agreed upon transport and messaging frameworks.

In the demonstration, participants stretched their respective internal IFC toolboxes to enable slightly more interoperability among their proprietary BIM software applications and data processing engines. In doing so, the teams discovered that some aspects of the IFC data model are not amenable for interoperability as the word is commonly defined and practiced by industrial communities that rely on collaboration via network processing, cloud computing, and distributed data repositories to achieve results for decision support faster.

Recommendation: The IFC structure, first developed in the 1990's, should be modernized so that a more complete suite of benefits from interoperability reaches critical mass and market adoption. With IFC modernization, a far more open, comprehensive and intelligent life-cycle data model for buildings can be achieved.

IFC modernization working in parallel with highly efficient network-based communication, process management, decision support, and performance simulation of design alternatives is the sweet spot for achieving benefit in real property industry projects. IFC modernization will also tend to reduce the costs and inefficiencies that now result when builders and owners attempt to maintain consistent and unambiguous use of original project information by all project participants and stakeholders.

Annex A provides additional explanation about what can be done by bSa and other AEC-related standards bodies to address the means to introduce messaging and web services for interoperability. This annex explains and defines the mutual and supporting roles for the IT and AEC communities about how they may come together to work these challenges.

6.5 Future Testbeds

At the outset of the AECOO-1, bSa and OGC set out a number of goals for this effort. They included the following:

- Develop wide ranging and reusable technology solutions that support community business transformation;
- Create a cost-effective and resource-efficient environment for industry to create standards and implement and adopt market driven solutions;
- Foster a vibrant and knowledgeable AECOO community of practice that builds industry capacity to sustain transformation goals;
- Induce software developers to meet broad user requirements with enhanced software capabilities;
- Promote market driven targets of opportunity for academic research; and
- Pilot a repeatable industry process that with success leads to continuous requirements definition and use of lessons learned.

Industry stakeholders, driven by economic necessity and global competition, desire applications that can be knitted together and mate according to their individual practices and processes to provide client with their brand of architecture, construction and building products and services. Companies have also long sought to more effectively integrate information systems across their organization to better support business processes that cover all present and prospective requirements needed to run the business end-to-end.

No one vendor has the best software for everything needed to author and/or evaluate a building’s design, its cost, possible energy consumption, thermal comfort, lighting, acoustics, etc. The industry requires the ability to seamlessly exchange and share building information among these sets of information technology tools. These facts are what drove this testbed. A generalized illustration of these problems is illustrated in Figure 8 below.

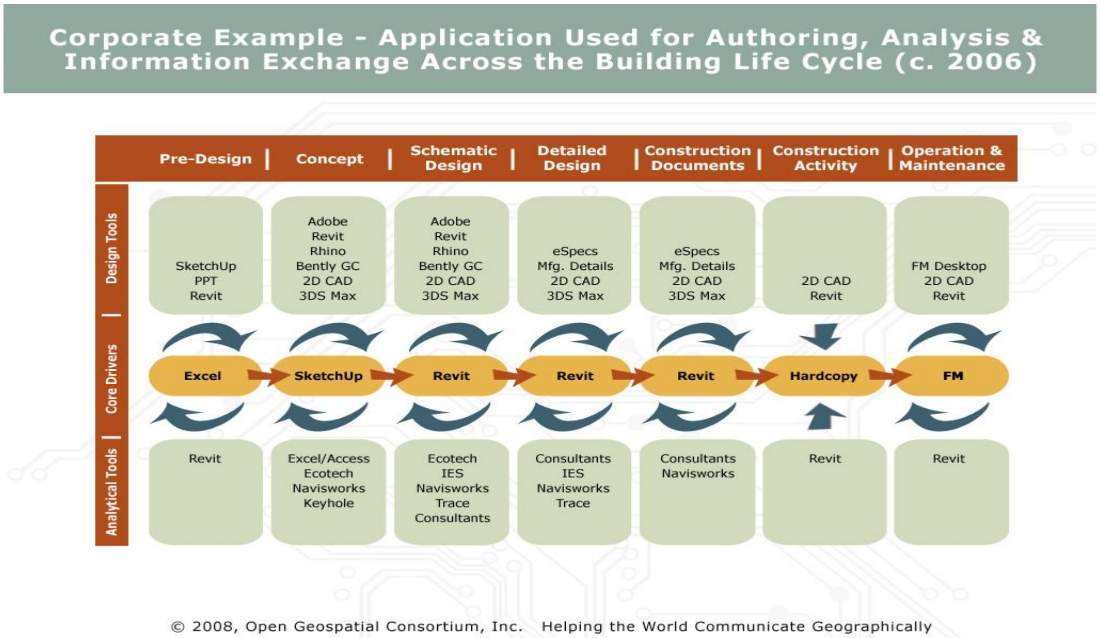

Figure 8 – The Corporate Example for Authoring, Analysis and Information Exchange Across the Building Life Cycle

Given the broad and well accepted, but inefficient, ways that buildings and other capital facilities are defined and constructed, the Sponsors have identified a few concerns about how virtual building models need to perform with cost estimating and energy information analysis practices during the iterative definition of space, design intent and construction quantities and their characteristics.

Let's presume for the moment that the NBIMS project is operational, and there exist operating committees, working groups, that there are procedures for taking inputs and requirements in to that body for defining candidate standards, and there is in place a voting mechanism for consensus adoption. Where should Testbeds (as defined by this Report) be used? Where in the overall process can their use be most helpful (by that we mean addressing requirements in the form of IDM's and MVD's that are shown to work and seamlessly exchange information across vendor products)?

Lesson: From our experiences in AECOO-1 we witnessed that many private businesses and public sector organizations have similar, if not the same requirements. This lesson should be accounted for going forward in future work of NBIMS.

Lesson: a more clear delineation will need to be made about the role and place of bSa fostering "ad hoc projects and aquariums" and formal Testbeds (that we presume will happen within in the NBIMS project). We found bSa members confused by the purposes for each. Each does have a distinct purpose and each can and usually does involve the expense of resources (both cash and in-kind), however, the important difference for members to consider is about the payoffs, as well as the longer-term status of standards development using accepted consensus approaches and adoption throughout the market.

Formal Testbeds are the best known way to address both national and international requirements where outcomes could result in the formal adoption of standards. Only through standards, can the organizations across the AEC market reasonably address broader issues of risk. The Testbed processes summarized here demonstrate that organizations can come together and work common areas of interest, and by pooling their resources, achieve expected results with less individual outlay, while providing a more rapid timeframe for success than with other means.

Recommendation: In considering the use of Testbeds and other rapid prototyping standards development procedures that bridge gaps in communication across the AEC market, it is an imperative that bSa and associated standards bodies create an underlying framework for their work. This underlying framework (or architecture) needs to be tailored to identifying gaps in communication between AEC information systems and define what processes and tools in the standards bodies inventory can be applied in particular instances. Generally, in the case of IDM's, AECOO-1 provides a template for future development of these kinds of documents that enables those specifications to be brought into the IT arenas for software development. However, Testbeds and other rapid prototyping activities are thought not the right venue for their development per se. IDM's comprise the information requirements that are the specification that define what Testbeds ought to undertake with subject matter experts and IT specialists working together to formulate an exactified representation of those specifications in software. MVD's that are shown to work in running code of provider's software are the most efficient outcome of Testbeds. Both IDM's and their companion MVD's should have an architectural framework that covers both syntactics and semantics so that interoperability is realized. (The reader is directed to Annex A for additional information and detail about this recommendation.)

Annex A: A Theory for Bridging Communication Gaps Among AEC Stakeholders

Open software and data standards are the interlocking parts that enable interoperability standards. For standards to be risk reducers, efficient and adoptable there needs to be an architecture on which the standards rest. This framework is developed using reference models developed by non-exclusive industry consortia and task forces (like the OGC, Organization for the Advancement of Structured Information Standards (OASIS), the World Wide Web Consortium (W3C), the Open Mobile Alliance (OMA), the Internet Engineering Task Force (IETF) and others). These organizations' frameworks guide developers and integrators in designing community-based and customer-specific open standard architectures for systems implementation, based on community open data models, information exchange standards, open interfaces, protocols, etc. that are intended to meet the needs of business enterprises, their user needs, business models and workflows. The same must be in place for the AEC industry.

One of the characteristics present in the AEC market today is the lack of a clear separation concerns between AEC business practices and domains and the means by which information technology is supplied. The concept of separation is necessary so that systems and applications meet their intended expectations. Separation of concerns comes from exact philosophy, mathematics, programming and systems thinking that is the culmination of a shared exercise between stakeholders in the AEC market and IT experts. These shared exercises are described using reference models to document the architectures that bind international information standards, domain information standards, and agreed to means for communication and messaging.

It is time to apply disciplined approaches to BIM standard making. As we consider more explicitly the build out and structural aspects for BIM standards in more disciplined manners, requires all stakeholders to **exactifiy** concepts and approaches that elicit understanding and specify the semantics of what are non-trivial facility design, construction and management practices and their respective IT system requirements. Creating these joint concepts across the industry is the basis for successful communication between business professionals in the AEC market and IT experts that build interoperable systems AEC professional want.

Throughout the Summary Report we have used the term interoperability and have defined that term in its broadest sense. Now we must place adjectives in front of that term so that we can define more explicitly the kinds of disciplined work that lies ahead for both community stakeholders and the IT providers that deliver systems and applications.

Let start with “Syntactic Interoperability”, which is all about parsing data correctly, and “Semantic Interoperability” which is all about the action of mapping terms and content analysis. These two expressions have important ramifications for NBIMS standards -- syntactics is what the MVD is about, and semantics is what the IDM is about.

Semantic interoperability requires formal and explicit specifications of domain information models, and agreed to definitions of the terms used, their relationships and expected behaviors of that information. (Note another word for these kinds of models and which is often used in the work to define IFD is ontology.)

These expressions may be used not only for dealing with computer-based information systems but also — and perhaps more importantly — for dealing with *human stakeholders communicating with other humans with computer-based systems*.

The AECOO-1 Testbed has shown that communication gaps exist between AEC industry practice stakeholders and IT experts. So, bSa's role and purpose in developing NBIMS can be exactified to correct instances where there is an absence of interoperability.

Firstly, without *syntactic* interoperability AEC business stakeholders are with their choice of applications unable to parse data, so providers often resort to their own independent means to provide that capability without the community's agreement. Of course, business experts cannot (and should not!) read code, but they also often cannot read specifications written by IT experts using notations (or terminology) that are overly complicated or alien to business terminologies. As we repeated often in the Summary Report, we need to understand the domain before addressing software. Business models are the basis of an organization's entire activity. They are to be understood by CEO and CFO, not just by CIO and explained without 'method calls to XML representations'.

Using the same natural (colloquial) language as a notation is not sufficient since in order to preserve meaning we need also to preserve the same context, the same language experience, language norms, cultural tradition, and so on, and often these properties of different people acting in the AEC market are often implicit and different at the same time. For the information technologist, also at the same time, there needs to be a restrictive artificial language *with precisely defined semantics* that does not have context, cultural traditions, and so on, but still guarantee an adequate transmission of a message's *semantics*, provided, of course, that it can be adequately represented in that language. This is both the conundrum and opportunity for the AEC industry to apply a level of discipline to its information handling approaches.

An AEC Industry Architecture makes it possible (although not trivial!) to formulate understandable specifications in a <u>disciplined</u> manner. Specifications will be read by people who are non-experts in technology specification and especially applies to business specifications that are all too often reduced to "business rules" encased in software code.

Discipline means precision and abstraction. Precision means (among other things) that a developer will not have to invent business rules that have not been described and agreed to, or have been described in ambiguous or incomplete ways. Abstraction means (among other things) that the subject matter expert (e.g., architect, structural engineer, etc.) will not waste time and effort trying to understand business rules in terms of a particular computer-based implementation. Business rules (and a business enterprise in general) should be specified using **<u>abstract and precise</u>** concepts understandable to any subject matter expert, analyst, developer, or non-IT manager.

An AEC Industry Architecture uses these concepts for all kinds of specifications — thus providing *an excellent foundation for interoperability* — and has been formalized by ANSI, IEEE, OASIS and ISO. This concept, if applied can describe the traditional businesses within AEC, as well as describe the essentials of any existing or to-be-created information system where interoperability is a requirement. In this manner, the business and IT stakeholders are able to use a common system of concepts and therefore to communicate in a meaningful manner. Of course, the syntactic representations used by different stakeholders to represent the same semantics may and often does differ, and also of course, different stakeholders may be interested in different levels and viewpoints when describing the same system, but the underlying semantic framework still remains the same.

While using this concept for all kinds of specifications, we should explicitly separate business from IT system specifications because traditional business and IT ontologies are different. (As a well-known example, a patient is not the same as the patient's records.) The Architecture offers us the means to separate concerns. (For example, when we see that a specification becomes too complex for human understanding and is in danger of having "too much stuff". "Precise" is not the same as "detailed", and therefore being abstract does not mean being imprecise. Good specifiers, in the same manner as good engineers, postpone decisions so as to not get drowned in details. The higher the level of abstraction the more important it is to be precise).

Precision (exactification) is not sufficient for human understanding. Indeed, hundreds or thousands of pages of precise material are useless if the material is not well-structured. In other words, understanding requires abstraction — "suppression of irrelevant detail", so that essential aspects of a specification are clearly separated from accidental ones. Clearly, this is not a new approach, but it has not been stressed in most work undertaken in the AEC market, and it is instructive that the concepts of abstraction, levels and viewpoints are among the first issues described in the application of reference models to industry architecture .

Industry architectures use abstraction within the context of *levels*. Industry architecture also uses abstraction within the context of *viewpoints* — form[s] of abstraction achieved using a selected set of architectural concepts and structuring and sub-setting rules, in order to permit stakeholders the room to focus on particular concerns within a system.

All viewpoints in any of the Reference Models are based on the same basic concepts of viewpoints — enterprise, information, computational, engineering, and technology. It is possible to define correspondences between viewpoints and Reference Models show how this is accomplished, but often, one viewpoint cannot be defined in terms of another. Of course, the five basic viewpoints are not the only ones that may be used to describe a system. In accordance with the definition of a viewpoint, any reasonable set of architectural concepts and structuring rules may be chosen to focus our attention on particular concerns within a system; and therefore we might simplify the work by defining *business viewpoint* and *information system viewpoint* which are analogous to IDMs and MVD's, but at higher levels of abstraction. In this manner, for example, we can exactify the slogan "no requirements in terms of solutions" since requirements and solutions belong to different viewpoints.

Creating and elucidating an AEC Industry Architecture domain model cannot be automated. There is no algorithm (or tool) to do that. The architecture is created and elucidated by teams consisting of domain subject matter experts and analysts who would work in NBIMS committees. Even when the subject matter experts are experienced in formulating semantics and ontologies of their domain in an abstract (that is, understandable) and precise manner, analysts are still essential to discover, elucidate and exactify tacit assumptions common to all, or some, subject matter experts. (We found this particularly evident in our work on Quantity Take-off).

Ignorance — real or perceived — of the subject matter cannot be present if a specification includes tacit assumptions that need or should become explicit. As early as the 1960's (in computing technology history) IT experts would comment "Get some intelligent ignoramus to read through your documentation; [...] he will find many 'holes' where essential information has been omitted. Unfortunately intelligent people don't stay ignorant too long, so ignorance becomes a rather precious resource."

It is not sufficient to discover, formulate and use reference model concepts and structures essential for a good architecture. The intent is to start communicating these discoveries, both for communicating an understanding of the architecture and for its usage, but to let evolve. If we begin the architecture work using a concise and elegant suite of basic concepts then this provides the foundation for the standards that follow.

In this context, it is instructive to reinforce the thought that "requirements always change, and therefore it is useless to formulate them". Indeed, business *processes* often change. Such changes may lead to a competitive advantage for a segment of the industry or they may even be perceived as necessary for the industry to survive. Similarly, decisions about using IT systems to automate business processes may also change. At the same time, the basics of a business — its ontology — have usually remained the same for centuries. The changes due to modernity are minimal and are mostly additions to or refinements of the existing classical semantics and their use.

These considerations apply to any kind of business architecture initiative as well as to requirements about information discovery and specification, independently of whether a computer-based IT system will be created, or bought to automate some business processes or workflow steps. As noted earlier, a crisp business architecture is used *to make demonstrably effective business decisions* only some of which are IT-related. Nonetheless, when viewed holistically the concepts, constructs and ultimate standards created based on that architecture define the art and science of effective reasoning.

From over 50 years of systems development experience It is now well understood that attempts to comply with a specification that has incomplete or unclear semantics will not guarantee interoperability because important information will be lost. Use of reference models and their concepts makes it possible to completely and precisely define the essential aspects of the universe of discourse, be it to describe a business or an information management system.

Using the approach suggested for NBIMS standards using the semantics of the appropriate domain rather than on existing products or solutions, standards can be devised based on an architecture that itself is defined in a clear and crisp manner. If so, then the specifications can be *read*, understood, and thus agreed or disagreed upon by all stakeholders confidently. Moreover, specifications of existing products or systems, including legacy systems, can be introduced back into architecture and lead to demonstrably justified user decisions about acquiring such systems.

Annex B: AIA Statement on Interoperability (Proposed)

NEW POSITION STATEMENT REQUEST ON INTEROPERABILITY (Related to Project Delivery)

Request for new Position Statement Submitted by the Board Integrated Practice Discussion Group 2009 (IPDiG)

Interoperability Position Statement

The American Institute of Architects believes that all industry-supporting software must facilitate, not inhibit project planning, design, construction, and commissioning and lifecycle management. This software must support non-proprietary; open standards for auditable information exchange (such as the building SMART International Industry Foundation Classes (IFC); open XML schemas; CIS/2; and other widely accepted open standards that may emerge over time) and allow for confident data exchanges across applications and across time.

This is best accomplished through professional, public- and private- sector adoption of open standards. The American Institute of Architects recognizes that it and its members have a significant role in the ongoing development of open standards.

Interoperability Position Statement Explanation

Why Interoperability?

Not all architects (or consultants, contractors, subcontractors, suppliers or owners) use the same software packages for their work, nor should they: each should use the best tool for the job in their particular business enterprise. But industry stakeholders do not work in a vacuum: they must share information in order to complete projects, and the amount of necessary information sharing is increasing at a dramatic pace. Transforming business processes require data interoperability. Data interoperability demands clear definition of necessary business information exchanges. Not every exchange must contain all data; however, business information exchanges required to facilitate the project should contain the information appropriate and necessary to perform the function of the exchange or task at hand.

There are many dimensions to the data or information contained in software packages used in the AEC industry today. Begin by considering a building information model: every single object in a model has dozens or hundreds of discrete pieces of associated alphanumeric or geometric data. Multiply that by the hundreds or thousands of objects in the model. Then layer on possible other uses of the data beyond the model, like performance analysis of the design (structural, thermal, lighting, etc.), project management, estimating or facility management software, or sharing of the data between different BIM applications, and so on. Acknowledge that some of the data is time-sensitive and may change over the life of the model. The complexity of ensuring those hundreds of thousands of pieces of data be shared between packages in an accurate, consistent, complete and effective fashion, especially when one acknowledges the proprietary nature of the software packages, is mind-boggling. It’s also hugely wasteful and ineffective: a 2004 study by the National Institute of Standards and Technology suggests that $15.8 billion is lost annually in the AEC industry due to the lack of accurate and effective information exchange. The 2007 McGraw Hill SmartMarket Report on Interoperability states that on average, 3.1% of the cost of every project is waste due to lack of interoperability. The AIA must assume a leadership role in seeking a solution to this problem and should work with other organizations to reach effective and positive outcomes.

Why open standards?

Effective information exchange requirements in other technologically intensive fields such as emergency response, GIS, finance and healthcare are demonstrating the fundamental value of open standards based information exchange. The AEC industry is not an exception and may anticipate benefits similar to those experienced in other fields. Consider:

Every AEC software package is based on a particular, unique data schema (data organization framework—how content is organized). This data schema is typically proprietary and hidden.

To accurately exchange information between any two software packages, one of the following must be true:

1) Package B must be based on the same schema as package A; or

2) Package B must be able to directly import (map) data into its schema from the schema of package A; or

3) Package A must be able to export (map) data from its schema into a transfer format or neutral exchange schema, from which package B must be able to import (map) the same data into its schema.

Condition 1 is uncommon; schemas are typically unique to every software package, and are protected as proprietary information. Condition 2 involves close collaboration of the developers of the two software packages but limits an exchange to just those implemented. Condition 3 is potentially the most robust, but requires that the two developers agree to the specifics of the neutral exchange schema.

If the example is expanded to include not just two packages but the larger world of software packages used by all project participants, and the complexity of the hundreds of thousands of pieces of necessary data exchange outlined above is layered on top, it becomes clear that two developers agreeing on a neutral exchange schema is insufficient and that the AEC industry as a whole needs to agree on and support a neutral transfer schema. This is most practical through industry-wide adoption of an open data-sharing standard (exchange schema), visible and transparent to all, supporting business workflows defined as much as possible by users.

Why should AIA members care?

Overall productivity loss and fragmentation in the capital facilities development industries is no longer tolerable. Architects need to practice the best way they know, and practice profitably; software interoperability problems must not hold them back. Potential of loss of competition in the software market is not acceptable.

Without software interoperability:

- Expense to the AEC and Owner in training and re-training in multiple platforms will increase;
- Waste in time, materials, energy and money will increase;
- AEC and Owner productivity will continue its decline as data re-entry, document versioning and checking, and other workflow problems increase;

- The capital facility industry may segment again, this time around software solutions;
- Collaborative delivery models such as Integrated Project Delivery will not deliver the benefits the profession anticipates;
- Architects may not be able to access files in the future without fear of loss of data or loss of whole file;
- Lack of competition may yield fewer affordable software solutions necessary to support architects' business practices;
- Architects may lose future commissions and necessary collaboration partners;
- The software industry will not achieve the robust development of the analysis and simulation tools and interfaces necessary to serve the rapidly changing industry;
- New software concepts, tools and opportunities may be marginalized if dominant software companies release interoperability features following their own agendas.

A large, competitive, interoperable software market is needed for innovation to flourish.