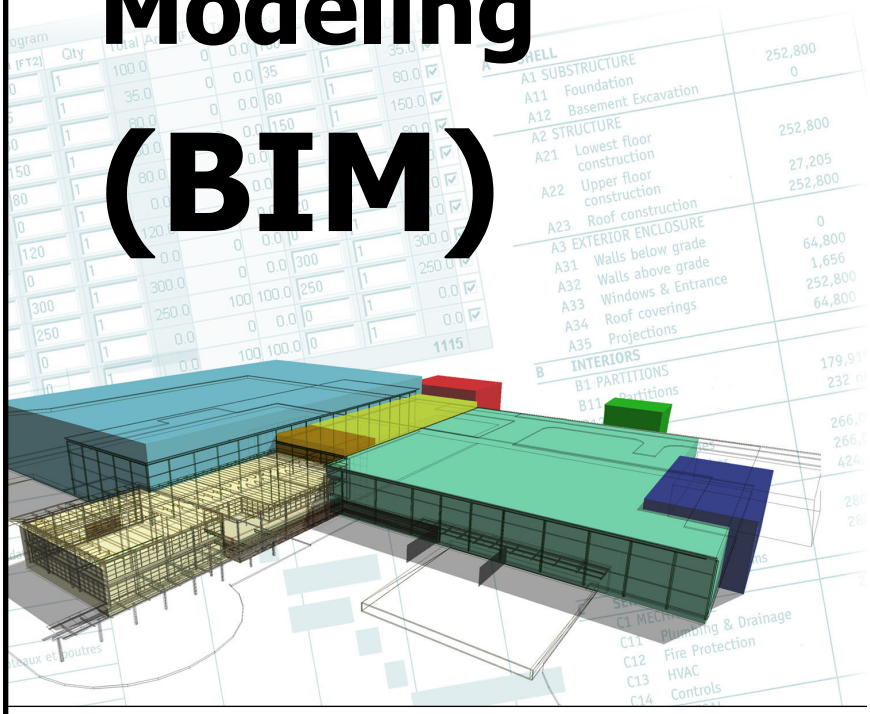
RAIC PRACTICE BUILDER

Building Information Modeling (BIM)



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Introduction

Many architecture practices in Canada are currently flirting with a fundamental change in the way building designs are conceived, completed and delivered. Building Information Modeling (BIM) is the technological mechanism behind this paradigm shift. BIM is "*the creation and use of coordinated, consistent, computable information about a building project in design that yields reliable digital representations of the building – representations used for design decision-making, production of high-quality construction documents, performance predictions, cost-estimating and construction planning, and, eventually, for managing and operating the facility.*"

While BIM's benefits are numerous, many architectural practices are cautious about the amount of time and financial investment required to change from current practices. This Practice Builder will provide a guide for the gradual implementation of BIM within an architectural practice and demonstrate the benefits of BIM.

What is Building Information Modeling?

The term Building Information Modeling (BIM) was coined by Autodesk[1] to describe "*3D, object oriented, AEC-specific CAD*" and popularized by Jerry Laiserin as a common nomenclature for these capabilities which are offered by several technology providers. A building information model is a digital representation of the building process that facilitates exchange of information in digital format.

BIM is more than just a shift from paper-based design to electronic design. The parametric information resulting from the BIM makes possible accurate cost estimates, simulations, scheduling, and energy analysis, furthermore, BIM facilitates coordination with engineering, fabricating and construction partners.

Opportunities, or why change?

One of the most compelling reasons to adopt BIM is the inherent advantage of three-dimensional (3D) representations when designing and documenting a project over two dimensional representations. 3D representation allows the design team to better understand, visualize and resolve the design problems throughout the process. Coordination within a single model is greatly improved over that required by multiple 2D documents. Design "errors" (notably poor coordination) are significantly reduced leading to fewer changes during construction. After the initial implementation period, BIM enables architects to provide higher quality deliverables and ultimately a better building.

[1] www.autodesk.com

A summary of the advantages of switching from 2D CAD to BIM include:

- BIM works the way designers think by using the common language of building elements (wall, door, floor etc.);
- Document coordination is enhanced and simplified. A single building information model allows consistent and coordinated views and details to be selected easily for sheet layout and printing;
- Clients now expect 3D visualizations. BIM software allows an output, ranging from simple grey scale 3D representations, cut-away 3D sections to photorealistic renderings from a single building information model without the need for specialized software or skills;
- Collaboration with other architects, designers and consultants is simplified with the interoperable platform of BIM software;
- BIM models can be exported to common drawing formats (such as .dwg or .dxf), and to spreadsheets to create schedules (invaluable for costing, material take-offs, etc.)

What is an Integrated Design Process and what does it have to do with BIM?

The Integrated Design Process (IDP) is based on the "whole building systems approach". It brings together key stakeholders and design professionals, such as building owners, facility managers, developers, designers, engineers, consultants, and occupants, as a core team to work collaboratively and interactively from the early planning stages through to building occupation.[2]

Many architectural practitioners have recognized the value of IDP and are already employing integrated design and integrated project delivery systems. The adoption of BIM within the IDP complements and facilitates the design teams' identification and understanding of the various design goals, and it provides a mechanism to realize those multiple design goals. A design team, whose participants are all working within single or linked BIMs, are better able to visualize problems, analyze potential points of conflict, provide creative solutions, and ultimately minimize design "errors".

Why does Interoperability matter?

Overview

As architects and most architectural practices embraced computer-assisted design (CAD) in the 1980's it became very clear that there was no common computer language linking one

[2] www.gvrd.bc.ca

software file type to another. It also became clear that there was no means to allow the export of "vector-based information" in a way that the information could be read or analyzed in other emerging software. By the early 1990's computing power had increased permitting many analysis programs to be run with relative ease; however, there was no way to import the data developed by the architect in CAD and use this data in software programs designed for energy, structural or daylight analysis.

Certain software providers took up the challenge to move from vector-based geometric objects to 3D-based parametric objects. One of the key developments was that of ARX (Advanced Resourcefiles). ARX helped software developers manage and access huge repositories of static data. This allowed for data synchronization, referencing external data from remote sites, such as "http" or "ftp" servers, and merging multiple ARX archives into one. Initially, ARX was intended for game developers but it was also found to fit other data intensive contexts.

ARX is the combination of four concepts with varying degrees of complexity and usability. Its intent is to help software developers manage any static data their applications may require. The four applicable areas are:

- **Archive**
- **Merging**
- **Unified Data Source**
- **Templates**

International Alliance for Interoperability (IAI)[3]

In August 1994, 12 US-based companies examined the potential for making different software applications work together. Their efforts were based on the newly created ARX development system found in AutoCAD Release 13, and they felt that there was significant economic benefit to be gained from the ***interoperability*** of software.

The original participants in the interoperability project decided that their work should be available to the construction and facilities management industry as a whole and to all software vendors. By doing so, they felt that it would be possible to develop a neutral standard for software interoperability. In October 1995, they established the Industry Alliance for Interoperability (IAI) in North America. The early members of the IAI realized the increasingly global importance of their work. They took their message to other countries, initially in Europe and then to Asia and Australasia. Subsequently, other Chapters of IAI were established and the name of the organization was changed to the International Alliance for Interoperability to reflect its global reach.

An early technical decision of the IAI was to base development work on the data definition language that had been developed as an ISO standard. A key benefit of this decision was the immediate availability of a large body of development work in basic technologies as well as providing access to substantial research and development efforts from many leading industry

[3] www.iai-international.org

centres throughout the world. In particular, work on the development of the Building Construction Core Model within STEP[4] advanced considerably.

Industry Foundation Classes (IFC)[5]

The Industry Foundation Classes (IFC) data model is a neutral and open specification that is not controlled by a singular vendor or group of vendors. It is an object oriented file format with a data model developed by the International Alliance for Interoperability (IAI) to facilitate interoperability in the building industry, and is a commonly used format for Building Information Modeling (BIM)[6]. The IFC model specification is open and available. As a result of its focus on ease of interoperability between software platforms some governments have made the use of IFC format(s) compulsory for publicly funded building projects.

BuildingSMART[7]

The IAI coined the term BuildingSMART to describe what it does, and, to identify the best forum for developing rigor in how the design and construction industry exchanges information to ensure that this process truly serves the interests of all.

BuildingSMART = BIM + IFC

BuildingSMART means working within an integrated project delivery process that explores (amongst other things) value-based life cycle management using Building Information Modeling and IFCs. Recently, the IAI has turned its attention to the broader issues of achieving beneficial change to the industry, using Building Information Models (BIMs) and IFCs as the trigger for finding smarter ways of working.

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[4] STEP is an acronym for STandard for the Exchange of Product Model Data. An ISO standard for product modeling. It is designed to provide a vendor-neutral and computer readable definition of a product throughout its life cycle.

[5] http://en.wikipedia.org

[6] External links:

- Understanding the different purposes of IFCs and aecXML in achieving Interoperability at the International Alliance for Interoperability, North America, website
- Data Design System Building services engineering CAD software - working with IFC building models
- A list from DDS of products supporting IFC
- http://irc.nrc-cnrc.gc.ca
- IFC for Structural Steel at NIST
- AECbytes Feature (March 30, 2004) on the IFC data model.
- IfcWiki Beginning of an open-for-all Wiki on the IFCs (initiated by Forschungszentrum Karlsruhe)
- Solibri IFC Optimizer is an IFC file optimization tool.

[7] www.buildingsmart.org.au

Introducing BIM to Architects – lessons learned and suggested strategies

Overview

Over the course of BIM deployment, an architectural practice can expect the following five stages of evolution[8] which describe an increasing level of collaboration and coordination using BIM:

Stage 1 – Visualization

Stage 2 – Production drawings

Stage 3 – Coordination

Stage 4 – Analysis

Stage 5 – Supply chain

For most architectural and engineering practices, the initial transformation, deployment and learning will fall under stages one and two and those stages are the focus of this Practice Builder. Stages three through five will evolve only once a practice has fully embraced Building Information Modeling and all projects are completed using BIM software. However, a general understanding of all five stages is vital before selecting and purchasing any software.

Stage 1. Visualization

The visualization stage is that period where a practice considers and embarks on using BIM on test projects. This is the stage where architects learn how BIM works and begin to understand its potential to transform architectural design and the production of construction documents. Experience suggests that a carefully considered choice for the "beta" or test project is critical to the successful adoption of new software.

The following are recommended when first implementing BIM:

1. Select a small scale project – a maximum 1000 m^2 building should be considered;
2. Limit the number of team members in order to allow them to concentrate on learning the new software. Two to three employees can provide each other with support and their "loss" of productivity while training will not have a substantial impact on the firm's production capacity;
3. Select team members that will be receptive to learning new software. Experience has shown that employees who have the least experience using 2D software are able to adapt more quickly than those with ingrained habit;
4. Complete software tutorials and rapidly move into a live application and experimentation on the selected project;

[8] www.di.net

5. Gradually implement the adoption of BIM software throughout the practice by incrementally adding new projects and team members to the process;
6. Utilize online resources such as software user bulletin boards (i.e. Autodesk User Group International) to ask questions and further learning beyond that provided by the software "help" files and tutorials;
7. As deployment proceeds, encourage collaboration within the practice and ensure that project teams have a mix of experienced and inexperienced BIM users.

Stage 2. Production Drawings

One of BIM's greatest strengths is improving collaboration and reducing design "errors" due to incomplete coordination. An important aspect of selecting BIM software is giving careful consideration to the end product. A practice should consider the desired final output carefully. Is the practice considering BIM software for preliminary and/or design development only? Will BIM be used to produce construction and contract documents? Does the practice want to engage in collaborative design with sub-consultants using shared, linked or integrated BIMs?

Stage 3. Coordination

While a practice can successfully use BIM independently of project consultants, digital collaboration is the true benchmark of evolution from traditional practice. When selecting a BIM program, consideration should be given to the following collaborative capabilities:

- Does the software have companion suites available for other disciplines?
- Does the software allow .dwg or .dxf or other formats for import?
- Is the software compatible with that used by the architect's subconsultants?

Stage 4. Analysis

Building Information Models have great potential for expanding architectural practice through their various embedded analysis tools. As sustainable design becomes fundamental to many practices, the ability of BIM to embed energy modeling within the program or to export data to similar analysis programs becomes an advantage over traditional 2D or 3D software programs. Similarly, the parametric qualities of BIM objects allow designers to quickly do take-offs for costing; areas for leasing and functional programming, and to create custom schedules for virtually all building components including doors, equipment, millwork and finishes. There is an emerging potential for Building Information Models to be used for facilities management and therefore an opportunity for architectural firms to diversify their services.

Stage 5. Supply Chain

The final stage of BIM deployment within a practice will be into the areas of the construction supply chain: the so-called 4th dimension of the construction of a building. BIMs can be used for fabrication of part or all of a building project – the model can either be exported to another format for use by a fabricator, or it can be used in its original state. Again, the potential for errors is reduced while quality is improved. BIMs will become an invaluable tool for the contractor who may use them as a dynamic drawing set and eventually rely more on the digital information and less on hard copy 2D representations. BIMs also have applications for facilitating design development and for the production of Computer Numerically Controlled (CNC) models.

Challenges

Some challenges occur in the adoption of BIM which are common to all architectural practices regardless of size. These include:

- Overcoming employee comfort with familiar software tools;
- Expending the financial investment to shift from existing software platforms;
- Convincing management to explore a new paradigm;
- Reduced productivity during training and transition;
- Developing component libraries and details;
- Establishing office standards.

Some challenges, however, are specific to the size of the architectural practice. Small practices are likely to find the investment in a new product more of a financial burden than a larger firm with greater resources and cash flow. Small practices may also be less able to absorb the drop in staff productivity that occurs while learning a new software program and applying that knowledge. Fewer staff members means a limited internal support network of experienced BIM users from which new users can draw advice and assistance. Reliance on one or two advanced BIM users can result in decreased productivity for those "experts" because they are answering questions or helping others.

Larger firms may have difficulty convincing diverse management groups to adopt BIM software and change established ways. The inherent inertia of a larger organization may extend the deployment of BIM over years instead of months. If the firm's projects are typically large and complex, they may also have difficulty selecting a beta project of appropriate scale for BIM implementation. Identifying employees who are very open to changing the way they work may be more difficult. If the firm has multiple offices in different cities, sharing the knowledge and processes between locations may be difficult and will require a more comprehensive strategy for deployment. Finally, strategies and standards may need to be modified to be regionally responsive, particularly if the firm operates in different countries and jurisdictions.

Energy Modeling + BIM

Sustainability is an urgent design challenge for the profession, and fortunately BIM offers new opportunities for energy modeling and analysis. Currently energy analysis often falls within the scope of work of mechanical and electrical consultants. Architects have limited and often onerous tools available to complete their own analyses. Energy analysis software that is integrated or compatible with BIM software should facilitate more architectural investigation of a building's energy use.

Building energy modeling within BIM is clearly in its infancy. Currently two products offer interoperability with Building Information Models:

- IES Virtual Environment
- EcoTect

Green Building Studio offers a free web-based service that enables the design team to look at the energy impact of early design decisions by uploading an exported gbXLM file. The US General Services Administration has a number of pilot projects comparing BIM based energy modeling methods and results to more traditional energy modeling practices.[9]

IES Virtual Environment is a UK-based company that has recently opened offices in the US and is expanding its North American customer base. The program offers various analyses such as thermal simulation, displacement ventilation, energy analyses for LEED accreditation, daylighting and electric lighting analyses, solar analyses, internal and external CFD airflow studies, and occupant evacuation. Last March 2007, IES Virtual Environment announced a partnership with Autodesk signaling their alliance with the Revit platform.[10] The integration of an analysis program within a BIM software platform should significantly further ease of use and encourage more energy analyses by architects.

Ecotect is a product developed by SquareOne Research, an "environmental consultancy and software firm" [11] in Perth, Australia. Ecotect is aligned with ArchiCAD although it is not currently integrated within the BIM software. The product can import 3DS and .dxf files for analysis. The imported data must be reviewed prior to analysis to ensure it meets the requirements of the specific analysis being run – a potentially laborious task.

Summary of the Benefits of BIM

The key benefit of a building information model is the production of an accurate geometrical representation of all components of a building in an integrated data environment.

[9] www.gsa.gov

[10] www.iesve.com

[11] www.squ1.com

Other benefits include:

- **Faster and more effective production** and sharing of information;
- **Better design** through more analyses, simulations and evaluation of options;
- **Better client services** due to better understanding of proposals through accurate visualization;
- **Better control of costs and environmental performance**;
- **Better documentation**;
- **Automated assembly** through data being used in downstream manufacturing and fabricating processes;
- **Integration of Planning and Construction** – using common data protocols for Authorities Having Jurisdiction and those in the design and construction industry;
- **Better Facility Management** by producing design construction and operational information;
- ***A More Productive and Competitive Design and Construction Industry!***

What software is available for BIM?

The following is a list of the most common software available as at September 2007.

Software	Company	Website
ArchiCAD	Graphisoft	www.graphisoft.com
Architectural Desktop	Autodesk	http://usa.autodesk.com
Bentley Architecture	Bentley Systems	www.bentley.com
Constructor	Graphisoft	www.graphisoft.com
Data Design System	Data Design System	www.dds-bsp.co.uk
DProfiler	Beck Technology	http://dpearth.com
JetStream	NavisWorks	www.navisworks.com
REVIT	Autodesk	http://usa.autodesk.com
SDS/2	Design Data System	www.dds-bsp.co.uk
Tekla Structures	Tekla Corporation	www.tekla.com
VectorWorks Architect	module of Vectorworks From Nemetschek	www.nemetschek.net
ONUMA Planning System ONUMA Inc.	Add ons for ArchiCAD	www.onuma.com

***Bold font** indicates software commonly found in the Canadian Market.*

Software Comparision

The table below provides a very simply overview and comparison of common software available in Canada.

Software	Type	Cost	Platform	Product Training	IFC 2x3*
Autodesk Architecture	2D/3D	$$$	PC	Authorized training centers (ATC), self-directed tutorial + help files, online communities, e-learning	no
Revit Architecture	BIM	$$$	PC	As above	yes
ArchiCAD	BIM	$$	PC/MAC	Product tutorial + help files, online communities + training guide	yes
VectorWorks Architect	BIM	$	PC/MAC	Independent training courses; Nemetschek sponsored classroom seminars (Toronto), online, onsite, CDs.	no
Bentley Architecture	BIM	$$$$		Distance learning, e-seminars, resellers training.	yes

**IFC stands for industry foundation classes (IFC is an open building exchange standard) the open standard means information can be read and manipulated by any compliant software*

When comparing the available BIM software, an architectural practice should consider the following:

- Does the software enable collaboration with fellow designers and consultants?
- Can the BIM be converted to standard drawing formats (such as .dwg, .dxf or .dgn)?
- Does it offer industry-wide interoperability?
- Can the software work with files created from the practice's current software?
- Is the software intuitive? Is it easy to learn?
- Is it from a dependable and stable company and is it a well established product?
- Does the software take a project from concept to construction?
- Does it offer building management tools for post-construction?
- Does the software have companion products for engineers and other consultants to further facilitate coordination?
- Are object libraries (doors, windows, furniture, etc.) available? Are manufacturers providing objects that are compatible with the software? Are there other resources for expanding the library?
- Can new versions of the software access legacy data?

ArchiCAD – Graphisoft

Interoperability

ArchiCAD's dxf/dwg translator supports up to AutoCAD® 2006 and accurately maps layers, pen colors, fonts and blocks. ArchiCAD can write out DXF/DWG data that contains both Paper Space and Model Space information in the same file. ArchiCAD's intelligent handling of AutoCAD Xrefs, at input and output, not only preserves the link but allows Xref administration (including linking, unlinking and binding) within ArchiCAD. ArchiCAD supports IFC 1.5.1, 2.0 and 2x2 format.

Case Studies (www.graphisoft.com)

Soft Plan for Downtown Detroit
Urban Strategies Inc.

Toronto-based urban design firm Urban Strategies Inc. utilized ArchiCAD to transform a 2D DXF file into a 3D model of downtown Detroit in just a few weeks.

> View this case study at www.graphisoft.com

Revit Architecture

Revit Architecture was formerly known as Autodesk® Revit® Building.

Interoperability – Import/Export Capabilities

Revit Architecture supports a wide range of industry standards and file formats, including DGN, DWG, DWF™, DXF™, IFC, SAT, SKP, AVI, ODBC, gbXML, BMP, JPG, TGA, and TIF. In addition to transferring standard lines, arcs, and circles, Revit Architecture can also transfer complex 3D model geometry for use in programs such as Autodesk® VIZ or Autodesk® 3ds Max® software. This capability provides opportunities to create stunning photorealistic interior and exterior renderings

White Papers (http://usa.autodesk.com)

Revit: Implementation in Practice, by Dr. Lachmi Khemlani

Prepared by noted industry analyst Dr. Lachmi Khemlani, this important industry report focuses on the process changes, benefits, and challenges that firms today are experiencing as they implement building information modeling with Revit®-based software. The unvarnished reporting as well as real-world case studies and data used are invaluable to anyone looking to use building information modeling and Revit Architecture to improve their business.

> View the report at http://usa.autodesk.com

Revit ROI White Paper and Calculator

Want to know if a technology investment is worth it? Understanding the financial concept of return on investment, or ROI, is the first step. Using real-world productivity data from a survey of Revit® Architecture users as an example, this white paper explains exactly what ROI means and how to compute it. An interactive ROI worksheet is included.

> View the Revit ROI White Paper and Calculator at http://usa.autodesk.com

Case Studies (http://usa.autodesk.com)

NEAT Environmental Education Center
HIP Architects, Edmonton, AB

For one award-winning Canadian architectural firm, the path to a greener design is made possible with building information modeling (BIM) and Autodesk® Revit® Building.

> View this case study at http://usa.autodesk.com

Stantec, Edmonton, AB

Passionate about the multidisciplinary value of BIM, Stantec began implementing Revit Systems for MEP engineering in July 2006, just shortly after the product was released. Stantec now utilizes the entire Autodesk Revit platform for all key disciplines, including MEP engineering, structural engineering, and architecture.

> View this case study at http://usa.autodesk.com

VectorWorks Architect – Nemetschek

Interoperability

None

White Papers

www.nemetschek.net

Case Studies

www.nemetschek.net

Software Providers

Autodesk Revit

www.autodesk.ca

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Web Links and References

- BIM definitions http://en.wikipedia.org
- IFC open resource www.ifcwiki.org

Building Information Modeling Software

- ArchiCAD from Graphisoft (a subsidiary of Nemetschek AG) www.graphisoft.com
- Allplan from Nemetschek AG www.nemetschek.com
- Architectural Desktop from Autodesk http://usa.autodesk.com
- Bentley Architecture from Bentley Systems www.bentley.com
- Constructor from Graphisoft www.graphisoft.com
- Data Design System www.dds-cad.com
- Digital Project from Gehry Technologies www.gehrytechnologies.com
- DProfiler from Beck Technology www.dpearth.com
- JetStream from NavisWorks www.navisworks.com
- Revit from Autodesk http://usa.autodesk.com
- SDS/2 from Design Data http://dsndata.com
- Tekla Structures from Tekla Corporation www.tekla.com
- VectorWorks Architect (module of VectorWorks) from Nemetschek N.A. (a subsidiary of Nemetschek AG) www.nemetschek.net
- Solibri Model Checker by Solibri A BIM model checker www.solibri.fi
- ONUMA Planning System from ONUMA, Inc. Add ons for ArchiCAD www.onuma.com

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Glossary and Definitions

BIM or Building Information Model

A Building Information Model (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 life-cycle from inception onward.

A basic premise of BIM is collaboration by different stakeholders at different phases of the life cycle of a facility to insert, extract, update, or modify information in the BIM to support and reflect the roles of that stakeholder. The BIM is a shared digital representation founded on open standards for interoperability.

From the National Building Information Model Standards (NBIMS) Committee

IFC or Industry Foundation Classes

A neutral and open specification that is not controlled by a singular vendor or group of vendors. It is an object oriented file format with a data model developed by the International Alliance for Interoperability (IAI) to facilitate interoperability in the building industry, and is a commonly used format for Building Information Modeling (BIM). The IFC model specification is open and available.

Integrated Project Delivery

Integrated Project delivery is a project delivery approach that integrates people, systems, business structures and practices into a process that collaboratively harnesses the talents and insights of all participants to reduce waste and optimize efficiency through all phases of design fabrication and construction.

Integrated project delivery principles can be applied to a variety of contractual arrangements and Integrated Project Delivery teams will usually include members well beyond the basic triad of owner, architect and contractor.

From "Working Definition – Integrated Project Delivery" Task Force of the AIA California Council and McGraw Hill Construction

IAI or International Alliance for Interoperability

International Alliance for Interoperability is a not-for-profit organization that supports the development of the IFC (Industry Foundation Classes) specification and the deployment of BuildingSMART. IAI is an alliance for organizations dedicated to changing and improving productivity and efficiency in the construction and facilities management industry.

Interoperability

Connecting people, data and diverse systems. The term can be defined in a technical way or in a broad way, taking into account social, political and organizational factors. With respect to software, the term interoperability is used to describe the capability of different programs to exchange data via a common set of business procedures, and to read and write the same file formats and use the same protocols.

The National Institute of Standards and Technology (NIST) defines interoperability as "the ability to manage and communicate electronic product and project data between collaborating firms and within individual companies' design construction, maintenance and business process systems."

Object-oriented Programming (OOP)

Object-oriented programming may be seen as a collection of cooperating objects, as opposed to a traditional view in which a program may be seen as a list of instructions to the computer. In OOP, each object is capable of receiving messages, processing data, and sending messages to other objects. Each object can be viewed as an independent little machine with a distinct role or responsibility.

Project Alliance Agreement

In a project alliance the key participants collectively assume responsibility for agreed project performance. The Profit or loss to each participant is determined by the team's success in meeting project goals, not individual performance. The shared opportunities and responsibilities align the parties' interests and provide an incentive for collaboration and blame-free performance. To further enhance the collaborative process, all decisions must be unanimous, disputes must be resolved without litigation and within the Alliance and compensation is determined on an open-book basis.

From "Working Definition – Integrated Project Delivery" Task Force of the AIA California Council and McGraw Hill Construction

4D or Fourth Dimension

A model that incorporates the dimension of time used to visualize a construction schedule.

5D or Fifth Dimension

A model that incorporates cost data used to automate quantity takeoffs for cost estimating. Coupled with 4D it can be used to predict cash flow.

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