An Introduction to the IPD Workflow for Vectorworks BIM Users

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Prologue

Many architects and architectural designers, particularly those with governmental or institutional clients, are being asked by their clients to "deliver BIM". This can be a directive leading to a good deal of anxiety and not a small amount of confusion, because more often than not, neither the client nor the practitioner understands what is being sought with this request. Is "BIM" a file format, a 3D model, or a way of doing business? What are the legal and contractual implications of "doing BIM"? And, most importantly, how can the practitioner properly respond to (and satisfy) the client who wants a BIM delivery?

This paper is intended to answer those questions and introduce to users who are "thinking BIM" yet another three-letter-acronym, IPD, which stands for "Integrated Project Delivery".

Motivation

Before diving into the "who, what, where, and when" of BIM and IPD, it may be best to start with a brief overview of the "why". This initial section briefly covers the motivation for "delivering BIM" starting with the perspective of national policy, and ending with the perspective of the individual architect.

Motivation for National Policy

Recent studies repeatedly cite inefficiencies and waste in the construction industry. For example, an *Economist* article from 2000 identifies 30% waste in the US construction industry; a NIST study from 2004 targets lack of AEC software interoperability as costing the industry $15.8B annually; and a US Bureau of Labor Statistics study shows construction alone, out of all non-farm industries, as decreasing in productivity since 1964, while all other non-farm industries have increased productivity by over

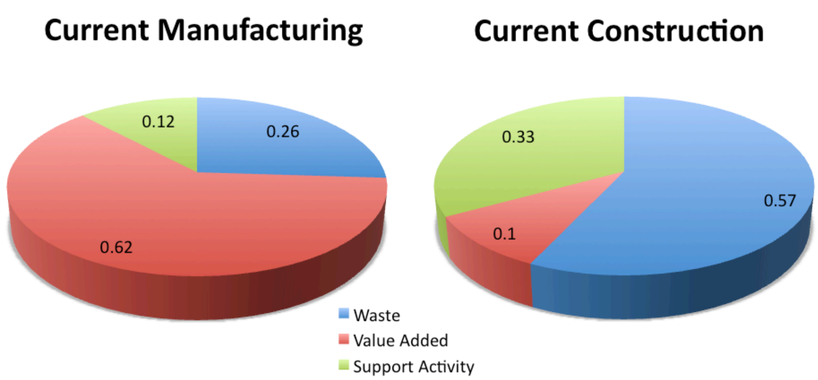

Figure 1 – Comparative Efficiency of Industries (after D. Smith, NIBS, 2009)

200% during the same period. The heart of the matter is this: the construction industry as practiced in the United States is grossly inefficient, and is becoming more so, at least compared to other segments of the economy (see Figure 1). The construction industry has been characterized as having "*adversarial relationships where contractual arrangements encourage risk avoidance and risk shed-*

ding.[1]" (For those readers who may be following the ongoing US debate on health care costs, this may sound similar to the behavior of the large health insurers!)

Even more frightening, though, than an industry that is less than 50% efficient is an industry that is less than 50% efficient and has a truly voracious appetite (see Figure 2).

Stipulated, then, that motivation number one is the paramount need to increase the efficiency in our production methods in the construction industry.

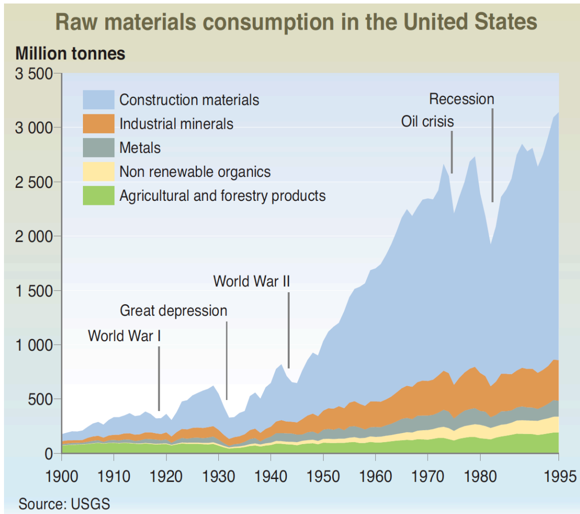

Figure 2 – Raw Materials Usage Curve, US, 1900 - 1995

Owner motivation

While we as a society all pay in some manner (abstract or otherwise) for the loss of natural resources, it is the building owner/operator who is likely to be driving the adoption of any process that will save him money, of course. Who can blame him? As any architect will attest, there are owners and then there are owners. Some owners (government agencies, educational institutions, healthcare, etc.) understand well the cost of ownership, but what about the real-estate developer?

Well-planned IPD projects using BIM can show cost reduction during design and construction as a result of:

- Increased design quality through model-based analysis and simulations;
- Better cost prediction through repeated, accurate bill-of-materials costing;
- Lowered risk through reduced errors and field changes resulting from 3D interference checking[2];
- Greater potential for prefabrication due to predictable field conditions; and
- Improved field efficiency by visualizing the planned construction schedule.

At the end of the construction phase, the BIM model may be transferred to the facility operator to improve the long-term facility performance with:

- Asset management
- Space planning / Real estate utilization, and
- Maintenance scheduling.

[1] *Bilar Succar, "Building information modelling framework: A research and delivery foundation for industry stakeholders", Elsevier, 2008*

[2] *Also referred to as "clash detection".*

The long-term owner who understands life-cycle cost concepts will probably have little trouble in perceiving the value of a data-rich, query-able model of his building that is kept up-to-date. Even the sophisticated owner, though, should anticipate some re-thinking of his facility- and asset-management processes. (Looking at Figure 3, one is struck by the proportion of overall savings that is accomplished while the owner has control over the building. If a Building Information Model is a central tool in the savings, then the Owner's employees will by extension need to become competent in BIM.)

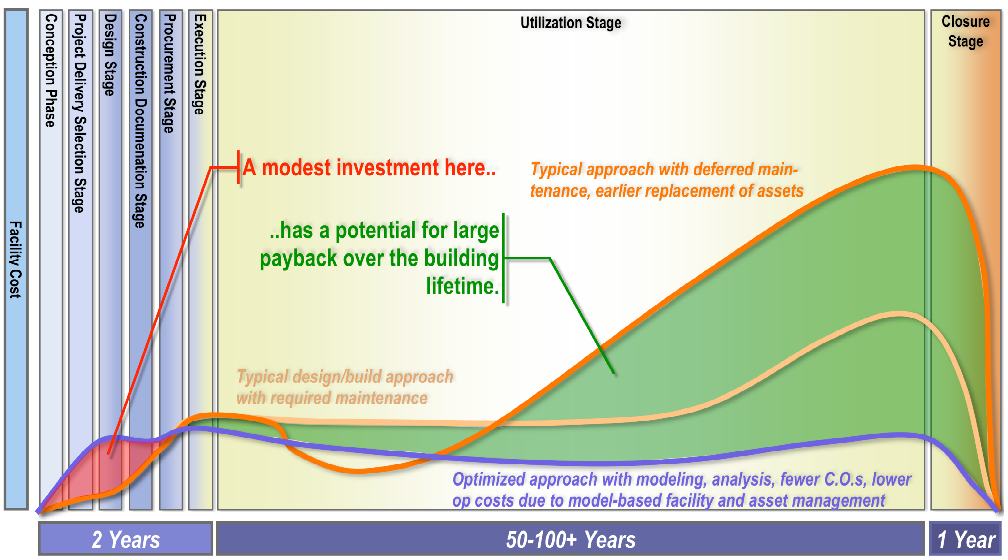

Figure 3 – A "Notional" Chart of Life-Cycle Facility Costs (after D. Smith, NIBS, 2006)

The short-term "investment owner" actually may have to spend a little more money on services (see Figure 3), but even he can probably be mollified by the fact that the BIM/IPD process reduces his risk (especially the risk of high-dollar change orders) during the construction phase. Risk reduction is not exactly cost reduction, but developers understand risk and will pay some amount to avoid it.

Architect Motivation

Most if not all architects will (perhaps ruefully) acknowledge the ubiquitous waste in their industry, but may feel that a solution is beyond the scope of their training, beyond even the legal definition of their professional authority. Can a new way of doing business that provides greater efficiency and waste reduction help architects become "part of the solution," no longer sitting on the sidelines? This may be a compelling "external" goal for architects to use a better, more efficient business model. The responses to the McGraw-Hill 2009 BIM survey showed in more detail the *perceived* benefits of BIM to architects (see Figure 4).

It seems clear, then, that there are compelling reasons to change the way we in the construction industry do business. And the context of this thinking—*about business models*—is the right place to being the discussion of BIM and IPD. Because while there may be those who describe BIM as “a technology”, or “a software package,” BIM and IPD are not so much technologies as they are ***business models***. As just one affirmation of this, the Wikipedia article on Building Information Modeling notes, *“BIM goes far beyond switching to a new software. It requires changes to the definition of traditional architectural phases and more data sharing than most architects and engineers are used to.”*

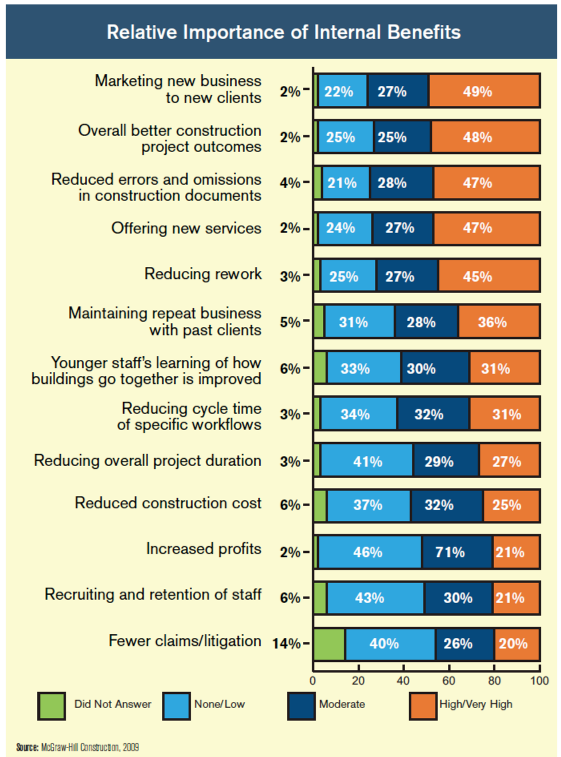

Figure 4 – Architect's Perceived Benefits of BIM (from McGraw Hill Market Report, 2009)

Definitions

The verbosity of many industry terms has driven the creation of three-initial acronyms (TIAs)[3]. Worse, in the case of “BIM”, a single acronym actually refers to two different things (a product deliverable and the activity that creates it)!

Building Information Model

A **Building Information Model (BIM)** is a digital representation[4] 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. The Building Information Model encompasses building geometry, spatial relationships, and quantities and properties of building components.

Building Information Modeling

Building Information Modeling (BIM) is the process of generating and managing building data during its life cycle. Typically it uses three-dimensional, real-time, dynamic building modeling software to increase productivity in building design and construction. Essential to Building Information Modeling is the idea of *collaboration*: different stakeholders at different phases of the life cycle of a facility must

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[3] A feeble attempt at a joke.

[4] The term “digital representation” is sometimes additionally described as “computable” (AutoDesk) or “machine readable” (Charles Eastman). In this context the term means a representation that can be interpreted without human/visual intervention.

be able to add, extract, or edit information in the shared model to support the needs and function of that stakeholder. BIM is sometimes used as a shorthand for **IPD** (see below).

Exchange Requirement

An **Exchange Requirement (ER)** is the specification (in non-technical language) of an information exchange (often a file transfer) required by the project sequence. See also **MVD** below.

Industry Foundation Classes

Industry Foundation Classes **(IFC)** is an open-standards (i.e. non-proprietary and publicly available) software data format for the exchange of building information. It is the only open-standards software sufficiently rich to exchange a complete building model.

Integrated Delivery Manual

An **Integrated Delivery Manual (IDM)** is a business-process chart that is used as a "roadmap" (alternatively called "Process Map") in the planning of IPD projects. The IPD is usually represented as "swim-lanes", with the "lane" representing the domains of project team members, activities as within "lanes" or (for shared activities) operating across "lanes", and links across "lanes" representing information exchanges required by the project sequence.

Integrated Project Delivery

Integrated Project Delivery (IPD) is a business model for design, execution, and delivery of buildings by collaborative, integrated and productive teams composed of key project participants. Building upon early-phase contributions of team members' expertise, these teams are guided by principles of trust, transparent processes, effective collaboration, open information sharing, team success tied to project success, shared risk and reward, value-based decision making, and utilization of full technological capabilities and support. The outcome is the opportunity to design, build, and operate as efficiently as possible.

Interoperability

Interoperability is the ability for the various stakeholders in the BIM or IPD process to exchange data in a meaningful manner, no matter the various kinds of specialized software they may be using to do their work. Interoperability requires a disciplined process supporting all of the following:

- A specific business case that includes an exchange of building information;
- The users' view of data necessary to support the business case; and
- The machine interpretable exchange mechanism (software) for the required information interchange and validation of results.

Open-Standard Interoperability is interoperability based on the IFC information standard.

Model View Definition

A **Model View Definition (MVD)** is a software specification setting out the contents of a model to be used in an information exchange. The specification covers which types of objects are required in the model, how they must be related, and what are the minimum properties that they must have populated.

Single Purpose Entity

A **Single Purpose Entity (SPE)** is a particular form of joint-venture legal entity created for the purpose of executing the project. IPD in its most complete implementation involves the creation of an SPE.

Integrated Project Delivery: The Basics

Overview

In 2007, AIA National and the AIA California Council jointly produced a publication, "Integrated Project Delivery: A Guide" (downloadable from [this web-page](#))[i] that set out the general approach for architects to this new business model.

The MacLeamy Curve and how it explains IPD Decision Making

Patrick MacLeamy, CEO of HOK (Hellmuth-Obata-Kassebaum), one of the world's largest architecture firms[5], made a presentation at the General Session on BIM at the AIA 2005 National Convention[6] where he introduced the graph now almost universally known in BIM circles as the "MacLeamy curve" (pictured in Figure 5).

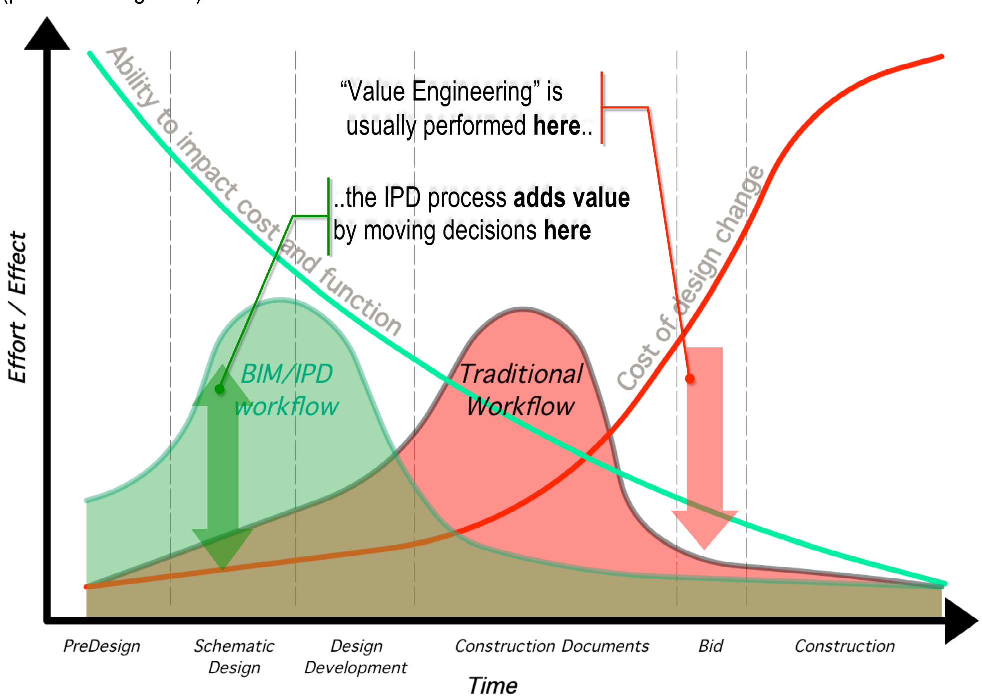

Figure 5 – The MacLeamy Curve used to explain IPD resource timing

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[5] *HOK has more than 2000 employees and grossed $757M in fees in 2008.*

[6] *Chronology by Lachmi Khemlani. See http://www.aecbytes.com/feature/2008/HOK_CaseStudy.html*

The MacLeamy Curve is a graph of the cost of decisions mapped along the timeline of a typical construction project. It clearly shows that decisions made early in a project (during design) can be made at lower cost and with greater effectiveness. A reasonable inference to draw from this graph is in fact the idea that projects will benefit by having more diverse expertise (i.e., more interested parties) in the room during design, so that value engineering decisions, especially ones that affect the life cycle costs of the project, can be moved forward in time, when decisions are relatively inexpensive.[7]

An Outline of IPD Phasing and Collaboration

The IPD process outline follows directly from the MacLeamy curve and provides that, once the project is conceptualized, there is a new phase (or "stage" as they are referred to in the OmniClass[8] system) called "Project Delivery Selection" wherein the project delivery is planned and the team assembled. We will see that this early team creation and planning of the project delivery is central to the success of the project.

A diagram comparing the phasing and team participants of traditional delivery and integrated project delivery is shown in Figure 6. At a minimum, an Integrated Project includes tight collaboration between the owner, the architect, and the general contractor, from early design through project handover. Larger or more complex projects may well involve select subcontractors (usually structural and HVAC, where "clashes", unless mitigated early, can lead to expensive changes.)

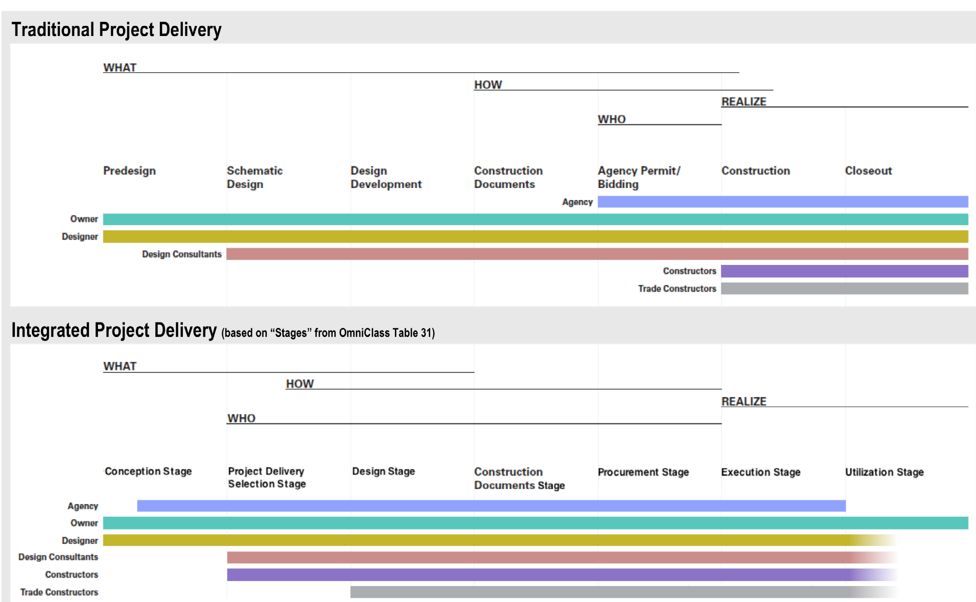

Figure 6 – Chart comparing Traditional with IPD Phasing and Participation

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[7] For more information about Patrick MacLeamy and his current thinking on BIM and IPD, see http://www.aecbytes.com/feature/2008/HOK_CaseStudy.html

[8] For more information on the OmniClass multi-table taxonomy for the built environment, see http://www.omniclass.org/

The Essential Principles of IPD

The following list and description of principles of Integrated Project Delivery comes from the publication *Integrated Project Delivery – A Working Definition* that, along with many other IPD oriented publications, is available online from the IPD website[ii] jointly sponsored by the AIA California Council and McGraw Hill Construction. The first draft of the *Working Definition* was released May 2, 2007 in conjunction with the AIA's Integrated Practice Conference in San Antonio, TX.

- *Mutual respect*

In an integrated project, owner, architect, consultants, contractor, subcontractors and suppliers understand the value of collaboration and are committed to working as a team in the best interests of the project. To harness the collective capabilities of the integrated team, all key participants should be involved as early as possible with multiple disciplines and interests represented. Roles are not restrictively defined, but assigned on a "best person" basis.

- *Mutual Benefit*

All members will benefit from integrated project delivery. Because the integrated process assumes early involvement by more parties, the compensation structure must recognize and reward early involvement. Compensation should be based on the valued added by an organization and risk should be equitably allocated. Integrated projects will use innovative business models to support, rather than discourage, collaboration and efficiency.

- *Early Goal Definition*

Project goals are developed early and communicated to all participants. Insight of each participant is valued in a culture that promotes and drives innovation and outstanding performance. True value engineering is obtained by collaborative focus on the project goals, including system performance throughout the facility lifecycle.

- *Enhanced Communication*

Focus on team performance leads to communication between all participants that is open, straight and honest. Responsibilities are clearly defined in a no-blame culture leading to identification and resolution of problems, not determination of liability.

- *Clearly Defined Open Standards*

Open and interoperable data exchanges based on a disciplined and transparent data structure is essential to support Integrated Project Delivery. Enhanced communications between all participants is made possible with open standards. All technologies used on an integrated project should use open standards to eliminate the costly practice of integrating every application (and version) with every other application (and version).[9]

[9] It should be noted that "open standards' are becoming the standard among sophisticated clients. The US General Services Administration, public building entities of several US state governments, institutions of higher education that have published BIM standards, and the American Institute of Architects have all come out in support of open BIM standards.

- *Appropriate Technology*

Integrated projects will often rely on cutting edge technologies. Technologies should be specified at project initiation, to maximize functionality, generality and interoperability.

- *High Performance*

Integrated projects will lead to optimized design solutions, higher performance buildings, and sustainable design.

A change in the Delivery of Architectural Value

With the broader acceptance and use of a true, collaborative IPD process, the nature of the Architect's role will undergo a change. No longer will he be the only arbiter of what goes into the design and the sole defender of "design intent". Design (at a macro as well as a detailed level) will become the product of a team of knowledgeable professionals, and each will have a real contribution to make. The Architect will be looked to for design leadership, to be sure, but Architects who want to really add value to their projects will not only design, but become leaders of the problem-solving IPD team. As the IPD process becomes more standard in the profession and used for smaller and smaller projects, this leadership will become a more and more important part of the Architect's professional and business value.

What degree of sophistication is appropriate?

What level of BIM planning and exchange does the project require? Certainly a $300 million hospital is different from an $850,000 custom home. Each may benefit from BIM technology, but they may not both benefit from an IPD process. In the case of the home, an IPD process may not even be possible because of lack of available contractor sophistication and lack of user-driven life-cycle benefits. This article[iii] has an interview with a 4D-software vendor that suggests that the "bottom end" for detailed construction modeling may be a construction budget of $40 million. However, even the homeowner will benefit from savings achieved through BIM techniques such as energy modeling and prefabrication of wall panels.

The National BIM Standard

Background

The National BIM Standard (NBIMS or NBIM Standard), version 1, part 1, was completed in December 2007 by volunteer committees working under the auspices of the National Institute of Building Sciences to create a process for definitions for building information exchanges that could be implemented by BIM software vendors. The intent is to provide an open-standard basis for accurate and efficient interoperability needed by the building industry. Among other benefits, the NBIMS is intended to help all participants in facilities-related processes achieve more reliable outcomes from commercial agreements. The NBIMS documentation and some templates may be downloaded from this website[iv].

The NBIMS Process, part 1 – the IDM Process Map

The NBIMS Committee based the NBIM Standard on two international consensus-based standards for information exchange: the Information Delivery Manual (IDM) and the Model View Definition

(MVD). The IDM, adapted from international practices, is used by the BIM practitioner to identify and document information exchange requirements (ERs) in human-readable form. MVD is the technical process (essentially a software specification for information transfer) that integrates ERs coming from many IDMs to the most logical Model Views that will be supported by software applications using a specific version of the Industry Foundation Classes (IFC or ifc) specification.

The “Process Map” component of the IDM is a business process model using standard Business Process Model Notation, a graphical format that describes sequential processes used to achieve a business goal. Each unit in such a diagrammatic assembly is a ***process***, a single one of which is shown in Figure 7:

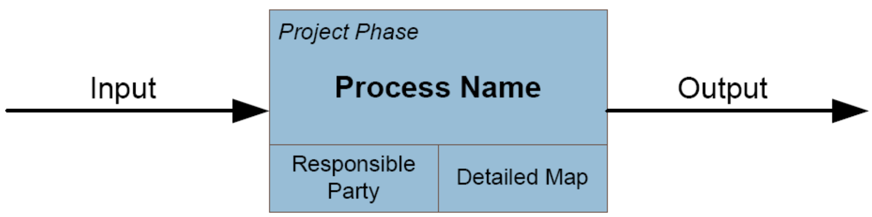

Figure 7 – A business process as portrayed in Business Process Modeling

These individual Process units are assembled (along with their input and output links) into a complete process map, an example of which (for a hypothetical construction project) is shown in Figure 9 below[10]. This kind of diagram may seem familiar to architects who have created PERT[11] or critical-path planning diagrams, but the scope of these diagrams is rather larger, because a process usually encompasses more work activity than a “task” which is the typical unit in a PERT chart. These particular charts use BPMN, or Business Process Modeling Notation, which is a focused graphic language for modeling of this form of information flow. A legend of BPMN symbols is shown in Figure 8.

Element	Description	Notation
Event	An Event is an occurrence the course of a business process. Three types of Events exist, based on when they affect the flow: Start, Intermediate, and End.	
Process	A Process is represented by a rectangle and is a generic term for work or activity that entity performs.	
Gateway	A Gateway is used to control the divergence and convergence of Sequence Flow. A Gateway can also be seen as equivalent to a decision in conventional flowcharting.	
Sequence Flow	A Sequence Flow is used to show the order (predecessors and successors) that activities will be performed in a Process.	
Association	An Association is used to tie information and processes with Data Objects. An arrowhead on the Association indicates a direction of flow, when appropriate.	
Pool	A Pool acts as a graphical container for partitioning a set of activities from other Pools.	
Lane	A Lane is a sub-partition within a Pool and will extend the entire length of the Pool, either vertically or horizontally. Lanes are used to organize and categorize activities.	
Data Object	A Data Object is a mechanism to show how data is required or produced by activities. They are connected to the activities through Associations.	Name
Group	A group represents a category of information. This type of grouping does not affect the Sequence Flow of the activities within the group. The category name appears on the diagram as the group label. Groups can be used for documentation or analysis purposes.	

Figure 8 – A legend of symbols commonly used by BPMN

[10] *Figure 9 is highly simplified and is not intended to show a real projects’ complexity.*

[11] *PERT stands for Program Evaluation and Review Technique.*

In the IDM Process Map, the various players each have a DOMAIN, represented as a "swim lane" in the project "pool". The PROCESSES for each player are shown as rectangular regions within their respective lane. Shared activities span across lanes. The INFORMATION EXCHANGES are shown as sequence flows (usually drawn as arrows) between the activities.

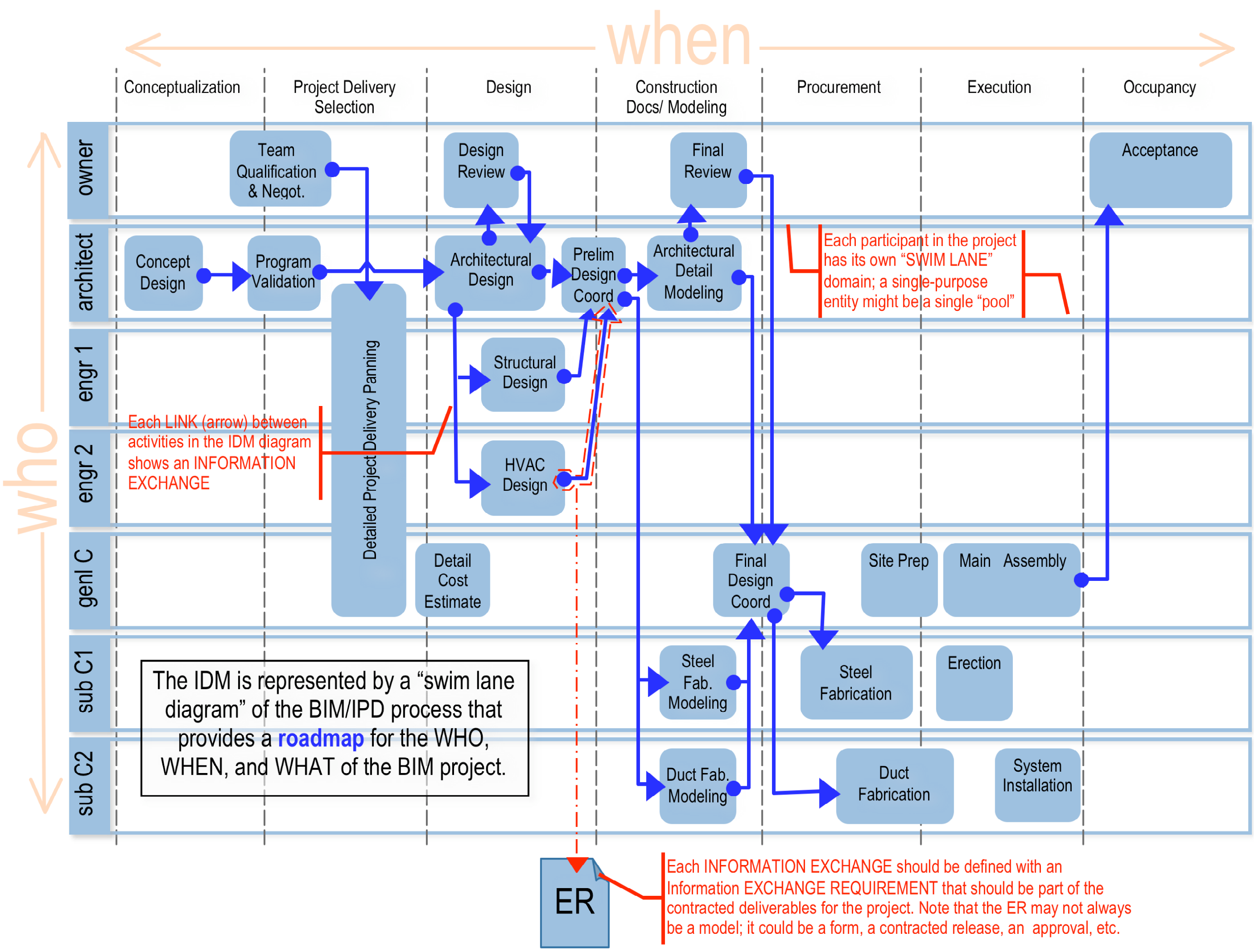

Figure 9 – A "Swim Lane" diagram of the IPD Process

The NBIMS Process, part 2 – the IDM Exchange Requirements

The second major component of the IDM is the set of Exchange Requirements, one for each link in the IDM Process Map representing an information exchange. An Information Exchange Requirement (ER) is a specification of each exchange created in such a way that the completeness of the exchange can be verified when it occurs. The NBIMS approach to these ERs is to verify that the who, why, when, what, for whom, how, and outcome are all specified in advance. In addition, for improved consistency, all these "questions to be answered" for each exchange, when categorized, are also intended to be regularized by conformance with the OmniClass standard, one of three reference standards used by the NBIMS.

	Business Case		OmniClass		Comments
1	**Who**	Party requesting information to support a process or decision.	33	Disciplines	
			34	Org. Roles	
2	**Why**	Why is this information important to the recipient activity?	32	Services	This OmniClass table describes all the services used in a construction project
3	**When**	Stage in project	31	Phases	This table introduces the term "Stage" as a sort of super-phase and introduces the "Project Delivery Selection" Stage
4	**What**	data set	NA	NA	This could be a BIM data set in IFC, or in the file format of a BIM authoring application, or a form/approval, etc.
5	**to Whom**	Provider/Developer of the information	33	Disciplines	
			34	Org. Roles	
6	**How**	Tools / Formats / Results	22	Work Results / Quality	Table 22 is the MasterFormat, 2004 edition. Table 35 describes any tools used or needed to deliver the information.
			35	Tools	
7	**Inputs / Outcome**	Information, Product or Service Delivered	36	Information	The overlap or redundancy between this item and item 4 is not fully clear. It may be that this simply categorizes item 4.

Figure 10 – Table of Information in an Exchange Requirement

Obviously, the ER described in Figure 10 is a very high-level outline specification. Several parties, in trying to provide practical implementations of the NBIMS, have broken down the requirements in smaller components. One example, shown later in the Appendix to this paper, is the Project Execution Planning Guide developed by the Computer Integrated Construction Research Program of Penn State University, which uses a detailed model-oriented Exchange Requirements worksheet shown in Figure 11 below.

	Information Exchange Title		**Design Authoring**			**3D Coordination**			**Energy Analysis**	
			OUTPUT			**INPUT**			**INPUT**	
	Time of Exchange (SD, DD, CD, Construction)					DD			DD	
	Model Reciever		N/A			C, TC			MEP	
	Reciever File Format									
	Application & Version									
	Model Element Breakdown	**Info**	**Resp Party**	**Notes**	**Info**	**Resp Party**	**Notes**	**Info**	**Resp Party**	**Notes**
B	**SHELL**									
	Superstructure									
	Floor Construction	B	A		B	A		B	A	
	Roof Construction	B	A		B	A		B	A	
	Exterior Enclosure									
	Exterior Walls	B	A		A	A		B	A	R Value
	Exterior Windows	B	A		B	A		A	A	Rvalue
	Exterior Doors	B	A					C	A	
	Roofing									
	Roof Coverings	B	A							
	Roof Openings	B	A		A	A		B	A	
C	**INTERIORS**									
	Interior Construction									
	Partitions	B	A		B	A		B	A	
	Interior Doors							C	A	
	Fittings	B	A		B	A			A	
	Stairs									
	Stair Construction	B	A		B	A		B	A	
	Stair Finishes									

Figure 11 – Part of a detailed, model-oriented ER worksheet

The NBIMS Maturity Model and "Minimum BIM"

Building Information Modeling (as recognized by the NBIMS) is a process, not a product or a technology. One of the goals of NBIMS was to define a "Minimum BIM" for quality assurance purposes. The NBIMS provides a worksheet called the "Capability Maturity Model" that allows any BIM practitioner to rate his process and establish what level of completeness his BIM process comprises. An image of one of the worksheets in the Maturity Model worksheet is shown in Figure 12. In the opinion of the author, this represents a level of BIM practice reasonably attainable (without extraordinary methods such as software customization) in Vectorworks Architect 2010.

	A	B	C	D	E
1	TODAY:	December 30, 2009			
2	© NIBS 2007	The Interactive BIM Capability Maturity Model			
17		Area of Interest	Weighted Importance	Choose your perceived maturity level	Credit
18		Data Richness	84%	Data Plus Some Information	3.4
19		Life-cycle Views	84%	Add Construction/ Supply	2.5
20		Change Management	90%	No ITIL Implementation	0.9
21		Roles or Disciplines	90%	Partial Plan, Design&Constr Supported	4.5
22		Business Process	91%	Separate Processes Not Integrated	0.9
23		Timeliness/ Response	91%	Most Response Info manually re-collected	1.8
24		Delivery Method	92%	Network Access w/ Basic IA	2.8
25		Graphical Information	93%	3D - Intelligent Graphics	6.5
26		Spatial Capability	94%	Basic Spatial Location	1.9
27		Information Accuracy	95%	No Ground Truth	1.0
28		Interoperability/ IFC Support	96%	Limited Info Uses IFC's For Interoperability	6.7
29			National Institute of Building Sciences Facilities Information Council National BIM Standard	Credit Sum	32.8
30				Maturity Level	Minimum BIM
31					
32	ADMINISTRATION		Points Required for Certification Levels		
33			Low	High	
34			20	29.9	Minimum BIM

Figure 12 – The NBIMS Maturity Model worksheet

Legal and Contractual Considerations of IPD

Legal and Risk Overview

A white paper such as this is of course not an adequate legal review of an entirely new business model, however it is possible to touch on some of the main points that architects will have to consider in undertaking a project using IPD.

BIM Model Integrity and Risk

The move from paper-centric physically documented information to data-rich, model-based information means that the digital design can be used directly (through an exchange) for a variety of uses: cost estimations, performance and energy simulations, scheduling, structural design, GIS integration, fabrication, erection, and facilities management.

It will become incumbent for the architect (at least while the model is a design-intent model, prior to construction modeling) to control ***who on the design team has model access*** and ***what they are allowed to do with model data***. It is common for IPD contracting regimes to have a standard protocol for the architect to document and control allowed uses of the model at every stage; this is a major role of the AIA E202 BIM protocol.

Despite the apparent ability of BIM authoring applications to maintain the integrity of a model, the Architect will have to exercise professional judgment in coordinating the model, especially during and after information exchanges. This will apply whether the Architect is releasing the model to the Client or to any other party. Unlike graphic communications, it is likely that all parties will expect to be able to rely on the accuracy of the model exchanged.

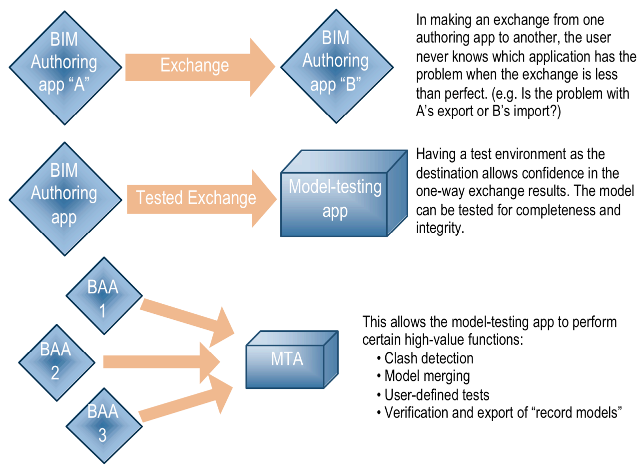

Figure 13 – Model-Checking as a fundamental IPD strategy

The use of model-checking software for itemizing and determining the integrity of a BIM model is highly recommended, and the Architect is encouraged to obtain or develop "rule sets" for such checking software that reflect his standard design and exchanges processes. With the current state of BIM authoring software and their ability to exchange data, it may be preferable to minimize the critical exchanges from one authoring software application to another and perform the high-value checking and "clash detection" in the model-checking software (see Figure 13). This minimizes the variables in the process.

Legal Issues Yet to Resolve with BIM/IPD

The "traditional" way of doing architecture, wherein drawings serve as the basis for a contract between a building owner and a skilled builder who is fully capable of understanding the drawings and delivering the building they intend, took a long time to develop. (If you question how far we've come with the graphical process, consider the drawings that Palladio used[v] to build his villa masterpiece, the Rotonda, just 450 years ago.) Likewise, it will take some time to resolve many business and communication issues that remain unresolved with BIM and the IPD process. A recent article by CNA/Schinnerer[vi] (a professional services insurer) in the online newsletter of the AIA Trust outlined some of these issues, which include:

- *Definition of professional services and the design process*

The protection of public health and safety requires that a licensed design professional be in charge of the "design" (in this case, the data that forms a digital model). However, that may not always be the final outcome. With a interchangeable BIM model, design elements may be delegated to unregulated parties such as contractors, fabricators, and manufacturers, who are not, by contract, under the direction of a registered design professional.

- *Ownership and control of the digital information*

The ownership of the intellectual property generated in the IPD process has not been addressed. In the shared design philosophy intrinsic in IPD, there are contributions of intellectual property provided by any and all design participants that are incorporated into the final model. Who ultimately "owns" it? Must it be licensed? What if it builds upon other proprietary data?

- *Regulation or control of revisions to modeling information*

The contractual doctrine that treats electronic data as an inferior representation of "hard copies" no longer make sense. Limitation of liability to control "detrimental reliance" is counter to the BIM process (mutual reliance is, after, one of the main ideas). IPD must allow a free exchange of data and the ability to rely on such data. Errors can still occur, however, and there must arise a contractual basis for dealing with errors in a manner commensurate with the shared reward from the project.

- *Relationships of the various parties with concurrent design and construction authority*

Roles and responsibilities change under IPD, and these will force existing contractual relationships to change also. Contractual forms have traditionally separated, defined, and allocated responsibilities and risks among contracted parties. These agreements are based on a legal system that differentiates between design, as a professional service, and construction work, as a contractual and warranty obligation. The merging of these roles under IPD lies outside the current legal framework.

AIA "Transitional", AIA-SPE and ConsensusDocs: new contract forms

The American Institute of Architects has for many years served as the standard-setter and primary publisher for contract forms used in the construction industry. Over the past two years, the AIA has developed two sets of documentation for IPD[12]: firstly, the ***A195 Owner-Contractor Agreement for IPD*** and the ***B195 Owner-Architect Agreement for IPD***. The AIA refers to these documents as "Transitional Agreements" (aka "IPD Lite"). The AIA describes these contract forms as "a comfortable first step into IPD, providing an early collaboration of architect, contractor, and owner in an arrangement modeled after existing construction manager agreements."

The "heavyweight" IPD agreement is the new ***C195 Single-Purpose Entity Agreement for IPD***. A SPE is a specialized kind of joint venture for construction. The AIA describes this arrangement as "[allowing] a complete sharing of risk and reward. With this arrangement, owners, architects, and construction managers work together from the beginning to carry out projects with mutually agreed-upon goals and target costs."

Two additional IPD-oriented contract forms produced by the AIA (and closely allied with the above contracting frameworks) are:

- The ***E202 BIM Protocol***, a subsidiary contract attachment that describes the "Levels of Detail" (LODs) that are embedded in a BIM model, and the "Model Component Authority" (MCA) for each region of responsibility; and
- The ***A295–2008 General Conditions of the Contract*** for Integrated Project Delivery.

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[12] *Although they may be slightly paraphrased for readability in this white paper, all AIA document designations and titles are trademarks of the American Institute of Architects.*

The AIA has competition in the construction contract form business from a company called ConsensusDocs. ConsensusDocs provides an alternate form defining the contractual relationships between Architect, Contractor and Owner called ConsensusDocs 300. A table comparing the characteristics of the AIA "Transitional", the AIA SPE, and the ConsensusDocs 300 form can be downloaded from this online location[vii].

As noted at the very top of this section, a broad summary white paper such as this one cannot even begin to address the legal and contractual topics that are attendant to a new business model such as this one. Below are links to a few additional online papers for those interested in pursuing the legal topic further:

- Link to AIA documents page of interest[viii]
- Link to Jay Wickersham white paper 4/2009 [pdf][ix]
- Link to Wickersham slides [pdf][x]
- Link to Ballobin paper [pdf][xi]

Using Vectorworks in a BIM / IPD Project

Transitioning from CAD to BIM in Vectorworks

Most Vectorworks users use it as a 2D- or 2D-3D CAD product. They may use Vectorworks' "hybrid design" capabilities to develop a visualization model, then "break" the model to create CAD drawings once the design is approved. Or they may be working in a 2D-only environment, taking advantage of Vectorworks' graphics capabilities. In either case, the user may be unaware that he can use Vectorworks as a fully interoperable BIM authoring tool, or he may be uncertain of just how to initiate such a workflow in Vectorworks.

Vectorworks is a design tool. Architects using Vectorworks, in the designer tradition of "flexible, versatile, affordable" have always been able to "do their own thing" -- as long as the basis of exchange was the physical drawing. And one advantage of Vectorworks for any architecture firm is that it allows the designer to use Vectorworks to "do CAD" or to "do BIM" or even "just design" as the particular design or architectural problem requires.

The BIM delivery of architecture is (not unfairly) perceived as being a more constrained, less flexible environment in which to work. This is true, not the least because the team is now a larger one and the teammates need a common playbook which will not be so tolerant of improvisation or individual style (at least as far as the processes are concerned).

As an introduction to "how to do BIM in Vectorworks", the table shown in Figure 14 lays out a variety of topics, comparing the role of Vectorworks tools and techniques when "doing CAD" vs. "doing BIM".

Topic	CAD characteristic	BIM characteristic	Comments
SUMMARY			
Information Base	Drawings	Data-Rich Models	
Technology Base	Low-tech	High-tech	From drafting analog to sophisticated integrated business interchange
Business Domains	Adversarial	Collaborative	This is particularly true in a "full IPD" business model.
Design Effort	Back-Loaded	Front-Loaded	Much of the "front loading" comes from additional designers in other disciplines
Information Exchange	File Transfer	Interoperability	
Information Value	Limited	Persistent	The model deliverable itself has life-cycle value
DRAWINGS & DATA			
Drawing Role	Fixed Data Container	View onto Data	In BIM, drawings can be extracted at any time, for any reason, on demand
Drawing Quality	Must LOOK correct	Must BE correct	Dimensioning overrides no longer possible with a BIM process
Coordination	Manually supervised	Automatic	Major workflow advantage of BIM
Quality Driver	Drawing "Look"	Information Flow	In BIM, the "Office Graphic Standards" are de-emphasized
Interpretation	Subjective	Objective	BIM Standards exist to remove subjective interpretation from the process
VECTORWORKS CONCEPTS & TOOLS			
Classes	Graphic Attributes	Taxonomy	In BIM, classes are used more centrally for categorization and visibility at a drawing-object level, although sub-classing may control things like 3D texturing, etc.
Design Layers Organization	View Control	Spatial / Discipline	Design Layers move from being "overlays" to "Building Stories"
Sheet Layers / Viewports	Optional	Mandatory	Viewports are required for automatic coordination in elevation, section, plan details
Saved Views	Plot setup	Model Navigation	Working "snapshots" for BIM model
Walls and Floors	Optional	Needed for "virtual construction"	In CAD, lines may suffice, but in BIM, accurate quantities, space definitions, and model integrity require objects
Spaces	Static Room No. only	Programming/Central Data Element	The space is the most basic, elemental unit of BIM, where the name, type, program requirements and size of a occupied area are stored
Objects	Static 2D graphics	Interconnected, data-rich, construction elements	Object in BIM have semantic and quantitative "intelligence"
Worksheets	Static Tables	Hot-linked Database Reports	Since Vectorworks 2009, users can use worksheets to enter data from a schedule into the referent objects as well as report it.
Interoperability	Proprietary 2D (.DWG)	Open Standard 3D (.IFC)	The BIM IFC standard encompasses 3D, semantic data, quantitative data, and object relationships.

Figure 14 – Table comparing Vectorworks usage in CAD and BIM

While this section of the paper will not be a step-by-step instruction on "doing BIM with Vectorworks", it is anticipated that it will provide guidance for the experienced Vectorworks user to begin to re-think his workflows within the application to develop competent, interoperable BIM models.

Project Initialization Concerns: Determine the "Why"

Strictly speaking, the contents of this section apply no matter the BIM authoring application, and they are reprised significantly in the Appendix, which gives an overview of the Penn State Project Execution Planning system, but the first rule of doing a BIM project, particularly a multi-party BIM/IPD project, is ***know why you are doing BIM***.[13]

This may seem obvious; after all, isn't BIM the new thing? And shouldn't any professional be "doing" the latest thing? Well, perhaps. Consider the graph in Figure 15, which comes from the automation-consulting firm Gartner, Inc:

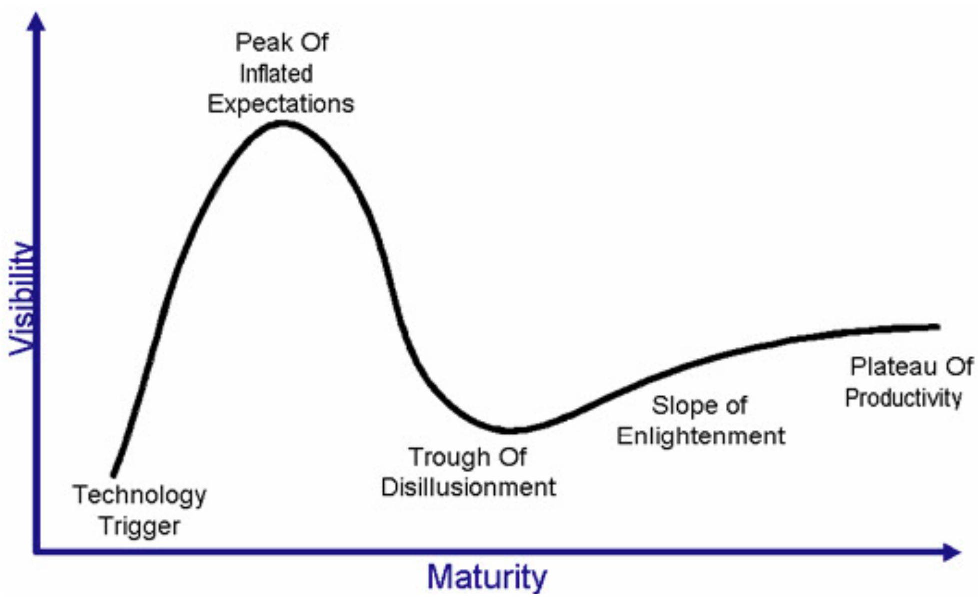

Figure 15 – "The Technology Cycle" (attributed to Gartner, Inc.)

This graph comes from an entertaining and informative article on the AECBytes blog[xii] by Eric Lamb, Dean Reed and Atul Khanzode of DPR Construction, Inc.[14] In the article, the authors remind us of the dot-com boom and its unreasonable expectations. After all, building owners are reading about BIM and may want it without giving due consideration to its costs, the change it exacts in the business model (*their* business model, too, not just the architect's) and may expect wholly unrealistic results. Lamb, et al give the trenchant warning that anyone using BIM needs to "Determine the WHY first".

This is echoed strongly in process outlined in the Appendix, which goes into some detail in outlining project goal setting and determining the exact uses for the BIM. So, consider your owner's goals: does he place top priority on:

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[13] *Another way of saying, "Know why your Owner really wants BIM."*

[14] *DPR Construction is no stranger to BIM. They are a national general contractor and construction management company based in Redwood City, Calif., specializing in technically complex and sustainable projects for advanced technology, life sciences, healthcare and corporate office markets.*

- ***Lifecycle costs?*** if so, energy modeling and worker environmental quality issues will be a primary concern;
- ***Decreasing construction cost risk?*** If so, BIM-enabled engineers and early incorporation of contractors will serve his needs; or
- ***Lowering design costs?*** This may be a client who requires a lot of 3D visualization (aka "Virtual mockups",) in the early phases of a project, to make sure he understands the project he is getting in three dimensions. After all, nothing ruins a design budget like having to do a re-design because the owner didn't understand the original.

In any case, you must align your client's goals with your BIM modeling strategy. For more detail, refer to the Appendix, "Step 1 – Identify BIM Goals and Uses".

Vectorworks Modeling Recommendations

Particularly for those Vectorworks users who are not already doing detailed building modeling, it is important to model thoroughly and correctly. This consists in properly setting up the modeling environment and using the Vectorworks hybrid plug-in objects to their full advantage. These recommendations are summarized immediately below and detailed in Figure 16, the "Vectorworks BIM Maturity Model" chart.

- *Use the Model Setup command (or the manual equivalent)*

Each story of your building should have three corresponding Design Layers:
Mod-Floor-#: This contains the exterior and interior walls, doors, windows, fixtures, millwork, etc. If electrical receptacles are drawn, they may be on this layer (inserted in the walls).
Mod-Slab-#: This contains the floor slab and space objects. It may also contain the floor structural elements (Framing members) if the architect models them.
Mod-Ceiling-#: This contains ceiling elements: the ceiling itself, and HVAC and lighting elements (which are referenced to the ceiling level.)

- *Use Standard Objects (and symbols) wherever possible*

These objects are automatically converted to the appropriate BIM object when exporting to the IFC interoperability format.

- *Unconventional Use of Standard objects*

If you have a "creative" use of a Vectorworks standard object, (e.g. a floor object used as a custom countertop,) you should override its standard BIM identity using the "IFC Data…" command.

- *Use of Custom Symbols or Custom 3D Geometry*

Custom symbols, and the ease with which they can be created and used, is one of the strengths of Vectorworks. Using them in BIM projects, though, requires attention to two issues so that they may be properly identified: first, they should be 3D or hybrid symbols; and secondly, the user must identify the type of object and associated data using the "IFC Data…" command. The same holds for one-off 3D geometry that may not be created as a symbol.

	Vectorwork BIM Maturity Level:	[1] - 2D with Embedded Data	[2] - 3D Conceptual Visualization	[3] - Integrated Design & Development	[4] - Detailed Design Intent
		"Smart Plans"	BIM "Lite"	BIM "Medium"	BIM "Full"
	Narrative Description	Users are thinking in "mylar". They still can take advantage of automatic count, length, area measurements. Schedules can carry building data via formats/PIO data. Doesn't correspond well to an AIA-LOD, but is consistent with good practice, especially for smaller projects.	***Previous level plus:*** Users are thinking 3D; Enough effort is put into 3D exterior shell to provide 3D renderings, backgrounds for elevs/sects. Graphic conventions control, so model gets "broken" to deliver drawings, often not maintained. If maintained, for exterior massing/visualization purposes only.	***Previous level plus:*** Users maintain 3D information that is surface-correct. They use PIOs (or hybrid symbols) throughout the model. Elevations, Sections, and Details are viewport derived from the (plan-initiated) model, with enhancements in VP annotations. Schedules are all hot-linked. BOM quantification worksheets. Exportable in whole or in part to IFC for downstream apps or for consultant exchanges.	***Previous level plus:*** Detailed framing members, slabs and roof planes reflect structural elements, not cavities. Large building cavities (attic, floor-ceiling assembly) are modeled. Ductwork is modeled using PIOs. Electrical is data-modeled (circuited and assigned to panels), but conduit is not modeled. Major piping is modeled. Custom 3D model elements have IFC data specified. Exportable in whole or in part to IFC
	Model Centric Delivery	Drwg	Drwg	√ Drwg/Mod	√ Drwg/Mod
	Corresponds to AIA LOD:	(N/A)	100	200	300
	Technique				
File Struct / Setup	Layers for "Acetate"	√	√		
	Layers for Floors / Disciplines		√	√	√
	Classes for Attributes	√	√	√	√
	Classes for Taxonomy			√	√
	Classes	Attributes	Building Categories		
	Layers	View Organization		Stories / Disciplines	
Site Modeling	Site Model-Topo Drafting	√	√	√	√
	Site Model-Grading/Cut&Fill		√	√	√
	Site Model-Drainage		√	√	√
	Site Model-Slope Analysis			√	√
	Site Area Analysis (e.g. property, FAR, bldg areas)	√	√	√	√
	Site Quantification (e.g. parking counts)	√	√	√	√
Space Planning	Finish Schedules	√	√	√	√
	Area Studies	√	√	√	√
	Volume Studies and calculations		√	√	√
	Programming Analysis (matrices, bubble diags)	√	√	√	√
	Programming Verification (Prog. vs. Actual Space)		√	√	√
Worksheets Data	Door / Window Schedules	√	√	√	√
	Quantifying / BOM		√	√	√
	Other Calculations (e.g. ventilation)			√	√
	Object Data Management		√	√	√
Presentation	Presentations using Design Layers / Saved Views	√	√		
	Convert to Lines for Elevations / Sections	√	√		
	Viewports for Plans			√	√
	Viewports for Elevations			√	√
	Viewports for Sections			√	√
	Viewports for Section Details			√	√
	Viewports for Plan Details			√	√
	Viewport Annotations			√	√
	Graphic Enhancement of Linked VPs			√	√
	Sketch Plans / Perspectives		√	√	√
	Supplemental 3D in CD package				√
	Movie Export for walkthroughs		√	√	√
	Movie Export for Solar Studies		√	√	√
Modeling	Model Used as "Background" only for Elevations		√		
	Model Linkage Maintained throughout			√	√
	Massing Model objects for Environment		√	√	√
	Model Setup to establish Building Stories			√	√
	Maintained 3D Level detail				√
	Use of Standard Internal Arch Objects		√	√	√
	Use of Slabs in 3D			√	√
	Use of Hybrid Plug-in Objects	√	√	√	√
	Use of Roof features / accessories		√	√	√
	Custom 3D Modeling				√
	Advanced Freeform Modeling				√
	Detailed Hybrid Objects (Structural elements)				√
	Detailed Hybrid Objects (MEP)				√
	Selective 3D Detailing			√	√
Model Sharing & Exchange	Multi-File Design Layer Viewports	√	√	√	√
	DWG Backgrounds to consultants	√	√	√	√
	PDF Record documents	√	√	√	√
	"BIMstorm"		√		
	Federated BIM Model using Solibri / Navisworks			√	√
	New GSA Initiative for fourfold IFC data			√	√

Figure 16 – The Vectorworks BIM Maturity Model chart

Vectorworks Model Progression

The increasing model maturity shown in the rightmost columns in the chart in Figure 16 are more intended to show increasing maturity in office workflow, rather than progression in model data through a single project, although the "BIM Medium" and "BIM Full" columns are similar enough that a firm could conceivably progress from one to the other through a single job.

Vectorworks Model Quality Control

If you are using IFC interoperability in your BIM project (and this will be a feature of almost any IPD project using a variety of authoring tools,) you should integrate model testing and model analysis into your process. This means using a model-verification program such as Solibri Browser or Solibri Model Checker to verify that IFC output is delivering the desired results. If you decide to use Solibri Model Checker and your project is for a client using SMC testing, be sure to obtain the Solibri "rule sets" that your client requires for model verification. For more discussion of this issue, see "BIM Model Integrity and Risk" elsewhere in this paper.

Because Vectorworks' IFC interface is undergoing quality and feature updating with each release and service pack, it is recommended that all Vectorworks users whose workflow depends on interoperability be using the latest version of Vectorworks.

Using Vectorworks in a BIM/IPD Project

The techniques outlined in this section demonstrate a successful way to use Vectorworks in a BIM / IPD type project. Most users will need to re-think their workflows somewhat to move to a model-centric process, and for successful interoperability should consider employing third-party model-checking applications. Vectorworks' traditional design values of flexibility create value for the design-oriented BIM user, in allowing the user to create and add BIM meaning and construction data to virtually any geometric inspiration they can model.

But the workflow changes in using Vectorworks as a BIM authoring tool are really just the tip of the iceberg for the practitioner. BIM, and especially BIM in an IPD environment, is a completely different business model for all the players in the AEC milieu: the Owner, the Architect, the Engineers, and the Contractors. Understanding this change and particularly the importance it places on early project planning, role definition, and information exchange is the key to executing a successful BIM project.

Appendix: A Detailed Procedure for Planning an IPD Project

More than anything else, the NBIMS v1 is a high-level project planning methodology. NIBS has, through the NBIMS, recognized that careful planning is essential to a successful IPD project; indeed, the success of an IPD project probably owes at least as much to its teamwork and planning than to the technology used in its execution. In this section we will examine a relatively new set of tools for IPD project planning, called the ***BIM Project Execution Planning Guide*** (PxP Guide) and developed by the Computer Integrated Construction Research Program of Pennsylvania State University and released on October 8, 2009.

A Formal Project Planning Process

The PxP Guide provides a practical manual that can be used by project teams for designing their BIM strategy and developing a BIM Project Execution Plan at the early stages of a project. The *Guide* includes a four step structured procedure for creating a BIM Project Execution Plan:

- Identify BIM Goals and Uses
- Design BIM Project Execution Process
- Develop Information Exchanges
- Define Supporting Infrastructure to Support the BIM Process

These steps are graphically depicted in Figure 17.

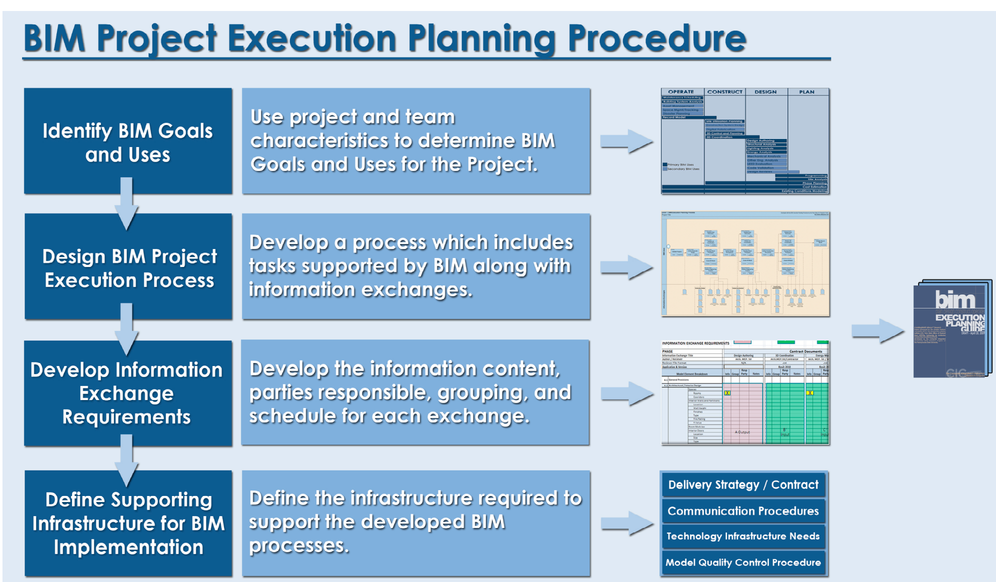

Figure 17 – The Penn State procedure for planning a BIM/IPD project

This paper will provide a brief outline of the process only; the full BIM/IPD planning guide and process template files can be found at the Penn State website[xiii] and downloaded from there.

Step 1 – Identify BIM Goals and Uses

- *Assemble the Planning Team*

A BIM planning team should be assembled in the early stages of a project. The project "Stages" as defined by OmniClass have a "Project Delivery Selection Stage" following the initial project conceptualization that is probably the best time to assemble the team and begin the detailed delivery planning process. This team should include representatives from all primary project team members including the owner, designers, contractors, prime specialty contractors, and facility manager. (Note that the inclusion of "prime specialty contractors" at such an early stage presumes a full-on IPD process.)

This team's initial job is to set measurable goals for the project, which will serve as the foundation for the entire project plan. The lead party for coordinating and compiling the BIM Plan should be clearly identified at the time of team formation.

- *Identification of Goals*

Whether project goals are performance-based or more aspirational in nature, the goals need to be ***measurable*** as to their achievement. Some examples of goals are ***construction goals***, such as reducing the schedule duration, increased quality through offsite fabrication, or higher field productivity. ***Design goals*** might include obtaining a particular LEED rating or meeting a SF/employee measure. ***Aspirational goals*** may relate to advancing the capabilities of the project team members, for example, the owner may wish to use the project as a pilot project for other divisions within his organization, or a design or contracting firm may seek to gain experience in the efficient use of digital design applications.

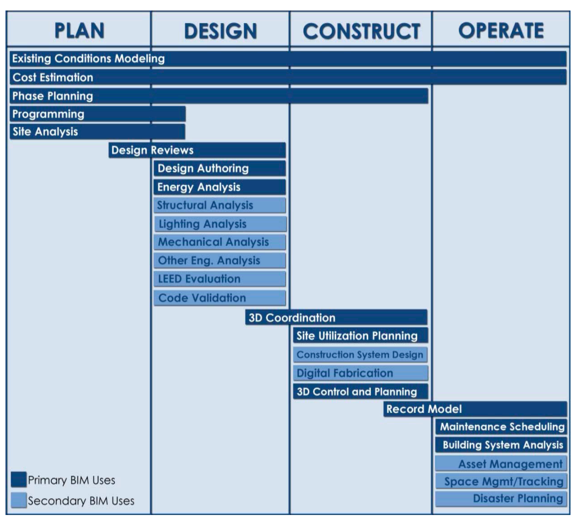

Figure 18 – Timeline of possible BIM uses in an IPD project

- *BIM Uses*

Once the team has defined measurable goals, both from a project perspective and company perspective, then the specific BIM uses appropriate to meet the project goals can be identified. The Penn State team identified 25 candidate uses for the BIM in the course of an IPD project, including occupancy (operational) phase uses. Elaborations of the 25 BIM uses may be found on the [Penn State website][xiv] as well as in the appendices of the Project Planning Guide.

For BIM to be implemented successfully, team members should "begin with the end in mind" and understand the future use of the information that they are developing. The future use of data can frequently impact the methods used to develop the model, or identify issues related to the data accuracy for tasks that may later on the information.

Penn State provides a number of planning tools, such as a BIM use planning worksheet, on the download page of its website. See Figure 19 for an example.

BIM Use*	Value to Project	Responsible Party	Value to Resp Party	Capability Rating			Additional Resources / Competencies Required to Implement	Notes	Proceed with Use
	High / Med / Low		High / Med / Low	Scale 1-3 (1 = Low)					YES / NO / MAYBE
				Resources	Competency	Experience			
Record Modeling	HIGH	Contractor	MED	2	2	2	Requires training and software		YES
		Facility Manager	HIGH	1	2	1	Requires training and software		
		Designer	MED	3	3	3			
Cost Estimation	MED	Contractor	HIGH	2	1	1			NO
4D Modeling	HIGH	Contractor	HIGH	3	2	2	Need training on latest software	High value to owner due to	YES
							Infrastructure needs	phasing complications	
								Use for Phasing & Construction	
3D Coordination (Construction)	HIGH	Contractor	HIGH	3	3	3			YES
		Subcontractors	HIGH	1	3	3	conversion to Digital Fab required	Modeling learning curve possible	
		Designer	MED	2	3	3			
Engineering Analysis	HIGH	MEP Engineer	HIGH	2	2	2			MAYBE
		Architect	MED	2	2	2			
Design Reviews	MED	Arch	LOW	1	2	1		Reviews to be from design model	NO
								no additioanl detail required	
3D Coordination (Design)	HIGH	Architect	HIGH	2	2	2	Coordination software required	Contractor to facilitate Coord.	YES
		MEP Engineer	MED	2	2	1			
		Structural Engineer	HIGH	2	2	1			
Design Authoring	HIGH	Architect	HIGH	3	3	3			YES
		MEP Engineer	MED	3	3	3			
		Structural Engineer	HIGH	3	3	3			
		Civil Engineer	LOW	2	1	1	Large learning curve	Civil not required	

Figure 19 – A BIM Use selection worksheet from the BIM Planning Guide

Step 2 – Design the BIM Project Execution Process

The so-called "Level 1" Process Maps used in the PxP Guide are IDM diagrams divided into two "lanes", the top lane representing BIM uses by the unified project team and the bottom one detailing the information exchanges represented by the arrow-linkages in the top area.

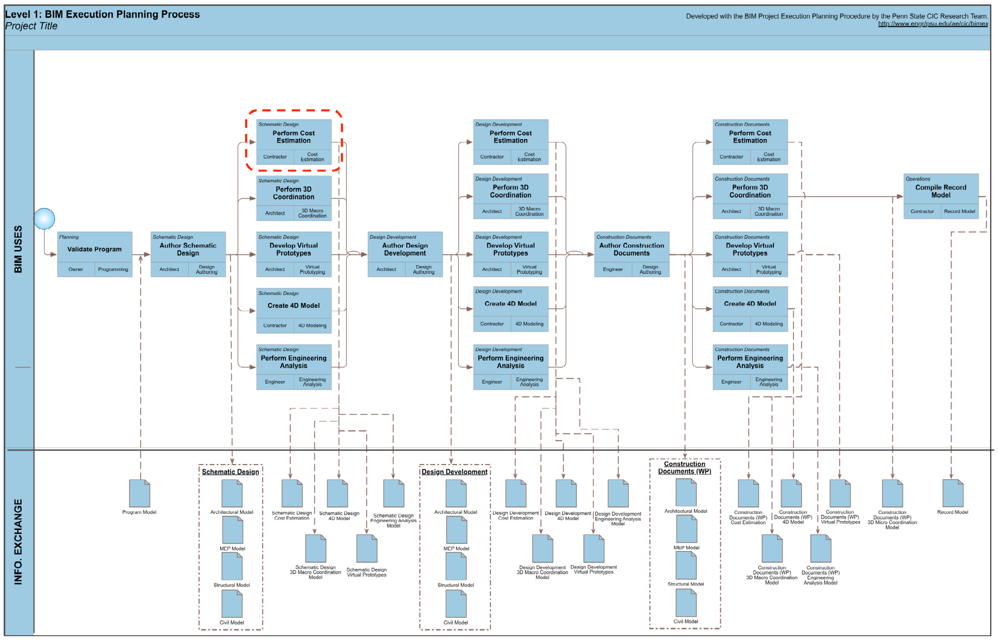

Figure 20 – Example of a "Level 1" Process Map for a BIM Project

Each of the process units in this "Level 1" diagram may be in turn represented as a collection of more detailed processes in a so-called "Level 2" process map. Below for example in Figure 21 is a detail of the cost estimation process highlighted in Figure 20, expressed as a series of more detailed processes.

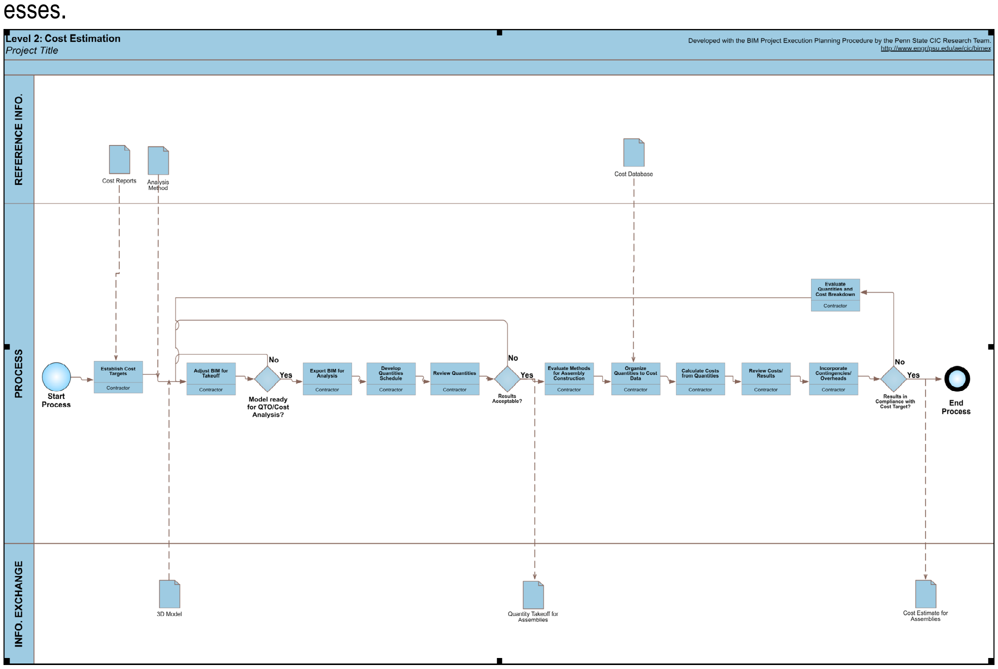

Figure 21 – Example of a "Level 2" Process Map for a BIM Project

Clearly, for a major project such as a university building or a hospital, a planning process to this level of detail is appropriate. For those unused to a rigorous planning element like this in their design projects, this kind of planning process may seem like a lot of administrative overhead. For large, complex projects, it is just this level of detail in planning the activities and information exchanges in the project that will enable the success of the rest of the project. For simpler projects, a more streamlined planning process is appropriate. In either case, however, the planning process must be truly committed to by all the project team players and must be budgeted for.

Step 3 – Develop Information Exchange Requirements

The PxP Guide notes that one role of an effective project plan is to determine who on the project team is the best, most appropriate, author of information required for downstream BIM uses. The PxP Guide presents a worksheet for developing ERs (a portion of which is illustrated in Figure 11.) The use of this worksheet has the five following steps:

- *3.1 – Identify each information exchange from the Process Map;*

Each Information Exchange required by the project activities should be drawn and identified on the Process Map.

- *3.2 – Choose a Model Element Breakdown for the project;*

Based on the character of the Information Exchanges in the project, a subdivision of the elements in the models to be exchanged should be established. There are several available templates for this: CSI Uniformat (as used in the PxP Guide and in the AIA E202), or OmniClass Table 21 (Elements) are the primary ones.

- *3.3 – Develop the Information Exchange Requirements (ER) for each exchange;*

The PxP Guide identifies the following critical information for each exchange (note: Compare this list to the NBIMS list as shown in Figure 10):

- Model Receiver: who will be receiving the model for a future use?
- Model File Type: What format and version of BIM authoring tool or interoperability file?
- Level of Detail (LOD): To what qualitative degree is the information developed? (LOD is a concept also used in the AIA E202. The PxP Guide has attempted to harmonize with the AIA protocol.)
- Notes: Additional information as may be required.

- *3.4 – Assign an Author to each Exchange*

Each line item in an Information Exchange should have a party who is responsible for creating the information. This will usually be one of the following:

- Owner
- Architect
- Contractor
- Civil Engineer
- Structural Engineer
- MEP Engineer
- Facility Manager
- Trade Contractor

- *3.5 – Compare Input vs. Output Content for Each Exchange*

Using the PxP Guide Exchange Requirements worksheet, the project team should discuss the specific elements where the Output information as authored does not match the Input information as required (for the next BIM use). When this occurs, one of two potential remedial actions needs to take place. Either the information can be revised to a higher level of accuracy or specificity, or the author needs to be changed to the party performing the BIM use.

Compare the information developed in steps 3.3 through 3.5 above to the items in the table in Figure 10.

Step 4 – Develop the Infrastructure for the BIM Project Execution Plan

The final step in the BIM Project Execution Planning Procedure is to define the project infrastructure required to effectively realize the developed implementation process. Nine specific categories are identified by the PxP Guide and should be addressed in this step. They are listed and elaborated upon below.

- *4.1 – Project Goals / BIM Objectives*

The team should document the justification for implementing BIM on the project and explain the operative BIM Use decisions. There should be a clear list of the BIM goals and intended uses.

- *4.2 – BIM Process Design*

The project team should develop process maps for each BIM activity. The maps should provide a detailed plan for development of each BIM Use, and should define the specific information exchanges for each activity. The plan should include the overview map of the BIM Uses, a detailed map of each BIM Use, and a description of elements on each map.

- *4.3 – BIM Scope Definitions*

The team must determine the model elements by discipline, level of detail, and any specific attributes important to the project. The model breakdown should define the model components and discipline specific deliverables to maximize value and limit unnecessary modeling.

- *4.4 – Organizational Roles and Staffing*

The specific organizations, their project roles, and their detailed staff contributions to the project should be defined and documented.

- *4.5 – Delivery Strategy / Contracts*

The optimal project delivery process to meet the project goals should be determined. In order to achieve team objectives, the project may be CM-at-risk, Design-Build, Transitional IPD, or Single Purpose Entity IPD. The team must define the impact of the project delivery structure, team selection, and contracting strategy for the project. Procurement methods, work breakdown schedule, and payments need to be specified. Model ownership and reliance issues need to be addressed.

- *4.6 – Communication Procedures*

The team must develop and document their electronic and meeting communication procedures, including model management (e.g., model check-out, revision procedures, etc.) and standard meeting actions and agendas.

- *4.7 – Technology Infrastructure Needs*

The team should determine the requirements for hardware, software, space, and computer networks for the project. Team physical arrangement should be determined (co-location or separate locations with high-speed WAN). Training needs and budgets should be determined and documented. Specific software should be considered for the following uses:

- Design Authoring
- 3D Design Coordination
- Virtual Mockups (Design Visualization)

- Cost Estimating
- 4D Phasing or Modeling
- Energy Modeling

- *4.8 – Model Structure and Quality Control*

Model quality control procedures must be defined and implemented. Each model created must be preplanned considering model content, LOD, format and responsible party. Quality control of deliverables must be assured at each design review, coordination meeting or milestone. Any corrupt information must be further investigated and procedurally prevented in the future. The deliverables need to comply with agreed-upon standards considering symbology, dimension style, line styles, text styles, levels and other standards. 3D interference checking must also be done within each discipline and across various disciplines in coordination models. Model-checking software for semi-automated checking is recommended. Documentation confirming that a quality check was performed should be part of each submittal or BIM report.

- *4.9 – Valuable Project Reference Information*

The team should review and record critical project information that may be valuable for the BIM team for future reference. This includes project overview information, BIM specific contractual requirements, and key project contacts.

Endnotes – URL references

These endnotes reference the URLs for links embedded in the document, for those reading this in hard copy:

[i] http://www.aia.org/contractdocs/AIAS077630
[ii] http://www.ipd-ca.net
[iii] http://www.hegra.org/EDS Independent voice Jan 2008.html
[iv] http://www.wbdg.org/bim/nbims.php
[v] http://www.architecture.com/LibraryDrawingsAndPhotographs/PalladioAndTheVeneto/PalladioAndHisRegion/Villas/LaRotonda/Rotonda2.aspx
[vi] http://www.theaiatrust.com/newsletter/2009/07/bim-and-transition-to-ipd/
[vii] http://www.agc.org/galleries/contracts/CCR COMPARISON OF AIA IPD DOCUMENTS WITH THE CONSENSUSDOCS 300.pdf
[viii] http://www.aiacontractdocuments.org/ipd/agreements.cfm
[ix] http://isites.harvard.edu/fs/docs/icb.topic552698.files/Wickersham BIM-IPD legal and business isssues.pdf
[x] http://www.ipdconference.com/userfiles/Wickersham BIM_IPD.pdf
[xi] http://www.nspe.org/resources/pdfs/Licensure/Resources/MFLResearchFellowshipIPDReport.pdf
[xii] http://www.aecbytes.com/viewpoint/2009/issue_48.html
[xiii] http://www.engr.psu.edu/ae/cic/BIMEx/index.aspx
[xiv] http://www.engr.psu.edu/ae/cic/bimex/bim_uses.aspx