CIDB MALAYSIA

BIM CONCEPT & THEORY

Aim of the Module	This module is specifically designed for the individuals or organizations that are involved in the construction and keen to explore new technology with the aim to bring awareness of the recent developments in Building Information Modelling (BIM). The program explains and discusses BIM concept and theory, its benefits to the organizations, challenges and opportunities, case studies and the implementation. The participants will be able to discuss the impact of BIM deployment on their organizations, e.g. on their work practices, contracts, IT infrastructure and skills development.
Learning Outcomes	Following completion of this program, participants will be able to: ▪ Understand the important of project information and collaboration; ▪ Understand the need for client leadership to successfully implement BIM; ▪ Recognize the importance of BIM and understand common BIM terminology; ▪ List the most common BIM-based applications; ▪ Understand BIM tools and implementation challenges; ▪ Understand barriers for BIM implementation; ▪ Understand the benefits of greater collaboration and integration in design and construction and how BIM supports it.
Duration	1 Day
Accredited by	CIDB MALAYSIA

TABLE OF CONTENTS

Aim of the Module i
Learning Outcomes i
SECTION 1: CONSTRUCTION INDUSTRY SCENARIO 1
1.1: The Issues and Challenges 1
1.2: Project Information Issue 2
1.3: Client Leadership 4
1.4: Improving the Industry Performance 4
Summary 5
Section Break – Questions 5
SECTION 2: INTRODUCTION TO BIM 6
2.1: The Evolution of AEC CAD 6
2.2: The Evaluation of the BIM Concept 7
2.3: Key Advantages of the BIM Concept 8
2.4: Lessons Learned from IEC Case Study 10
Summary 12
Section Break – Questions 12
SECTION 3: BIM IMPLEMENTATION 13
3.1: The Approaches 13
3.2: The Planning 14
3.3: BIM Software and Application 15
3.4: BIM Execution Plan 16
3.5: Level of Detail and Level of Development (LOD) 17
3.5.1 What is Level of Development? 18
3.5.2 What is Level of Detail? 20
3.6: BIM Visualization 21
3.7: Barriers to BIM Implementation 24
3.8: Defining Roles and Responsibilities 25
Summary 27
Section Break – Questions 27
SECTION 4: COLLABORATION 28
4.1: BIM and Collaborative Environment 28
4.2: The Advantages of IPD 30

4.3: Barriers to IPD Implementation 32
Summary 33
Section Break – Questions 33
REFERENCES 34

LIST OF FIGURES

Figure 1: Conventional design and construction 1
Figure 2: Conventional information exchange to shared project model 3
Figure 3: AEC CAD Timeline 7
Figure 4: BIM Benefits Study by CIFE 9
Figure 5: The investors report, UK (BIM Task Group, 2012) 10
Figure 6: Project integration BIM model 14
Figure 7: Example of BIM software 16
Figure 8: Level of Development 19
Figure 9: Level of Detail 20
Figure 10: Different Layers of BIM Model 21
Figure 11: Integrated Project Delivery 29
Figure 12: The “MacLeamy Curve” IPD impact on the project 32

LIST OF TABLES

Table 1: BIM Applications for Project Stakeholders 9
Table 2: Conventional Project Delivery Methods vs IPD 30

SECTION 1: CONSTRUCTION INDUSTRY SCENARIO

The demand for construction in Malaysia is expected to grow further, especially as our economy continues to expand. The expected growth is evident in the Eleventh Malaysia Plan (RMK11) that estimates the construction industry to expand by 10.3 per cent per annum over the next five year period. Construction is a highly competitive industry and Malaysian companies with high capability and expertise can leverage these attributes to capitalize on significant business opportunities abroad. International construction opportunities are significant – investment in global infrastructure is set to rise from USD 2.6 trillion to USD 4.5 trillion by 2030.

1.1: The Issues and Challenges

Despite fast construction growth in the Malaysia, construction industry contributes large significant waste. Recent study has identified the top ten most significant causes of construction delays, of which the key ones are the "approval of drawings", "inadequate early planning" and "slowness of the owners" decision - making process. It is also reported that the construction industry has typically been slow in adopting new technology, and that 30% of costs go to waste as a result of co-ordination issues, inefficiencies and wasted materials. 60% of all capital programs fail to meet their schedules and budgets.

The entire building and design process is characterized by high levels of fragmentation. There are multiple stakeholders involved, including Architects, Engineers, contractors and clients where they producing and exchanging large amount of drawings, specifications, manuals, etc. as shown in Figure 1.

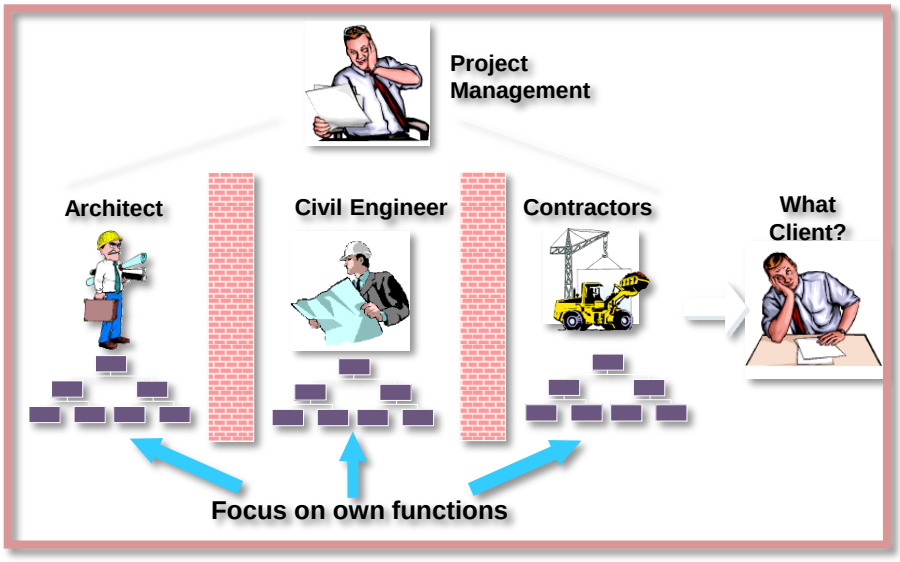


Figure 1: Conventional design and construction

The main issues highlighted above are the global issues. At a macro level, the construction industry is facing a number of challenges such as:

1. Increasing globalization of products and services which give clients, consultants and contractors alike the opportunity to select products and services from around the world;
2. The availability of a variety of procurement methods which can re-define the roles and responsibilities of project's participants in the interest of the project/client;
3. Clients are demanding better value for their investments and projects are becoming more complex than ever which require projects to be deliver on time and higher quality but at a lower cost; and
4. The long-term economic down turn which has significantly affected the industry.

These global challenges impose great pressure on construction organizations to adopt new work environments that will allow them to provide better service to clients in a very competitive market.

At micro level, the major challenge facing the industry to improve its performance is its ability to capture the shear amount for information generated in construction and make them available, in the right format, for professionals to evaluate alternative solutions based on life-cycle analysis.

1.2: Project Information Issue

The main reason behind the above issue is the fragmentation nature of the industry. Any construction project involve many practitioners, including architects, engineers, contractors, subcontractors and suppliers to deliver a one-of-a-kind project which requires tremendous amount of coordination as shown in Figure 1. This involves the collaboration of a number of organizations which are brought together for the duration of the project to form the "project team".

These organizations vary in terms of size, capability, skills, practices, IT systems, etc. and more often are based in different locations but need to work collaboratively and share the same project information. This impose a great challenge in meeting projects' objectives of time, cost and quality and most importantly meeting client requirements through better collaboration between the project partners.

There are challenges with the quality of the information being generated and used on the project and with the means by which this information is communicated and shared amongst the project team. Such flow of information

needs to be managed so that it will be received or accessed when required. Information management is not for handling drawing issues only, but if it is correctly administered, it can provide the necessary framework whereby all involved individuals are aware of their responsibilities and how to carry them out.

By providing an intelligent, digital structure for project information and ultimately a means by which information can be held centrally as a 'single' model, project information efficiently can be made freely available to all project stakeholders as shown in Figure 2.

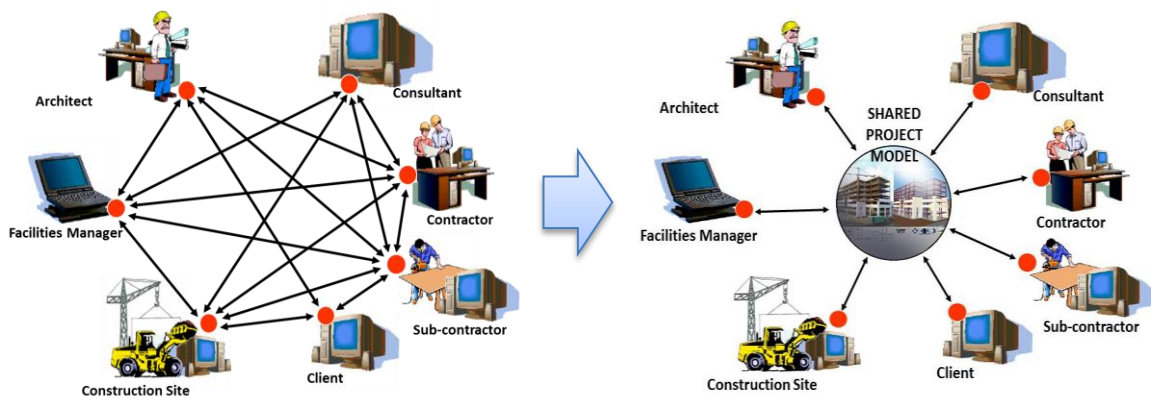


Figure 2: Conventional information exchange to shared project model

There are two issues here that need to be addressed as follow:

1. **Collaboration:**

   The performance of the industry can be improved with effective collaboration and communication among project stakeholders, which has been brought about through more effective procurement approaches Most recently, there is a focus on creating and reusing digital project information of stakeholders throughout the life cycle to facilitate the exchange of information among partners. This shift is based around BIM (Building Information Modelling) and collaborative environment.

2. **Building Information Modelling (BIM):**

   BIM was conceived to remedy to information sharing issues by providing a model based mechanism to manage all building related information in a particular project in a shared repository that could be accessed by all project participants and readily incorporated into project documents. BIM provides the construction industry with a virtual prototyping tool to test and simulate the design before production. Likewise, by using a shared project model, information can flow both upstream and downstream, enabling more concurrent ways of working during project design, execution and during later phases of the project lifecycle.

1.3: Client Leadership

Client leadership is strongly recognized in bringing change through better collaboration between project stakeholders. However, one of the major challenges is that collaboration is operated under conventional procurement methods, which hugely limit the stakeholders' roles and responsibilities to bring about the required level of collaboration.

Lessons learned from the UK whereby recent Gibson Review on productivity and skills in the engineering construction industry has found numerous examples in the UK in which client leadership was absent. It is noted that clients often didn't have the capability or the inclination to engage with contractors on the detail of projects which often led to breakdowns in communication and, in the worst cases, a claim's culture with both parties blaming each other for problems with projects.

Client Leadership also was highlighted as a key area in the 2012 Construction Commitments to achieve success of any project and enables the construction industry to perform at its best (The Strategic Forum for Construction, 2006). It also outlined the client leadership principles as follow:

(i) the client continuity in leadership for the duration of the project

(ii) the client commitment engendering cooperation with all organizations involved in the project; and

(iii) the client development of a clear, collaborative and flexible procurement policy.

Another beneficial factor is client's leadership is whereby clients need to take a leading role in creating a collaborative environment where project stakeholders can share experiences and exchange project information in the interests of the project.

The use of new types of collaborative environment procurement systems and the use of digital project information by stakeholders throughout the project life-cycle have started to be demanded by the clients who realize the potential benefits of such procedures.

1.4: Improving the Industry Performance

As mentioned in previous section, the major challenges to improve the performance of the industry is the ability to capture the large amounts of information generated during the lifecycle of projects and to make these available, in the right format. This performance of construction can be improved through the following points:

a. End users consideration in the design and construction of buildings, including future needs;

b. Better integration of the various stages in the construction process - design, planning, construction and completion to remove waste and inefficiency;

c. Partnering between clients, contractors and consultants to resolve problems collaboratively;

d. Longer term relationships between clients and contractors to promote continuous improvement in the cost and quality of final products;

e. Recognition that accepting the lowest tender price for the initial capital costs does not give value for money and more consideration needs to be given to the costs of a building over its whole life;

f. Move away from adversarial approaches between the industry and clients which have produced high levels of litigation; and

g. Greater use of prefabrication and standardised building components in construction to improve quality and cost effectiveness.

Again, BIM information is centrally managed entered once by multiple disciplines, thus it creates the communication base for collaboration. Hence, BIM's power is enhanced by collaboration which in turn is made more effective through BIM.

Summary

- Construction industry facing a biggest challenge to meet the client's demand and also effect of the global economic down turn;
- The collaboration need to be improved for effective exchange of information among partners. This shift is based around BIM (Building Information Modelling) and collaborative environment; and
- Strong client leadership is recognized in bringing change through better collaboration between project stakeholders and BIM implementation.

Section Break – Questions

1. What are the main issues contributes to the significant waste in the construction industry?
2. Why project information need to be managed and shared among the project stakeholders?
3. How client can play their role for bringing the change to the construction industry performance?

SECTION 2: INTRODUCTION TO BIM

Section 1 discussed the key challenges in construction processes resulting from fragmentation, functional organisation and document centric communication model inherent within the construction industry.

Building Information Modeling (BIM) was conceived to remedy such problems by providing a model based mechanism to manage all building related data and information in a particular project in a shared repository that could be accessed by all project participants and readily incorporated into project documents.

BIM is a digital representation of the project (geometric and non-geometric information) in a relevant software environment to allow for full 3D visualization of all building elements.

BIM is different than conventional CAD system where it uses many separate documents (usually 2D) to explain a building. CAD output is essentially a collection of lines and text on a page. Because CAD documents are created separately, there is little to no correlation or intelligent connection among them.

The following sections will explain more on CAD and BIM.

2.1: The Evolution of AEC CAD

The history of CAD (Computer Aided Design) goes back to the early sixties. CAD applications have gone through major changes over the course of time. The evolution of CAD software was particularly significant in the AEC (Architecture, Engineering and Construction) industry, in which simple two dimensional drafting programs have evolved into integrated building information modeling (BIM) applications during the past 30 years. The most important milestones of AEC CAD are the following:

- **2D solutions** – Electronic drafting board
- **3D solutions** – Modelling for purely visualization purposes
- **BIM solutions** – Models with integrated architectural information
- **Construction Coordination (5D)** – Timing/scheduling and cost estimation

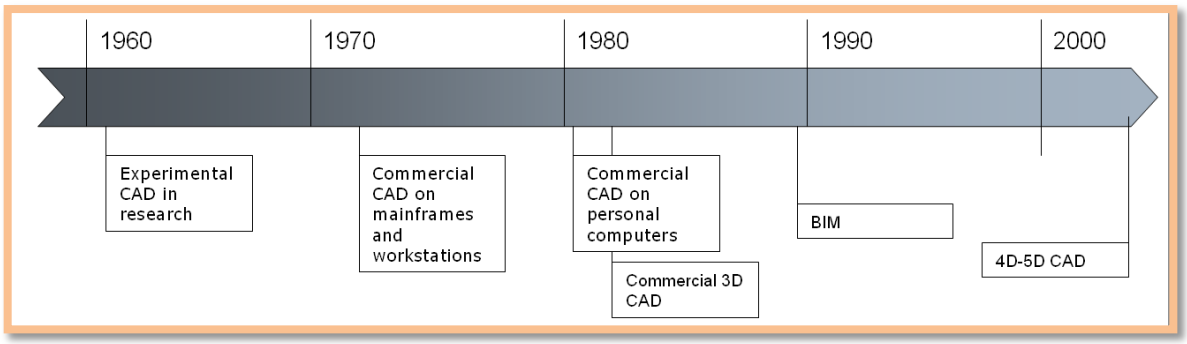


Figure 3: AEC CAD Timeline

A major milestone of AEC software history was the release of 3D CAD applications capable of handling three-dimensional models in addition to the 2D documentation. 3D CAD programs allow users to create a spatial model of the building together with the necessary 2D documentation. 3D applications provide many advantages for architects and designers compared to 2D CAD and hand drafting. Visualization and listing are just the two most obvious benefits of 3D modeling.

Contemporary BIM applications provide integrated solutions for architects and designers. Developed specifically for the AEC industry, BIM programs feature real building elements, automatically attached building information data and rich visualization capabilities.

The latest AEC applications focus on the construction industry. Adding time and cost information to the 3D BIM model (making it into a so-called “5D” model) allows construction companies to optimize their processes and minimize the risk of building errors.

2.2: The Evaluation of the BIM Concept

The basic concept of BIM modeling is that architects are able to use the 3D building model to extract all the required project drawings and building views – including sections and elevations, presentation drawings, renderings and detailed construction drawings, as well as quantity calculations and price estimations. Consequently, changes to the model are instantly updated on all drawings.

The most significant highlights of the BIM method are:

- Single file concept. The complete building model and all of its representations are included in the single file;
- Real architectural elements used for modeling;
- Changes to the model affect all related drawings (and vice versa);
- Automatic generation and updating of documentation;

- Architectural content (design libraries); and
- Building information data attached to the elements.

The BIM model serves as a central database, by assembling all information into one location and cross-linking that data among associated objects. All documents within the BIM model are interdependent and share intelligence. A change anywhere in the BIM model is propagated throughout all relevant views and documents for the project.

The BIM application has an intelligent understanding of the fact that objects created by users represent real-world components of building such as windows, walls, doors and roofs. Thus, BIM objects have characteristics similar to their real-world counterparts such as windows can only exist in a wall and walls always have a thickness attribute. Use of such intelligent objects distinguishes the geometry created by BIM from a 3D model.

2.3: Key Advantages of the BIM Concept

BIM provides a platform for sharing knowledge and enhance communication between project participants. Using BIM-based visualization, project concepts can be visualized quite early in the project life-cycle. Conventionally a lot of time and effort is wasted along the interfaces of various design disciplines, as a lot of information is reproduced and validated along those interfaces.

BIM Models are developed to cater information needs of various disciplines and integrated together to form a parametric relationship for viewing, data sharing and coordination of design of the facility as a whole. Thus, a coordinated relationship is established between design and information from various disciplines, incorporating all the project details. Unlike conventional 2D drawings, coordinated BIM models consist of connected drawings detailing design elements and specification information. Such co-ordination allows for validation of design and co-ordination issues.

Clashes in designs from various disciplines can be identified quite early in the life-cycle, allowing for conflict resolution prior to things going wrong during construction.

A study undertaken by Stanford University Center for Integrated Facilities Engineering (CIFE) based on 32 major projects that have used BIM indicates the benefits that can be gained, as shown in Figure 4 (Kunz & Gilligan, 2007).

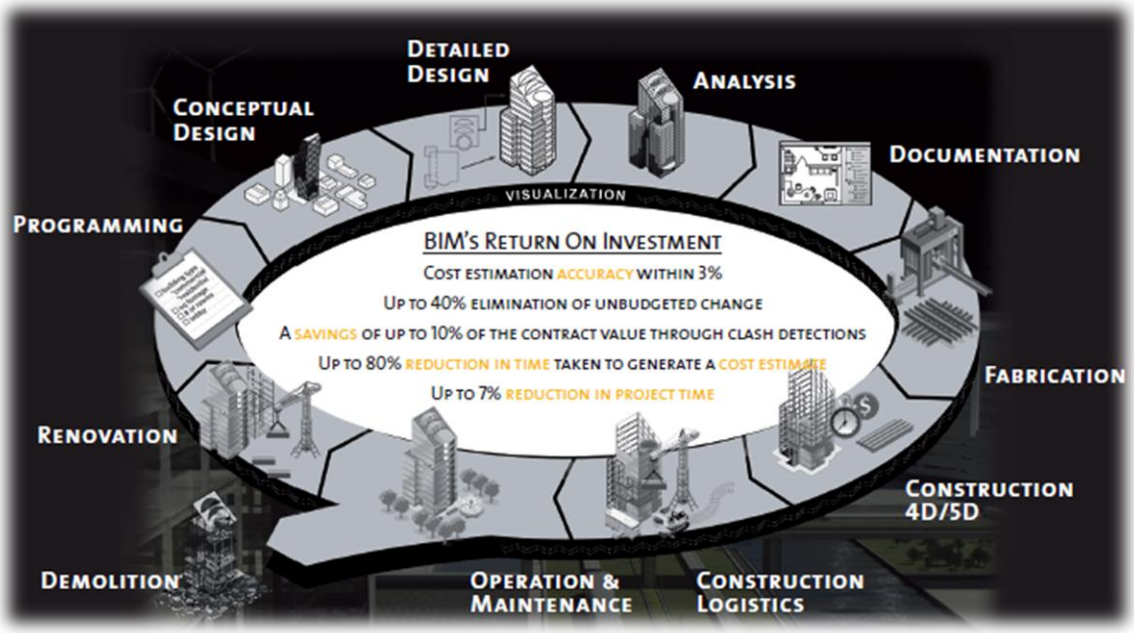


Figure 4: BIM Benefits Study by CIFE

A summary of the benefits of BIM to the project stakeholders can be seen in Table 1 below (Azhar *et al.*, 2012).

Table 1: BIM Applications for Project Stakeholders

BIM Application	Clients	Consultants	Contractors	Facility Managers
Visualization	x	x	x	x
Options Analysis	x	x	x	
Sustainability Analyses	x	x		
Quantity Survey		x	x	
Cost Estimation	x	x	x	
Site Logistics	x		x	
Phasing and 4D Scheduling		x	x	
Constructability Analysis		x	x	
Building Performance Analysis	x	x	x	x
Building Management	x			x

A study also was conducted at UAE in 2013 by a BIM Consultant (IEC) to investigate the impact of BIM and IPD, from a client perspective, on a large scale construction project which is procured on a conventional approach, i.e. design-bid-build. It was found that the estimated total cost impact by these three factors; BIM, IPD and Client Leadership Role, is about 39.5% of the estimated total cost of the project. This result is very much in line with the "*Investors Report"* (BIM Task Group, 2012) which proposed that there is a potential of 40% saving if BIM is used at the "tender" and the "construction" stages through (as shown in Figure 5):

a. The coordination of the contractor design information; and

b. The delivery of coordinate information to the construction team and the use of 4D (construction simulation) which offers clear understanding to package contractors.

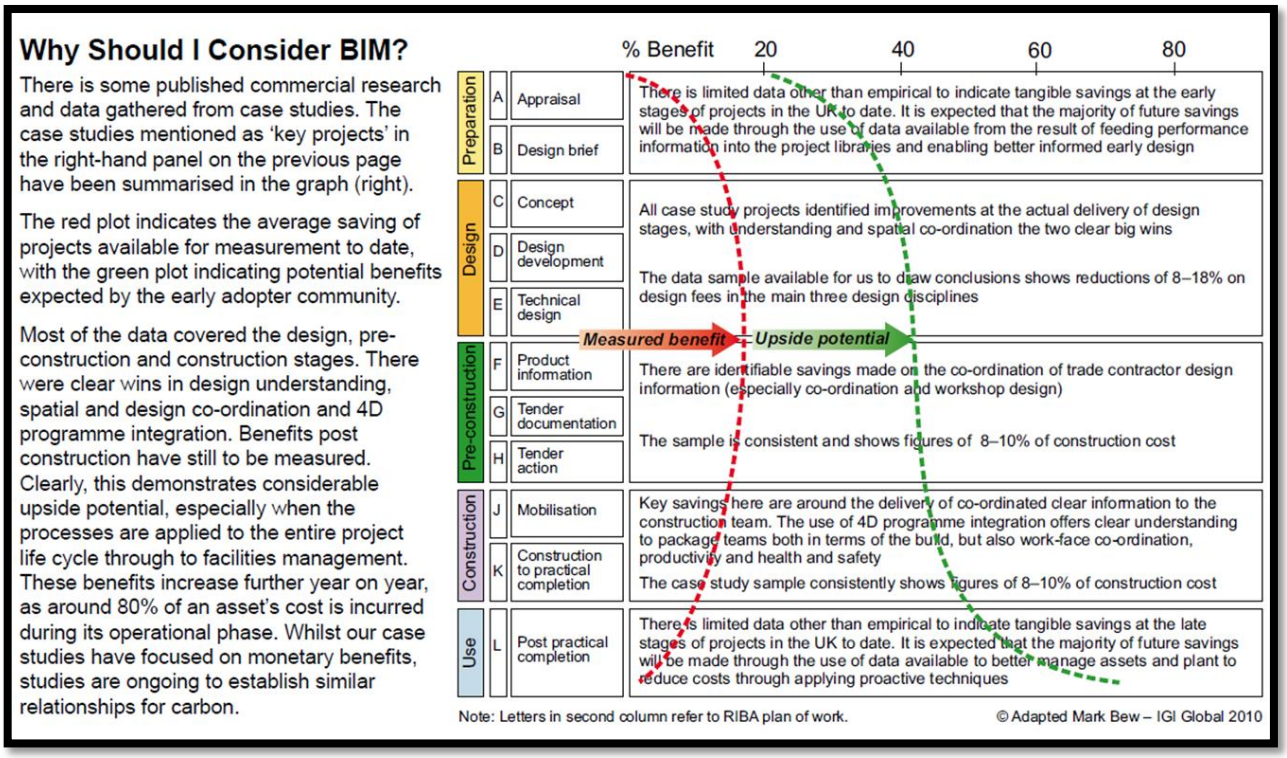


Figure 5: The investors report, UK (BIM Task Group, 2012)

2.4: Lessons Learned from IEC Case Study

The study conducted by IEC on local UAE construction industry project has identified three main factors that could have played a significant role in avoiding similar problems in the future. These are:

1) **The Client Leadership:**

It is quite evident that this role has to be exercised effectively in order to maximize benefits to client organisations. As in any construction project

which is constructed under a conventional procurement, each party (being a consultant, contractors or subcontractors) will be mainly looking after their own interest and avoiding taking any risk which might jeopardize their contractual agreement with the client.

Clients need to take a leading role in creating a collaborative environment where project partners can share experience and exchange project information for the interest of the project. In addition, the client needs to enforce clear quality assurance and quality control procedures to ensure that project partners deliver the best service to the client.

This has clearly demonstrated in the lack of clear "client brief" and "quality control procedures" which are essential to ensure that clients' requirements are met at all time during the design process as well as at the construction process.

2) Collaborative Environment:

The lack of collaborative environment is reflected in almost all of the identified delays. Such an environment could have played a significant role in the production of an effective design in line with the local culture and environment, the impact of which would have been fewer clashes with contractors' ability to construct the project and meeting material specifications required by the consultants.

Secondly, the collaborative environment would have led to the production of a fully coordinated design's amendments which was imposed during the construction stage with minimum impact on (a) existing construction and structures; (b) specified equipment and building systems; (c) materials delivered to site; and (d) site interruptions.

Currently there is no "best practice" of how best to create a collaborative environment based on shared risks and benefits. This is an area which required immediate attention from both academia and industry.

3) BIM Deployment

High level of collaboration can be facilitated by making relevant project information accessible to all project partners as and when required so that they can evaluate the impact of their solutions/decision on the project quality and performance.

With strong leadership and management, BIM can provide the platform within which alternative design solutions can be quickly and easily evaluated for the best interest of the client; being energy or construction simulation, initial and detail costing, return on investment, accurate quantities, list of building elements, etc.

Summary

- BIM which is a digital representation of the project (geometric and non-geometric information) and provide a model based mechanism to manage all building related data and information in a particular project in a shared repository;
- BIM used a single file concept and serves as a central database, by assembling all information into one location;
- BIM models consist of connected drawings detailing design elements and specification information. Such co-ordination allows for validation of design and co-ordination issues; and
- Clashed or conflicts in designs from various disciplines can be identified quite early in the project life-cycle, allowing for conflict resolution prior to construction.

Section Break – Questions

1. What are the key advantages of BIM over 3D CAD systems?
2. How can the construction participants use BIM as a communication platform during the design and construction phase of a building?
3. How BIM can be used to resolve clashes and conflicts during design development?
4. What are the possible benefits that can be gained by using BIM in the project development?

SECTION 3: BIM IMPLEMENTATION

Section 2 introduced BIM concept and the different between BIM and conventional CAD systems. The benefits and advantages of using BIM are also discussed. This section reviews key steps that need to be taken to effectively plan and implement BIM in construction projects. Issues for using a single shared digital model for information sharing and the need for project integration BIM model are highlighted.

3.1: The Approaches

BIM has been highlighted as a single file/model concept where single BIM model serves as a source of a single information repository. All building related information, including geometry and all sort of alpha numeric data is derived from the building model. The perception was that all of the building related information would be contained in a single information repository on a secure web server accessible to any party who might need to query, add to or remove information from the model at any time in the project life-cycle.

However, application of such a single model concept in a real-world construction project poses a number of business challenges including: (Smith & Tardif, 2012)

- Who owns the shared project information model?
- Who pays for the development of the single model and for data storage and access infrastructure?
- Who is responsible for maintaining the information in the shared model and ensuring data reliability, security and integrity?
- Who has the responsibility of accuracy of the information model?
- Who will be accountable and responsible for any errors and omissions?
- How liability is shared amongst various project stakeholders?

There are numerous challenges in implementation of a single model for all disciplines containing every possible piece of data and information. Each discipline has the awareness that they require their own information model to fulfill their contractual obligations. Each of these discipline specific models need to be fed into the central project shared working area, often referred to as “Project Integration BIM Model” (Figure 6).

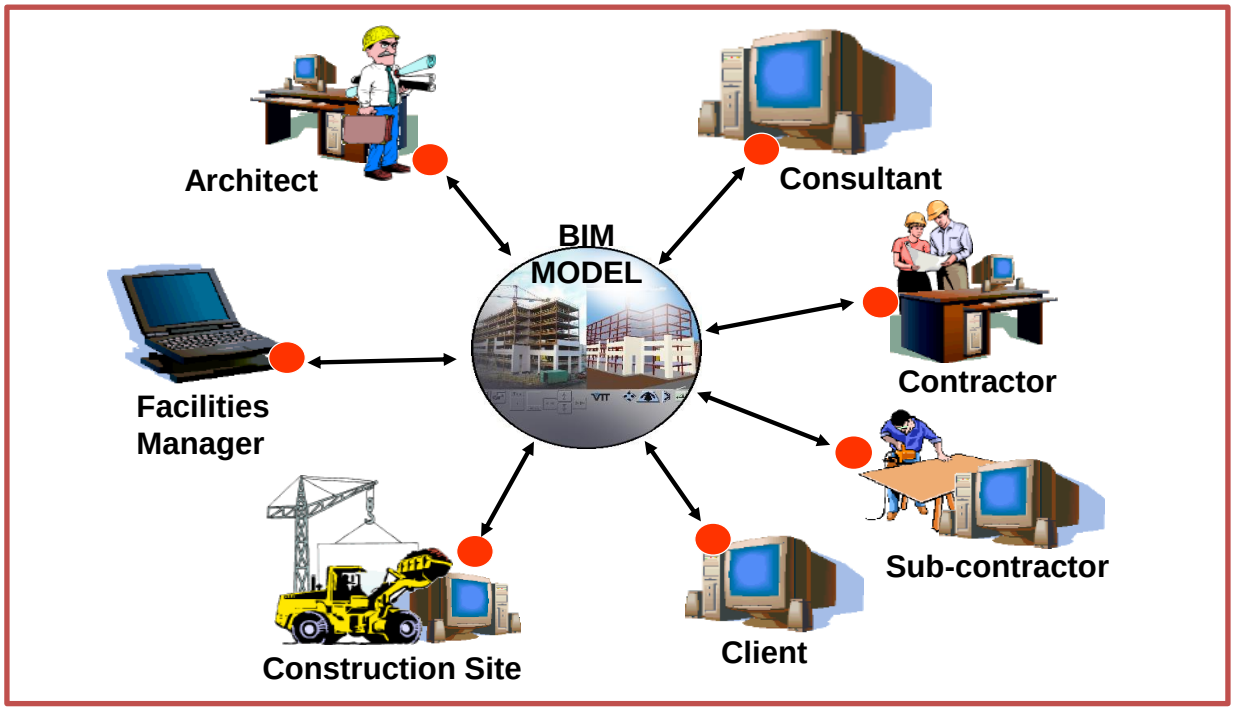


Figure 6: Project integration BIM model

3.2: The Planning

In order to ensure that each discipline will feed their information to the "Project Integration BIM Model", an adequate BIM planning is needed prior to its implementation in a project. The scope of the BIM implementation needs to be clearly defined. Some of the key factors that need to be considered prior to BIM implementation include:

- Number of different models required in a project and interoperability between multiple models and tools. It is important to ensure that BIM models from various disciplines (e.g. Architectural, Structural, and MEP) are clash free;
- Central to BIM concept is Information Sharing. It is important to determine at the project outset what information is necessary, potential users of the information, how it is collected and how it will be incorporated in the building model and used both upstream and downstream;
- Roles and responsibilities for developing, updating and maintaining the building model;
- Goals for productivity improvements as a result of using BIM;
- Standardization of communication methods and Information sharing protocols between multiple participants;
- Use of different BIM authoring, review and analysis tools;

- Contractual and liability issues related to the use of BIM in a project; and
- Control of project cost, schedule, scope and quality using BIM.

Organizations adopting emerging or new technologies such as BIM will face many significant issues. These include costs versus benefits, reliability and maturity of technology, resource availability, stakeholder "buy-in", schedule impact, and introduction of uncertainty. For such changes, it is important to identify champions within the organization, typically from senior management, who could provide necessary encouragement and support during the change process.

At least one representative from each stakeholder organization involved should be identified including the client, design consultants, main contractors, sub-contractors, manufacturers, and suppliers. These representatives could include personnel such as Project Managers, BIM Managers, Discipline Leads, Superintendents and other major project roles.

It is important to clearly define goals and objectives across organizations and teams with regards to purpose of using BIM.

3.3: BIM Software and Application

There are a number of BIM software and application currently available in the market. The selection of BIM software and applications are very subjective matter. There is no standard to select BIM software, and most BIM users depend on their own insight and market share of the software (i.e., they select the best-selling program). However, a study by Khemlani (2007) provided 14 important factors to identify when selecting a BIM software application as follow:

1. How well a software application currently supports a function of interest;
2. Are there known successful BIM cases for the software application?
3. How interoperable a software application is with other applications;
4. Expected economic impact (return on investment);
5. The scalability of the software (how large of a building can a software handle?);
6. Are major subcontractors or business partners currently using the software?
7. Easiness to model and add new libraries;
8. How well do current employees use the software application?
9. Is the use of the software application required by contract?

10. Learning curve to use the new BIM tool;
11. Is the software application already in use in several departments?
12. Initial investment costs, including hardware, software, and training
13. The possibility of obtaining a targeted function in the near future in association with a software vendor's long-term strategy; and
14. How good content libraries are.

Example of BIM software use in different applications is shown in Figure 7.

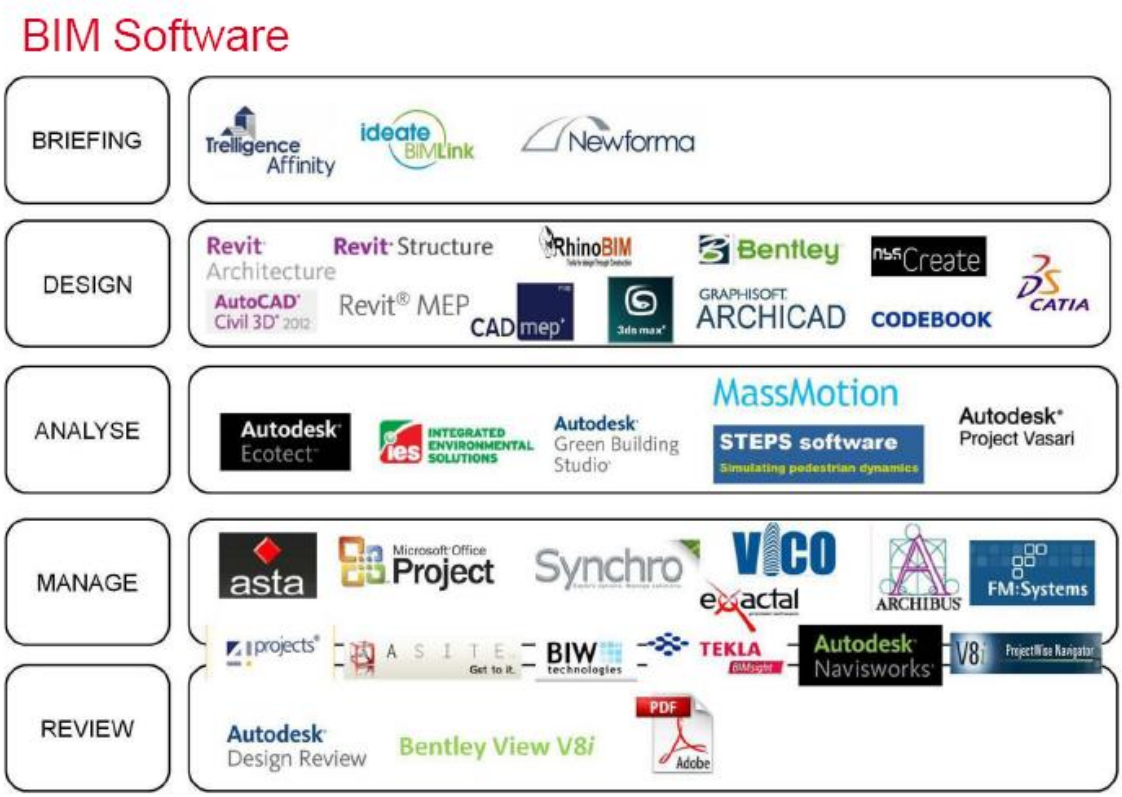


Figure 7: Example of BIM software

3.4: BIM Execution Plan

At early stage, the scope of BIM implementation need to clearly defined. Later, an execution plan needs to be developed to carry out the project. The BIM Execution Plan should define all BIM-related aspects that will be applied to the project (including the objectives, activities, data and design protocols). These, typically comprising the following components:

- Executive summary;
- Introduction;
- Project Information;

- Key Project Contacts;
- Project Goals, BIM Uses and Capabilities;
- Roles and Responsibilities;
- BIM Process Design;
- Model Element LOD and Responsibility Worksheet;
- Facility and Asset Management Requirements;
- Collaboration Procedures;
- Quality Control;
- Technological Infrastructure Needs;
- Model Standards and Guidelines;
- Delivery Strategy Agreement; and
- Appendices.

The detail of the templates in use by different organizations will vary such as how the information will be exchanged between project team members and requirements of different BIM based deliverables at different stages in the project life-cycle. However, their purpose and overall structure are likely to be similar to that described above.

3.5: Level of Detail and Level of Development (LOD)

The concept of LOD was developed by Vicosoftware (now part of Trimble) in 2004, a software company that produces construction costing software. They saw the advantages of costing straight from a BIM model, but had a problem. How do you tell how accurate, or how definitive, the model elements you are connecting to in the model are? Conventional methods of costing have a human between what was being measured and the way it was being measured. But automatic take off from the BIM model doesn't. They developed the concept they call "Level of Detail".

Later the AIA (American Institute of Architects) decided that this system would be a good one to apply to all uses of a BIM model, from energy analysis to 5D programming. They sensibly renamed it "Level of Development" because "Level of Detail" could get confused with the amount of information, rather than the decisiveness of the information. Although both still have an acronym of LOD so the two continue get confused.

In 2013, the BIMForum published the Level of Development Specification based on the AIA protocols. It is a reference that enables practitioners in the AEC Industry to specify and articulate with a high degree of clarity the content and reliability of Building Information Models (BIMs) at various stages in the design and construction process. These documents then became the point of reference of several BIM Guidelines and documents in a number of countries – including Australia, Canada, Singapore, China, Taiwan, Germany and France. Other countries developed their own variant specification. For example, in New Zealand, the LOD specification follows the AIA (2013) but defines 'Level of Development' (LOD) as a sum of four different aspects: 'Level of detail' (LOd), 'Level of accuracy' (LOa), 'Level of information' (LOi) and 'Level of coordination' (LOc)

3.5.1 What is Level of Development?

LOD, as in "Level of Development", is a measure of how seriously you take the information represented by a BIM element. It is not necessarily a measure of the amount of information, although obviously there must be enough information to satisfy the LOD level it is at. It is also not a measure of the amount or accuracy of graphical information. The appearance of a BIM element is only one piece of information about that object, and usually the least important. A contractor doesn't need to know what a desk looks like to order it, nor to place it in the building. But they do need to know what the manufacturer and model number is. Others may need to know its dimensions to coordinate with things around it, but they too do not necessarily need to know what it exactly looks like.

Therefore LOD levels for a chair might go:

LOD 100 = there is a chair
LOD 200 = there is a chair that has nominal space requirement of 500x500
LOD 300 = there is a chair with arm rests and wheels
LOD 400 = manufacturer and model number.
LOD 500 = manufacturer and model number, supplier, date purchased

or in general terms:

LOD 100 = there is a thing
LOD 200 = there is a thing about this size
LOD 300 = there is a thing with these functions and options
LOD 400 = it is this particular thing.
LOD 500 = this particular thing provided by this person on this date.

The purpose of an LOD table is that it tells others what information they CAN USE. To put it another way, it is a measure of the certainty, or confidence, of that

information. So even if a chair in the model contains information that would satisfy LOD 400, only the portion of that information that satisfies LOD 100 can be relied upon with any certainty. This means a chair family from a manufacturer could be used at LOD 100, but everyone knows (by referring to the LOD table) that this particular chair is not necessarily the one that will be actually used. Refer Figure 8.

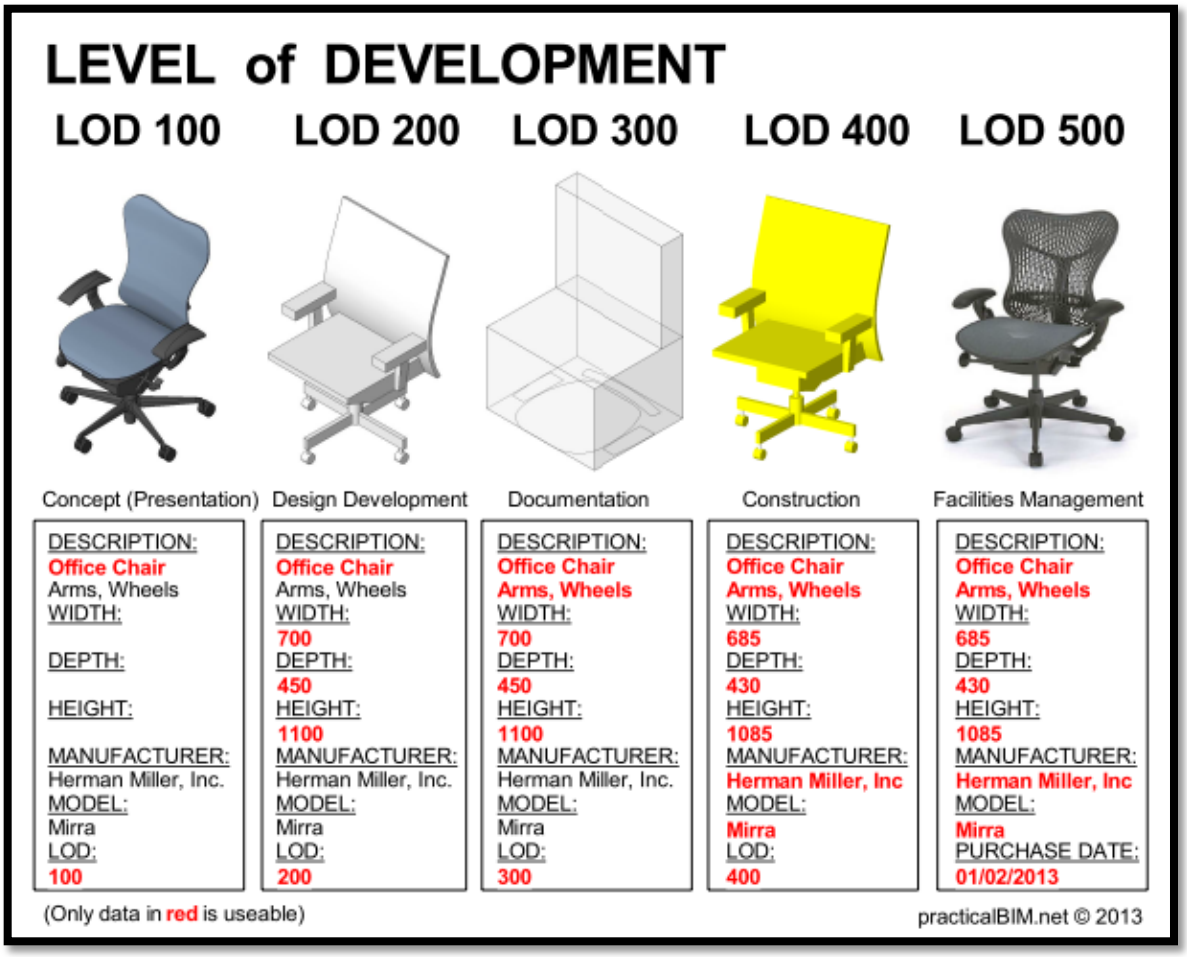


Figure 8: Level of Development

LOD is also a measure of progress. At LOD 100 there is obviously more work to do to reach LOD 300. In that sense it is like the traditional percentage complete of drawings. Assuming LOD 500 is 100%, then LOD 100 = 20%, LOD 200 = 40%, LOD 300 = 60% etc. except LOD contains more information. It tells you how decisive each element is, not just how complete its representation is on a drawing. It is more useful to know that on a plan the floor is 60% complete (LOD 300), the walls are 50% complete (LOD 250) and the service ducts are 40% complete (LOD 200), rather than the whole drawing is 50% complete (the average of all elements).

3.5.2 What is Level of Detail?

Level of Detail is a measure of the amount of information provided. Because it is only a measure of quantity, the underlying assumption is that all provided information is relevant to the project and so can be relied upon with certainty.

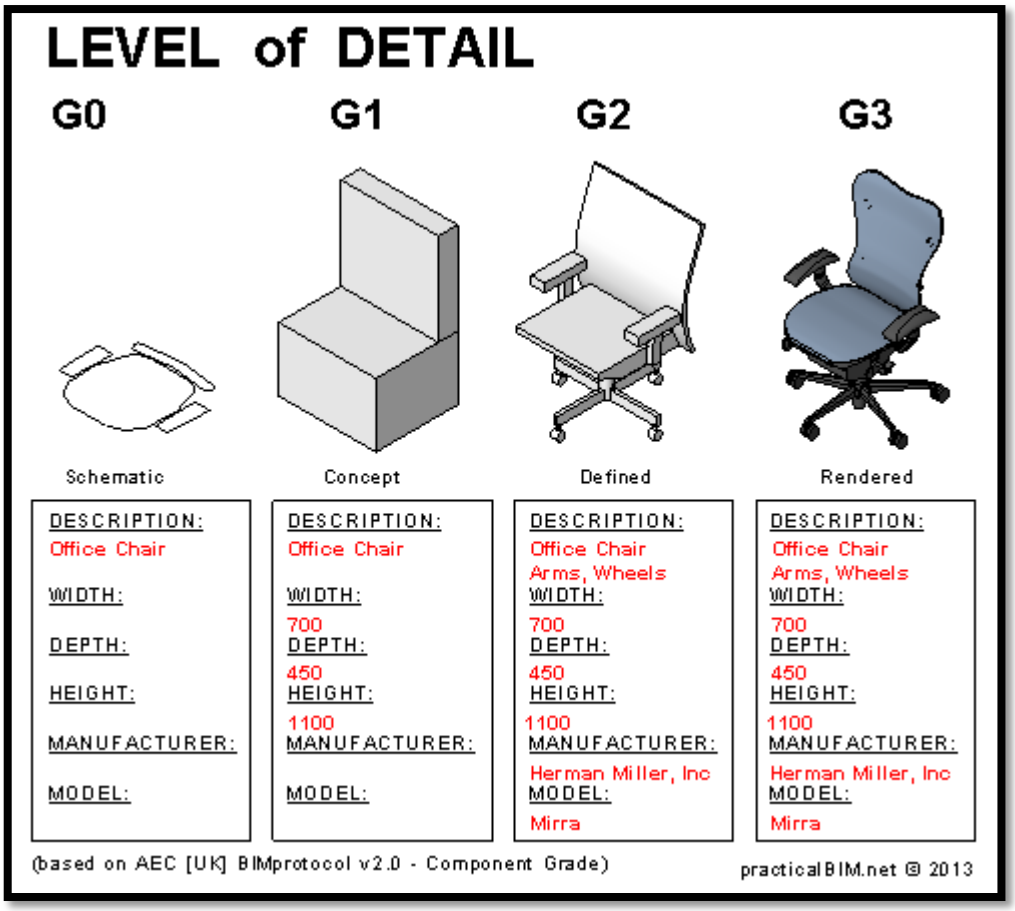


Figure 9: Level of Detail

Because of the confusion between the two LODs, most BIM guides and plans use other terminology for Level of Detail. For example, AEC (UK) BIM Protocol uses "Graded Component Creation" as shown in Figure 9 above which detail as follow:

- G0 - Schematic
- G1 - Concept
- G2 - Defined
- G3 - Rendered

The AEC (UK) grades include 'Rendered' which is purely graphical, which seems to suggest it is a measure of graphical detail only.

3.6: BIM Visualization

Building Information Modeling (BIM) has changed how architects and engineers design, build and manage buildings and infrastructure. This model-based process uses digital representations of a project in order to document its design and construction. The scope of the final document depends on the amount of information that is included. Most BIM visualizations are done as a 3D model, but the layers are added.

The BIM-enabled project may also contain different layers of information which are described as 2D, 3D, 4D, 5D, 6D and 7D as shown in Figure 10. 2D BIM represents the ubiquitous CAD (computer-aided design), with 4D, 5D and 6D representing respectively the addition of time, cost, post-delivery facilities management and end of use demolition and recycling.

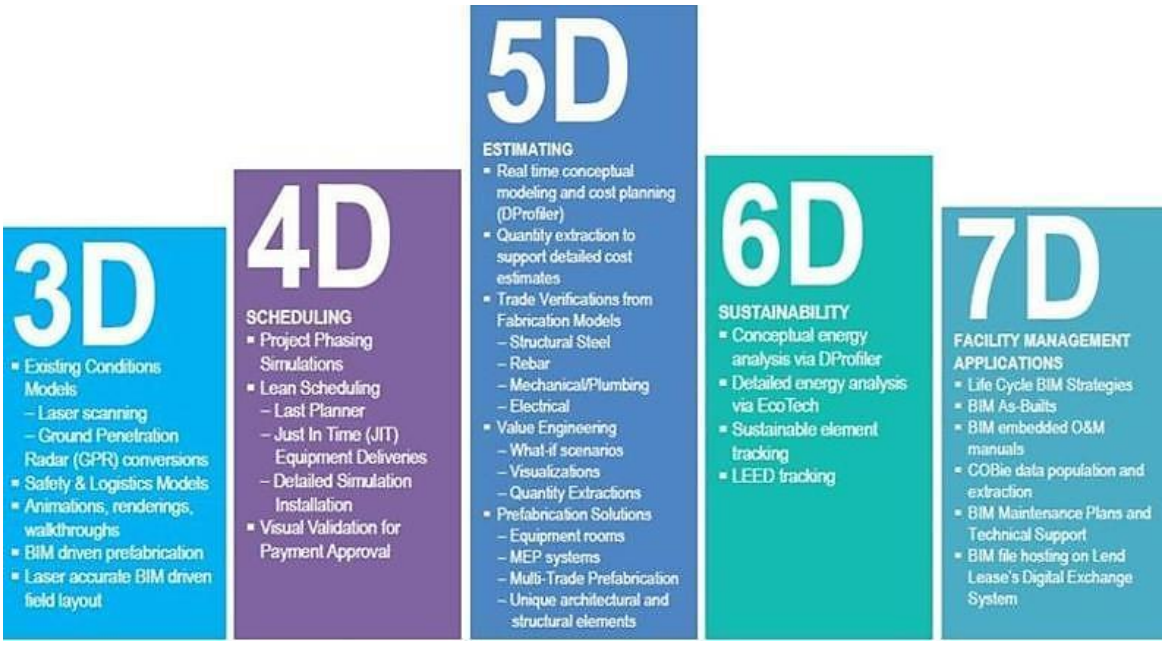


Figure 10: Different Layers of BIM Model

Brief explanations of BIM 3D, 4D, 5D, 6D and 7D models are as follow:-

BIM 3D – PARAMETRIC DATA IN A COLLABORATIVE MODEL

BIM revolves around an integrated data model from which various stakeholders such as Architects, Civil Engineers, Structural Engineers, MEP System Engineers, Builders, Manufacturers and Project Owners can extract and generate views and information according to their needs. 3D BIM's visualizations capabilities enables participants to not only see the building in three dimensions before ground is ever broken, but also to automatically update these views along the project life cycle, from earliest conception to demolition. BIM 3D helps participants to manage their multidisciplinary collaboration more effectively in

modelling and analysing complex spatial and structural problems. Furthermore because accurate data can be collected along the project life cycle, and stored in the Building Information Model, new value can be added to predictive models allowing resolving issues proactively.

Benefits

- Improved visualization of the project, communication of design intent
- Improved multidisciplinary collaboration
- Reduced rework

4D CAD – SCHEDULING

4D-BIM (four-dimensional building information modelling) is used for construction site planning related activities. The fourth dimension of BIM allows participants to extract and visualize the progress of their activities through the lifetime of the project.

The utilization of 4D-BIM technology can result in improved control over conflict detection or over the complexity of changes occurring during the course of a construction project. 4D BIM provides methods for managing and visualizing site status information, change impacts as well as supporting communication in various situations such as informing site staff or warning about risks.

Benefits

- Integrating BIM with 4D CAD simulation models bring benefits to participants in terms of planning optimization.
- Builders and manufacturers can optimize their construction activities and team coordination.

5D CAD – ESTIMATING

5D-BIM (fifth-dimensional building information modelling) is used for budget tracking and cost analysis related activities. The fifth dimension of BIM associated with 3D and 4D (Time) allows participants to visualize the progress of their activities and related costs over time.

The utilization of 5D-BIM technology can result in a greater accuracy and predictability of project's estimates, scope changes and materials, equipment or manpower changes. 5D BIM provides methods for extracting and analysing costs, evaluating scenarios and changes impacts.

Benefits

- Integrating BIM with 5D CAD simulation models enables the development of more efficient, cost-effective and sustainable constructions.

6D CAD – SUSTAINABILITY

6D-BIM (sixth-dimensional building information modelling) helps perform energy consumption analyses.

The utilization of 6D-BIM technology can result in more complete and accurate energy estimates earlier in the design process. It also allows for measurement and verification during building occupation, and improved processes for gathering lessons learned in high performance facilities.

Benefits

- Integrating BIM with 6D CAD simulation models leads to an overall reduction in energy consumption.

7D CAD – FACILITY MANAGEMENT

7D-BIM (seventh-dimensional building information modelling) is used by managers in the operation and maintenance of the facility throughout its life cycle. The seventh dimension of BIM allows participants to extract and track relevant asset data such as component status, specifications, maintenance/operation manuals, warranty data etc.

The utilization of 7D-BIM technology can result in easier and quicker parts replacements, optimized compliance and a streamlined asset life cycle management over time. 7D BIM provides processes for managing subcontractor/supplier data and facility component through the entire facility life cycle.

Benefits

- Integrating BIM with 7D CAD simulation models optimizes asset management from design to demolition.

3.7: Barriers to BIM Implementation

Besides the numerous benefits of BIM for project stakeholders there are also many risks and barriers its execution. BIM is a relatively new approach that is yet to be adopted widely across the construction industry. BIM related risks are divided into two broad categories: (i) Technology-related risks; and (ii) Process-related risks. The following presents brief discussions on each of these categories.

i. Technology-related Risks

The first technology-related risk is the lack of wide spread BIM standards for model integration and management by multidisciplinary teams. Integrating multidisciplinary information into a single BIM model requires multi-user access to the BIM model. This requires the establishment of protocols in the project planning phase to ensure consistency in information context and formatting styles. Due to the lack of comprehensive standard protocols, each firm attempts to adopt its own "standards". This could create inconsistencies in the model, which if not properly detected, could lead to an inaccurate and inconsistent BIM model.

The "immaturity" of software, particularly in terms of data exchange and inter-operability issues, still poses a considerable risk. Inter-operability is the ability to exchange data between applications to facilitate automation and avoidance of data re-entry. Inter-operability is also 'the ability of two or more systems or components to exchange information and to use the information that has been exchanged'. As there is no single piece of software that can carry out all tasks throughout the construction process, the need for good inter-operability is essential due to the large number of data exchanges required. Inter-operability is a major issue and international efforts have been mounted to establish exchange formats to address it.

ii. Process-related Risks

The process-related risks include legal, contractual and organizational risks. Firstly, there is a lack of determination of ownership of BIM data and the need to protect it through copyright laws and other legal channels.

Another contractual issue is who will control the entry of data into the model, and be responsible for any inaccuracies. Taking responsibility for updating building information model data and ensuring its accuracy entails a great deal of risk.

Requests for complicated indemnities by BIM users and the offer of limited warranties and disclaimers of liability by designers are essential negotiation points that need to be resolved before BIM technology is used.

Studies by Ashcraft (2008), Davidson (2009) and the BIM Industry Working Group (2011) asserted that due to the large number of companies and stakeholders involved in a construction project, BIM introduces unique issues of responsibility and ownership of building models and intellectual property rights. As the building model is transferred between each stakeholder, it needs to be clear who is responsible for ensuring the model is accurate and up to date. Standard forms of a building contract – including design and consultant appointments – do not currently make specific provision for BIM. The implications for design liability and associated insurance arrangements of the greater integration of design, construction and operation information envisaged under BIM have not yet been fully addressed (Langdon, 2012).

A number of obstacles facing the wider adoption of BIM also been identified. Key impediments to the widespread adoption of BIM that were identified are as follows:

- Procurement, legal issues and insurance;
- Adoption of common BIM guidelines and information exchanges;
- Multi-disciplinary BIM education;
- Product information and BIM libraries;
- Business process change; and
- Compliance and certification.

3.8: Defining Roles and Responsibilities

The roles and responsibilities of parties involved in the development of a BIM process are no different from those of involved in conventional delivery processes. The main difference is in the effort required by the team members to produce, manage, and deliver more detailed, precise, and accurate information.

At the start of a project, it is important to identify the roles and responsibilities of the design team and of specialist subcontractors who have design content in their work packages. It is also necessary to define the roles and responsibilities of individual team members as well as the schedule of responsibilities for deliverables of the overall team with the important factors a being ownership, responsibility and authority.

i. Consultants:

The consultants consist of a group of designers including architects as well as structural and MEP engineers. A lead designer is responsible for coordinating the designs of the various disciplines, checking their information as it is produced and generally ensuring that design work is coordinated.

Consultants (both design and pre-construction) should be bound by metrics established in the BIM execution plan and monitored closely to avoid unexpected cost overruns or delays due to indecisiveness about design changes.

ii. Contractors and Sub-Contractors:

Conventionally, contractors deal with all problems, of varying levels of difficulty, which arise at any stage of the design and construction process. The conventional design-bid-build approach limits the contractor's ability to contribute their knowledge to the project during the design phase, when they can add significant value.

However, to makes the best use of BIM as a collaborative tool, a joint contract requires the architect, designers, contractor and sub-contractors to work together from the start of a project.

iii. Clients:

Client teams will evolve to include more advisors who can add specific value to the design, construction and in-use process in order to ensure the success of BIM on each project.

To ensure that projects start on the right path, it is likely that the client representative and their advisors (or a third party) will prepare a delivery plan at the commencement of the project. This would be the primary plan for setting out how project information is to be prepared, who does so, and what protocols and procedures to use. The document would be owned by the client but may be updated and managed using change control as the supply chain procedures and protocols are expanded and agreed.

Summary

- Numerous challenges in achieving the collaboration among disciplines can be resolved by using Project integration BIM model which is used as a single model for all disciplines containing every possible piece of data and information;
- A few factors need to be considered prior to BIM implementation including role and responsibilities, standardization and communication protocols, BIM authoring tools, contractual and liability issues;
- New roles and responsibilities of parties involved in the development of a BIM process need to be clear defined; and
- BIM related risks are categorized by technology-related and process-related risks.

Section Break – Questions

1. What challenges can be encountered in application of a single BIM model concept in a real-world construction project?
2. What are the main criteria for selecting the right BIM software application?
3. What are the main barriers for BIM implementation?
4. What is the difference between Level of Detail and Level of Development?
5. What is the importance of LOD?
6. Define the advantages of BIM using 3D, 4D, 5D, 6D and 7D.
7. What are your main roles and responsibilities when implementing BIM?

SECTION 4: COLLABORATION

Section 2 and 3 discussed the introduction of BIM and how it can be implemented within the organization. One key competitive advantage of BIM is its ability to promote greater transparency and collaboration. A key driver of the rapid adoption of BIM by clients and industry is that its benefits are shared by the client and the entire supply chain – with downstream benefits to customers who make use of built assets and, even further, to society at large.

Designing, building and managing a building is a highly complex process that requires smooth communication and collaboration among all members of the project team.

Collaboration requires replacing conventional processes with a culture of sharing to achieve common goals such as cost effectiveness, improved efficiency and greater quality and innovation while still satisfying the individual's expectations of each partner.

Advanced BIM applications offer integrated data communication and data sharing solutions for all project stakeholders. It is only such advanced data-sharing technology which will enable effective enough communication to support this collaborative approach.

4.1: BIM and Collaborative Environment

Effective deployment of BIM requires project stakeholders to work together from the early stages of the project to ensure the delivery of a fully integrated and evaluated design. This requires high collaboration levels which can only be achieved by implementing and managing collaborative relationships among project stakeholders.

The power of collaborative BIM goes beyond improving efficiency. Sustainability, perhaps the most important challenge for the design and construction community, is at the intersection of BIM and collaborative project delivery, drawing strength from both. BIM provides the tools for iteratively analysing and optimizing design. Whilst collaboration provides the content and the creativity that empowers the tools.

In 2007, American Institute of Architecture (AIA) has introduced Integrated Project Delivery (IPD) which 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" (AIA, 2007a).

Although IPD is a new type of procurement, IPD principles can be applied to a variety of contractual arrangements and IPD teams can include members well beyond the basic triad of clients, architects and contractors. A basic principle of IPD is the reliance on knowledge integration. Given that IPD encompasses highly collaborative processes that rely on the collective expertise of the project stakeholders (including designers, contractors, subcontractors, and clients).

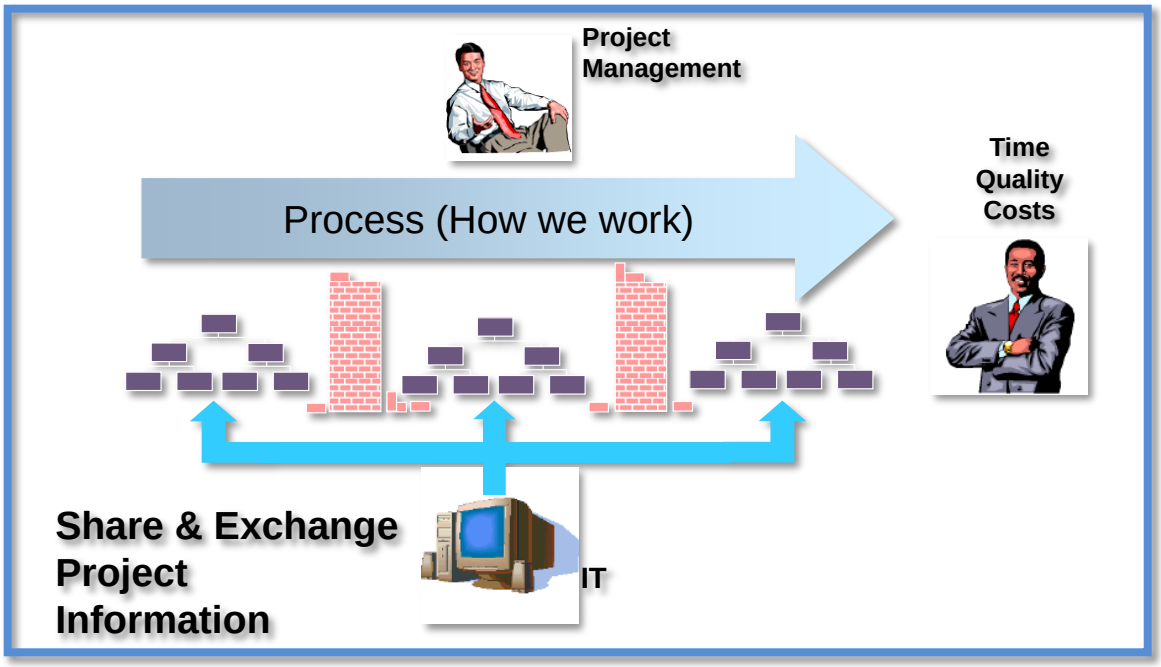


Figure 11: Integrated Project Delivery

The first three phases of the integrated project: conceptualization, criteria design, and detailed design involve more effort than their counterparts in the conventional flow. The result is that the project is defined and coordinated to a much higher level prior to the construction's start than is typical with conventional delivery methods, enabling a more efficient construction phase and a potentially shorter construction period.

Table 2 shows a comparison between Conventional Project Delivery methods and IPD ones. In practice, integrated project delivery exhibits fundamental differences from conventional models in two primary areas: team assembly and project phasing/execution.

Table 2: Conventional Project Delivery Methods vs IPD

Factor	Conventional Project Delivery	Integrated Project Delivery
Teams	Fragmented, assembled on a "just-as-needed" or "minimum-necessary" basis, strongly hierarchical and controlled	An integrated team entity composed of key project stakeholders, assembled early in the process, open and collaborative
Process	Linear, distinct, segregated; knowledge gathered "just-as-needed" information hoarded; silos of knowledge and expertise	Concurrent and multi-level; early contributions of knowledge and expertise; information openly shared; stakeholder trust and respect
Risks	Individually managed, transferred to the greatest extent possible	Collectively managed, appropriately shared
Compensation/ Reward	Individually pursued; minimum effort for maximum return; (usually) first-cost based	Team success tied to project success; value-based
Communications/ Technology	Paper-based, 2 dimensional; analog	Digitally based, virtual; Building Information Modelling (3, 4 and 5 dimensional)
Agreements	Encourage unilateral effort; allocate and transfer risk; no sharing	Encourage, foster, promote and support multi-lateral open sharing and collaboration; risk sharing

4.2: The Advantages of IPD

IPD provides positive value propositions for the three major project stakeholders (AIA, 2007b):

i. **Clients**

a. Early and open sharing of project knowledge streamlines project communications and allows clients to effectively meet their business enterprise goals.

b. Strengthens the project team's understanding of the client's desired outcomes, thus improving the team's ability to control costs and manage the budget.

ii. Contractors

a. IPD allows contractors to contribute their expertise in construction techniques early in the design process resulting in improved project quality and financial performance during the construction phase.

b. The contractor's participation during the design phase provides the opportunity for strong pre-construction planning, a more timely and informed understanding of the design, anticipation and resolution of design-related issues, and the visualization of construction sequencing prior to its start, and improving cost control and budget management.

iii. Consultants

a. Allows the designer to benefit from the early contribution of contractors' expertise during the design phase, such as accurate budget estimates to inform design decisions and the pre-construction resolution of design-related issues resulting in improved project quality and financial performance.

b. Increases the level of effort during early design phases, resulting in reduced documentation time, and improved cost control and budget management.

Patrick MacLeamy has produced a graph to show the impact of IPD on project life-cycle and shows how the IPD approach transforms the conventional phases of projects., well-known as the "MacLeamy Curve" as shown in Figure 12 (MacLeamy, 2004). It also demonstrates the idea of making design decisions earlier in the project when the occasion to influence positive outcomes is maximized and the cost of changes minimized. Some construction figures suggest that by spending 1% of design and build cost, 70% of your total budget is pre-determined.

The addition of early input from constructors, fabricators, installers, suppliers, and designers as well as the option to model and simulate the project using BIM tools enable the design to be brought to a much higher level of completion before the documentation phase is started (AIA, 2007a).

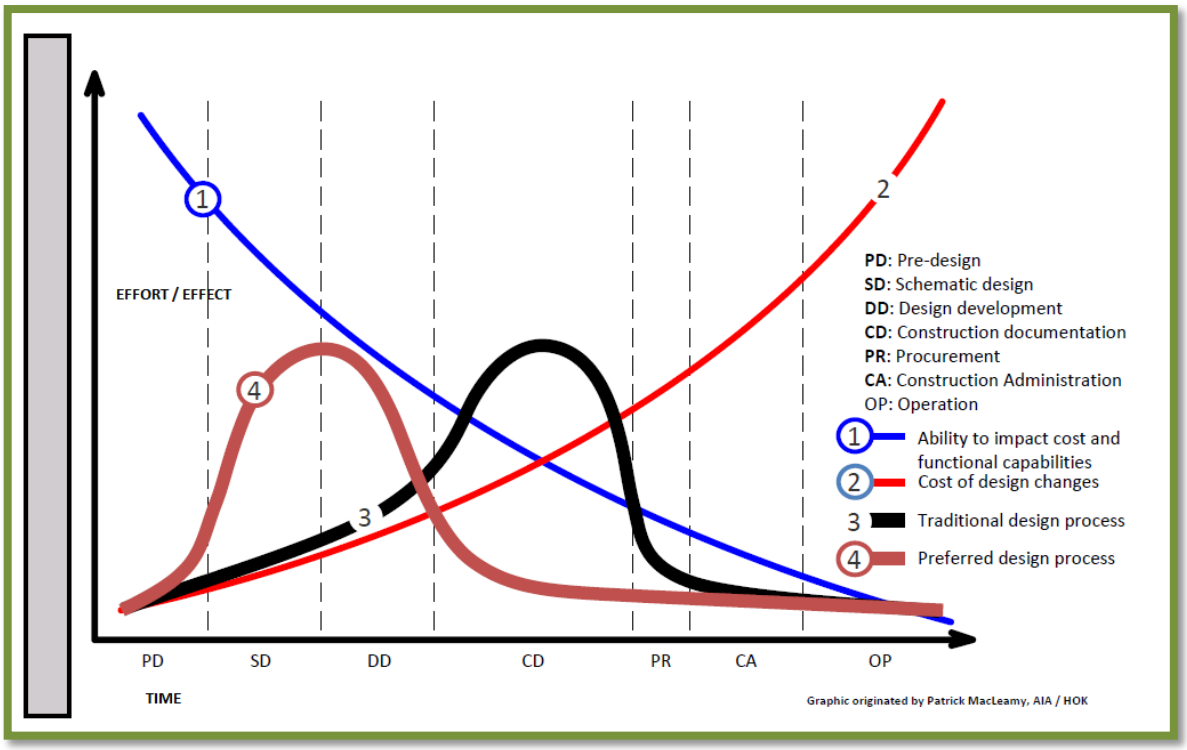


Figure 12: The "MacLeamy Curve" IPD impact on the project

4.3: Barriers to IPD Implementation

In conventional contracts each party has clear roles and responsibilities towards the achievement of its contractual agreement for the project. Whereas IPD's principles are based on full collaboration between the client, consultant, contractors, subcontractors and suppliers starting at the early design stages and continuing until the project handover. It highlights the importance of client leadership in establishing a framework for IPD implementation.

On the other hand, achieving a high level of collaboration requires sharing and "believing" in common objectives, which are to deliver the best service to the client. The most vital catalyst in achieving this aim is the ability to share risks and rewards. As IPD is generally a new concept, there is no clear or standard business model that should drive IPD contracts. Also, there is no typical definition for sharing risks and rewards. It is all to be led by clients. This, yet again, highlights the critical role of the clients in this process.

Trust is another essential factor which underpins successful collaboration between project stakeholders. Obtaining an optimal collaboration requires a transparent process, open information sharing, shared risk and reward, value-based decision-making and utilization of full technological capabilities and support. Each member's success will rely on the team, which is tied up in the success of the project. Client organizations can play a leading role in establishing

trust between the project stakeholders as being the ultimate owner and beneficiary.

Achieving the above is challenging and highly dependent on the maturity of project stakeholders, but most importantly on the maturity of Client organization. The more mature the latter originations are the greater likelihood of the selection of appropriate partners and the creation of effective contractual arrangements and collaborative environment based on trust and risk/reward sharing.

Summary

- Effective deployment of BIM requires project stakeholders to work together from the early stages of the project;
- Integrated Project Delivery (IPD) was introduced as a project delivery approach that integrates people, systems, business structures and practices into a process to reduce waste and optimize efficiency throughout project life-cycle;
- IPD provides many advantages to project stakeholders such as clients, consultants and contractors where all parties sit together and share their views and knowledge at the very early stage of project life-cycle; and
- People are the main issue that hindered the successful implementation of IPD in the project. Client leadership is an important factor in establishing a framework for IPD implementation.

Section Break – Questions

1. How BIM play a significant role in project stakeholder's collaboration?
2. What is the main difference between IPD and conventional project delivery?
3. What are the main advantages that can be gained when applying IPD in the project?
4. How current contractual issues can be resolved when applying IPD in the project?

REFERENCES

AIA. (2007a). *Integrated Project Delivery (IPD): A Guide*: The American Institute of Architectures.

AIA. (2007b). Integrated Project Delivery: A Working Definition (2 ed.).

Ashcraft, H. W. (2008). Building information modeling: a framework for collaboration. *Construction Law, 28*, 5.

Azhar, S.*, et al.* (2012). Building information modelling (BIM): now and beyond. *Australasian Journal of Construction Economics and Building, 12*(4), 15-28.

BIMForum (2013), Level of Development Specification for Building Information Models, Retrieved from http://www.bimforum.org/lod

BIM Industry Working Group. (2011). A Report for the Government Construction Client Group Building Information Modelling (BIM) Working Party Strategy Paper: Cabinet Office. Retrieved from http://www.bimtaskgroup.org/wp-content/uploads/2012/03/BIS-BIM-strategy-Report.pdf.

BIM Task Group. (2012). The Investors Report: British Standard Institution Group UK, Retrieved from: http://www.bimtaskgroup.org/wp-content/uploads/2012/03/InvestorsReport-BIM.pdf.

Davidson, A. R. (2009). A Study of the Deployment and Impact of Building Information Modelling Software in the Construction Industry *Student Papers*: Faculty of Engineering, University of Leeds, UK, Issue 1, Autumn.

Faridi, A. S., & El - Sayegh, S. M. (2006). Significant factors causing delay in the UAE construction industry. *Construction Management and Economics, 24*(11), 1167-1176.

Gibson, M. (2009). Changing to Compete. Review of Productivity and Skills in UK Engineering Construction. Submitted to the Secretary of State for Business *Department for Business, Innovation and Skills*.

Khemlani, L. (2007). Top criteria for BIM solutions: AECbytes survey results, AECbytes Special Report.

Kunz, J., & Gilligan, B. (2007). *Value from VDC/BIM Use: Survey Results-November 2007.* Paper presented at the Construction Users Roundtable (CURT) meeting November.

Langdon, D. (2012). Getting the Most Out of BIM - A Guide for Clients.

MacLeamy, P. (2004). The “MacLeamy Curve”, illustrates the advantages of Integrated Project Delivery *Introduced in the Construction Users Roundtable’s “Collaboration, Integrated Information, and the Project Lifecycle in Building Design and Construction and Operation”*.

Smith, D. K., & Tardif, M. (2012). *Building information modeling: a strategic implementation guide for architects, engineers, constructors, and real estate asset managers*: John Wiley & Sons.

The Strategic Forum for Construction. (2006). 2012 Construction Commitments *Retrieved from: http://www.constructingexcellence.org.uk/pdf/news/2012_construction_commitments.pdf*.