CHALMERS

State of the art report on the flow of information in a bridge life cycle

Master of Science Thesis in the Master's Programme Structural Engineering and Building Performance Design

EDWIN OGBEIDE

Department of Civil and Environmental Engineering
Division of Structural Engineering
Concrete structures
CHALMERS UNIVERSITY OF TECHNOLOGY
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Master's Thesis 2010:66

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Cover:
Figure 4, illustration of Bridge information model

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ABSTRACT

In this day of age we have come a long way from using only words or pen and paper as means of communication. The development is fast and there are a lot of new approaches and systems being developed even as this report is being written. Within the construction industry, there is great development in the information flow. Models and software are being introduced for making the flow of communication better. In this report interesting aspects of these new approaches are being explored. It also takes a deeper look at some specific models that are currently used.

The construction industry has been in the focus for all the wrong reasons lately, a lot of negative aspects have been discussed in the media. With all right, there is a lot to be done to improve communication and collaboration. The different actors in a construction project need to work more side by side and all have access to the latest updates in the project. A great deal is to be gained by this, improved quality, shortened project time, financially by less costs and environmentally by saved material resources. Furthermore, the reputation of the industry will be restored.

Building Information Model (BIM) is the technology being theoretically dissected in this thesis. A focus on bridges is being made; Bridge Information Modeling (BrIM). A literature study is the method used. During the project it became evident that BIM is the way to go in the future. It is becoming more and more important for all the key actors in the construction industry to communicate effectively. Furthermore, the client wants to play a bigger role in the project delivery than before and BIM gives the client the possibility to communicate with other project members. BIM also gives an opportunity to see the end product at an early stage.

Key words: Communication, collaboration, model, information, BIM, construction industry, project delivery, technology

Aktuell forskning om informationsflödet i en bros livstid
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SAMMANFATTNING

I dag har vi kommit en lång väg från att bara använda ord eller penna och papper som kommunikationsmedel. Utvecklingen är snabb och det finns en hel del nya metoder och system som utvecklas. Inom byggbranschen pågår det en stor utveckling i informationsflödet. Olika modeller och programvaror håller på att införas för att göra kommunikationsflödet bättre. Detta projekt tar upp intressanta aspekter av dessa nya metoder. Projektet tar också en djupare titt på några specifika modeller som för närvarande används.

Byggindustrin har på senare tid varit i fokus av helt fel orsaker, en hel del negativa aspekter har diskuterats i media. Med all rätt finns det mycket att göra för att förbättra kommunikation och samarbete i branschen. De olika aktörerna i ett byggprojekt behöver arbeta mer sida vid sida och alla ska ha tillgång till de senaste uppdateringarna i projektet. Det finns en hel del att vinna på detta, ökad kvalitet, kortare projekttid, ekonomiskt med mindre kostnader och miljömässigt genom sparade materiella resurser. Dessutom kommer anseendet i branschen att återupprättas.

Byggnadsinformationsmodellering (BIM) är den teknik som teoretiskt dissekeras i detta projekt. Fokus ligger på broar, Broinformationsmodellering (BrIM). Projektet bygger på en litteraturstudie. Under arbetets gång stod det klart att BIM är vägen att gå i framtiden. Det blir allt viktigare för alla nyckelaktörer i byggsektorn att kommunicera effektivt. Dessutom vill klienterna idag spela en större roll i projektleveransen än tidigare och BIM ger kunden möjlighet att kommunicera med andra projektmedlemmar. BIM ger också en möjlighet att se slutprodukten på ett tidigt stadium.

Nyckelord: Kommunikation, samarbete, modell, information, BIM, byggnadsindustrin, projektleverans, teknik.

Contents

Preface

This Master's Thesis is a part of a prestudy called "Structural engineering potentials and applications for effective industrial bridge construction." This prestudy is carried out by Kent Gylltoft, Mario Plos, Ingvar Olofsson and Rasmus Rempling at the Department of Civil and Environmental Engineering, Division of Structural Engineering, Chalmers University of Technology.

Gratitude to the following persons that allowed me to use their diagrams and figures; Management of Bentley Systems, Incorporated USA, Nicki Dennis Stephens, (Director of Member and Component Resources at American Institute of Architects), Stuart S. Chen, Ph.D,(Department of Civil Engineering, University at Buffalo), Neveen Hamza, Ph.D, (School of Architecture, Planning and Landscape, Newcastle University).

I would also like to thank my supervisor Rasmus Rempling and Professor Kent Gylltoft who guided and helped me along the way. Thanks also to other members of the prestudy group; Ingvar Olofsson, Mario Plos and Peter Harrysson from Trafik-verket for their support. During this project I have shared room with Paulos Abebe Wondimu and Hamid Ahmed Hassan and I also want to thank them for their cooperation and encouragement.

Finally I give thanks to my opponent Mattia Tosi.

Göteborg, May 2010

Edwin Ogbeide

Notations

AEC	Architecture/ Engineering/Construction
AGC	Associated General Contractors
AIA	American Institute of Architects
ASCE	American Society of Civil Engineers
BIM	Building Information Modeling
BrIM	Bridge Information Modeling
CAD	Computer Aided Design
CADD	Computer Aided Design and Drafting
D-B	Design-Build
DBB	Design-bid-build model
FM	Facilities Management
IAI	International Alliance for Interoperability
IDM	Information Delivery Manual
IFC	Industrial Foundation Classes
IFD	International Frameworks for Dictionaries
IP	Intellectual Property
IPD	Integrated Project Delivery
MVD	Model View Definition
NBIMS	National Building Information Modeling Standard
NIBS	National Institute of Building Science
2D	Two-Dimensional
3D	Three-Dimensional
3D CAD	Three-Dimensional CAD
4D	3D with real time project sequencing and scheduling
5D	4D with real time and cost estimates
6D	4D and 5D with real time cycle management and engineering

1 Introduction

This chapter is covering the background, aims and objectives, problem/assignment, limitations and methodology.

1.1 Background

There has been a really negative sight on the building industry in Sweden the last ten years or so. Media has produced a number of articles and TV-reports about the sloppiness and the unserious ways of the industry. With all this negative attention it was clear that the industry was in serious problems.

This problem is not exclusive for Sweden, it seems to be universal. All over the globe there have been reports and investigations stating the same difficulties no matter the country. There is a much talked about report, Eagan (5), from UK that states that they have equivalent problems. It was estimated that the construction industries in United States loss about 734 billion dollars yearly due to the current traditional business practice and construction model. This report resulted in actions being taken to change the malfunctioning ways of the industry.

Some of the unique characteristics of the construction industry when compared to other industry sectors are: the long service life of the product and the fact that the construction site changes for each project, the work is regularly done outdoors, and the location of operational office is often different from the construction site (Chan & Leung, 2004).

The working process in construction industry is based on collaboration, many stakeholders and project-based systems (Harty, 2005), but this collaboration system between stakeholders is within a limited period of time (Anumba et al., 2002). Chan and Leung (2004) also points out that within the Architectural, Engineering, and Construction (AEC) industry co-ordination among participants are difficult. The industry is very traditional (i.e. conservative), faced with inadequate information and weak communication, it is resistant to change and slow in adopting modern and state of the art technologies (Peansupap and Walker, 2006; Titus and Bröcher, 2005).

There are evidences that a material specification is being made approximately 7-9 times during the building process. This is due to the fact that different actors do not trust the previous actor's calculation to be accurate (Jan-Olof Edgar, 2002). The aim with Building information modeling (BIM) is that there is only one original central information model of the project and other information attached to it. All actors will use this model and the model will be used throughout the entire lifecycle of the project (Mihindu and Arayici, 2008).

1.2 Aims and objectives

The aim with this Master's Thesis is:

Define the communication and information flow from the different phases in a bridge building.

Examine and evaluate the current implementation of Building information model (BIM) in the bridge sector from a communication and management perspective with the main focus on the design phase.

Develop the communication process and the decision making process between all actors in the industrial bridge construction using BIM as a way to generate and manage building data during the life cycle of the building/structure.

1.3 Problem/Assignment

There is a lack of Industry standards for information and communication processes in the building sector, especially the civil engineering sector. The different phases: design, building and management phases are uncoupled and free processes without interaction. To increase the industrialisation of the bridge sector these phases and the information/communication must be coupled. Incomplete information, tools and procedures result in a loss for everyone: the owner/operators, engineers, architectures, builders/contractors and even the public.

Some issues:

What is it that determines whether construction professionals are working with BIM or not?

How can BIM be used?

Is it the right way to go?

What problem does it address?

What challenges can be expected?

Is it a collaborative process?

Is communication the key?

What is it that determines whether software is an associate's software used in connection with BIM or not?

1.4 Limitations

I didn't get the chance to actually use the BIM software myself and that somehow limits my knowledge of the software. It would also have been an advantage if I could have followed a current project using BIM-model.

1.5 Methodology

This work is based on a literature review and careful reading of existing reports and white paper and marketing publications by software vendors.

2 The current communication and information flow in a bridge construction process

For a wider understanding of communication and information flow in the current business practise in the construction industry, different models of project delivery is evaluated. In this chapter that follows some definitions is described such as the definition of information and communication. The difficulties and the need for change are also explored in this chapter.

2.1 The definition of terms

In a simplified definition communication is the activity of transfer and exchange of information. The information can be a thought, an idea, data and drawings etc. (Stephen W. Littlejohn, 2001).

Due to different meaning of information, it is difficult to have a universal definition. One commonly used definition is "Information is communication that has value because it informs" (G. Beekman and M.J. Quinn, 2005).

2.2 The current project delivery model

Project delivery model is the methodology used by clients to effectively secure a project. There are various types of project delivery model within the Architecture/Engineering/Construction (AEC) industry. In the construction industry it can be tricky to make a large number of people and paper-based documents work together as one, no matter the contract all the participants agreed on. Therefore the project delivery models are often consolidated down to two major methods which are the Design-Bid-Build model and Design-build model. Another term commonly used within the construction industry is the word procurement system. The term procurement system has been defined as "the framework within which construction is brought about, acquired or obtained" (McDermott, 1999).

In fact, communication and information is fragmented and paper based in the present project delivery model. The mistakes and neglected information data often lead to high field cost and delays of project (C. Eastman et al., 2008). Unfortunately, the stakeholders in Architecture/Engineering/Construction (AEC) project system are not concerned about the network of information flow in the different phase of the project (Halfawy and Froese, 2005).

2.2.1 Traditional workflow and Design-Bid-Build

In the Design-Bid-Build model (DBB) or the traditional model as it is known in the construction industry it is the practice guide that involves a sequential process in which the owner contracts an architect to design the project and draw up necessary details for construction drawings and specifications. This is normally done by the Architect and the Architects consulting Engineers. With the detailed drawings the owner now solicits competitive bids for the construction and the contract is awarded to the lowest bidder (Masterman, 2002). Another advantage is that the design team is selected based on the specific experience with the types of project the owner desires. But there are some issues with this model that calls for an alternative method. Some of those issues are:

a) This model leaves the owner to some extent vulnerable to the main contractor who might begin to change order and claims. The contractor might as well delay construction work.

b) Creation of additional costs for the owner as the owner tries to corrected post construction problems discovered in the occupancy or operational phase.

c) The subcontractor and fabricators are not easily involved in the design phase etc.

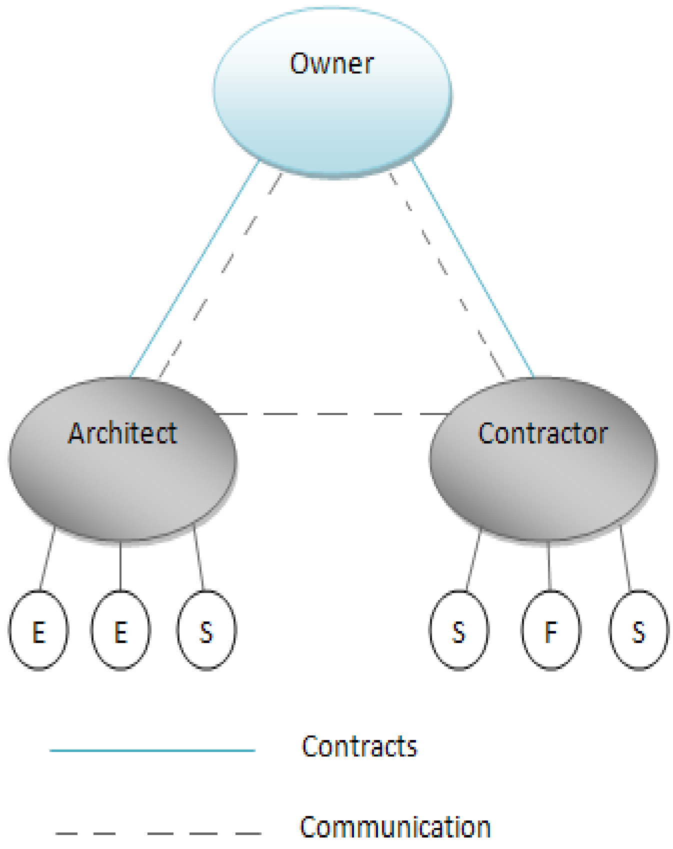


Figure 1: Existing Model (Design-Bid-Build)

Source: AIA/CC Handbook on Project Delivery.

2.2.2 Design-Build Model

Design-Build Model **(**D-B) is classified as an alternative to the design-bid-build model. Design-Build is a procurement arrangement where the owner contracts with a single entity for both design and construction. The American Institute of Architects (AIA) defines the term as “a process in which the owner contracts directly with one entity that is to provide both design and construction services” (Masterman, 2002).

The D-B process was developed to combine the responsibility for design and construction into a single contracting unity that would make things simpler for the owner (Beard et al., 2005). Due to a range number of benefits there is a high demand of Design-Build model. The benefits include:

a) Removing the owners as disputes intermediary agent between the contractor and the design firm as in traditional model.

b) Only the owner can make direct changes in the project.

c) The designer and contractor team, not the owner, is responsible for any errors and omissions in the construction documents.

d) The early involvement of contractors improves pre-construction estimations.

Unfortunately this model has not fully addressed the problem the construction industry is facing today (see section 2:3).

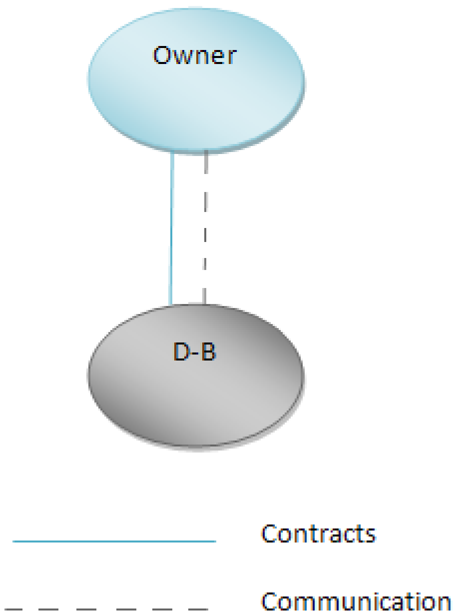


Figure 2: Design-build Model

Source: AIA/CC Handbook on Project Delivery.

2.3 Deficiencies in the current project delivery model

There is a great need to improve the traditional design and construction process in the construction industry, due to its poor performance in project delivery. There is lack of teamwork between the major actors in the project. The owners almost bear total risk in the project and the communication and information between the key actors is fragmented.

Numerous researchers have described the problem with the current delivery model. C. Eastman et al. (2008) conclude that the higher cost in the current delivery system is due to the amount of time and expense put in the proposed design, detail drawing and analysis due to paper-based communication. Also in most cases any mistake made in early design phase can only be changed after the analysis. Halfawy and Froese (2005) add to C. Eastman et al. findings by stating that the highly inter-dependent and numberless disciplinary nature of AEC objects is often causing lack of communication and exchange of project information. This also leads to higher costs, reduced standard, loss of design purpose and inefficient data information in a timely method. In addition, the view and the interpretation of information can be drastically hindered by the ability to communicate the actual information. In the construction industry this is a well known truth, even though it is not only the difficulties of communication, but also other problems that will occur. For instance the involvement of many actors in the construction process and the condition of handling information during the bridge's lifespan.

Besides the above stated difficulties there are some efforts being made toward changing and improving the current practice. Applying and utilizing information technologies is increasing, particularly when it comes to assisting in the complete lifecycle process. There is need to develop a new model in the construction industry (Cutting et al., 2000). Recently there have been some efforts made in the direction of a bigger use of alternative communication systems. The use of electronic data system and modified 3D CAD tools model are starting to get more common. Even though these tools have helped to save time there are still issues regarding conflicts caused by paper documents (C. Eastman et al., 2008). Studies have shown that some owners are now aware of the poor services in the construction industry. Owners are now demanding better service from the professionals in the industry (Alshawi and Faraj, 2001).

3 Building information modeling

Building information modeling (BIM) has become the topic of the day in the construction industry and there is a lot of confusion regarding the use of the word BIM itself. Therefore it is necessary to define what a BIM actually is and what is not a BIM. BIM technology depends on four neutral open international standards, which includes IFC, IFD, IDM and MVD and the way it is being used in the business process. The difference between traditional CAD packages and BIM is also being compared to emphasize the benefits of BIM. All the key actors in the AEC industry can gain from using BIM.

3.1 What is a BIM

Building information modeling is an approaching process supported by technology. By deploying the process the construction industry can optimise the use of technology to overcome the problem that was associated with the traditional model. Using technology in isolation is not unique only to the construction industry. In the 1980's, industries such as automotive, aerospace and manufacturing faced a similar dilemma. Those industry changes were needed for improvement and international competition. The solution was to adopt modern technology that encouraged collaboration and continuous flow of information. The construction industry can learn from those industries and from the past.

In 2002, the way professions in construction industry sectors thought about the use of new technology was changed, with the introduction of a new innovative approach by Autodesk. The technology support building projects throughout the whole lifecycle.

3.1.1 BIM Terminology and Definitions

There are numerous definitions of Building Information Modeling (BIM). Building information modeling is a new revolutionary approach supported by new introduced information technologies that will change the ways to design and build structures. (National Institute of Building Science, NIBS, 2007).

The American Institute of Architects has further defined BIM as ”A model-based technology linked with a database of project information”, and this reflects the general reliance on database technology as the foundation (AIA, 2007).

However, Associated General Contractors describe BIM as a new object-oriented tool that apply 5-Demissional principle and current information technology to improve work in different phases in a project (AGC, 2007).

”A building information model is a digital representation of physical and functional characteristics of a facility. As such it serves as a shared knowledge resource for information about a facility forming a reliable basis for decisions during its lifecycle from inception onward” (NIBS, 2007).

The terminologies and description of BIM can be categorized as follows:

1) Building information model, ”BIM as a product”.

- A structured data collection that represent a facility.
- Emphasis on end product and the most narrow view.

2) Building information modeling, ”BIM as human activity”.

- The process of making the product model.
- Using BIM software and technologies in creating real-life product model.

3) Building information management, ”BIM as a system”.

- Management structures to improve workflow and communication.
- The widest view and the process of producing the product.

(NIBS, 2007).

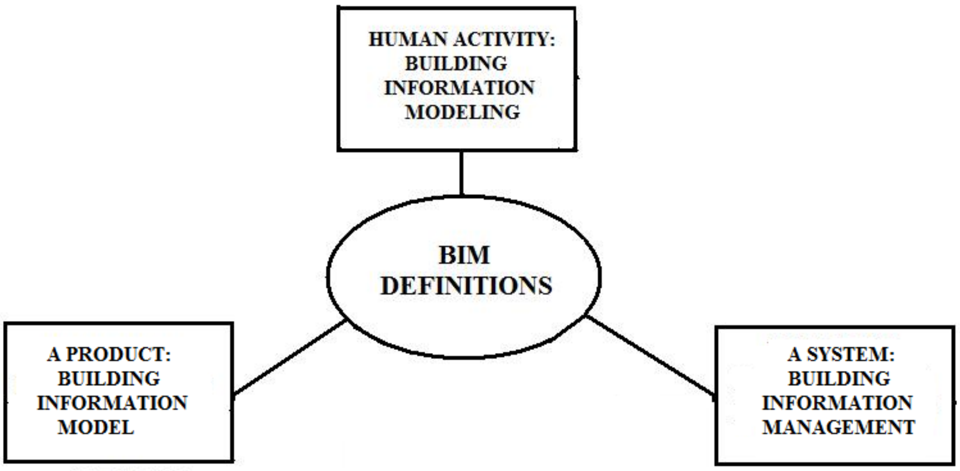


Figure 3: The different terminologies and description for BIM

Professional bodies (AIA, NIBS and AGC) define Building information modeling in different ways mostly based on the process, method and nature of their work or task. But Building information model is being defined or described in the same or similar way by all professional bodies.

3.1.2 BIM on Heavy Civil Project

The capabilities and technology of BIM can be used in challenging and complex civil engineering projects. If the actors involved in heavy civil projects should look at the word ”building” in BIM as the verb ”to build” then it can be applied in both vertical structures and horizontal projects (J. Mezher, 2009).

Within the bridge construction the term Bridge information modeling (BrIM) is used instead of Building information modeling (BIM). According to Stuart S. Chen, BrIM process uses 3D concept and applicable data in all the three phases in bridge structures. The model allow deploys and real-time utilization of data in the bridge lifecycle as the conditions is modified. However, the software vendor Bentley described BrIM as a ground-breaking approach in bridge building technology and project delivery model. Bridge information modeling encourages the use of data information not only in design phase but beyond it. BrIM promotes the reuse and sharing of project information asset.

Figure 4: Bridge information model processes

Source: www.bentley.com

The terms BIM/BrIM is used in this project study as Bridge information modeling which describes it as new information technologies and new ways of designing and building real time Bridge information model. It is also used as Bridge information management to represent the operational structures of the work and managing communication and information data.

Some professionals use the terms such as 3D data, 3-demissional concept, computable 3D data, relevant 3D data, 3D modeling, 3D-data set, etc. only when defining or describing BIM. However, BIM go beyond the 3D and in addition to 3D digital modeling, it can also include 4D-, 5D- and 6D modeling. The 4D means integration of 3D with real time project sequencing and scheduling and 5D include the integration of 4D with real time and cost estimates. 6D contains the integrating of 4D and 5D with real time cycle management and engineering (Meadati, 2009).

3.2 What is not a BIM

There is some confusion regarding what can and cannot be called BIM. Among software developers BIM has become a popular word to use to describe the capabilities of their products. The following words were used by C. Eastman et al. (2008) to describe what is not a BIM technology.

- Models that contain 3D data only and no object attributes. These programs are fine for visualization only but cannot provide support for data integration and design analysis.

- Models with no support of behaviour. This program can define objects but cannot adjust their positioning or proportions due to lack of parametric intelligence.

- Models that are composed of multiple 2D CAD reference files that must be combined to define the building. The 3D model that comes out of these programs is impossible to trust with the respect to the objects contained within it.

- Models that allow changes to dimensions in one view that are not automatically reflected in other views. It is easy to make undetected mistakes with these programs since the changes you make in one view do not transfer to all views.

- A software trademark. That is a typical product / company names and logo.

In order to know what a “true” BIM model constitutes of it is significant and fundamental to understand what is not a solution that utilizes BIM technology.

3.3 BIM methodology

The general idea about this new approach is to have all project information in digital format, better flow of information and communication among project participants (C. Eastman et al., 2008). However, information is shared by facilitating the communication between software tools applications that are used (Alshawi and Faraj, 2002). The use of Industry foundation classes (IFC), developed by Building SMART international (buildingSMART, formerly known as the international alliance for interoperability, IAI) is among other one of the means of improving information sharing between project actors.

The Industrial foundation classes (IFC) has gained solid industry support especially within the Architectural, Engineering and Construction (AEC) and Facilities Management (FM) industries (Alshawi and Faraj, 2002). The IFC model coordinated a schema that describes the systematic arrangement of a project data in Architectural, Engineering and Construction industry. The IFC model outline explains the information, characteristics, and interrelationships of the data object. The IFC is not specific to any vendor and it is neutral/open file format that enables efficient interoperability between different software applications in the life-cycle of a project (Halfawy and Froese, 2005).

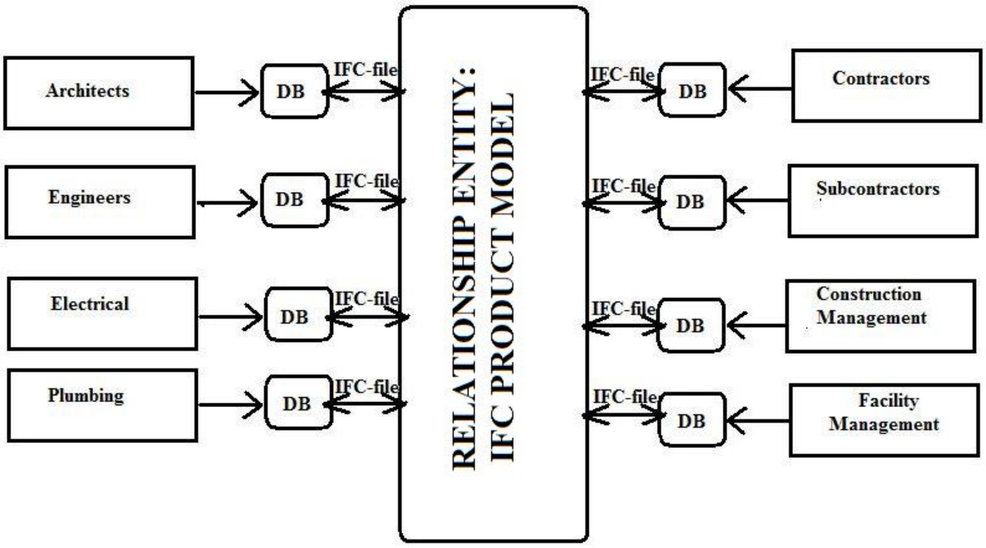


Figure5: Relationship entity of product model, through the IFC file format among project actors.

IFC is one of the highly mature standards, its development have reached a global acceptable advanced level. The International Framework for Dictionaries (IFD) standard (ISO 12006:3:2007) is implemented in the IFD Library, was preliminary designed to have a global reach but ran initially by USA, Canada, Norway, and the Netherlands to acknowledge the translation of IFC information in other languages (NBIMS, 2007). IFD can be simplified as a mechanism for the establishment of multilingual dictionaries. IFD "is a kind of dictionary of construction industry terms that must be used consistently in multiple languages to achieve consistent results" (NBIMS, 2007). Furthermore, IFD Library provides common understanding that is needed for the communication and information to flow smoothly in an IFC-based building information model (BIM) data.

Information Delivery Manual (IDM) methodology is used to capture specification of the information workflow exchange using BIM and IFC (C. Eastman et al., 2008). However, Information Delivery Manual provides an approach to providing the end users with the fundamental information identification and documentation. It describes standards for information demand and business processes (NBIMS, 2007).

Another method is Model View Definition (MVD) or IFC model view definition which is a subset that provides and defines needs for the exchange requirement in a complete IFC model. The software developers use model view definition as a base for developing technical data exchange (buildingSMART, 2010). MVD format has gained support from new software development such as the ”Structural design to structural analysis” or ”Architectural design to thermal simulation” (www.blisproject.org/IAI-MVD).

3.4 BIM tools and Integrated Project Delivery

Building information modeling is a technology and associated set of processes which can provide a framework to create a data rich bridge model and teamwork. It also facilitates integrated business structure benefits (Meadati, 2009).

To enable stakeholders to achieve integrated delivery, the BIM methodology must exhibit four main aspects. It must be:

1) An integrated delivery process, demanded by the owner leadership of the facility.

2) An integrated project delivery structure, where collaboration is the key among project participants.

3) A natural information model, where project data and information can be shared and contributed by all project stakeholders.

4) A virtual building model, which can create, interact, and transport digital information throughout the building process (CURT White paper, 2004).

The concept ”Integrated Project Delivery”, what is it? According to the AIA (2007) to protect the profession of all parts in the building process one can use Integrated Project Delivery: A system that integrates people, systems, business structures and practices. The system also reduces waste through collaboration, analysis of the design and material, and optimizes efficiency through all phases of building and bridge construction processes. An essential element of the IPD approach in bridge project is moving design decisions upstream from detailed analysis or construction phase to early conceptual design phase. There is time and money to be saved by collaboration.

Table 1: To compare the Design-bid-build model / Design-build model and the Integrated Project Delivery

Areas of comparison	**Design-bid-build model / Design-build model**	**Integrated Project Delivery**
Full collaboration among participants	Very little	Highly effective
Integrated processes	No	Yes
Open information sharing between participants	No, but information is based on "ask and rece-ive"	Yes
Utilization of technology	Limited capacity	Full capacity
Principles of trust	Little	Yes
Sharing risk and reward	No	Yes

Software's are needed to integrate the bridge model in 3D and 3D parametric both in the case of simple and complex model. The linking software tools produce configurable and versatile solutions from conceptual design phase throughout the remaining process to life-cycle maintenance operation phase (Figures 7 and 8).

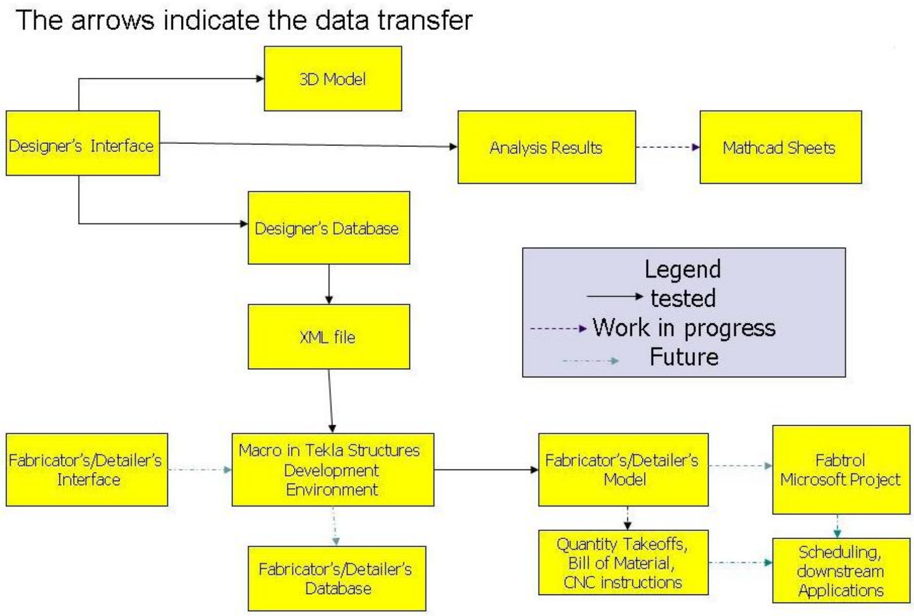


Figure 7: Information Transfer in model by participants

Source:"Towards BrIM (Bridge Information Modeling) for the Life Cycle" IHEEP

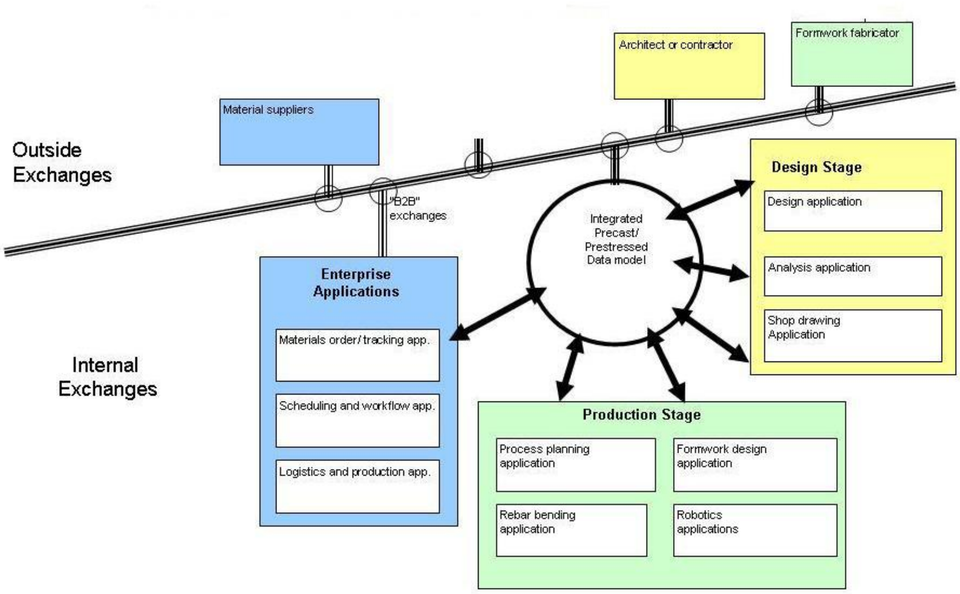


Figure 8: Integrated Central information model

Source:"Towards BrIM (Bridge Information Modeling) for the Life Cycle" IHEEP

3.5 Difference between traditional 2D / 3D CAD versus BIM

A new and important contribution to communication is the 3D model. In the BIM model concept a 3D geometric data representation is only one part. The other part consists of information about the bridges life-cycle (Conradl, 2009).

Currently, 2D and 3D CAD model are paper-based information/communication modes based on plotted drawings. In BIM model all CAD systems generate digital files (C. Eastman et al., 2008).

Using 2D Drawings in analysis numerous manual data information are needed. In BIM model there is possibility for direct analyses. Furthermore, in 2D coordination is unmanageable, information and specification documents are scattered between various drawings while in BIM model coordination is almost automatic and models is a central platform for all product information and specification (S. S. Chen, 2007).

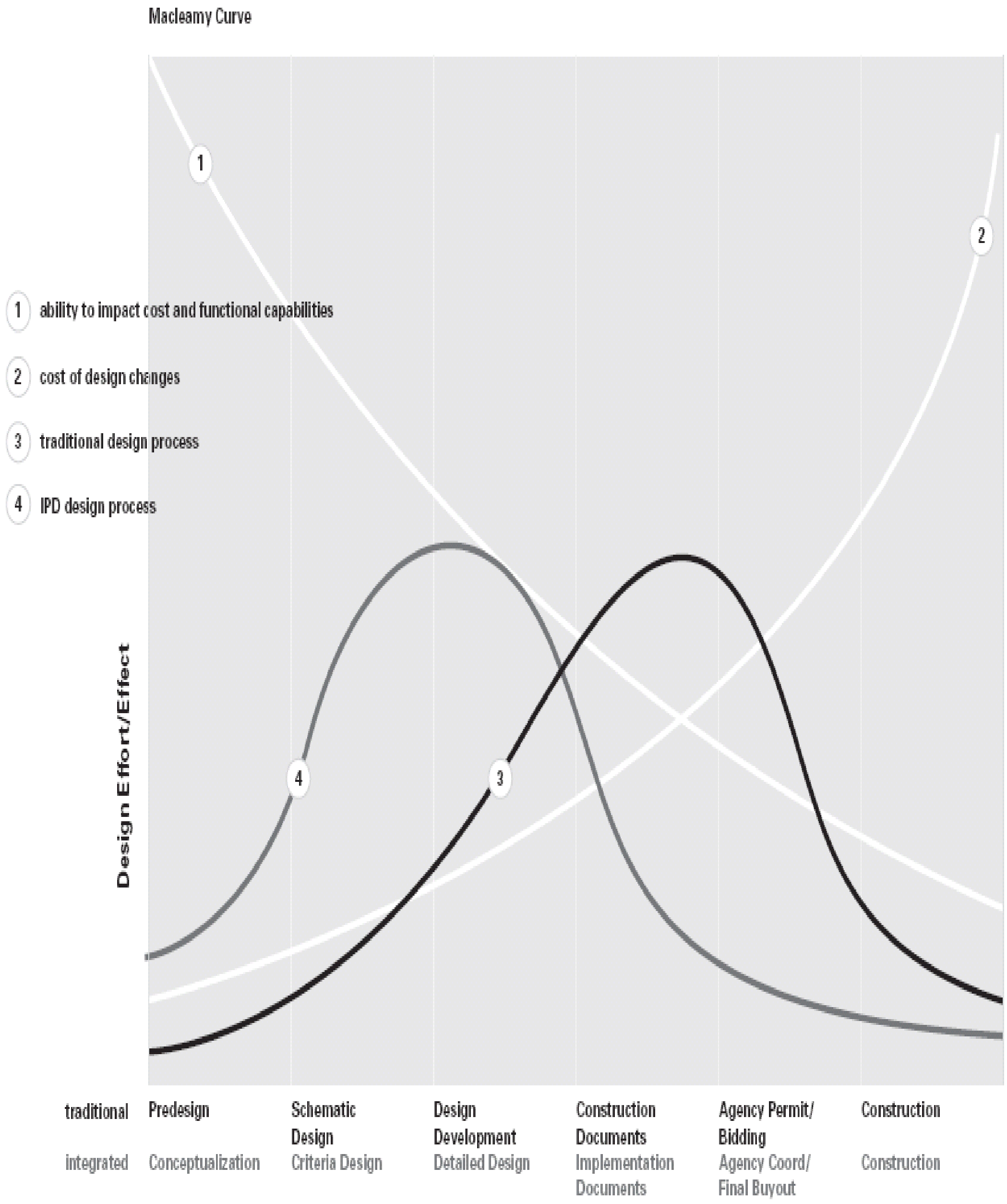
The traditional 2D and 3D CAD are explicit "simple" geometry objects, BIM is a objects-based "smart" geometry which also describe other non-geometry by using 4D (time), 5D (cost) and 6D (Facility management) (Halfawy and Froese, 2005).

However, C. Eastman et al. (2008) point out that BIM knowledge captured in data exchange, documentation of material, detailed cost estimation analysis, and many other actions are knowledge lost if only 2D drawing are used.

3.6 The benefits of BIM

BIM offers benefits in the three major phases in the bridge lifecycle-design, construction, and management. The benefits include integration of fragmented information, eliminating rework, repeated use of digital data information in the model without data regeneration, decrease the volume and amount of errors and mistakes that are associated with traditional model etc (Meadati, 2009). However, the intention of BIM is to accomplish best practices in the whole of the construction industry through integration, standardization and codification. The 3D computable model has been seen to assist designers and engineers in the virtual models of bridges and bridges component (Byron A. Ellis, 2006). In addition, drawings are produced more detailed and accurately which allows and support better and faster design decisions. This creates efficiency in the communication with construction documents (Jeong Han Woo, 2006). BIM enables better exchange in shared data and the management of other external data sources that depend on the model (Weise et al., 2008). According to Chen S.S. (2007) the bridge information modeling enables leverage design data, not only in construction phase but beyond it.

In addition, to data coordination benefits, BIM technology encourage collaboration in early phases of a project between stakeholders through the use of appropriate and more complete information more effectively than the traditional model (C. Eastman et al., 2008). The MacLeamy Curve figure 9: ”illustrates the concept of making design decisions earlier in the project ”and the benefits of early collaboration.



Introduced in the Construction Users Roundtable's "Collaboration, Integrated Information, and the Project Lifecycle in Building Design and Construction and Operation" (WP-1202, August, 2004)", the "MacLeamy Curve" illustrates the concept of making design decisions earlier in the project when opportunity to influence positive outcomes is maximized and the cost of changes minimized, especially as regards the designer and design consultant roles.

Figure 9: The "MacLeamy Curve"

Source: **The American Institute of Architects 2007**

Furthermore, there are two major conclusions from the chart: a) in the traditional design process, cost of design changes rises as the project develops. b) While in BIM and IPD design process, cost of design changes and functional capabilities effect is acknowledged in pre-design phase leading to cost reduction and avoiding of design changes conflicts in subsequent phase.

BIM technology provides effective and actual visualization project model (AIA, 2007) and the advance of visualization throughout construction processes (Weise et al., 2009). According to Taylor and Bernstein (2009) visualization is one of the major benefits when utilizing BIM. Visualization and communication among participants using the same project model can be improved mainly by adopting BIM visualization paradigm. In addition, BIM provides opportunities for visualizing alternative approaches and options. Furthermore, BIM model provide the possibilities of different types of analytical alternative and options within a project. With visualization physical pre-assembly can be avoided (Chen S.S., 2007).

The exact geometrical representation of bridges and bridges parts and other building parts in an integrated data-model is seen as the main benefit of BIM tools (Mihindu and Arayici, 2008). According to Forrest R. Lott (2008), optimizing site utilization, greater and faster prefabrication, just-in-time delivery methods are few benefits of BIM when its full capacity is utilized.

4 BIM for key actors in bridge building

Since all the key actors benefit from using BIM it is important to classify and clarify what is to be gained by each actor. In this section some of the different actors are being stated and the possibility and need to use BIM is analyzed.

4.1 Owner/client and Facility manager

The owner: An individual or an entity or group of people, who awards a contract of a project, provide the payment, make the decision to build and has the legal right of the facility. The owners are sometimes called the client within the AEC industry. Some example of a client is Swedish Transport Administration (Trafikverket) and Gothenburg Municipality (Göteborgs Kommun).

The book "Facility manager's handbook" describes facility managers as a professional who ensure the fullest operational physical build environment by coordinating and integrating people and technology (Gustin, 2002).

There are great benefits to be made for owners by using BIM during the building process. BIM makes it easier for the different parties in the project to collaborate and reduce mistakes. This leads to a more productive and trustworthy delivery process and cuts project time and costs. Owners can take advantage of BIM for various purposes:

- Increase and boost facilities value.
- Project schedule shorten with 4D sequence.
- Dependable and accurate cost estimates with 5D-estimating.
- Assure less rework.
- Perfect and functional facility management and maintenance.
- Early visualization.

All these benefits are open to all groups of owners, whether you are a big contractor or a one-shot builder etc. It is just for the owners to realize the great potential that BIM holds. Lots of owners are changing the way they used to work to be able to fit BIM into the projects. There are even owners that facilitate and support BIM training and research development (C. Eastman et al., 2008).

Owners have not been known for wanting change in the construction industry; they accepted cost overruns, schedule delays and quality issues as a part of the process. The market shifts conditions are however more or less forcing owners to rethink. Traditionally there has been a short-sightedness from the owners where they tend to call for changes that eventually affect design quality, project cost and time. Many are positive that the project owner is the greatest beneficiary. However, cost reliability and management, increasing complexity in the infrastructure design and construction processes, labour shortage, schedule management, language and communication barriers etc. are some drivers that motivates the owners to use BIM.

4.2 Architect and Engineers

An Architect is a competent professional who is involved in design and the supervision of buildings. In bridge design an architect exploit scientific, artistic and information technology to fulfil the client's unique vision (AIA 2007).

An Engineer is a person or professional who effectively adapts the application of science and mathematics to solve complex engineering problems and design process and products. Furthermore, a structural engineer is an engineer who is involved in the design, detail structural design and supervises constructions of tunnels, bridges, dam's etc (American Society of Civil Engineers, ASCE, 2008).

BIM is the most significant tool yet conceived for integrating bridge construction processes and management of bridges. BIM has a paradigm change effect. It guaranties consistency of entire drawings and documentation, checking spatial obstacle automatically, allowing Architects and Engineers to explore analysis/ simulation/cost applications and provides improved visualization at all levels and phases and therefore, enhancing understanding of the end product.

There are four major viewpoints on the impact of BIM on design which include conceptual design, integrated engineering services, construction level BIM modeling and integration of design-construction.

BIM is a great challenge and opportunity to design firms and companies, the benefit for design is not as easily measured as for the constructors. If one looks at the integration with analysis and simulation one can see that BIM improves the quality of design. This is most clear in the early stage of the designers work. The design quality is the bridge life time and is probably saving just as much money as the later part of the project with minimizing cost overruns and conflicts and so on. In this sense BIM increases the value that Architects and Engineers can give to clients and society.

Looking at history, drawing has always been the superior mode of representation. This fact was even used in the first attempt to atomise the design-to-construction process, in computer-aided design and drafting (CADD). In this sense BIM is quite revolutionary; it somehow alters the architectural thinking by replacing drawings with 3D digital models. There are so many advantages of 3D models to the designers; 3D is computer readable and writable, design detailes can be analysed automatically in 3D model method which is impossible with physical models.

BIM is a big help when it comes to interaction between different design software since it improves the access of information for those software's. One can simulate different scenarios and get feedback in a way that in the long turn will change the way designers think and the procedure of their work. BIM also opens up for effective collaboration compared to 2D drawings (C. Eastman et al., 2008).

4.3 Contractors

In raw term, contractor is used to describe an individual or a group that contracts directly with the client for the construction, reparation or demolition of a bridge and other structures. Furthermore, contractors might also prepare construction sites and provide installation services.

Saving time and money is among the key advantages of using BIM technology in construction. It also reduces the possibility for errors and conflicts. Traditionally the contractor had very little chance to contribute their knowledge and experience to the project during the design phase. By using BIM contractors can also take an active part at any stage of the process. Depending on what functions a building will have there are different levels of information and for correct cost estimation the model must be detailed enough so that it is possible to calculate the quantities of material needed.

Moreover, contractors who are involved in the design phase can understand design level BIM and take advantage of it, by managing and adding construction level details, subcontractors and fabricators information, part and member numbers and 4D and 5D information. This will then boost productivity, better the construction quality, allow the detection of clashes at an early stage. It will also improve its accuracy and enhance job safety in the site (C. Eastman et al., 2008).

A great benefit with contractors-coordinated BIM model is that all the major subcontractors can participate in using the model for detailing their part of the job. It is not all easy with the change from traditional models to the use of BIM, there is a learning period and contractors might need help from an experienced BIM user.

4.4 Subcontractors and Fabricators

Subcontractors which are sometimes called secondary contractors are a person, partnerships or company who contracts with a contractor to perform part or all of the construction work under the main contract. The subcontractors often perform special tasks such as embedment of reinforcement in concrete.

Fabricators are professionals who interpret structural and engineering drawings and then produce the product according to the drawing requirement and specification.

Bridges has become more complicated than ever before. Even though the pre-fabricated bridges and assembling of components are becoming more common there is still a lot of professionalism required in today's building industry. Today bridge components and member system is pre-fabricated based on "engineered-to-order" structural components which require specialization in design and fabrication.

To ensure proper fitness of member system and components into the whole bridge system, detailed engineering and considerate collaboration between all actors are needed. In the conventional model workflow, fabricators work is labour intensive and error-prone. Engineering drawing and specifications are reviewed, fabrication drawings produced and compared to old and similar design and drawings and then sent to engineers for further review before production. These are all time-consuming processes. The problem is avoided or reduced considerable by using BIM, which allow “virtual construction” of components and coordinating manufacturing process (C. Eastman et al., 2008).

There is a need for subcontractors to use BIM, since the work performed by sub-contractors in the entire construction process is around 80-90% of the total work of the project. When subcontractors and fabricators use BIM it reduces dimensional errors, it betters the products prediction, improves “just-in-time manufacturing and delivery method”. It also reduces engineering and detail costs and reduces process and production cycle-time. These are some of the benefits.

5 BIM in practice

The theoretical benefits are not enough to convince and encourage people to use BIM. There is also a great need to show in practice that BIM technology is workable and that there is availability of software tools that supports BIM technology. Example of a company that has used BIM and their gains are stated in this chapter.

5.1 Adoption of BIM in practice

BIM tools have not developed fully and only a handful case of whole bridge projects is known to have used BIM approach. But there are opportunities for further improvement than the current level in construction industry (Ning Gu et al., 2007).

Mihindu and Arayici (2008) point out that few companies have used BIM in many projects (example TOCOMAN).

Table 2: Shows benefits that was achieved by TOCOMAN in the adoption of BIM tool

Benefits that was achieved
a) Faster and more effective processes.
b) Better design.
c) Controlled whole life and environmental data.
d) Better production quality.
e) Automated assembly.
f) Better customer service.
g) Lifecycle data.
h) Integration of planning and implementation processes.
i) More effective and competitive industry.

In using BIM model in real life work every participant contributions are unique and valuable. The challenge and difficulties lies in coordinating knowledge and transferring information from one phase to another (Manning and Messner, 2008).

BIM have many benefits and possibilities, but those benefits do not immediately contribute to the total adoption of BIM in AEC industry. Some pilot studies have shown that there are issues which need to be addressed before attempting to adopt BIM in greater level:

> **Managing Software's version** - the lack of permanent standard in software tools and the regular updating of software products. The users see this issue of constant upgrading of software as a barrier to the adoption of BIM, since most

of the new versions does not allow fully use of information from the older versions. This means that a compatible version is often made in order to maintain the principal of collaboration between participants.

Integrated data management - in an organization with numerous participants and models that have multiple data stored in it. There are always issues of organizing, storing and the security of the data. The managing or who managed the data at different phase of the project life cycle needs to be determined. This is not issues of technology but rather that of database management method which poses an additional challenge to the participants in the AEC industry in the process of decision making.

Educational issues - the educational issues is not only the lack of initiative and training in firm and company, but also that of the engineering and architectural education which in recent years have faced a key criticism that the difference between the school's curriculum and professional practice is too wide. There is need to include BIM and many other computational approaches into schools educational curriculum, this will help to address the problem of "BIM as human activity"

Data security risk - the participants involved in data sharing and computing are concerned about their "intellectual property (IP) and protection of copyrights". The legal status of the BIM model, network security, loss of data and data misuse are some of the issues that need attention in real work environment (NING GU et al., 2007).

5.2 Associated software used in BIM

Most CAD vendors in building industry have software that support BIM technology. The table below shows a list of the major applications. The applications are mainly used in countries like USA, Finland, Denmark, Sweden, Norway and UK.

Table 3: Shows different types of BIM software, the system compatibility and functionality of the software applications.

BIM Software	System Compatibility	Functionality	Information Source
Tekla Structures	Steel, precast concrete. Reinforced concrete.	Modeling, analysis preprocessing, fabrication and erection detailing.	www.tekla.com
Bentley Bridge: RM Bridge LEAP Bridge	Structural design for all bridge types.	2D/3D/4D Bridge design, analysis, fabrication and construction.	www.bentley.com

Bentley Bridge: LEAP Bridge	Concrete design.	Modeling and analysis detailing.	www.bentley.com
Bentley Bridge: BridgeModeler and LARS	Load for most common bridge types.	Load-Rating analysis and modeling.	www.bentley.com
Bentley Bridge: Bentley PowerRebar	Concrete and reinforcement arrangements.	3D modeling, scheduling, charting and drawing production.	www.bentley.com
Bentley Bridge: ProStructures includes ProSteel and ProConcrete.	Structural steel, metal work, insitu/ precast and postt-ensioned concrete.	Structural detail-ing analysis, fabri-cation detailing for steel and concrete.	www.bentley.com
Bentley Bridge: Structural Modeler	Structural systems for buildings and industrial plants.	Design and documentation of structural systems.	www.bentley.com
Allplan Engineering	Structural steel, precast concrete, cast-in-place concrete.	Modeling, analysis, detailing rebar.	www.nemetschek.com
StruCAD	Structural steel.	Fabrication detailing.	www.acecad.co.uk
Revit Structure 2008	Structural steel, precast concrete, cast-in-place concrete.	Modeling, analysis, co-ordinate.	www.autodesk.com
ArchiCAD 13	Architecture Design.	Modeling, documentation workflow, team collaboration.	www.graphisoft.com
AutoCAD Architecture	Architecture Design	Modeling, creating drawing and documentation, schedules faster, smooth collaboration.	www.autodesk.com

Revit Architecture 2008	Architecture Design	Modeling Conception design to construction documentation, detailing, schedules.	www.autodesk.com
DDS-CAD Building	Construction, electrical, plumbing, HVAC.	Modeling, fabrication detailing.	www.dds-cad.net
Bentley Facilities	Facilities Management	Leveraging information, documentation, asset information.	www.bentley.com

6 Design phase as part of the bridge construction process

The history of design is as old as mankind. Design and modeling has been used to illustrate projects in order to present an alternative to reality. In this chapter the benefit of BIM to communication and information flow in the design phase is being discussed. BIM also offers a lot of benefits in the design phase and to the designer but that notwithstanding there are some obstacles in the implementation of BIM in design.

6.1 Design and modeling development

The use of models as external tools is a very old practice. Even the old Greeks and Egyptians used models of clay and wood to show something that they wanted to build. Today we have come a long way from those simple materials, 2D and 3D digital models are common nowadays.

The 3D phenomenon is not new. In fact we started with 3D hand models before 2D drawing. The development of 3D was then parallel to the creation of 2D drawings, initially without CAD. We did not stop making 3D models; we just changed the material, going from clay and wood to polystyrene or cardboard. Nowadays we make 3D models digitally in the computer, faster and at less cost.

A couple of years back we started to work with computer programs to make 3D models. One often talks about visualization as something crucial in order to get a good overview of the project. The problem that now occurs is that the 3D model is easy to change in the computer whereas the 2D drawing still has to be changed by hand at great costs and is time consuming.

The consequence is that the 2D drawings don’t show a true picture of the project after changes has been made. We have to create a common use of digital 3D visualization so that all disciplines work in the same way. Then different actors in the building project can at any time change the model to match reality as changes are being made. This way a great deal of cost and time is going to be saved. Not to mention that you will always be able to show an accurate model at any point of the project. There are some estimations saying that the cost of waste of the Construction Industry is about 20-30 percent of the total construction cost.

From conventional 3D design we have now moved on to BIM. With BIM you link a lot of extra information to the 3D model, more information than just geometric shapes.

6.2 Communication and information within the design phase

As described in section 2:2 and 2:3 the current method of communication and information is full of errors. It is paper-based and has a lot of manual information to handle. In the traditional practice in design phase the communication and information flow is fragmentized.

With BIM tools and IPD communication the information flow will be highly improved and smoother. The use of BIM in the design phase has lead to the creation of an information model with repository data when information exchanges requirement take place. The improved collaboration processes and contribution of critical information by all major participants immediately increased the availability of information. It also improved and enhanced the communication flow. However, adopting BIM techniques and taking advantage of some benefits (see section 3:7) such as design visualization, digital data information, etc. will not only enhance communication and information. In addition, it will improve the documentation process and better data management..

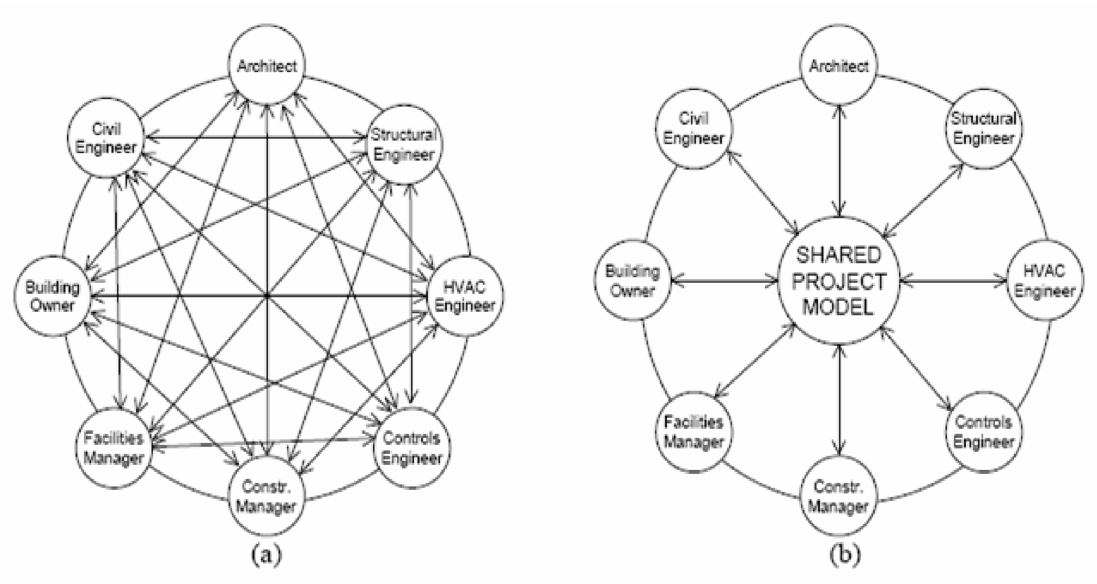


Figure 10: Two project model delineating communication and information flow with the design team. (a) The current traditional practice, (b) BIM and IPD model.

Source: BUILDING INFORMATION MODELING: ENERGY CONSCIOUS DEISGN [ASCAAD-07, Alexandria, Egypt].

6.3 Integration of BIM in support of the design

Some of the future uses and benefits of BIM are yet to be shown, but some is already obvious. Here are four of those benefits.

1) Conceptual design, the process in this phase involves creating the basic bridge plans (functional sketches and drawings) based on the owner requirement, outlining code and specification, primary BIM model, location of the bridge on the site, orientation, and so on. BIM can be to a great help in this phase of the process and give a quick feedback. It can for instance give information about cost constrains and environmental considerations.

2) The designers can use BIM to analyse different functional aspects of the bridge performance. This can be structural integrity, loads, construction materials, temperature control, ventilation in the case of tunnels, lightning

among others. This demands serious collaboration between the different specialists.

3) BIM develops construction-level information**.** This can expedite pre-defined construction documentation. The construction documentation should contain 4D tool to plan the project and 5D tool, design documentation and sub-contractors 4D model for each subcontractor.

4) Integration of design and construction. This benefit makes it easier to provide faster, more efficient construction of the bridge after design (C. Eastman et al., 2008).

6.4 Possibilities with BIM in design

The designers (Architects and Engineers) are normally paid a fee based on percentage calculated from the construction cost in the current business structure in the AEC industry. BIM technology and practices are offering new business opportunities to the major actors in the construction industry, the designers using BIM can now offer new set of services which adds more to the fee structure. There are more fees to be earned for the designers as they provide more valuable services then before (C. Eastman et al., 2008). The question is if the client is prepared to pay for this service?

There are opportunities for new Architectural and Engineering graduates as they can take advantage of BIM and adjust quickly into professional practices and become better designers within a short duration. It also creates new job opportunities as designers can become BIM managers and coordinators. Furthermore, it gives the designers a step ahead into the new international competitive market through better design presentation (Mihindu and Arayici, 2008).

6.5 Difficulties with BIM in the design

The misconceptions of BIM model and the confusion between 3D modeling CAD packages and 3D BIM tools modeling is one of the major difficulties in the implementation of BIM in design phase." The "Rush" versus "Wait" debate" is another factor that will delay the implementation of BIM in most design firms and companies (Ibrahim, 2007). Unfortunately Ibrahim did not explain what the debate contained. Beside those obstacles, questions have been asked if the designers comprehensive design data can be properly managed in a BIM model which is a single platform modeling system.

The building sector is well known for being technologically conservative and manually oriented which hardly gives room to changed work practice. The reluctance to change the current work and professionals practice, inadequate trained staff, insufficient management skills and lack of software that have the capability to integrate freehand drawing with BIM tools for drafting and modeling are some of the bottlenecks in adopting BIM technology in design (Stroeken, 2001).

Majority of the design work in the AEC industry is still being done on paper-based sketching and drawings. The design-level BIM model is having difficulties in supporting the entire design process and has not been used in early bridge design phases. Furthermore, the management of file format of a fully loaded BIM model is a major challenge due to the scale and complexity of the drawing files.

BIM tools and activities are mainly concentrated on new projects not on old and existing projects, currently there are larger numbers of valuable facilities in this category. Lack of BIM tools in renovation design is another obstacle that delayed the implementation of BIM in some design firms.

As always the financial aspect is an obstacle when it comes to new innovations, BIM tools are not different in this sense. Since about 70% of the design firms are small scale companies they will have problem finding funds to finance BIM technology and this pose a major constraint in implementing BIM in design phase (Stroeken, 2001).

7 Communication process development to efficiently utilize BIM

Major principles in aligning participants are efficient communication and collaboration. Communication takes place when information is bidirectional. The understanding of the actual information is important in communication and decision making. In this chapter construction work as communication base is explained and the significance of using the supply chain method in construction industry is noted. The process of communication and decision making is also mapped out in this section.

7.1 Construction work as communication base

For many years now a lot of research has been carried out on the importance of communication and information in improving the current construction practise. One major finding in those researches is that effective communication and information exchange within construction projects is one way of facilitating higher performance in the construction industry. Harty (2005) agrees by stating that to get an effective cooperation between different bodies in a project one needs to be very efficient in spreading the information and improving communication. Alshawi and Faraj (2005) add to the finding by concluding that a new situation have emerged where new and effective technologies that support better communication and information exchange is needed in order to make the current practices in construction more efficient. In fact, this has not been the easiest task in the construction industry. There are so many different areas that need to be thought of and addressed when it comes to building and the information needs to be accurate and well spread across the many collaborators. Time is of the essence so there is time and money to be saved in a well informed organisation.

Inter-organization relationship in construction industry is an important aspect in improving communication in the industry. The Supply Chain Management (SCM) method is concerned with tries to make the inter-firm relations better. Most of the concrete issues that is currently addressed in the construction sector such as innovation, communication and information flow, point to supply chains, not the individual firms or companies. The definition of supply chain management as is commonly used in construction industry is “Supply Chains Management is the integration of key business processes from the end user through original suppliers that provide products, services and information add value for customers and other stakeholders” (Titus and Bröchner, 2005).

There are many suggested techniques for implementing SCM: a) providing members in supply chain with long-term relationships, b) working cooperatively with key supplier, c) supply chain member must share information and d) all parties’ strong commitment are required. All these techniques have different strategies but studies show that they have a common basic principle which is to emphasize “the importance of communication and collaboration”.

Effective information sharing and transferring is the key to efficient communication and collaboration. Since communication routine involved the transfer and exchange of information it is necessary to have a standard communication model. The aim of this model is to understand the stream of information that occurs during the different phases of construction. The construction industry is not as linear as many other industries and this is one of the reasons that one cannot just use a method developed for another industry. Companies that cooperate in a building project are often divided in a natural way since they work with so many different phases of the project.

BIM tools are being used to make the different participants work more together and be more efficient in the financial aspect as well as in the time aspect. This type of project centred model makes the firms work more closely and opens up for collaboration and easy access to everyone's ideas and opinions. For example if a client has a request the question is communicated upstream to the supplier (for instance the architect, engineers, contractors, subcontractors and fabricators etc.). When the supply chain is recognized in the post-contracting phase the information regarding different materials, structural systems, environmental controls among others are communicated to the other project partners. Nowadays most companies are client-oriented and communication is crucial to the satisfaction of the client. One has to be able to fulfil the needs of the client in a quick and informative manner.

7.2 Communication and collaboration in BIM

BIM technology provides the necessary platform for coordination that is crucial for information sharing and decision making among project participant. The processes that are needed for communication and decision making to work effectively in a project include:

- Create collaborative environment, this should include early involvement of key stakeholders, agreement on business processes, open information exchange among stakeholders and participants sharing of knowledge and expertise.
- Definition of participant's roles and responsibilities in the project.
- Standard agreement on what information to be shared, specification of the data collection methods, and participants must also use open standard software appliance.
- Stakeholders must agree on how project documents will be handled.
- Communication plan which should include the mapped out ways of communication between participants. Most, if not all, communication throughout the design phase, construction phase, operational maintenance phase and demolition phase should be done electronically with open source and interoperable software appliances.
- Integrated business processes that change as the barriers between project team disappear through negotiation.
- Other major decisions should be evaluated by the project team and decisions should be made unanimously in the very best interest of the project.

The above process should be carried out by a "team of experts" from all the companies that are involved in the project. It is recommended that each firm or company that is taking part in the project should have one experienced member in the "team of experts" committee. The communications between all key stakeholders are shown in figure 11.

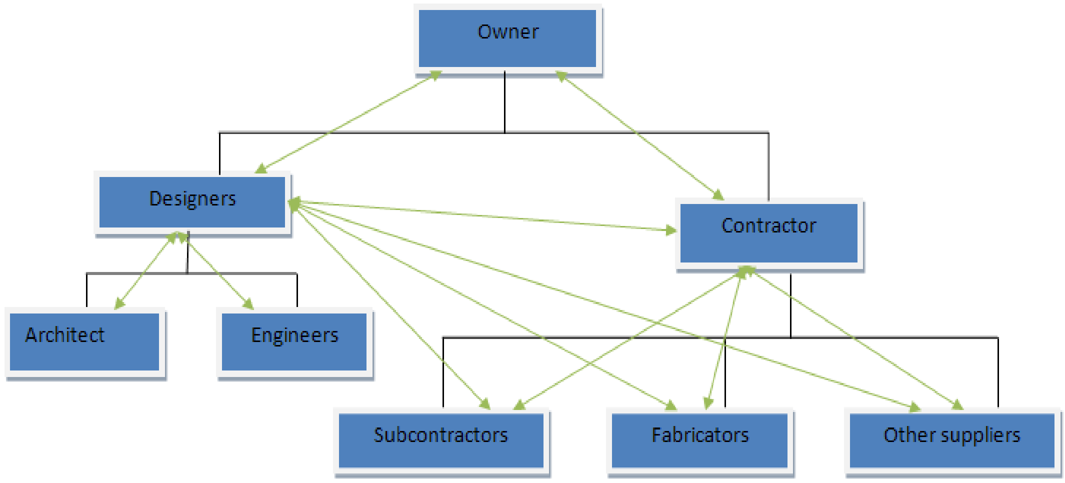


Figure 11: Communication Model in a construction project.

8 Conclusion

8.1 General conclusion

This Master's Thesis presents the concept of flow of information and communication in a bridge life cycle. Two main models of project delivery were studied to understand the information and communication in a complex civil engineering project. First is the current project delivery model which includes DBB and D-B models. This project delivery model is characterized by broken communication, unwillingness of the major actors to share information, use of outdated technology and lack of collaboration between the stakeholders. The second project delivery model is the IPD which integrates people and systems utilizing BIM technology.

BIM technology is the revolutionary technology the construction industry has been waiting for. The concept of BIM in terms of the way it can help the key actors in the construction industry to understand the importance of using state of the art information technology has been showing results. Professionals within the bridge sector now admit that the basic idea of BIM is solid and it seems to be the right way for the entire construction industry to take. BIM philosophy has the potential to change how the construction professionals describe their work, communicate and manage complex civil projects. It might lead to numerous new business potential.

It is clear that in order to be able to use BIMs full capacity and potential the existing project delivery method have to be changed. A project delivery model that supports integrated system is needed in order to have a true information managing system that improves communication and decision making.

However, only a handful case of whole bridge projects is known to have used BIM approach. On the contrary within the building sector there are a lot of projects that BIM approach has been used in, for example when the General Motors Flint V6 Engine Assembly Plant in Flint, Michigan was built. Looking at the example above it is clear that the larger and more complex a civil engineering project is the more potential it has to become a Building information model project. When the key actors realize the benefits and capabilities of BIM technology in supporting information and communication they will be prone to use it.

BIM model concept is currently seen as a platform for collaboration and information data exchange which enhance communication and decision making. It is also a possibility for bridge life cycle data management. However, the designers should see BIM technology as a method to be used when visualization and interactive information exchange in the later project phase is a must.

This thesis has also brought into light the importance of a communication model in the communication and decision making process. It is also showing the impact of modern technology, processes and new business environment in achieving effective communication and collaboration in integrated project environment.

Professionals working in BIM environment can expect five stages of evolution, which are; visualization, production of digital drawings, coordination, analysis and supply chain. The coordination paradigm, analysis paradigm and supply chain integration paradigm will evolve only once a practice has fully adopted BIM technology and most projects are completed utilizing BIM software. In addition, associates software used in connection with BIM should be able to represent the design as a series of intelligent objects and have object parametric attributes. Furthermore, all the objects information can be stored in a single BIM model.

The aim of BIM is to accomplish the best practices in the whole construction industry through integration, standardization and codification. However, the theoretical idea behind BIM is to address problems such as fragmented and paper based communication and information, lack of teamwork and collaboration between the major actors in a project, mistakes and errors based on 2D tool etc. In addition, managing software version, integrated data management, data security risk and needed financial investment to shift from present software platforms are some of the challenges that are expected in the adoption of BIM tools.

8.2 The future

Professionals in the AEC industry should be prepared to face the changes and challenges ahead. They should also be involved in the process of using the new technology and be prepared for changes in the organization. C. Eastman et al. (2008) sees those changes and challenges as a positive sign since most professional bodies in the construction field have noticed and reacted in an optimistic way.

With professional bodies such as AIA, AGC, ASCE and many other organizations involvement in BIM implementation in projects there is room for a rapid increase in the use of BIM in the years to come. The adoption of BIM in the bridge industry today is still slow.

Educational programs and courses needs to be developed at the Universities and other technological institutions to fit the future carriers of the graduates.

Due to the lack of model servers that supports design in the early design phase, there is currently lot of research being made in this area.

The owner has to take the initiative of demanding the implementation of BIM in the project simply because all research and studies point to the owner as the greatest beneficiary.

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