REVIEWING THE SCOPE OF BUILDING INFORMATION MODELING (BIM) FOR INDIAN SCENARIO

A DISSERTATION

Submitted in partial fulfillment of the requirements for the award of the degree of

MASTER OF ARCHITECTURE

By

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CERTIFICATE

Certified that this report entitled **"REVIEWING THE SCOPE OF BUILDING INFORMATION MODELING (BIM) FOR INDIAN SCENARIO"**, which has been submitted by Mr. VINOTH KUMAR J, in partial fulfillment of the requirements for the award of the degree of MASTER IN ARCHITECTURE, submitted in the Department of Architecture and Planning, Indian Institute of Technology Roorkee, Roorkee is the student's own work carried out by him under my supervision and guidance. The matter embodied in this dissertation has not been submitted for the award of any other degree of this or any other institute.

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CANDIDATE'S DECLARATION

I hereby certify that this report entitled **"REVIEWING THE SCOPE OF BUILDING INFORMATION MODELING (BIM) FOR INDIAN SCENARIO"**, which has been submitted in partial fulfillment of the requirements for the award of the degree of MASTER IN ARCHITECTURE, in the Department of Architecture and Planning, Indian Institute of Technology Roorkee, Roorkee is an authentic record of my own work carried out during the period from July 2008 to June 2009, under the supervision and guidance of Dr. Mahua Mukherjee, Department of Architecture and Planning, Indian Institute of Technology Roorkee, Roorkee, India.

The matter embodied in this dissertation has not been submitted by me for the award of any other degree of this or any other institute.

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ABSTRACT

BIM is an intelligent parametric, object-based design methodology that is compelling the design community to transition away from unintelligent nonparametric, computer-aided drafting (CAD) processes. The design communication is gradually being changed from 2D based to integrated 3D digital interface. Building Information Modeling (BIM) is a model-based design concept, in which buildings will be built virtually before they get built in the field, where data models organized for complete integration of all relevant factors in the building lifecycle which also manages the information exchange between the Architecture, Engineering, and construction professionals, to strengthen the interaction between the design team.

BIM is a shared knowledge about the information for decision making during its lifecycle. There's still much to be learned about the opportunities and implications of this tool. The impact of BIM on the evolution of design tools in the AEC industry has recently become a topical research area.

It is found that BIM adoption is much higher in the US and Finland than in the rest of the world. In India the use of BIM is quite low for AEC's till date and conventional entity based CAD software remains the drafting tools. The core barriers include a lack of training and technical support, a lack of requirements from client, and the unavailability of free trial software.

This report deals with the status check of BIM application in India. To do that a Survey has been designed to check the acceptance of BIM till date, and another methodology Hands on Experience, (HoE) has been adopted. The HoE identifies areas which provide added advantages and value through the use of BIM at the Schematic Design stage for communication of information and the manner the information is obtained. This application is widely accepted throughout the AEC industry in many countries for managing project information with capabilities for cost control and smoother facilities management.

The report concludes that

- Improvements are further required in the BIM technology development to make it more users friendly.
- BIM technology has been able to establish its supremacy over conventional CAD system; and the complete adoption of the technology by the AEC industry will take a few more years.

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ABBREVIATIONS

BIM	*Building Information modeling*
MEP	*Mechanical, Electrical and Plumbing*
NIST	*The National Institute of Standards and technology*
AIA	*The American Institute of Architects*
CAD	*Computer-aided design*
AEC	*Architect, Engineer, and Contractor*
LEED	*Leadership in Energy and Environmental Design*
ROI	*Return on Investment*
OST	*Open Space Technology*
MHS	*Material Handling System*
GRC	*Glassfibre Reinforced Concrete*
TQs	*Technical Queries*
RFI	*Request for Information*
LBNL	*Lawrence Berkeley National Laboratory*
OLED	*Organic Light Emitting Diode*
HVAC	*Heating, Ventilating and Air Conditioning*
IFC	*Industry Foundation Classes*
VBE	*Virtual Building Environment*
ADT	*Architectural Desktop*
GDL	*Geometric Description Language*

CHAPTER 1

INTRODUCTION

1.1. INTRODUCTION

Building Information Modeling (BIM) is the documentation process consisting of information about different phases of any project like design, construction planning, construction, facility management and operation. It is one holistic documentation process beneficial for operational visualization, and construction application such as estimating, scheduling and design coordination. Main advantage of implementing BIM application is the visual coordination of the building systems such as MEP systems and it also identifies the possible conflicts between the building systems. By detecting the conflicts, problems can be resolved before actual construction which in turn saves money and time invested (*H Yan and P Demian, 2008*). The National Institute of Standards and technology (NIST), reported (*Gallaher et al, 2004)* that the lack of adequate interoperability cost the U.S facilities industry about $15.8 billion per year. In India, the BIM application is not widely practiced till now has scope to use this technology in a much wider scale.

1.2. BIM DEFINITIONS

Building Information Modeling (BIM) is the process of generating and managing building data during its life cycle using three-dimensional, real-time, dynamic building modeling software to decrease wasted time and resources in building design and construction. This process produces the building information model (also abbreviated BIM), which encompasses building geometry, spatial relationship, geographic information, and quantities and properties of building components. (*Source: www.wikipedia.org*)

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. In the future, structured text documents such as specifications may be able to be searched and linked to regional, national, and international standards.*(Source:AIA)*

Bentley building solution - Building Information Modeling (BIM) is a new way of approaching the design and documentation of building projects. By applying information and model-based technology solutions to allow the automatic generation of drawings and reports, design analysis, schedule simulation, facilities management, and more ultimately enabling the building team to focus on the information and their decisions, rather than the documentation tools and process. (*Source: www.bentley.com*).

1.3. AIM OF THE PROJECT

Evaluation of BIM concept to enhance the current construction methodology in India

1.4. OBJECTIVES

Thorough review on BIM and its scope for application in India is not only a necessity for its approach, but also for its right timing when the concept is in budding stage in most of the countries.

1. To record evolution of architectural documentation process.
2. Analyze the strength of BIM concept over limitations of CAD.

3. To find the scope of application of BIM concept in India, three distinct strategies have been adopted,

- Project experiences recorded by BIM professionals in India.
- Hands on Experience.
- Responses from AEC professionals on BIM concept.

1.5. METHODOLOGY

The challenges are to be approached through different means. Basically it is divided into stages like:

i. Literature survey

ii. Analyze the conflicts in the ongoing projects in India using BIM.

iii. Critical review of information collected from different sources through survey.

iv. Comparative study of conventional CAD model and BIM model.

1.6. SCOPE OF THE PROJECT

Building Information Modeling (BIM) phenomenon started to gain momentum, and we are at the point where it has reached a certain level of maturity in India. Several BIM solutions are now available for individual disciplines such as architecture, structural engineering, MEP engineering, and construction. This is the time to validate its scope in Indian construction industries.

1.7. ORGANIZATION OF THE STUDY

This report starts with a literature review which outlines the historical evolution of design tools. The literature review and case studies describes the benefits of BIM claimed by its proponents as well as barriers to its implementation.

Following, Is the "Hands on Experience" which describes primary differences in design representations between traditional 2D documents and BIM for representation the Schematic Design information.

Next, the paper describes questionnaire data from the survey of about 58 individuals from the AEC industry on BIM adaptation, perceived both benefits and barriers. The questionnaire is intended to determine professional opinions about BIM and whether companies adopt BIM tool or plan to adopt this technology.

CHAPTER 2

LITERATURE REVIEW

2.1. INTRODUCTION

"First, the taking in of scattered particulars under one Idea, so that everyone understands what is being talked about........."

- Plato, Phaedrus, 265D.

Architectural practice usually reflects the needs of the work market. Therefore, it is very important to understand the needs and identify the directions where the architectural practice should go if the current trend of implementing the new technology will grow. It is obvious that slowly but surely, BIM based CAD is gaining more and more ground each year in the professional practice of architecture. This chapter is a collection of observations and suggested strategies that have acquired and thought of from design solution companies, as well as research papers by professional architect with the role of a CAD manager and academicians.

2.2. STRUCTURED ARCHITECTURAL DOCUMENTATION

Systematic documentation can be traced back during Renaissance, when Filippo Brunelleschi represented the plans for Santa Maria del Fiore in Italy in the drawings' format to make the patrons understand how the building would look like. Through ages, Architectural Documentation has evolved. Availability of computers opened scopes for creating a data model for a complete design process starting from conceptual phase to the operational phase. Fig 2.1 represents the evolution process of the architectural documentation. In the following section a brief sketch of the evolution has been depicted.

I phase – Till early 1980s: Before 80's design documents are made traditionally by drawing lines to represent a building. These documents like plan, section and elevation are the main source to describe the building to be built. In these traditional drawings each line meant to convey design so that a building can eventually be constructed.

II phase – 1980s to Late 1990s: With the introduction of computers, the major switch over started from manual drafting towards the computer aided drafting, which helped in producing drawings faster. As buildings became more complex, specialization in the design and construction process emerged, which in turn lead to more elaborate forms of information. Use of computers, especially for 2D drawings and reports are revolutionary changes into Architectural Documentation.

III phase – Beginning of the 2K: In the present day, buildings are much more complex than ever before. The numbers of people involved in producing drawings are too large. With the growth of technology, the building systems are also many. Today, buildings have more security, electrical, HVAC, and energy requirement. Computer based technology has been updated in order reduce errors, but in the end, they are still collections of manually created, non-intelligent lines and text.

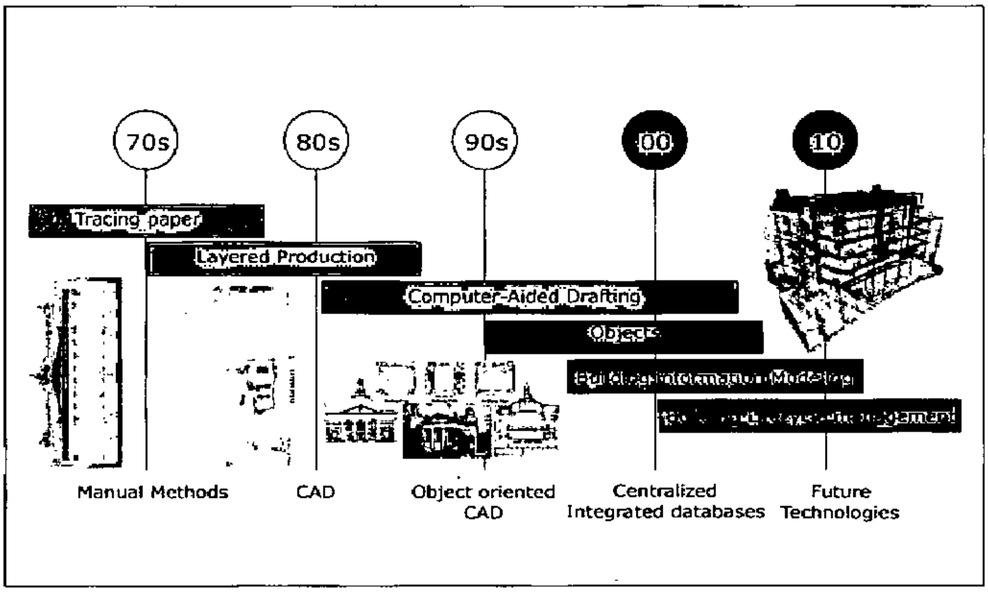


Fig 2.1 Evolution process of Architectural Documentation

2.3. APPROACH TO BIM CONCEPT

The ultimate benefits of BIM are still emerging in the market, and will radically change the way buildings are designed and built. A shift in process and expectation is happening in the construction market, and architects are stepping up to the challenge. The focus is shifting from traditional 2D abstractions to on-demand simulations of building performance, usage, and cost.

Traditionally, architects have used the centuries old method of plan and elevation design, accompanied by a physical model of the building, to explain building details to the client. But after all the sketches and planning, a CAD program is still just a documentation tool. The building and the fact that more information is inherently added to the design process in the early stages. However, BIM allows the designer to actually see the consequences of a design decision immediately and in three dimensions. This is no longer a futuristic fantasy, but a practical reality. In the age of information-rich digital models we can now have all disciplines involved with a project sharing a single database. Architecture, structure, mechanical, infrastructure, and construction are tied together and able to coordinate in ways never before possible. Energy analysis can be done at the very outset of design, and construction costs are becoming more and more predictable. These are just a few of the exciting opportunities that a BIM approach offers.

With BIM, a parametric 3D model is used to auto generate traditional building abstractions such as plans, sections, elevations, details, and schedules. Drawings produced using BIM are not just discrete collections of manually coordinated lines, but interactive representations of a model. Working in a model-based framework guarantees that a change in one view will propagate to all other views of the model. As you shift elements in plan, they change in elevation and section. This enhanced document-delivery system allows unprecedented control over the quality and coordination of the document set.

2.4. BIM AND CAD

The main differences between BIM and Computer Aided Design (CAD) are that CAD system is usually 2D document, which are created separately and have no intelligent connection between separately created documents. In CAD, two lines represent a wall. In BIM, wall is created in the form of an interactive tool, which has its own properties like width, height, bearing or non load bearing virtue, demolished or new, interior or exterior, fire rating, and materials (such as boards or brick) etc.

Table 2.1 The Efficiency difference between CAD and BIM applications

Task	**CAD (hours)**	**BIM (hours)**	**Hours saved**	**Time savings**
Schematic design	190	90	100	53%
Design development	436	220	216	50%
Construction documents	1,023	815	208	20%
Checking and coordination	175	16	159	91%
Totals :	1,824	1,141	683	

Source: (Rick Rundell, 2007)

The BIM platform assembles all information into one location and cross-links that data among associated objects. There is no linkage between the data created by CAD. Efficiency of BIM in comparison to CAD in different phases is being referred in Table 2.1.

By and large, CAD is strictly a 2D technology with a specific need to output a collection of lines and text on a page. These lines have no inherent meaning, whether inside the computer or on the printed sheet. CAD drafting has its efficiencies and advantages over pen and paper, but is really just a simulation of the act of drafting. This form of drawing is how architects and other designers have worked for the last couple of hundred years. Other software packages, like SketchUp, Rhino, and 3ds Max, are excellent modeling applications. Many architects use these tools to generate concept models, which can then be brought into a BIM application and progress through design, analysis, and documentation. Comparative analysis between Conventional and BIM documentation is being referred in Table 2.2.

Table: 2.2 Comparative analysis between conventional and BIM documentation

Information	**Conventional documentation**		**Building information model**	
Design concept	*Form taken*	*How it was obtained*	*Form taken*	*How it was obtained*
Floor plan(s)	2D	Printed sheets	2D & 3D	Visualized in BIM
Elevation	2D	Printed sheets	2D & 3D	Visualized in BIM
Section	2D	Printed sheets	2D & 3D	Visualized in BIM
Rendering	2D	Printed sheets	2D	Visualized in BIM
Architectural	Drawings & text	Finish schedule in drawings & specifications	3D images & texts	Seen in model, Properties window or generated finish schedule
Mechanical	Drawings & text	Found in drawings & preliminary specifications	3D images & texts	Seen in model or Properties window
Structural	Drawings & text	Found in drawings & preliminary specifications	3D images & texts	Seen in model, Properties window or generated finish schedule
Major materials / finishes	Drawings & text	Found in drawings & preliminary specifications	Visualized in model or plan	Properties window or generated finish schedule
System coordination	Not clearly evident		Conflicts in model	Conflict report, seen in models
Description of works	texts	Preliminary specifications	Not included	
Areas	Not included	Hand takeoffs & manual calculations	Schedule in model	Generated
LEED Information	texts	Achievable points listed in specifications.	Not included	
Constructability	Drawings & texts	Determine from review of documents	Model, plans	Determine from review of model

(Source: Robert M. Leicht, John I. Messner, 2007)

2.5. DESIGN SOLUTION COMPANIES VIEWS ON BIM

The various Design solution companies are started adopting BIM methodology using various BIM tools and the reason for the successful adoption is been briefly discussed.

2.5.1. Bentley Architecture Solution *(Source: www.bentley.com)*

BIM is getting much attention because it is so well aligned to providing value in relation to major converging conditions in the building professions:

- Sustainability awareness and objectives
- 'New' project delivery approaches
- Advances in design technology
- Globalization/Distributed Teams/Consolidation
- Competitive pressures and client demands.

The industry is driving change: The building industry has become increasingly aware of the need to improve the way buildings are designed, delivered, and operated throughout their lifecycle.

***There are benefits to be gained*:** BIM integrates the work, processes, and information for:

- Multiple disciplines
- Multiple companies
- Multiple project phases.

***Saving Time*:** Teams that have changed to BIM save time

During design, there is increased opportunity for design interactions, as information is exchanged between disciplines quickly. Professionals can spend less time documenting decisions and more time making them. Everyone can avoid redundant effort. And construction can better support fast-tracking, tightly managed schedules, and the shared risks and rewards of design/build.

Improving Quality: Teams that have changed to BIM improve the quality of work.

Improved coordination between documents, between disciplines, and across the entire team reduces errors and omissions. With coordinated documents and well-captured design intent, the enhanced design process makes for a far more informed design environment.

In addition BIM enables you to pursue better quality buildings, through issues such as:

- Integrated practice
- Sustainable "Green" design
- Innovative use of materials and methods
- New and exciting building geometries.

Enhancing Profitability: Teams that have changed to BIM enhance profitability and competitiveness

i. Lower the bottom line: Effectively applied man-hours, efficient deliverables, and lower error and omission remediation costs can all dramatically impact profitability. Moreover, the increased predictability of managed costs can be realized in lower contingencies. Many BIM practitioners can even point to lower insurance premiums as a result of reduced project claims.

ii. Raise the top line: With a faster delivery of service, more competitive quality of work and tighter bidding for design and construction services, BIM enables more profitable practice.

2.5.2. Cadalyst *(Rundell, Rick, 2004)*

a) Calculating BIM's return on investment

With the advent of BIM (building information modeling), the building industry is coming to appreciate that technology can radically transform the building design and construction process. But before committing the funds to purchase that technology, the bean counters in an organization will probably insist on ROI (return on investment) analysis.

b) ROI for BIM Investment

Calculating the ROI for a design system can be relatively easy. The diagram below (Fig 2.2) illustrates what happens after putting a new system into place. There's an immediate dip in productivity as users get up to speed on the new system.

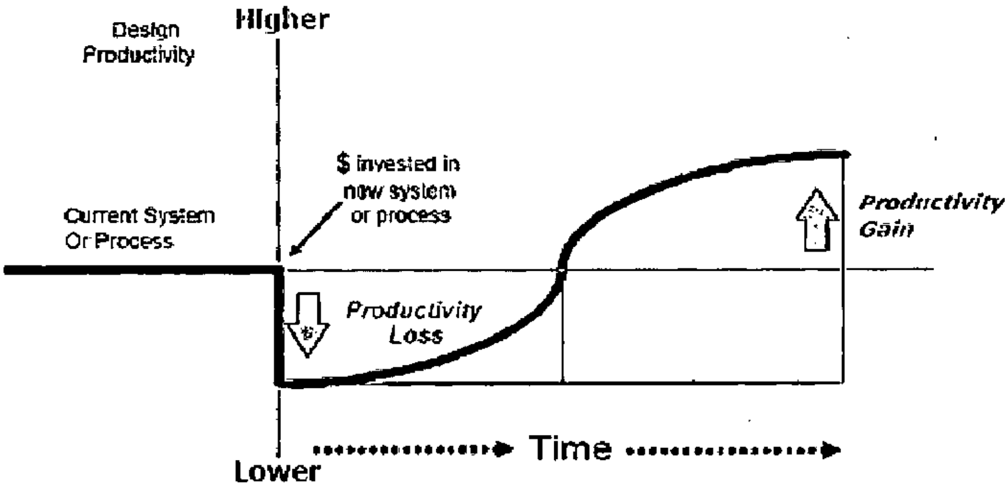


Fig 2.2. Visualize what happens when you put a new system into place.

A Standard formula for calculating the first-year ROI, it uses just a few key variables related to system cost, training, and the overall productivity cost savings of a system.

$$\frac{\left(B - \left(\frac{B}{1+E}\right)\right) \times (12 - C)}{A + (B \times C \times D)} = \text{First Year ROI}$$

A standard formula for calculating first-year ROI.

A = cost of hardware and software (dollars)
B = monthly labor cost (dollars)
C = training time (months)
D = productivity lost during training (percentage)
E = productivity gain after training (percentage)

The ROI formula variables.

The numerator represents the earnings portion of the equation, which comes from an increase in human productivity. The increase in average monthly productivity is represented in the left bracket (B - (B / 1 + E). The right bracket (12 - C) is the number of months in a year minus months in training (C). If the user needs three months to become as productive on the new system as on the old, then there are nine months left in the year to benefit from the productivity gains. The denominator, which is the cost portion of the equation, includes the cost of the system (A) and the cost of the productivity lost, in terms of labor cost, as the user learns the system. This second term is the product of the monthly labor cost (B) multiplied by months in training time (C) multiplied by productivity lost in training (D), therefore, BXCXD.

Fig 2.3. Donald Powers Architects

In Autodesk's recent online survey, more than half the respondents experienced productivity gains of more than 50% using the Revit building information modeling solution, and 17% experienced productivity gains of more than 100%. The building shown in the Fig 2.3 designed and developed using Revit by Donald Powers Architects, found that using Revit has resulted in a 30% productivity gain. The least important factor in our ROI calculation turns out to be the system cost, an interesting fact to remember the next time you're involved in a technology purchase. Doubling the system cost in the original set of numbers (from $6,000 to $12,000) reduces the ROI by only 20% (from 61% to 41%).

2.5.3. AEC Bytes *(Source: www.aecbytes.com)*

BIM is considered by many as an important incremental improvement to the way architects-contractors and fabricators have been working. It allows clash-free design, inherently consistent drawing sets and excellent visualization of the building design, during design, fabrication and erection. These are indeed grand improvements, and resolve some of the recurring problems and wasteful practices that architects and contractors have been putting up with in current practice.

However, consider that BIM has larger impacts than these attractive but evolutionary ones. BIM is a disruptive technology that will transform many aspects of the AEC industry. As a result, BIM invites strategic re-thinking of processes and production to achieve the three-part goal of better, faster and cheaper buildings.

- ***Better***: more knowledge about the building earlier in the life cycle regarding cost, energy use, organizational performance, 3D visualization by all members of the project team (including the owner)
- ***Faster***: ability to use construction and fabrication knowledge during design, ability for greater use of off-site fabrication, ability to use product information earlier in design and in procurement planning
- ***Cheaper***: much better coordination of project team using the model as source of decision-making and planning, faster procurement, greater use of fabricated components from global sources, fewer owner changes because of better understanding of the building and how it will function for its users, fewer errors, omissions and claims, use of "as built" model for facility management.

For many firms, this will mean closer forms of collaboration. The architectural firm has a two-way link in the collaboration. On one side are the design consultants, structural, mechanical, building type, materials that contribute to better performing designs. On the other side are the general and many types of subcontractor construction firms and fabricators providing early input of constructability, so that there is a smooth transition from design intent into realization.

2.5.4. Design Presentation *(Source: www.designpresentation.com)*

Design Presentation is a premier BIM support service provider to the AEC firms worldwide. AEC firms around the globe are transitioning from 2D CAD Platforms like ACAD and Micro station to 3D intelligent modeling in BIM. Design Presentation understands and caters to the needs of the industry has invested in the leading BIM solution software's like: Autodesk's Revit Building, Revit Structural and Revit MEP, ArchiCAD, Sketch-up, etc.

BIM technology provides a link between, design, construction and management along with improved productivity for easy retrieval of embedded data information. BIM support services at Design Presentation provide intelligent modeling in order to reduce project cost, increase profitability and save time. Following are the range of BIM support services:

i. ***3D Visualization:*** We can create 3D Models for renderings and animations. These models can also be used to study building geometry/massing and construction sequencing.

ii. ***Embedding/linking and extracting of various Information***: We can embed/link and extract project information in the model, e.g. generating cost estimates, quantities schedules, material specifications, area charts, etc. of the project.

iii. ***Conflict Detection:*** We help you to identify conflicts among various design disciplines and deliver you a fully coordinated BIM model.

iv. ***Content Creation:*** We help you create Family contents as per project specific needs or even as separate package. These details could be Parametric-Non-parametric in nature, host based, stand-alone or dynamic as per your needs.

v. ***Detail Library:*** We can draft details in BIM as a part of the project or as a separate library with customized line weights, hatch patterns, etc.

2.5.5. The American Institute of Architects *(Source: www.aia.org)*

What is a BIM Process?

First, it's significantly more than transferring electronic versions of paper documents. It's more than pretty 3D renderings with construction documents as a separate function. It's about information use, reuse, and exchange, of which electronic documents are just a single component.

When integrated 3D-2D model-based technology is linked with information, design firms have a faster, higher-quality, richer design process. Risk is reduced, design intent is maintained, quality control is streamlined, communication is clearer, and higher analytic tools are more accessible. Fig 2.4 shows the various tasks performed using BIM models.

Lower-level tasks such as drafting, view coordination, document generation, and schedule creation are automated. Drawings that represent different views of the same building object are automatically updated when modified.

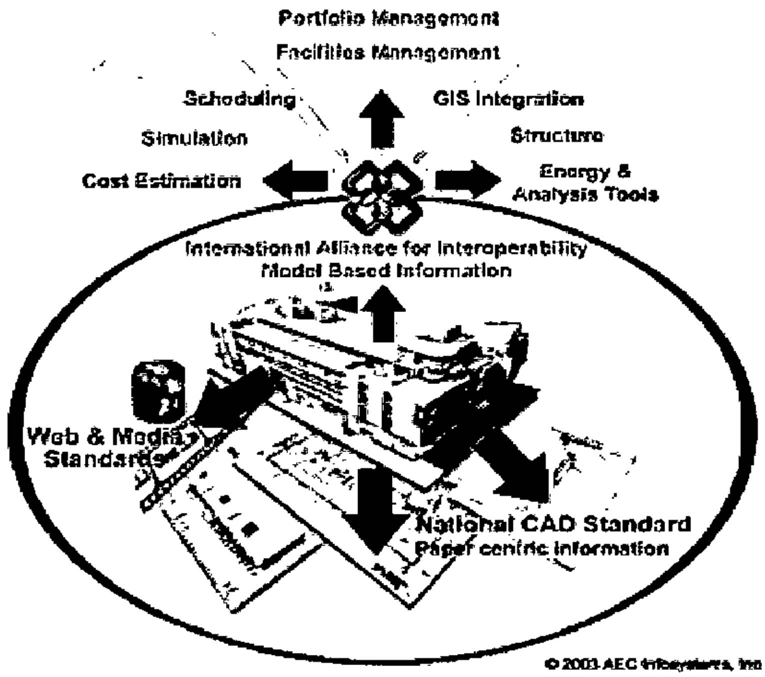


Fig 2.4: Various tasks performed using BIM models

2.5.6. Autodesk Building Solutions *(Source: www.usa.autodesk.com)*

Building Information Modeling in Practice

Building information modeling an innovative new approach to building design, construction, and management introduced by Autodesk in 2002 has changed the way industry professionals worldwide think about how technology can be applied to building design, construction, and management.

Building information modeling supports the continuous and immediate availability of project design scope, schedule, and cost information that is high quality, reliable, integrated, and fully coordinated. Among the many competitive advantages it confers are:

- Increased speed of delivery (time saved)
- Better coordination (fewer errors)
- Decreased costs (money saved)
- Greater productivity
- Higher-quality work
- New revenue and business opportunities

For each of the three major phases in the building lifecycle design, construction, and management building information modeling offers access to the following critical information:

- In the design phase - design, schedule, and budget information
- In the construction phase - quality, schedule, and cost information
- In the management phase - performance, utilization, and financial information

2.6. RESEARCH PAPERS ON BIM

There are many reviews and research carried out in this new methodology throughout the world by professional Architects and the Academicians to bring out the best and to make aware of this methodology. A few research papers are been reviewed and discussed briefly.

2.6.1. The Level of Knowledge of Cad Objects within the Building Information Model. *(Ref: Ibrahim & Krawczyk, 2003)*

On this topic *Ibrahim, Krawczyk (2003)* compares and analyses the advantage of present emerging generation of CAD systems over the first generation of CAD software's, and also discussed about different levels of knowledge in pursuing the potential of modeling true architectural objects.

2.6.2. A Web-Based Approach to transferring Architectural Information to the Construction Site Based on the BIM Object Concept. *(Ref: Ibrahim et al, 2004)*

Ibrahim, Krawczyk, Schipporiet (2004) describes the process to convey the information about the CAD objects to the construction site through the web by extracting the properties of the objects into an XML file which can be queried for the needed data.

2.6.3. Comparing Time and Accuracy of Building Information Modeling to On-Screen Takeoff for a Quantity Takeoff of a Conceptual Estimate. *(Ref: Adam, 2006)*

Adam (2006) made a study analyzing the time and accuracy of performing quantity takeoffs when using building information modeling (BIM) through a comparison study using Revit (BIM software) and On-Center's OST and performed a quantity takeoff using both Revit and OST. The result was then, analyzed comparing both the time and accuracy of each item taken off. This study focused on a conceptual estimate takeoff for a small commercial building. Findings of this study include methods, techniques, and cautions for performing a quantity takeoff using BIM.

2.6.4. Building Information Modeling for MEP. *(Ref: Jessica, 2007)*

Jessica E (2007) defines what BIM actually is and discusses the benefits and challenges that are associated with this new method of design and construction. Specifically, will take an in depth look at how BIM affects MEP design.

2.6.5. Are You Talking To Me? Why BIM Alone is not the Answer. *(Ref: Dominik holzer, 2007)*

Dominik holzer (2007) sheds light on the status-quo of BIM and questions how designers can complement the current BIM capabilities to increase design-communication and a more seamless flow of information between various parties in architecture, engineering and construction (AEC).

2.6.6. Building Information Modeling of Modern Historic Buildings. *(Ref: Hannu et al, 2007)*

Hannu, Rajala, Freese (2007) made a research study which evaluated the possibilities of building information modeling (BIM) within renovation of buildings of significant architectural, historic or cultural values. Renovation or restoration projects of historic buildings can be more demanding, challenging and complex than traditional renovation because there are more needs for various kinds of surveys, accurate data gathering and analyzing queries concerning the project.

2.7. SUMMARY

The benefits of using of BIM have been demonstrated in several literature studies, research papers and case studies of real construction projects. Benefits can be found in all phases in the building project ranging from the conceptual design to the realization of the building. It also seems that most stakeholders in the building process benefits from the use of BIM, but maybe the greatest beneficiary is the client. Therefore investments in BIM technology should be evaluated on the project level, sharing the costs and benefits between all stakeholders.

The next chapter is about the implementation potentials and constraints in using BIM in order to get the clear idea about this methodology before carrying out the real time analysis.

CHAPTER 3

CASE STUDIES

3.1. INTRODUCTION

These are some potential case studies to be reviewed in order to understand how the BIM process is carried out in different phases throughout the project.

3.1.1. Cathay Pacific Cargo Terminal *(Source: www.intelibuild.com)*

BIM (Building Information Modeling) Overview

Cathay Pacific will invest approximately HK$4.8 billion into their new air cargo terminal at Hong Kong International Airport which will have a designed annual air cargo throughput capacity of 2.6 million tones. The facility is planned to commence operation in the second half of 2011. The new cargo terminal will be built in the cargo area at the airport, adjacent to the existing cargo servicing facilities. The terminal facility will occupy a site area of approximately 10 hectares. The investment will strengthen HKIA's position as the world's leading air cargo and logistics hub.

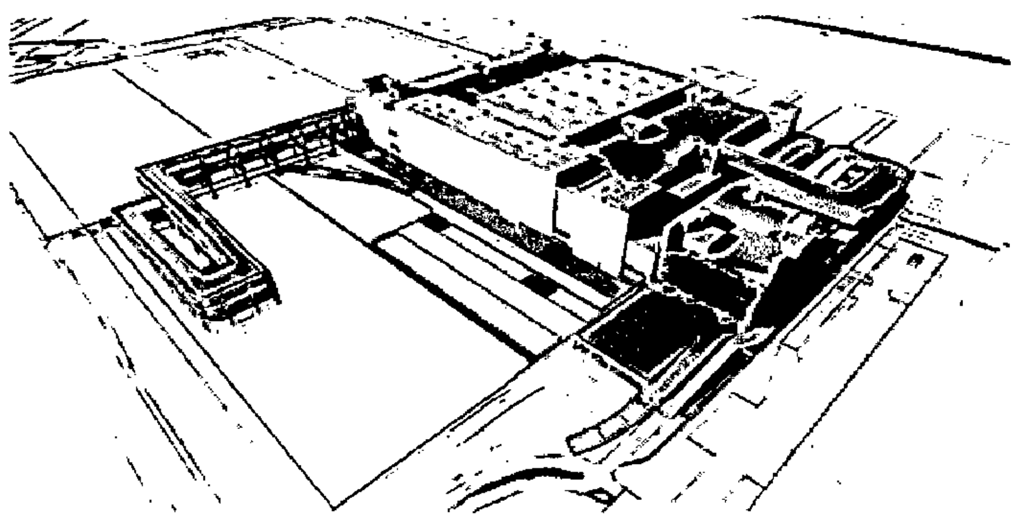


Fig 3.1 (a): BIM generated model.

Due to the complexities of designing and constructing the modern semi-automated material handling system (MHS) which demands very precise co-ordination with the building structure, architecture and building services systems, Cathay Pacific specified the project would be designed using Building Information Modeling (BIM) methodologies and processes. The primary purpose of the BIM is to ensure that all of the MHS equipment, structural framing, architectural components and building services systems are fully co-ordinate and clash free. The second purpose is to generate a set of consistent construction drawings produced from the 3D models.

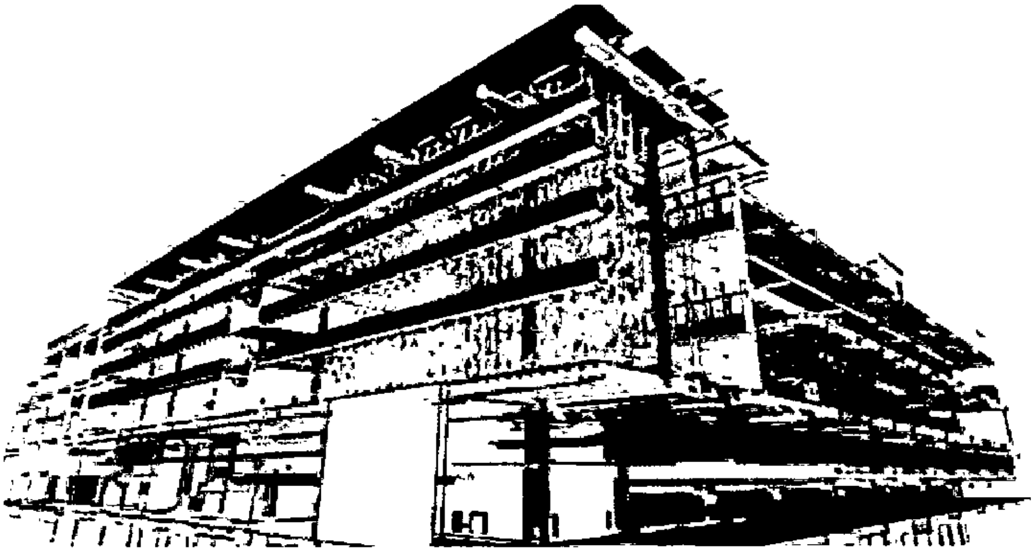


Fig 3.1 (b): BIM generated model.

To achieve these goals Meinhardt and InteliBuild created a dedicated BIM Team co-located with the engineers, architects and specialists responsible for the design of the large cargo terminal. At the start of the project the BIM team reviewed the available software for BIM and also assessed the software used by the MHS manufacturers. AutoCAD and Revit were selected as the most suitable applications. The BIM team is using Revit Structure and Revit Architecture to design and model the building fabric. The building services are modeled in AutoCAD MEP and the MHS systems are modeled by Siemens as 3D solids in AutoCAD.

InteliBuild established the necessary BIM Standards and Procedures for the project. These included specifications for the model co-ordinates, units, CAD file naming conventions, clash analysis tolerances and drawing production management systems. In order to co-ordinate 33 MHS 3D CAD models, 13 Structural, 3 Architectural and 54 MEP BIM models an elaborate system of live and published data was developed for this innovative project.

NavisWorks Manage is utilized for three key purposes by the BIM team. NavisWorks is the only application available that can compile and compress all of the Revit and AutoCAD 3D models into a single virtual building project as shown in Fig 3.1 (a), (b). This allows the easy sharing of the building model with the client, project managers and designers thus ensuring that everyone has easy access to the detailed visualization.

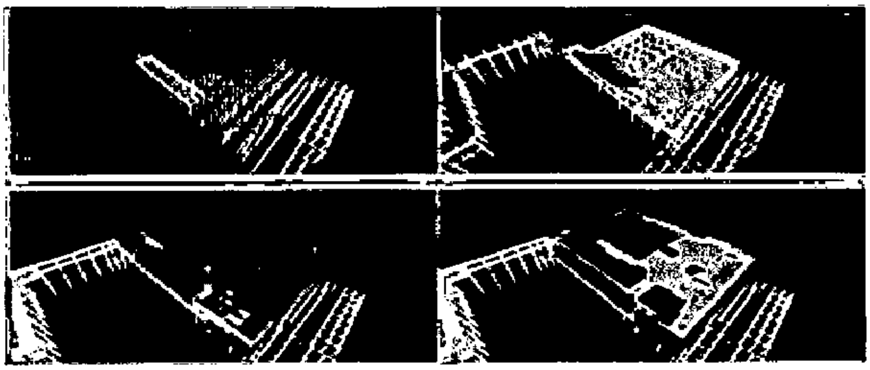


Fig 3.1 (c): Model showing the energy analysis of each part of the building.

NavisWorks Clash Detective is utilized by the BIM Manager to evaluate the design coordination progress and to assist the design team in identifying the key areas within the large complex facility that require detailed design co-ordination with the services installed model, shown in the Fig 3.1 (d), (e). The clash analysis matrix stipulates the specifications for hard and clearance checks for 93 different simulations, shown in the Fig 3.1. This analysis ensures that the operational requirements, spatial co-ordination and building services co-ordination are all reviewed.

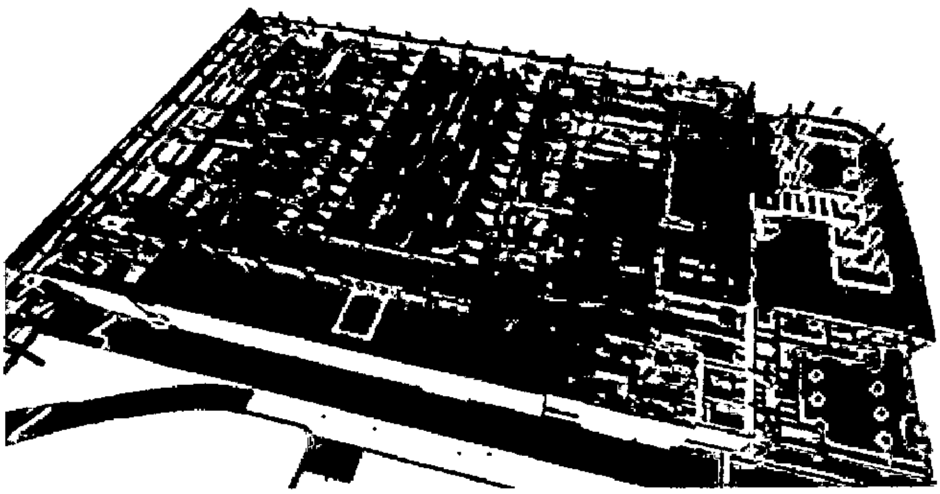


Fig 3.1 (d): BIM model showing the installed services for clash detection.

NavisWorks Timeliner links the planned construction programme to the BIM models thus allowing the Project Managers to understand the phasing of the structure frame erection with the installation of the MHS steelwork and equipment. The 4D virtual construction simulation depicts the construction sequence, zoning and interaction between the main contractors operations and the specialized MHS sub-contractor works thus allowing the client, designers, planners and contractors to discuss, review and plan the exact sequences to ensure the project is delivered in an efficient and timely manner in order to meet the operational demands for the Air Cargo Terminal.

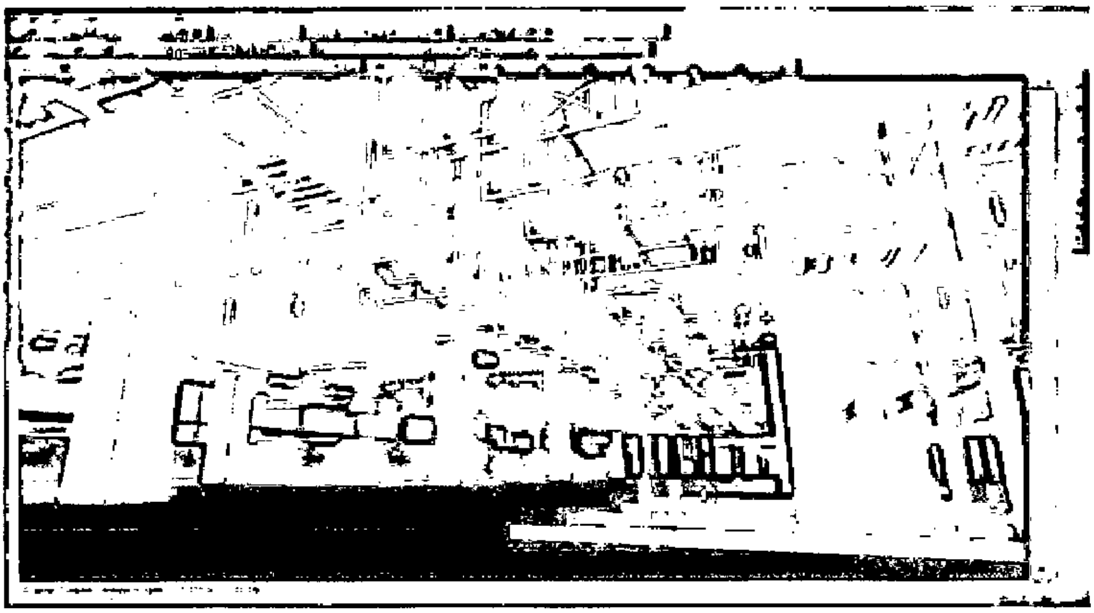


Fig 3.1 (e): BIM model showing the installed services for clash detection

The implementation of Revit, AutoCAD and Navisworks by InteliBuild and the BIM team on the Cathay Pacific Cargo Terminal has enabled the design team to focus on the building design co-ordination, drawing production and construction planning with the confidence that the BIM software will meet the demands of the project.

October 2008 - Cathay Pacific Cargo Terminal Press Release

Cathay Pacific today welcomed the announcement made by the Airport Authority of Hong Kong to award the airline's wholly owned subsidiary, Cathay Pacific Services Ltd, a franchise to invest in, design, construct and operate a new air cargo terminal at Hong Kong International Airport.

InteliBuild are leading the full implementation of Building Information Modeling (BIM) for the design and co-ordination of the new cargo terminal which will have a designed annual air cargo throughput capacity of 2.6 million tones.

As part of the Meinhardt and Aedas design team, InteliBuild are responsible for the structural, architectural, mechanical, electrical, fire protection and plumbing and drainage systems. The BIM also fully integrates the Material Handling System (MHS) being design and supplied by Siemens. The BIM models as shown in Fig 3.1 (f) will ensure that all of the contract drawings are fully co-ordinated and that there are no unforeseen conflicts between the building fabric, services and MHS systems.

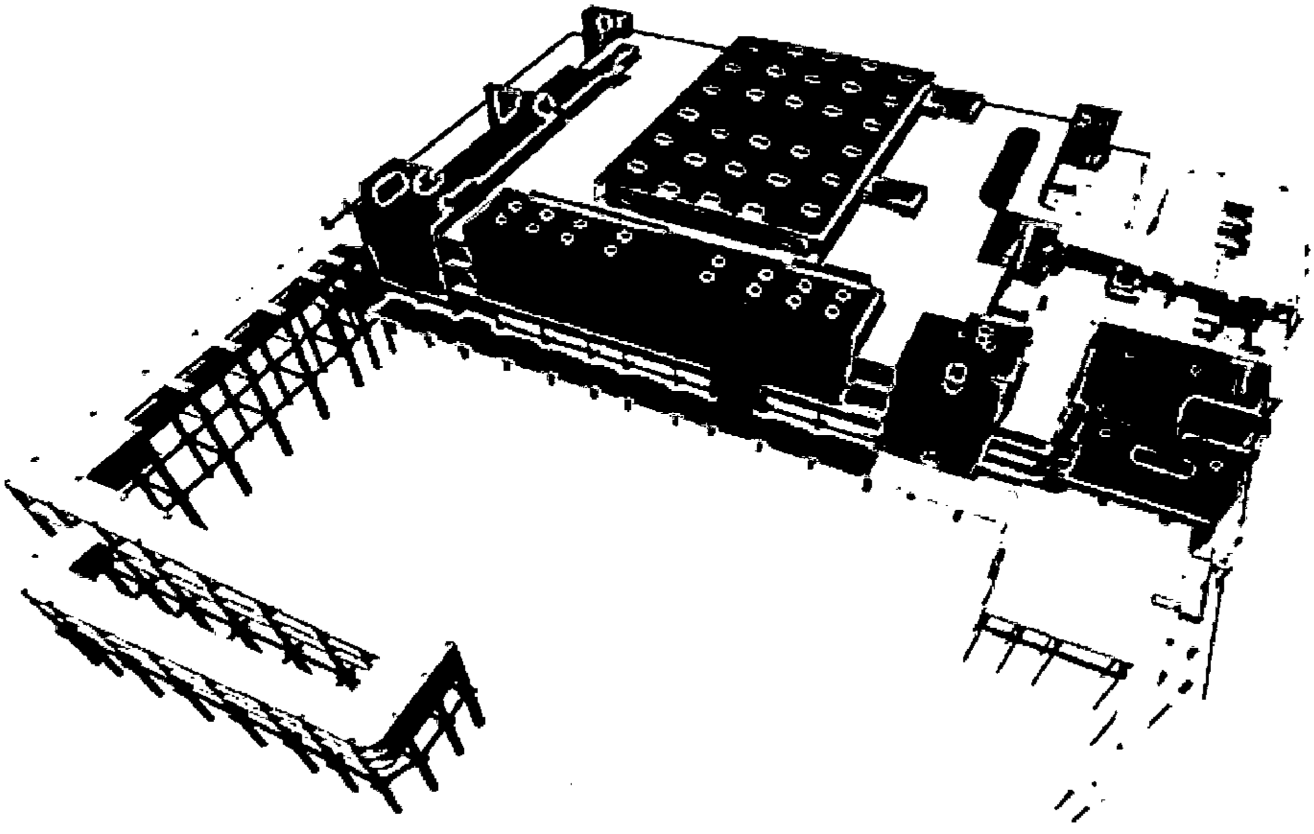


Fig 3.1 (f): BIM wireframe model

3.1.2. Al Maha Sofitel Hotel *(Source: www.intelibuild.com)*

Project Information

Project/Building Name:	Al Maha Sofitel
Location:	Doha, Qatar
Project Size (sq m):	52,000 sq m (constructed floor area)
Building Type(s):	5 Star Hotel
InteliBuild Project Type:	3D CAD Design Validation
Total Building Costs:	US$80m (estimated)
Owner:	Al-Mirqab Tourism Company
Architect:	South West Architecture
Structural Engineer:	South West Architecture
Building Services Engineer:	South West Architecture
Main Contractor:	Al Majal
InteliBuild appointed by:	Diplomat Group, MEP Contractor

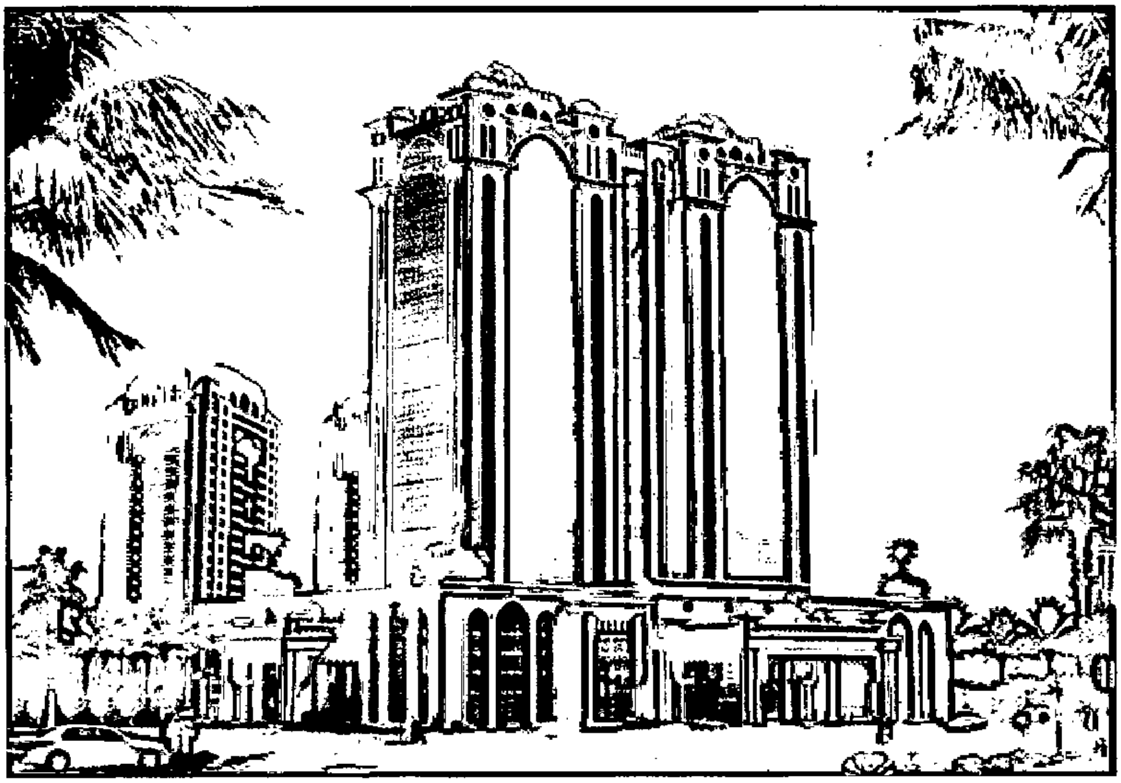


Fig 3.2 (a): Architectural Render (South West Architects)

InteliBuild services save time and money for clients on building projects. This case study describes the use of 3D CAD models for checking and coordinating building services during construction and highlights the benefits for the developer, consultants and contractors.

Project Description

The Al Maha Sofitel is a 24 storey hotel development with a mix of large hotel rooms and luxury suites, specialty restaurants, a grand ballroom, conference and function rooms, a spa facility and a basement car park. The ground floor entrance lobby incorporates a feature staircase and atrium.

The project consists of 52,000 square meters of constructed floor area. The primary structure is a reinforced concrete frame with post-tensioned floors. The external envelope is formed from pre cast GRC panels.

InteliBuild Scope of Services

Diplomat Group awarded a contract to InteliBuild to provide 3D CAD design validation services to the building services contractor during the construction phase of this prestigious hotel in Qatar. Comprehensive detailed 3D CAD models were required to be produced by the InteliBuild architectural, structural and MEP modeling team from the 2D design drawings provided by the client. InteliBuild managed the production of the 3D CAD models as shown in the Fig 3.2 (b) and maintained a register to record the information incorporated in the digital 3D models.

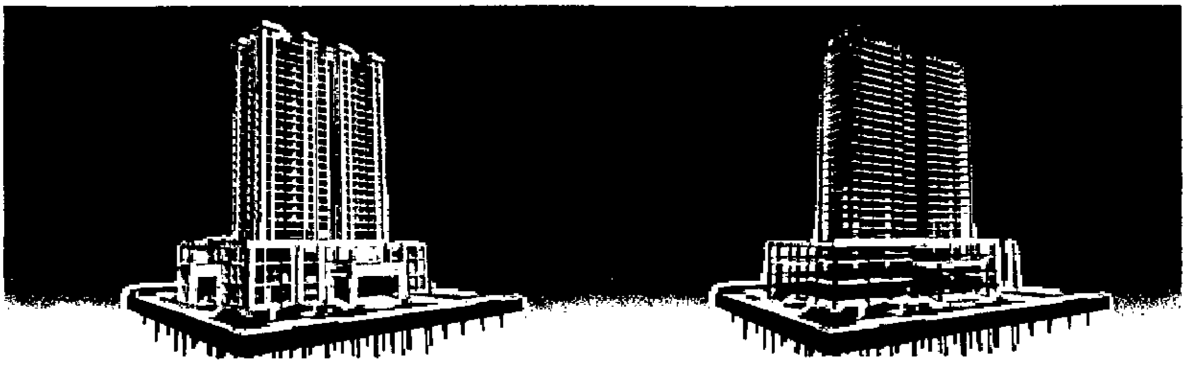


Fig 3.2 (b): Architectural and Structural 3D CAD models

Throughout the 3D modeling process, discrepancies in drawing details, lack of information, co-ordination problems, clashes and conflicts within the accurate CAD models were all identified by InteliBuild engineers and documented as Technical Queries (TQs). The multi-disciplinary models were also utilized for buildability assessments. TQs are a useful design review tool and provide a quick and easy method for contractors to raise RFI's early in the construction process.

The design consultants, structural engineers and mechanical and electrical engineers used the Technical Queries and RFI's produced by InteliBuild to revise and up-date their design drawings.

InteliBuild's in-house BIM specialists and engineers used the 3D CAD models to assist in the coordination of the building services. The MEP shop drawings for all the building services were produced from the fully co-ordinate 3D CAD models for use by the contractors during installation on site.

InteliBuild Process

The 3D CAD models for the Sofitel Hotel include all of the following building components, shown in the Fig 3.2 (c).

- Architectural walls & ceilings
- GRC I panels, windows and stone cladding
- Concrete structures including columns, core walls, beams and slabs with openings
- Vertical circulation systems (stairs, escalators and lifts)
- Mechanical air conditioning ducts, pipe work and equipment
- Fire Protection pipe work, pumps, sprinkler heads & valves
- Plumbing & Drainage pipe work
- Electrical conduits & cable containment
- Utilities including electric, gas, drainage and water mains

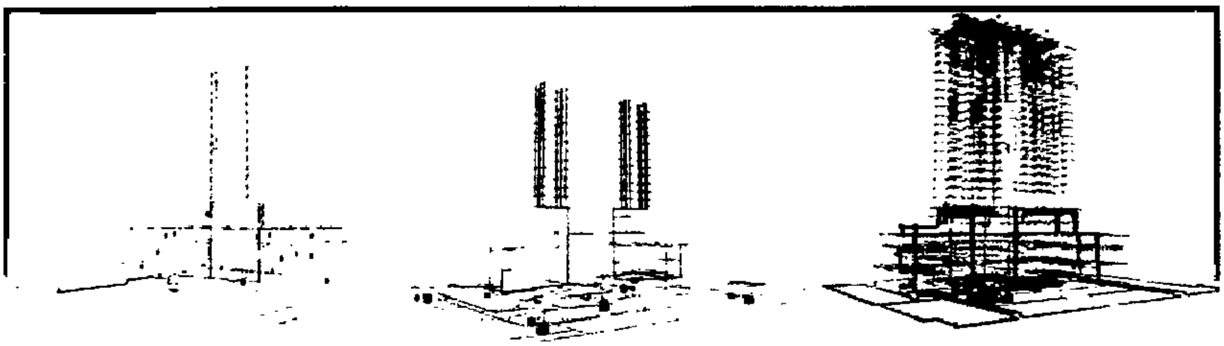


Fig 3.2 (c): Fire Services, Drainage and MVAC 3D CAD models

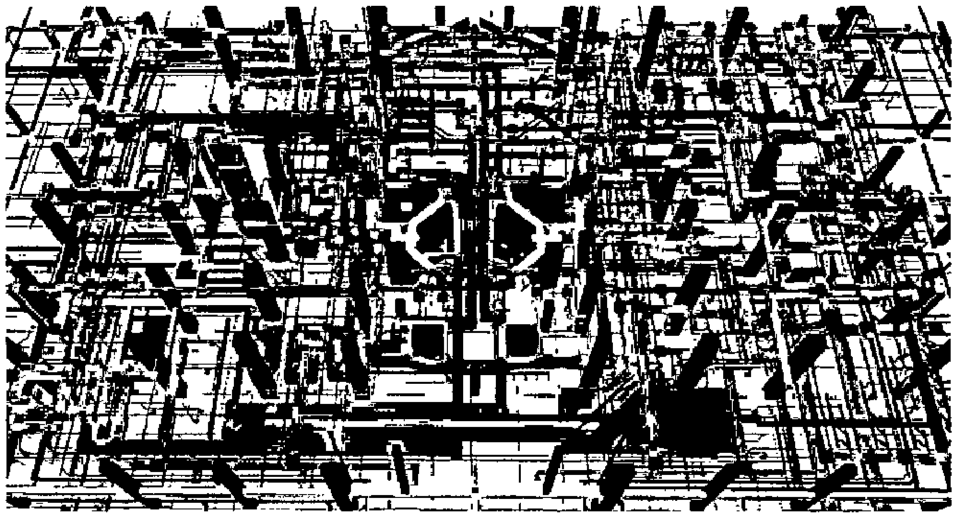


Fig 3.2 (d): Integrate Building Systems at First Floor Level

The InteliBuild engineers and 3D CAD modelers assembled the virtual building model in stages to suit the planned construction programme, as shown in the Fig 3.2 (d). Within the first two months, 254 TQs were produced identifying design and construction issues as shown in the Fig 3.2 (e), (f). Over 8,000 clashes were identified between each of the building services systems and the building structure and architectural elements.

Each TQ included a description of a particular design issue which needed to be addressed by the design consultants. Annotated 3D views were used to demonstrate each issue clearly and the TQ highlighted the relevant design drawings for quick and easy reference.

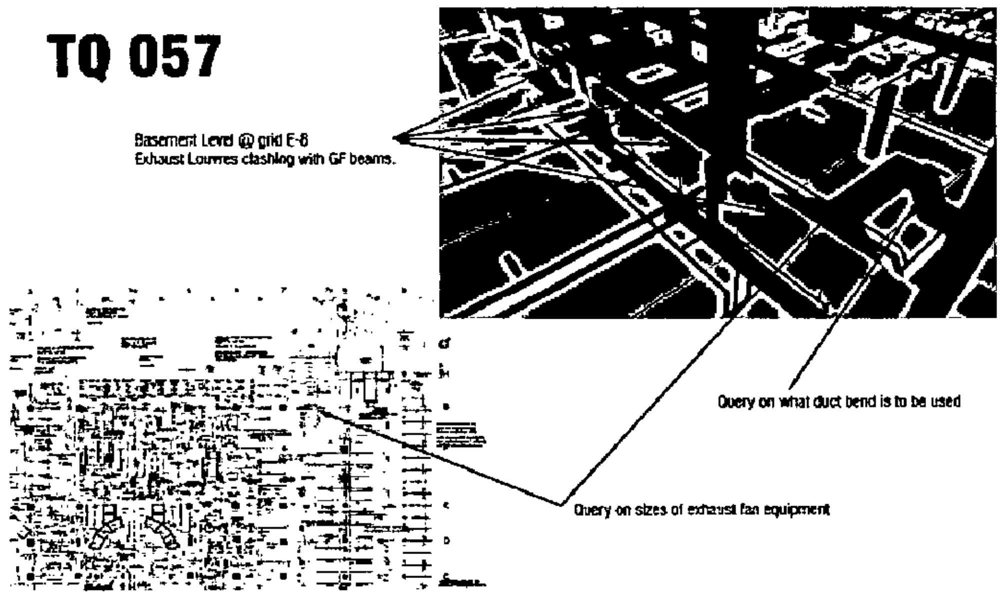


Fig 3.2 (e): Technical Query TQ 057

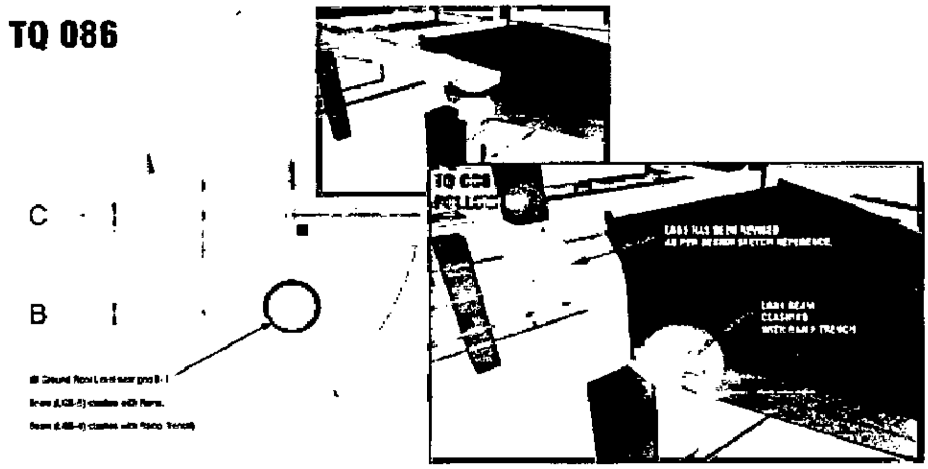


Fig 3.2 (f): Technical Query TQ 086

By creating the building virtually with the use of 3D CAD technology, all of the contractors and designers were able to review the building design quickly and to correct errors before they were □ealized on site. InteliBuild BIM Managers facilitated design co-ordination workshops with the design consultants so that each and every TQ was reviewed and discussed. Where possible the InteliBuild team suggested solutions for the design and construction team to consider.

A key advantage of having 3D CAD models as shown in the Fig 3.2 (i) of all of the building services is that MEP coordination, shown in the Fig 3.2 (h) can be done virtually and in advance of the building works. The MEP engineers and co-ordinators performed the building services coordination accurately by identifying clashes as shown in the Fig 3.2 (g) and validating clearance checks. Coordination performed using the 3D CAD model at the early stages of the construction phase ensured the contractors would save time, materials, and costs and reduced their commercial risks during construction.

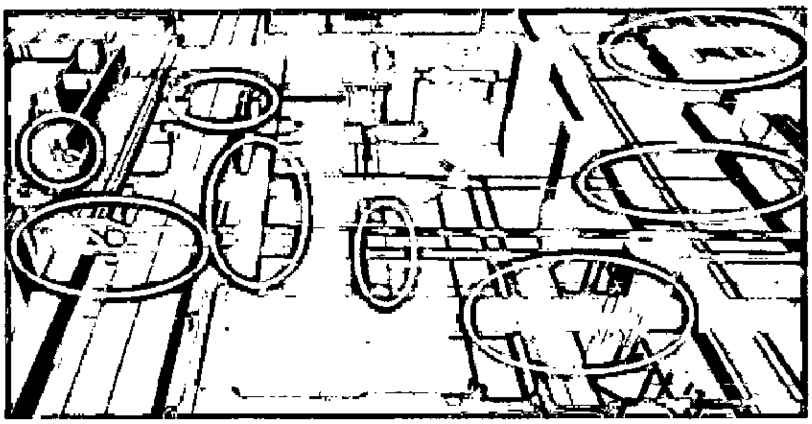


Fig 3.2 (g): Clashes Identified between basement drainage and MVAC systems

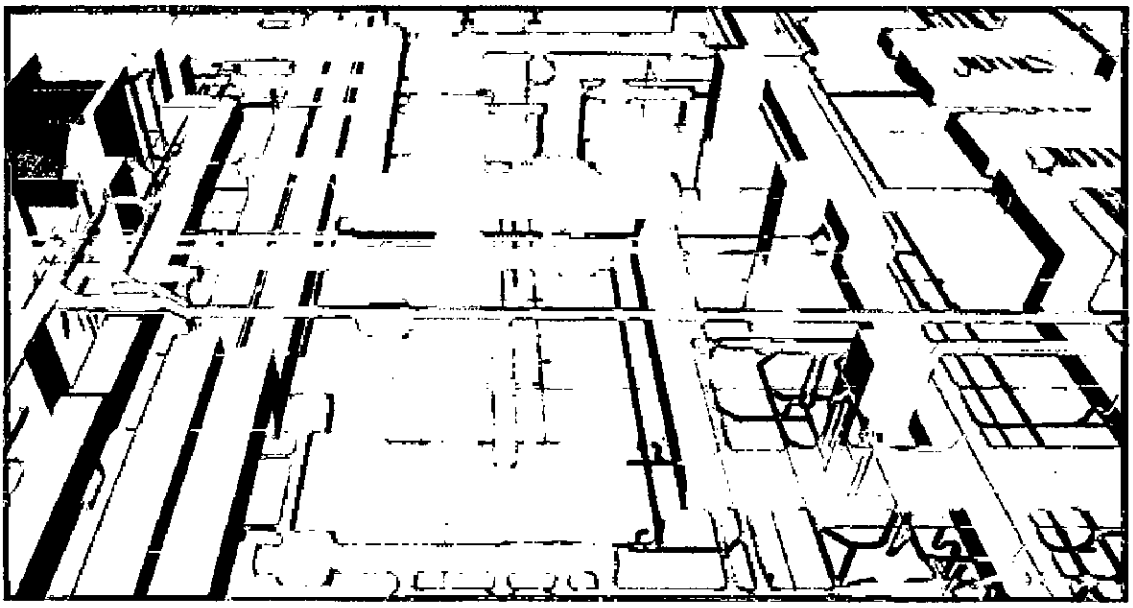


Fig 3.2 (h): Co-ordinated Building Services completed

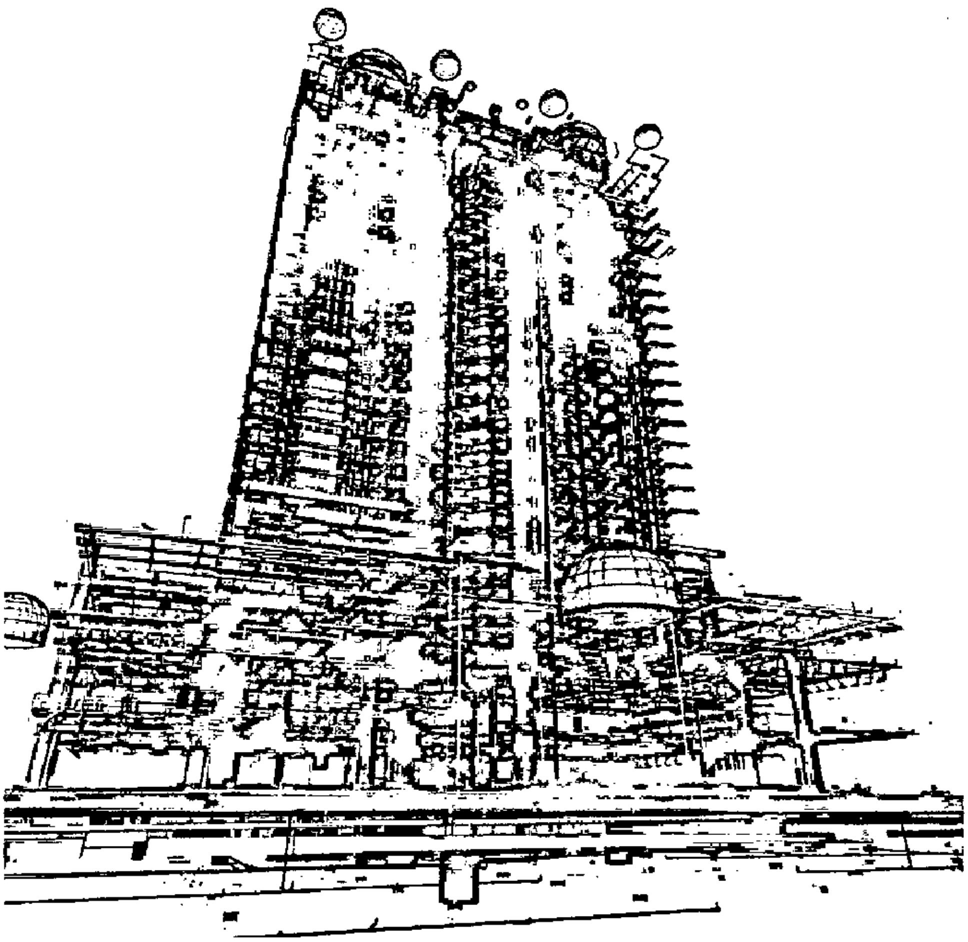


Fig 3.2 (i): Complete Combined Services 3D CAD model

Results

The primary purpose of the InteliBuild scope of work was to reduce the commercial risks to the contractors due to potential delays on site due to unforeseen structural and MEP design and co-ordination problems.

The 3D CAD models identified critical design conflicts between some of the structural systems and the ductwork ventilation systems which required detailed consideration by the mechanical and structural engineers. The virtual building models were used to illustrate the problems and to determine suitable solutions in advance of any construction on site thus avoiding potentially major delays and substantial disruption costs at a later date.

The InteliBuild 3D CAD team worked closely with the MEP Contractor to assist them with the co-ordination and shop drawing production. The production of the shop drawings from the coordinated 3D CAD models saved the building services contractor both time and money.

This was the first time that the main contractor, MEP contractor, architects and client were involved in the process of 3D CAD design validation. Due to the benefits demonstrated by InteliBuild each of the participants will consider the use of BIM and 3D CAD on future construction projects. The client noted that the BIM process should be adopted as early as possible by the design consultants and contractors on all of their future developments.

3.1.3. Willie and Coy Payne Junior High School, Gilbert Arizona

Project Summary Information:

Project Name:	Willie and Coy Payne Junior High School
Facility Type:	Educational
Location:	Maricopa County, Arizona
Client:	Chandler Unified School District #80
Date Completed/Occupied:	July 2005 (under construction)
Size:	120,080 s.f.
Lead Design, Office:	The Orcutt/Winslow Partnership, Phoenix, Arizona
Lead Construction, Office:	McCarthy Building Companies, Tempe, Arizona
Submitted by:	Russ Sanders, RA, Associate

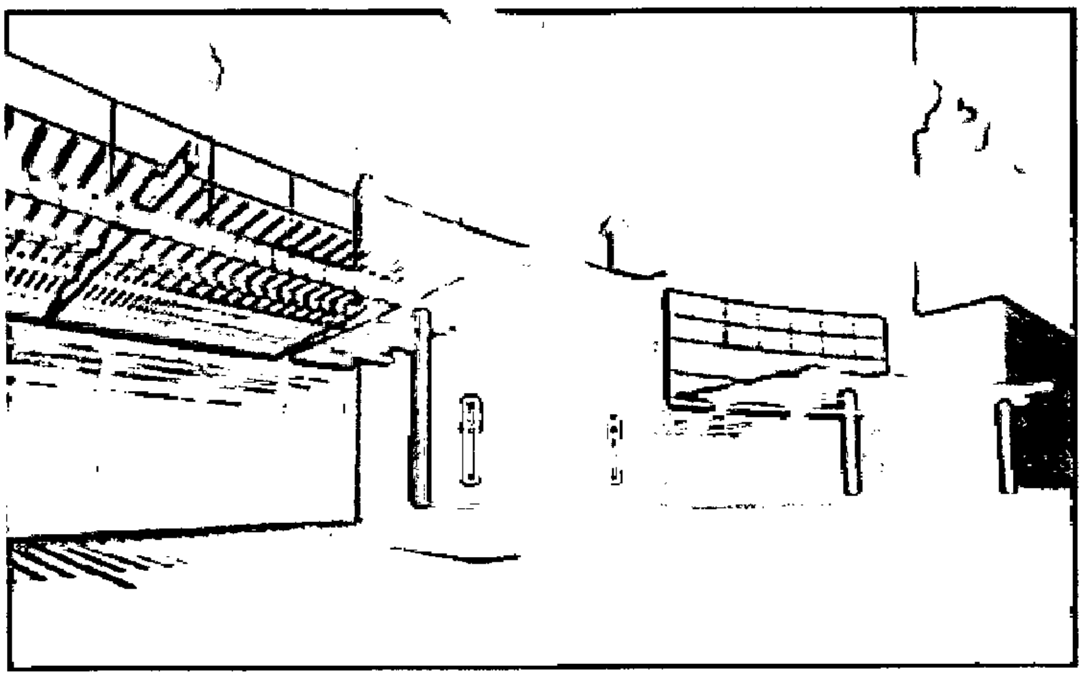


Fig 3.3 (a): 3D CAD model

Project Challenges:

Since 1995, **all** projects at The Orcutt/Winslow Partnership have been designed, presented, and documented using Graphisoft ArchiCAD's Virtual Building (or BIM) approach as shown in the Fig 3.3 (a), (b). There are a number of benefits to this approach as we see it. In this Junior High School example, the BIM approach facilitated design communication to the owner, ensured coordination and accuracy of the documents, and allowed the in-house design team, consulting engineers, and material suppliers to collaborate to produce a well-documented design.

Due to the integration of design and documentation that is possible through the use of Virtual Building (or BIM) methodology, the resulting construction documents are better coordinated. When changes are made to a single building model, the resulting documents are automatically updated. This integration results in fewer coordination issues to resolve during the construction phase and therefore saves time and money. Also, the model helps the design team to discover special detailing opportunities that they might otherwise overlook when preparing their contract documents.

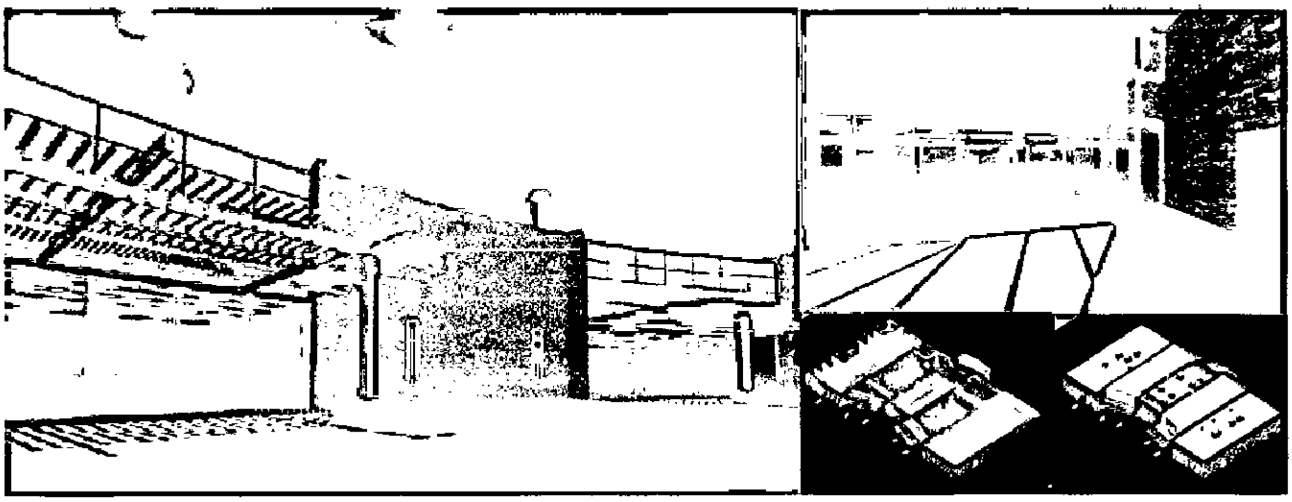


Fig 3.3 (b): Complete 3D CAD model

Having a building model at your fingertips allows for more timely feedback when reviewing the project with owners and consulting engineers. The model is always current, always available to produce presentation materials.

A Virtual Building or BIM model is a database of information. Quantity information can be quickly extracted from the database. Cost estimates were prepared on this project using the Interactive Schedule capabilities of ArchiCAD exported to excel. Interactive Schedule tools were also used to produce all of the window and door schedules for this project.

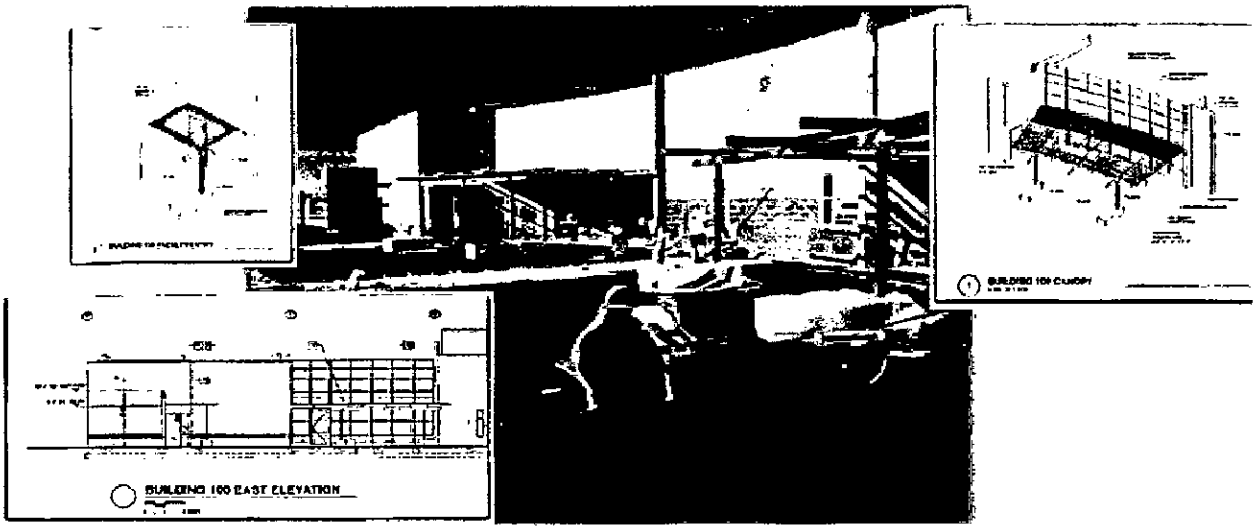


Fig 3.3 (c): Integration of 3D CAD model

Communication

- Model used for "selling" concepts
- Automatic coordinated documentation: model = drawings
- Virtual Building approach changes documentation techniques
- Model is useful throughout Construction Administration phase

Coordination:

- Consultants' 2d dwg files used to locate equipment - transformed to 3d in ArchiCAD.
- Outside vendors' dwg files used to enhance documents (see section below).
- Outside vendors' dwg details incorporated into contract documents as well.
- Window and door schedules auto-generated while building is being created..
- The 3D database provides feedback for use in cost estimating.
- Information was exported to excel and costs were applied to generate cost estimates.

Collaboration/Coordination:

- Civil (dwg) site information was linked to ArchiCAD site plan via x-referencing.
- Teamwork was used on individual building files to share each building model.
- 3D buildings were linked (hotlinked) to site file for consistency.
- All views of all buildings were linked to layout book = automatic documentation.

3.1.4. One Island East Project, Hong Kong

This case study documents the implementation of BIM to manage the functional and financial relationships between design, construction, and facility management on a large, complex project by an owner-developer. The owner identified the potential of BIM to manage information more efficiently and save time and cost over the project life cycle. The brief project data is as follows:

Project name:	One Island East, Hong Kong, China
Project scope:	$300M, 1,517,711 SF commercial building
Structure:	Reinforced concrete
Exterior:	Aluminum curtain wall
Owner:	Swire Properties Limited
Contractor:	Gammon Construction Limited
BIM scope:	Design coordination, clash detection, and work sequencing

The One Island East (OIE) is a large commercial office building with seventy floors. Figure 3.4 (a) shows a building information model of this facility.

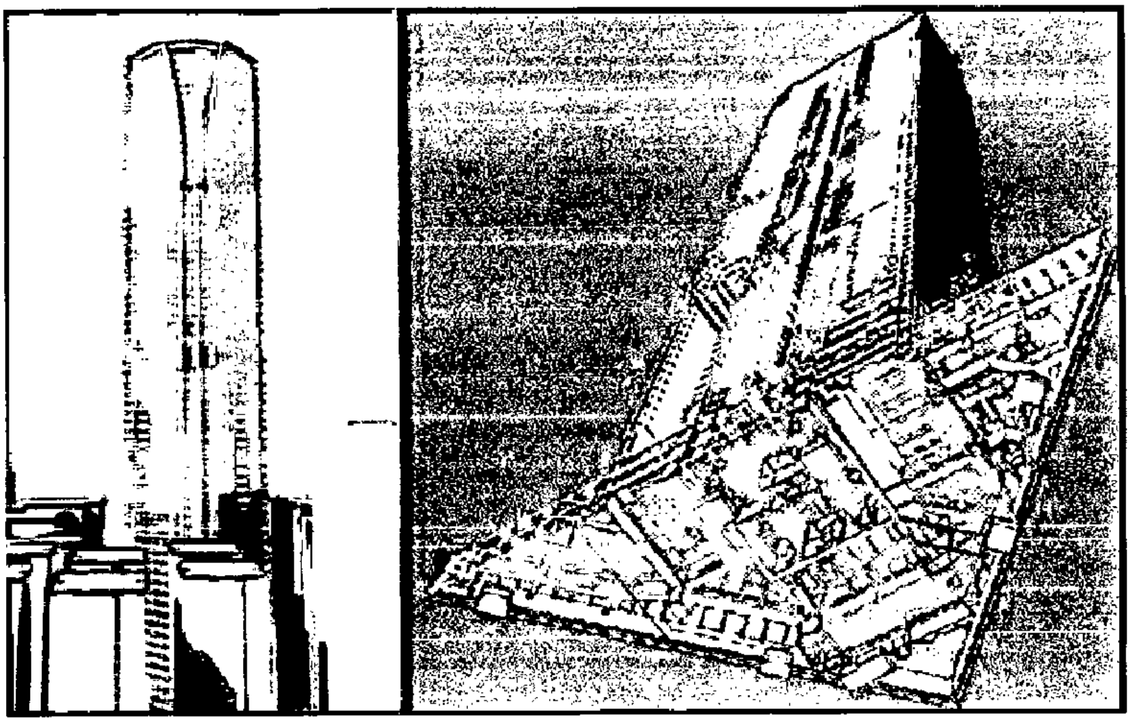


Fig 3.4 (a): Building Information Model of One Island East (OIE) Project.

Almost all coordination issues were managed using BIM. As shown in Figures 3.4 (b) – 3.4 (f), through BIM, over 2000 clashes and errors were identified prior to bidding and construction as shown in the Fig 3.4 (b), which means that a substantial cost savings was achieved, compared to the incomplete design information inherent in a traditional 2D process.

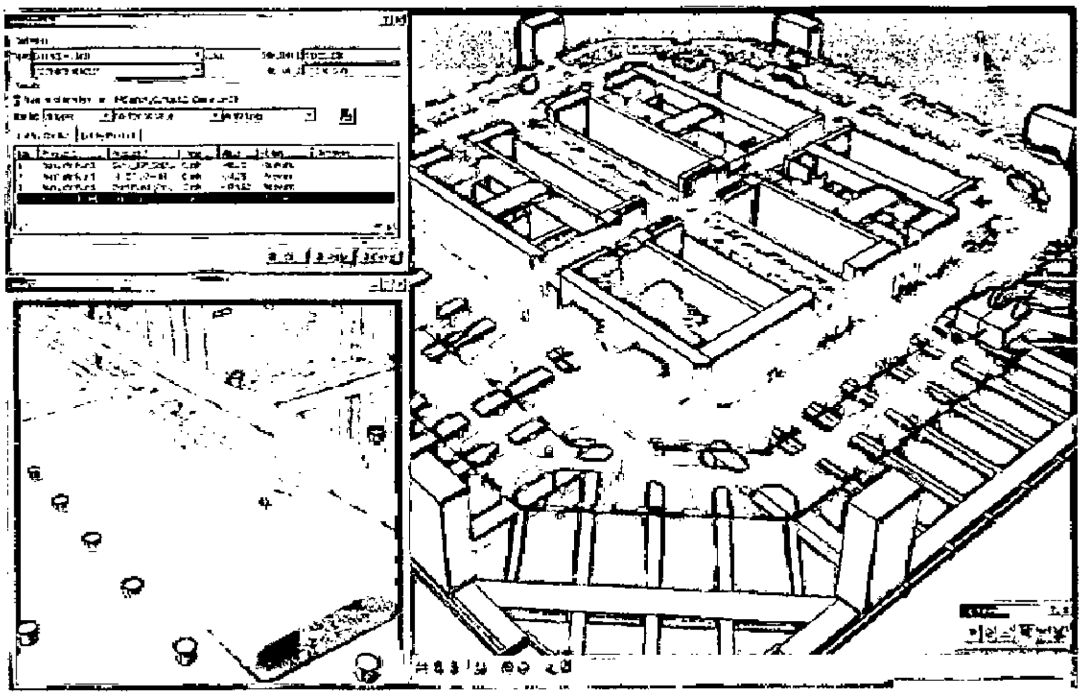


Fig 3.4 (b): Automated Clash Detections in OIE Project (Gammon Construction Ltd, HK)

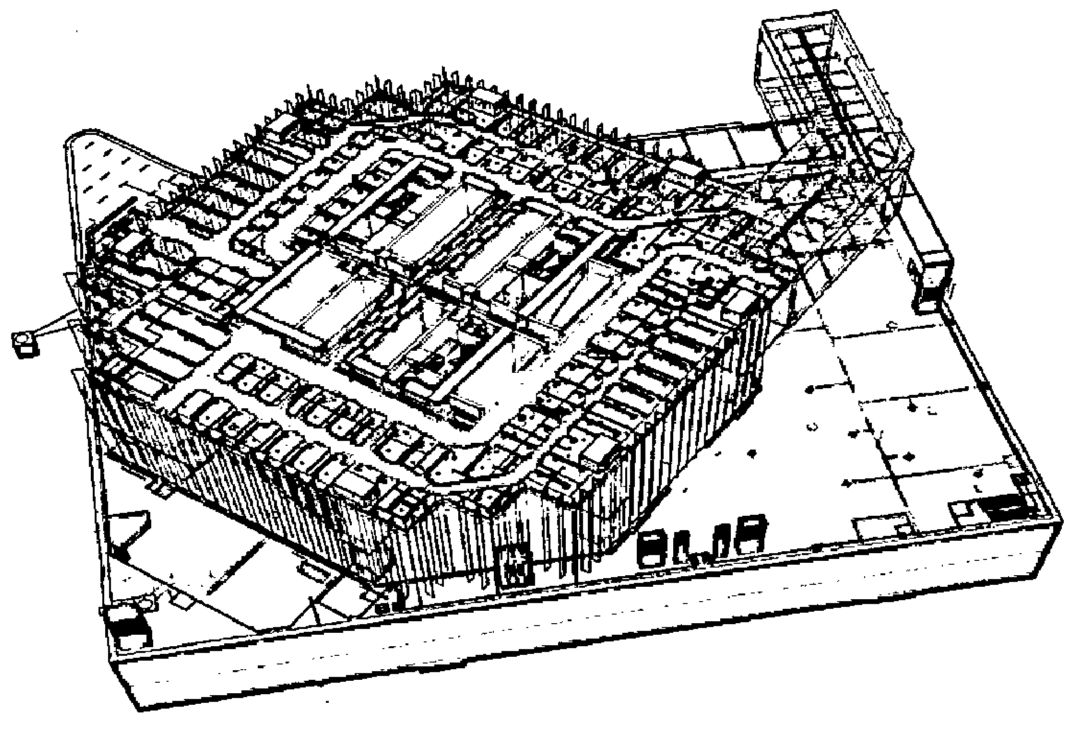


Fig 3.4 (c): Interactive Coordination Process:

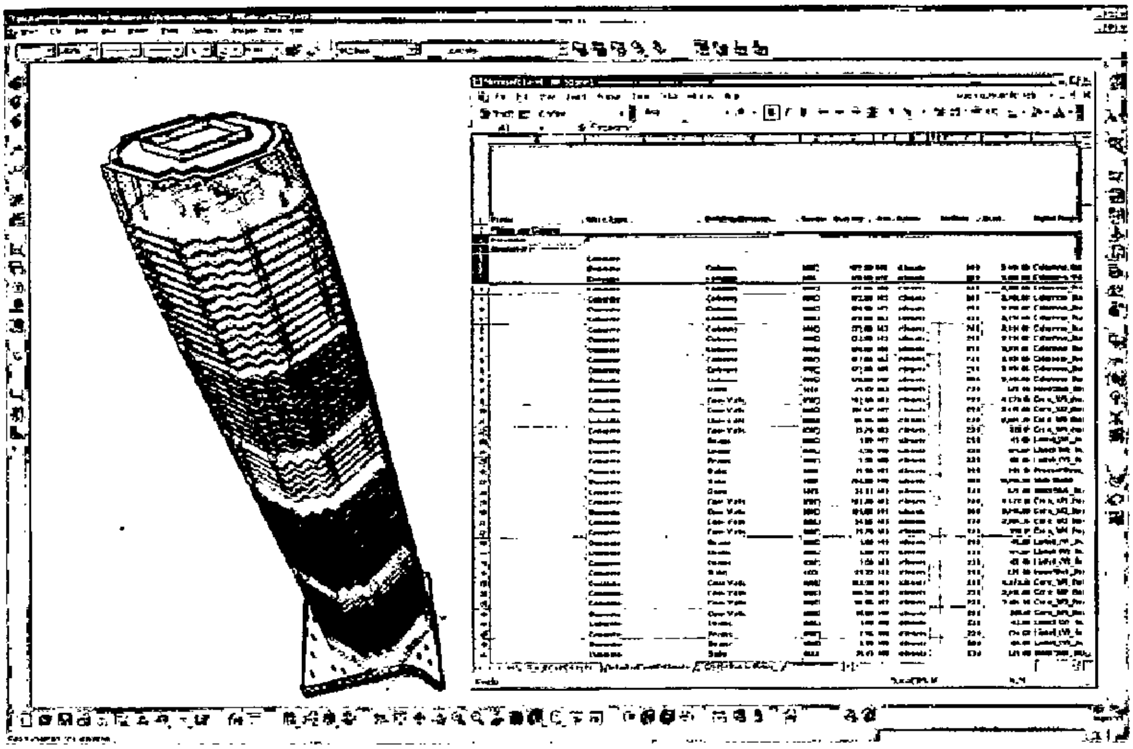


Fig 3.4 (d): Preparation of Automated Estimates (Gammon Construction Ltd, HK)

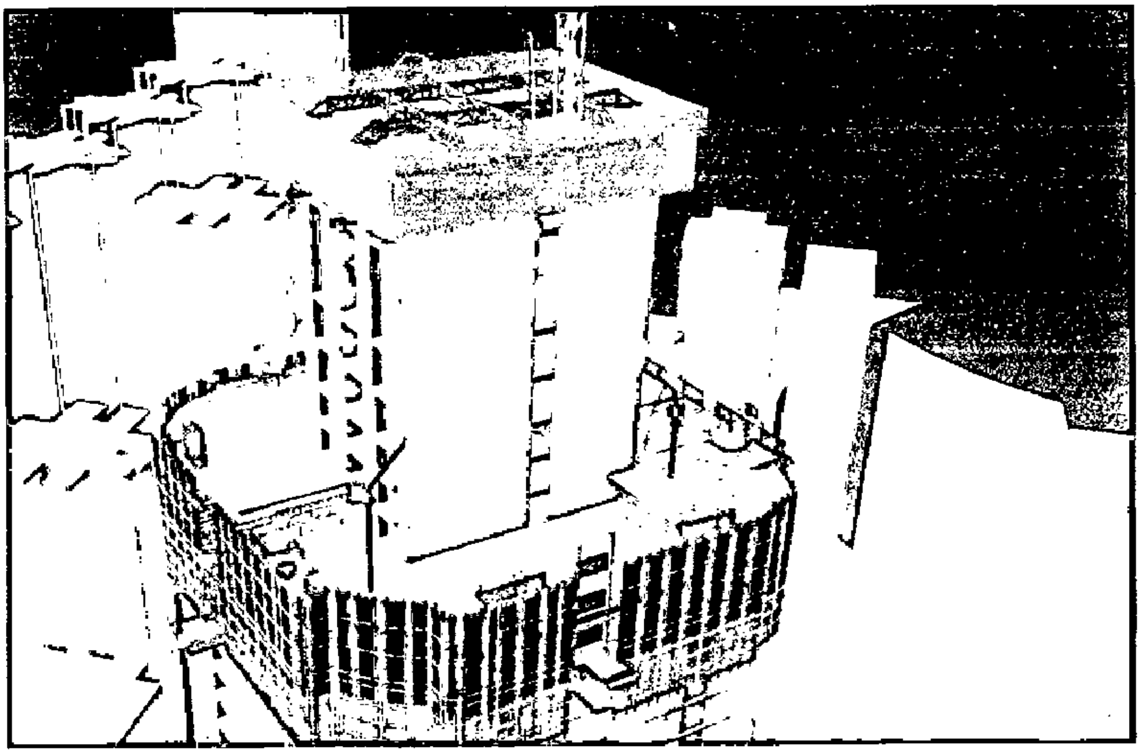


Fig 3.4 (e): Construction Sequencing Model (Gammon Construction Ltd, HK)

Future Challenges

The productivity and economic benefits of BIM to the AEC industry are widely acknowledged and increasingly well understood. Further, the technology to implement BIM is readily available and rapidly maturing. Yet, BIM adoption is much slower than anticipated (Fischer and Kunz, 2006). There are two main reasons, *technical* and *managerial*.

The technical reasons can be broadly classified into three categories (Bernstein and Pittman, 2005):

1. The need for well-defined transactional construction process models to eliminate data interoperability issues,

2. The requirements that digital design data be computable, and

3. The need for well-developed practical strategies for the purposeful exchange and integration of meaningful information among the BIM model components.

3.1.5. Morphosis San Francisco Federal Building San Francisco, Ca

Project Name:	San Francisco Federal Building
Facility Type:	Office Building
Location:	San Francisco, Ca
Client:	General Services Administration
Completion Date:	Spring, 2006
Size:	605,000 S.F.
Lead Design:	Morphosis
Lead Construction:	Dickcorp-Morganti Joint Venture
Design Collaborators:	Morphosis, Arup
Construction Collaborators:	Permasteelisa, T. & M. Manufacturing

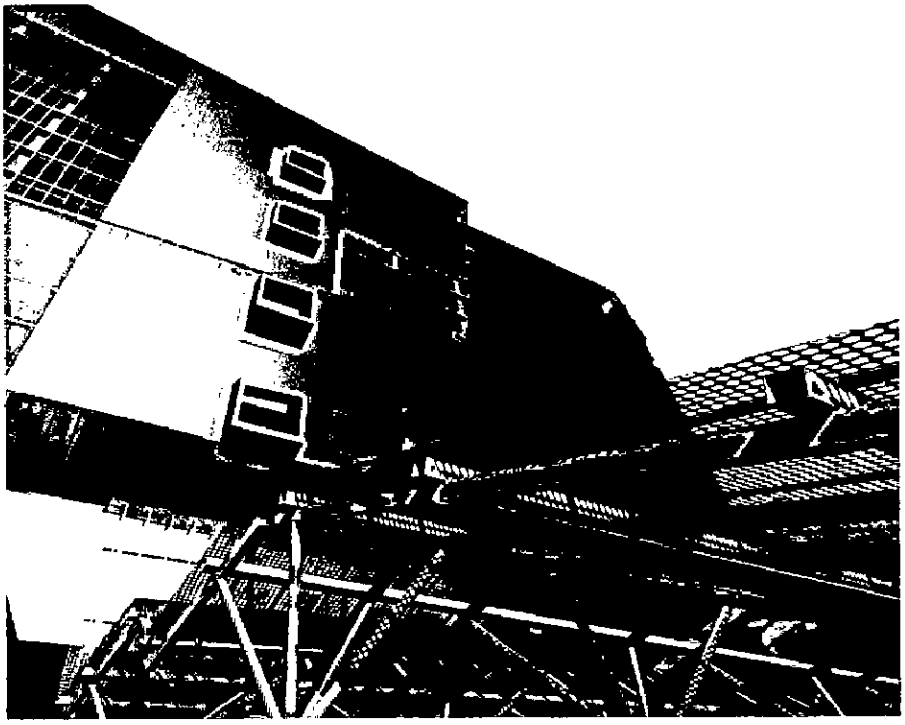


Fig 3.5 (a): BIM model

The new San Francisco Federal Building, commissioning under the aegis of the Design Excellence Program of the General Services Administration, is currently under construction. When completed in 2006, this 600,000 s.f. flagship office building will house five different agencies of the federal government. Among other innovative technologies, the building deploys an integrated custom window wall to regulate internal comfort standards through natural ventilation, thermal mass storage, and both passive and active sun shading.

As part of the project delivery method, Morphosis, the lead design architect for the project, elected to develop a Building Information Model as an in-house tool. Early uses of the 3 D model, shown in the Fig 3.5 (a) included generating quantity takeoffs for cost estimating, coordinating with the engineering team for control of geometry and layout, and managing the production of construction documents.

Though there exists no contractual requirement for the general contractor or their subcontractors to use a B.I.M., the model was accepted by several key subcontractors as a tool for the coordination of the exterior cladding system for the project. Comprised of 153,900 s.f. of custom perforated stainless steel panels attached to a tube steel frame bolted to the concrete frame of the building, the sunscreen is composed as multiple planar elements of varying geometry that wrap the south elevation of the building, continue over the roof, and transition to the ground as a series of plaza-level sunshades. The 3-D model was used over a period of 14 months as a baseline driver for the preparation of shop drawings and coordination between trades.

The use of BIM affords great benefits to large scale projects, both quantitative and qualitative. For example, the ease of translation between software platforms has greatly reduced time in preparation and checking of shop drawings.

Estimators are able to operate cost modeling with a higher degree of accuracy. And many laborious negotiations over fine-grained performance details can be greatly condensed, with all parties providing simultaneous review of the digital model. Key to the success of this is the willingness of both design and detailing team members to expose their models to scrutiny. At this stage, accurate quantification of benefits remains highly elusive as new relationships are forged between designers and fabricators. The construction industry is been encouraged to begin detailed analysis of the cost benefits that may accrue to the process: estimating, detailing, and scheduling. Open dialogue between all parties can move the discussion to a more sophisticated level and allow a predictive framework to emerge.

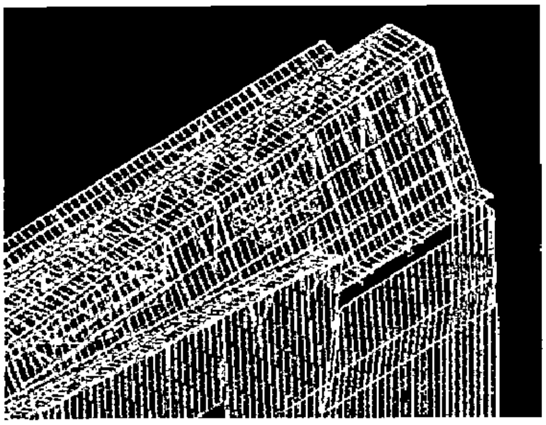


Fig 3.5 (b): Skin and Framing model

Fig 3.5 (c): B.D.S. detail model

Morphosis employs Bentley Microstation as its cad platform, and Bentley Triforma and Bentley Structural for BIM. The parametric steel detail models created in Tekla Xsteel, and Permasteelisa as shown in the Fig 3.5 (b), (c), (d) utilizes Autodesk Autocad for detailing, unfolding and drawing the perforated metal.

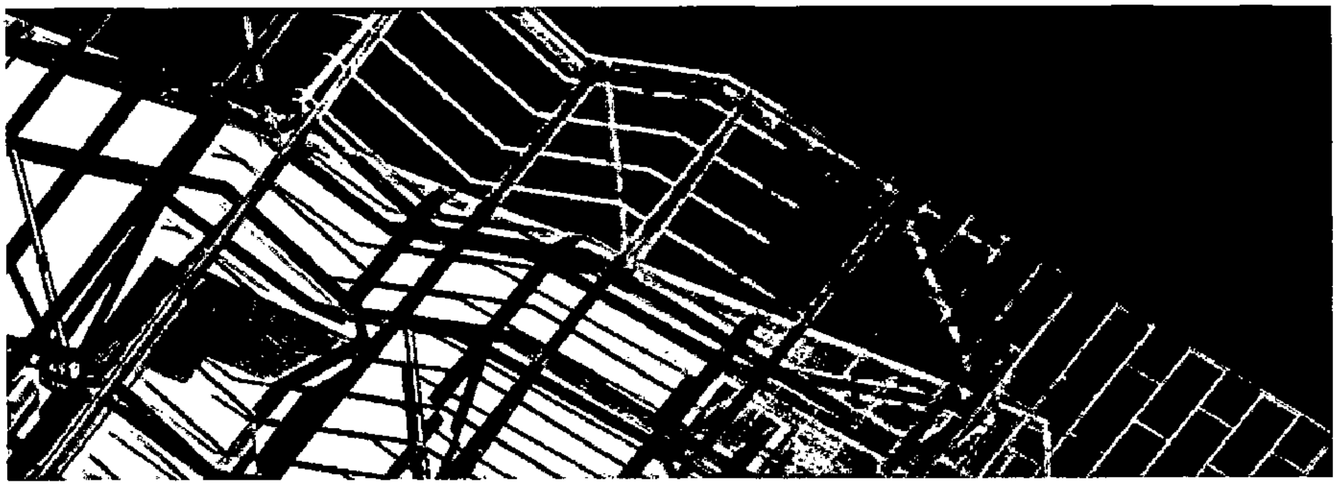


Fig 3.5 (d): Layers of trades: Structural Primary Frame, Secondary Steel, Sunscreen Panel Framing, Sunscreen Panels

3.1.6. Building Information Modeling for the e-Lab at LBNL

Project summary information

Project name:	e-Lab
Project/facility type:	New laboratory building for the Environmental Energy Technologies Division
Location:	Lawrence Berkeley National Laboratory (LBNL), Berkeley, CA
Client:	Lawrence Berkeley National Laboratory and U.S. Department of Energy
Date completed/occupied:	Schematic design competed in January 2002
Size:	32,938 sq.ft. (gross)
Lead design office:	Stanley Saitowitz, San Francisco, CA
Design phase collaborators:	LBNL, ArchVista (San Francisco, CA), Richard Creveling Consultants.

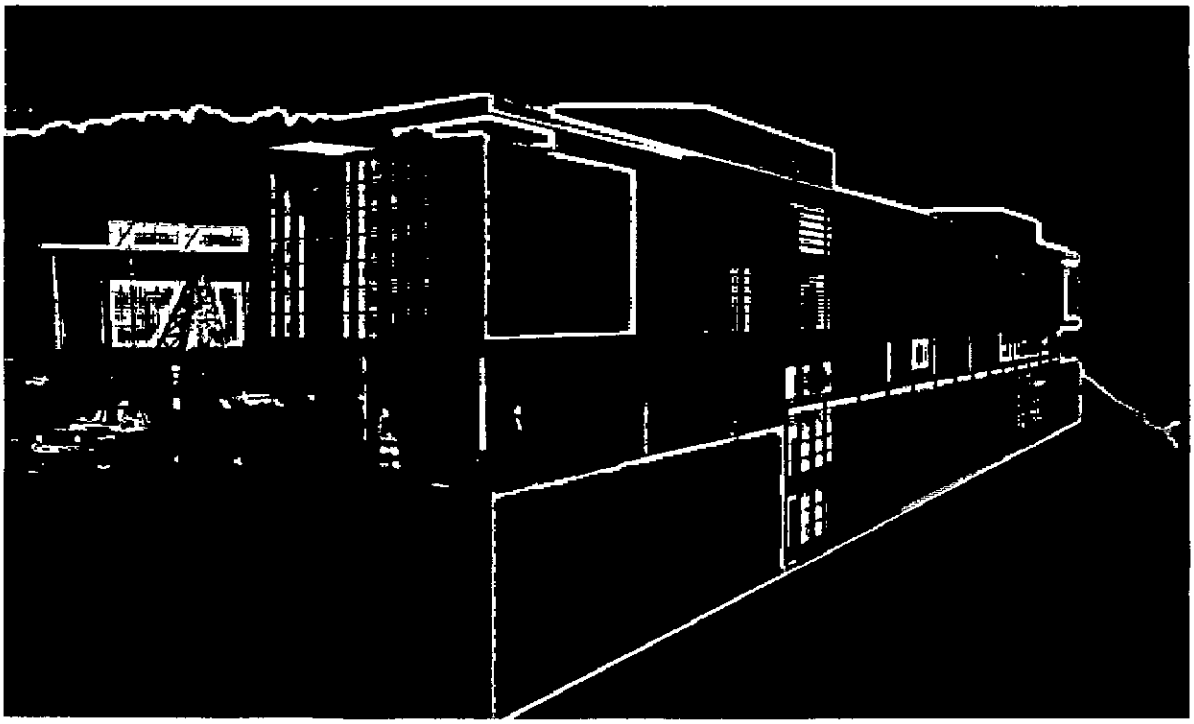


Fig 3.6 (a): E LAB

The Building Information Model (BIM) for e-Lab represents that status of the building during and at the end of schematic design for a proposed new laboratory building on a steep site at the Lawrence Berkeley National Laboratory (LBNL) in

Berkeley, CA. The design includes unique facilities for buildings related research, such as two physically rotating laboratories, ten areas of "replaceable" façade systems, wet labs, completely naturally lit and ventilated offices, public display areas, and more.

The building itself is designed to be a "living laboratory" for study of energy efficiency and sustainability by providing measured data during its operation and use. Fig 3.6 (a) e-Lab at LBNL (image generated with Art-lantis) While the project achieved its primary objectives, it was shelved after schematic design for lack of further project development and construction funding.

Project challenge that led to the adoption of BIM technology

Environmental Energy Technologies Division (EETD) management decided to apply for a new division laboratory building that would consolidate division laboratories scattered all over the LBNL campus and would also provide new and unique facilities for research in the division. These included laboratories for research on windows, day lighting, high-tech façades, lighting, electricity reliability visualization, OLED/thermal and optical materials, electrochemistry, HVAC and advanced controls, and a computer laboratory.

The original project was named Energy Efficiency and Electricity Reliability Laboratory (EEERL); it was later renamed e-Lab. By the time the decision was made (summer 2001), the new building request process had already started for the year. The U.S. Department of Energy (DOE) typically treated applications on "first come first serve" basis and the e-Lab request was going to be placed at the end of the queue. The typical application consisted of a large number of prescribed forms, very preliminary building floor plans and elevations, and a long narrative describing how the facility would function in the future.

To attract the attention of DOE selectors (and move the request upward in the queue), it was decided to submit a different type of application: Besides the regularly required forms and documents, the application would feature results of simulation of actual performance of each key feature of the building, rather than a narrative offering promises. Since LBNL is a DOE laboratory, the critical building performance to demonstrate was energy.

The time remaining for the schematic design of the building was short, and the number of different simulation sets needed to be performed was substantial. Each simulation set required the use of different simulation software that shared one common characteristic: input of building geometry. The process of entry of building geometry could be dramatically shortened with the development of a Building Information Model (BIM) and the subsequent use of interoperable software.

An IFC 2.0 based BIM was developed in parallel to the schematic design. It served as depository of building geometry data that were then imported into interoperable cost estimating and building energy performance simulation software.

Interoperability between software applications

The project started in a conventional manner. Internal discussions about perceived and real space needs, energy efficiency, air quality and sustainability resulted in charrettes, presentations and small group workshops (Fig. 3.6 (b)). The results were incorporated in schematic design.

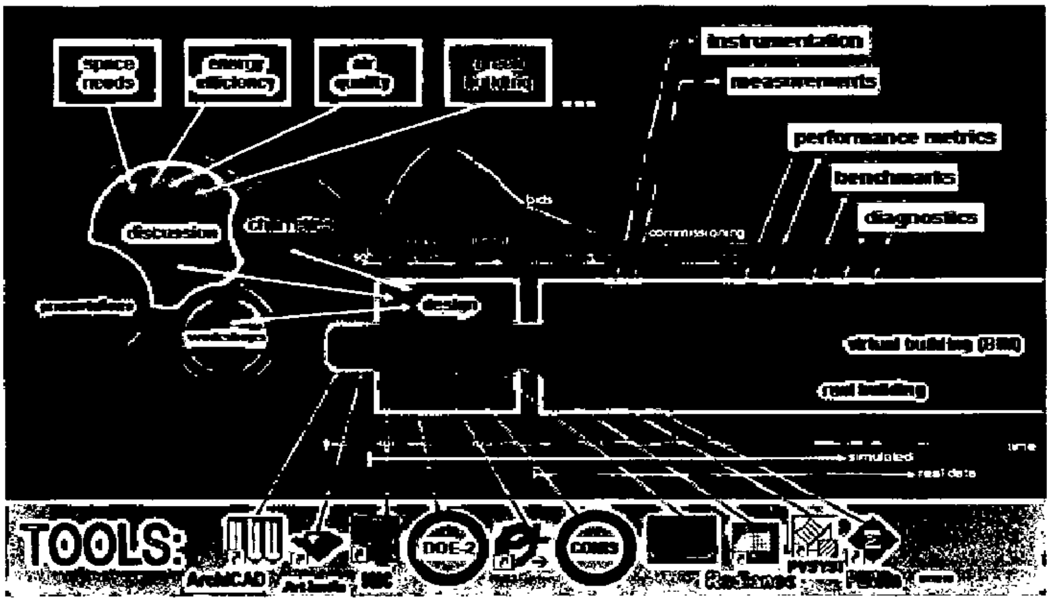


Fig 3.6 (b): e-Lab design process and use of interoperable tools

The architect used two dimensional tools in the design process; they "drew" the building in AutoCAD. As the design progressed, an object oriented definition of the building was developed with ArchiCAD using information from AutoCAD files, and was saved as a BIM in IFC 2.0 format. Building geometry definitions were imported directly from the BIM into interoperable tools.

The suite of directly and indirectly interoperable software tools used in the project included nine applications. Directly interoperable tools included ArchiCAD, Solibri Model Checker (SMC), EnergyPlus (E+), COMIS, BS Pro Server and PrecisionEstimating (PEWin). Indirectly interoperable tools (i.e. tools that can exchange data with an interoperable tool and thus import geometry data from a BIM via that interoperable tool) included Art-lantis, DOE-2 and Radiance. ArchiCAD was used for the development of the BIM. SMC was used extensively to test the accuracy of the BIM, Fig. 3.6 (c).

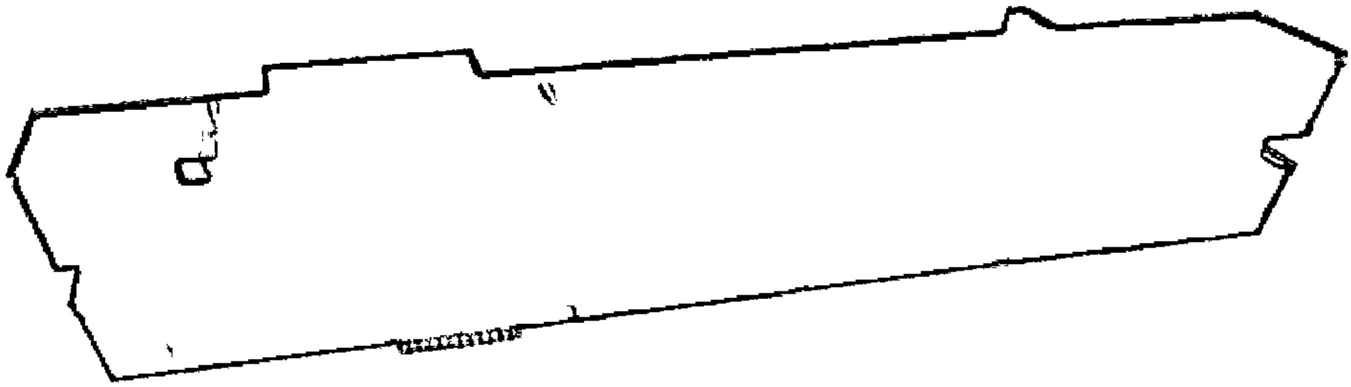


Fig 3.6 (c): e-Lab BIM viewed in Solibri Model Checker

EnergyPlus served as the main tool for energy performance analysis and natural ventilation. Air flows were checked with COMIS. BS Pro served as middleware to reduce "rich" geometry to that required by energy simulation. PEWin generated cost estimates. Visualization was generated with Art-lantis, running on top of ArchiCAD. Radiance was used for photometrically accurate lighting simulation of offices.

A tenth application, PVSYST (a simple stand-alone tool that calculates capacity of photovoltaic systems) was not interoperable; it does not require any building geometry for its calculations. 4-D software would have been used for construction planning and management, but the project did not reach that stage of development. In addition, plans included the development of performance metrics and benchmarking based on the BIM later in the project, and instrumentation and real time measurements with diagnostics once the building was to be in operation. The comparison between simulated and measured data would have yielded a lot of information very useful to calibration of simulation tools.

Benefits achieved

The effort to deploy a BIM and interoperable software achieved its primary goal: The application for e-Lab caused a lot of discussion and visibility at DOE and was at the time apparently moved to the top of the queue. The eventual lack of funding to proceed with the project resulted from forces that had little to do with the application evaluation itself.

The main quantifiable benefit was a reliable cost estimate. First cost estimates generated with PEWin were very low, as they were based on a not yet fully developed BIM and generic unit cost data (Fig. 3.6 (d)). The Division Director decided to fund an external cost estimate (by Davis Langdon Adamson from San Francisco, CA) derived at by conventional cost estimating methodology.

The first conventional external cost estimate was deemed too high; it was based on gross area calculations. Using precise quantity takeoff (from the BIM), that estimate was reduced from $20M to $14.5M; subsequently, using firm manufacturers' bids for unusual equipment it was further reduced to $13.2M.

In the meantime, localizing cost data to account for construction costs on a steep hill and the proximity of an earthquake fault increased the cost estimate obtained from PEWin to $7.9M; adding additional design data to the BIM increased that figure to $9.8M. At that point the Laboratory Director provided an experienced negotiator who "negotiated" an estimate of $11.9M that was deemed reliable and acceptable to everyone involved.

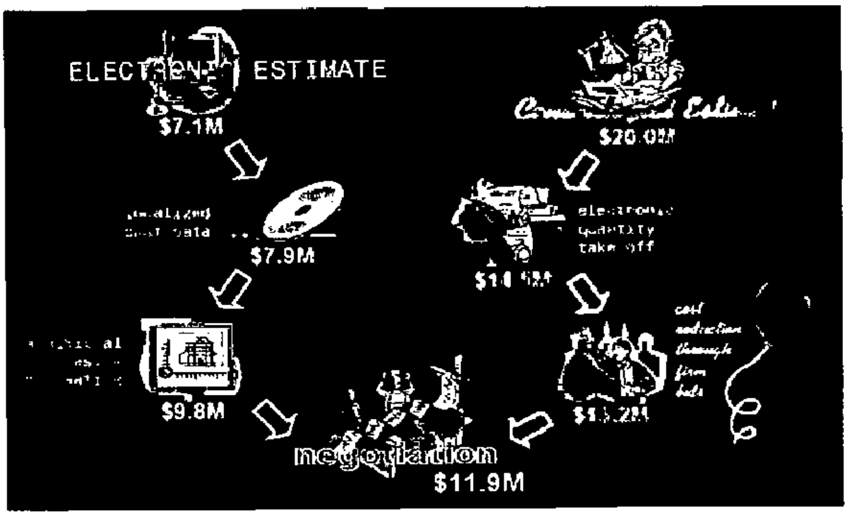


Fig 3.6 (d): Process of arriving at a reliable early cost estimate for e-Lab

The total budget predetermined by DOE for this building category was $20M. The original conventional cost estimate of $20M would have rendered the design scheme too expensive, the design would have had to be abandoned. The process of fine tuning both cost estimates on the basis of data contained in the BIM and the subsequent negotiation made the critical element in arriving at an estimate in which LBNL management had confidence. That confidence was one of the key factors in the decision to proceed and submit the application to DOE for a building as designed.

Other benefits are impossible to quantify. Using BIM and software interoperability it was possible to create and run all the simulations that required building geometry definition as part of the input without that ability it would have taken much more than the three available months to do it. Inter-relating results from the different types of simulation brought a much better understanding of the design problem than it would have been possible otherwise, which resulted in the design of a better quality building.

Defining a BIM forced changes to the conventional design process. Many design decisions, normally done in design development or even later, had to be made in schematic design to provide meaningful information for inclusion in the BIM.

Non-technology factors contributing success of e-Lab project

Two factors were instrumental to the success of this project: management that understood and at least partially trusted the technology and the process, and the composition of the team and effective team collaboration.

LBNL management understood the goals of the project, understood the technology that needed to reach these goals, and provided ample and participating support. This resulted in challenges and discussion at a level much higher and better informed than currently encountered on typical industry projects; it saved time and resulted in decisions made with confidence.

The design team formed effectively a Virtual Building Environment (VBE) team. The exchange of information was constant and effective, and all members were involved in each facet of decision making. The work was performed at distributed and partially remote locations without any difficulty; it was coordinated by the Virtual Building Design Coordinator at LBNL.

3.1.7. Redevelopment of St.Bartholomew's and the Royal London Hospitals

Project Summary

Project name:	Bart's and London Trust
Project /facility type:	mixture of general and specialist hospital building and specialist medical schools.
Location:	Barfs Hospital is on the eastern edge of the city
Client:	Skanska Innisfree.
Size:	$126{,}500m^2$
Date completed/occupied:	July 2005
Lead design office:	HOK international.
Lead construction firm, office:	Skanska – Bart's and The London.
Design Phase Design Partners:	TB&A DSSK. Skanska Technology and yolles.

Fig 3.7 (a): The Royal London hospital

The project has accommodation in excess of 160 departments, 900 In-patient beds and 10,000 rooms over 300,000 items of equipment that will be to be loaded into the BIM.

In February 2002 The United Kingdom National Hearth Service (NHS) solicited proposals for the renovation and expansion of its Bart's and The London campuses including the demolition of substantial existing structures, the renovation of $65,000m^2$ in *72* existing structure, and the construction of $165,000m^2$ of new facilities and the operation of both complexes for a period of 30 years.

A consortium led by the Skanska construction company and the Innis free infrastructure investment group was awarded a preferred bidder agreement in 2003 after a competitive process. HOK London, with support from other HOK U& offices participated in this proposal which included a complete architectural schematic design package.

The very large size and long duration of the Bart's and London Trust (BLT) project warrant a special effort in the planning of its CAD standards and procedures In addition, the project is well suited to be a demonstration of how the London office, the HealthCare group, and HOK as a whole, Advance their application of Building Information Modeling.

Capability

The approach to the structure of the BIM is very closely tied to the software design Autodesk Architectural Desktop is fundamentally an enhanced version of the non-object based AutoCAD software and achieves its BIM capability through a carefully structured system, of folders, files and xref relationship between the files. BIM standards that are capable of handling a very complex project since it can be assumed that they will then be capable of handling simpler ones.

Overall Structure

The file-based nature of ADT essentially creates "containers" of information that are, in effect, the "worksets" of the team sharing the model. They can be joined together and interact to some degree, but generally an individual works on one and only one file at a given time.

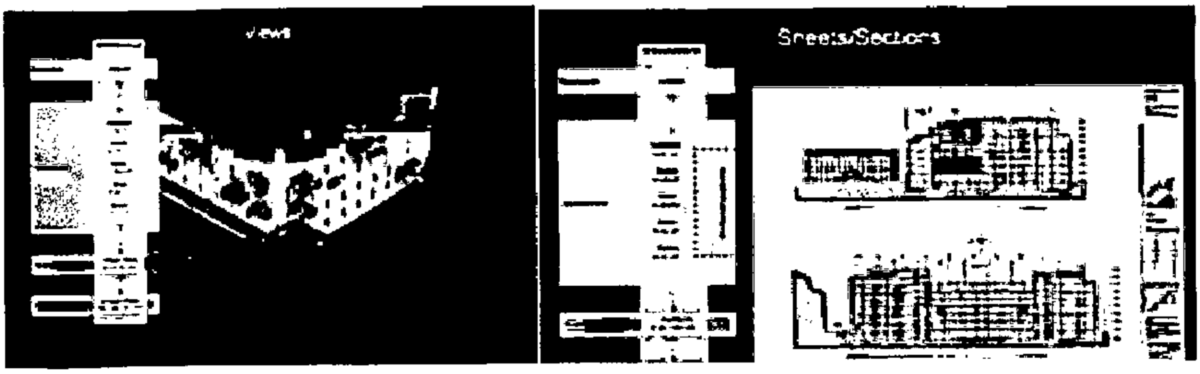


Fig 3.7 (b): Different layout

The folder and file structure is based on in ordered; hierarchy:

- Building: each building is a separate BIM
- Model Role: the model files are separated from the view and sheet files.
- Disciple each design disciple has separate files.
- Level: the primary geometric division is by floor level;
- Theme: within a level, building systems such as cores, stairs, shell, equipment and so on are given their own drawing. Within views, the various kinds of
- Sheets utilize separate views.

2D and 3D Distinction

An important component of the BIM strategy is the distinction between elements that are modeled in *3D* and elements that are drawn only in 2D (Fig 3.7 ©). The use of 2D is not viewed as a compromise, but as a feature of BIM that respects the history of orthographic drawing as a means to architecture.

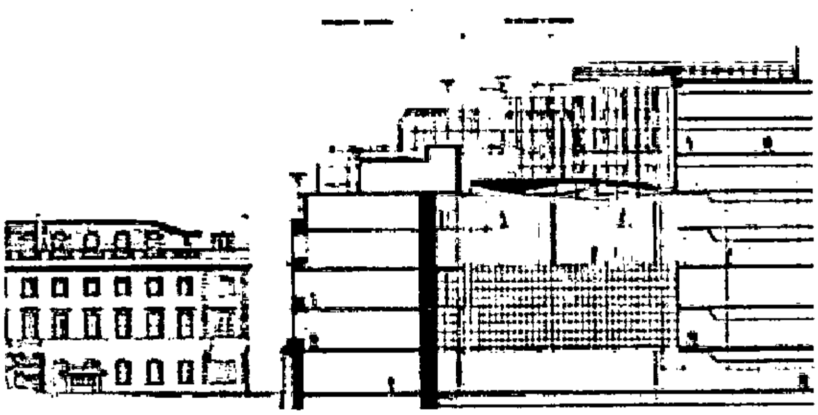


Fig 3.7 (c): 2D Drawing

Division of the models by components

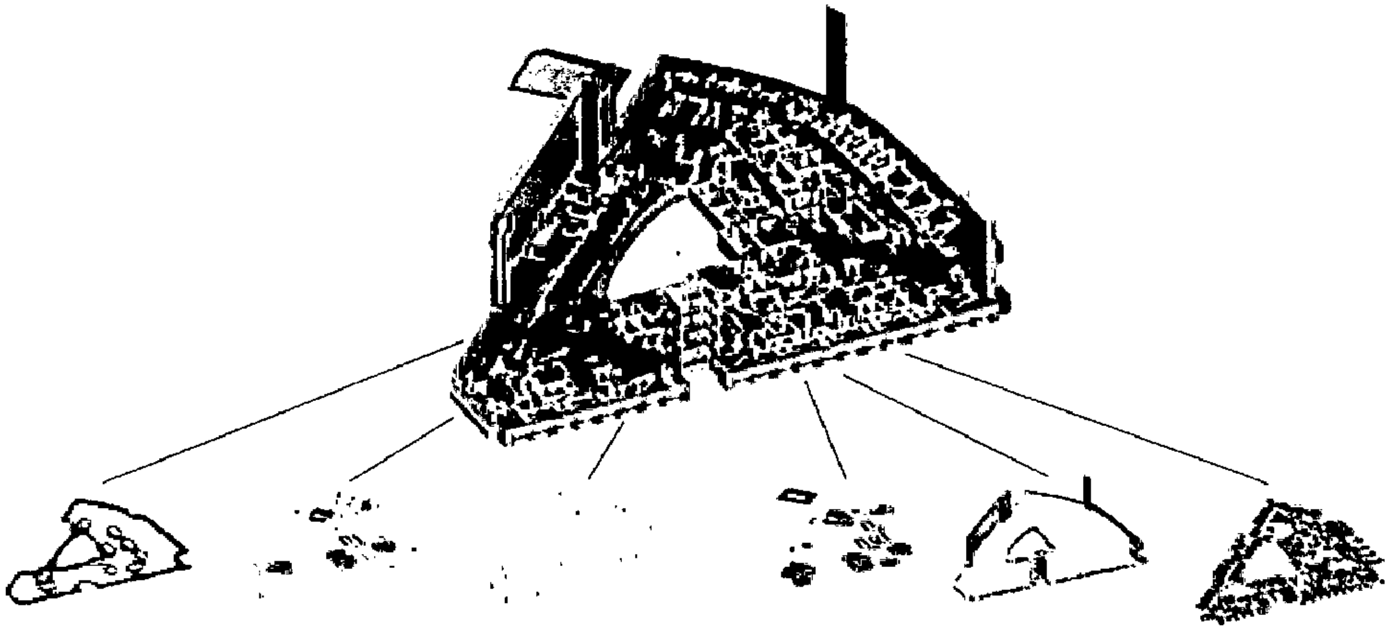


Fig 3.7 (d): Models by components

Division of the models by levels

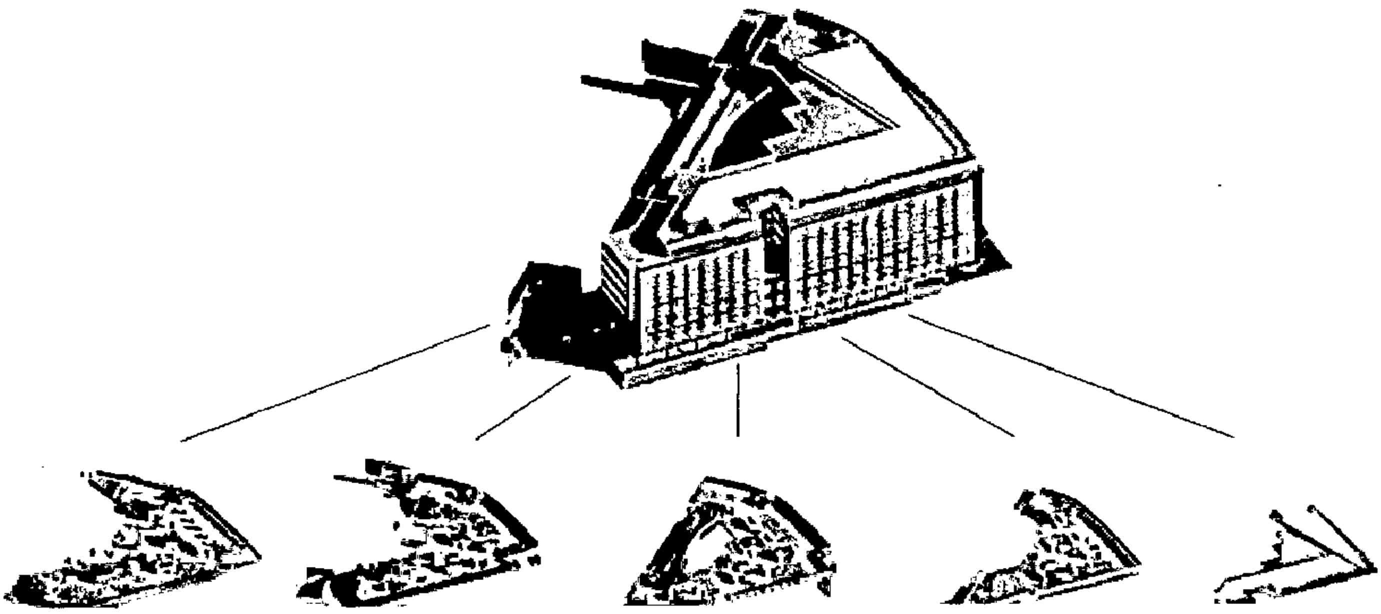


Fig 3.7 (e): Models by Levels

Division of the models by themes

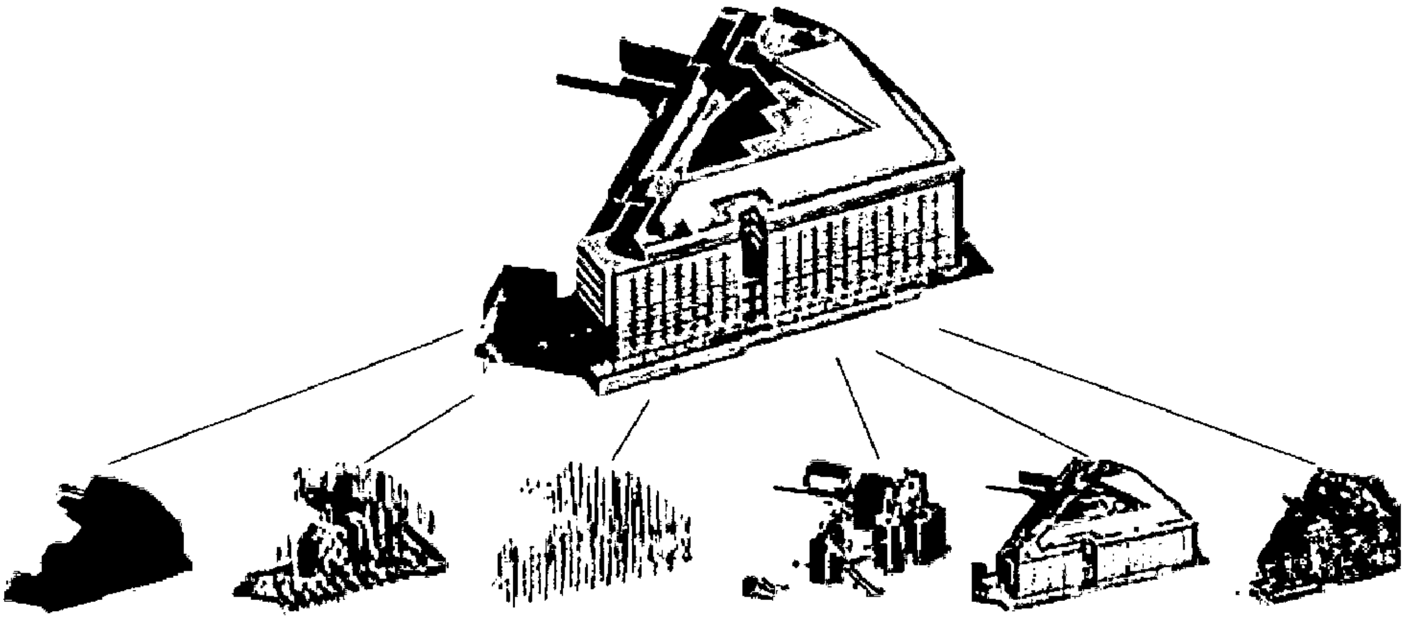


Fig 3.7 (f): Models by Themes

Products of the models

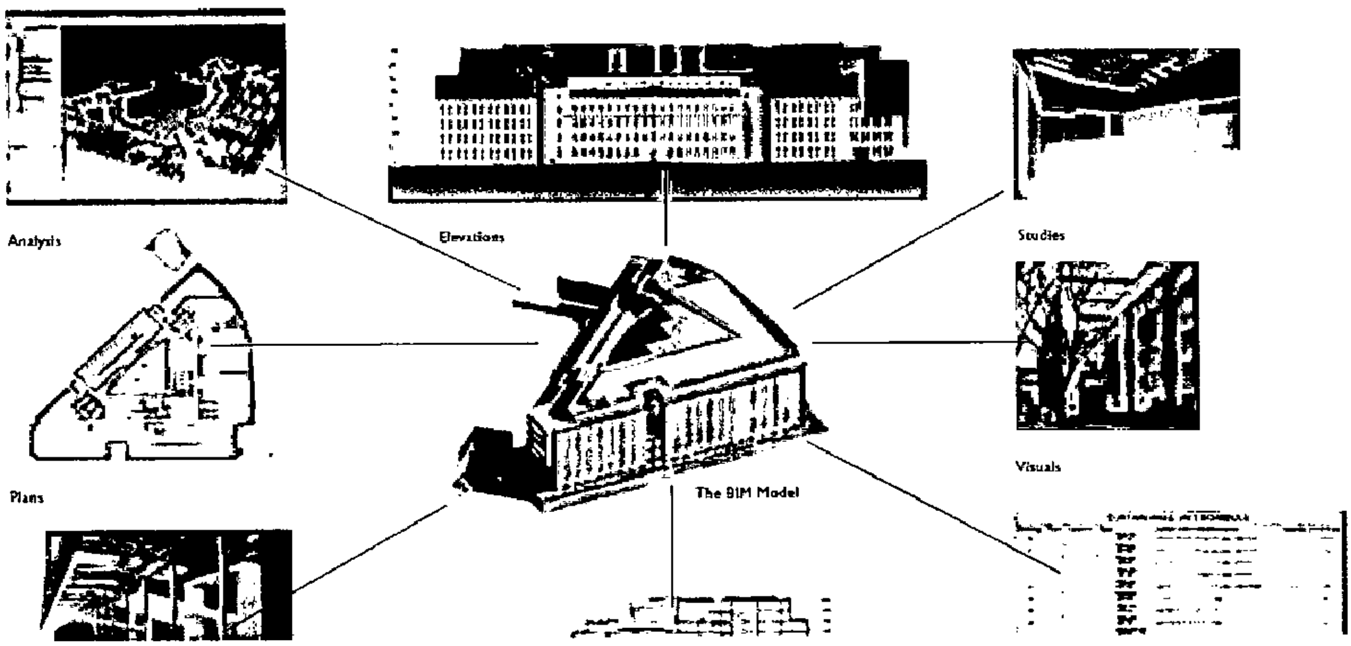


Fig 3.7 (g): Products of the Models

Design Iteration

The BIM is also used is a purely geometric *3D* model for design study. The most difficult task his been using the ADT model objects in a way that meets the visualization needs of the designer. While it is fairly easy to create 3D views in ADT that are adequate for in-house study, the very sensitive nature of the public review required that fully rendered *3D* Studio images be created as well. This is because the way in which the objects are created, in terms of their - geometry, layering, colour, material, and so on, has a significant effect on how easily they can be exported to *3D* Studio.

Design /Modelling /Visualization

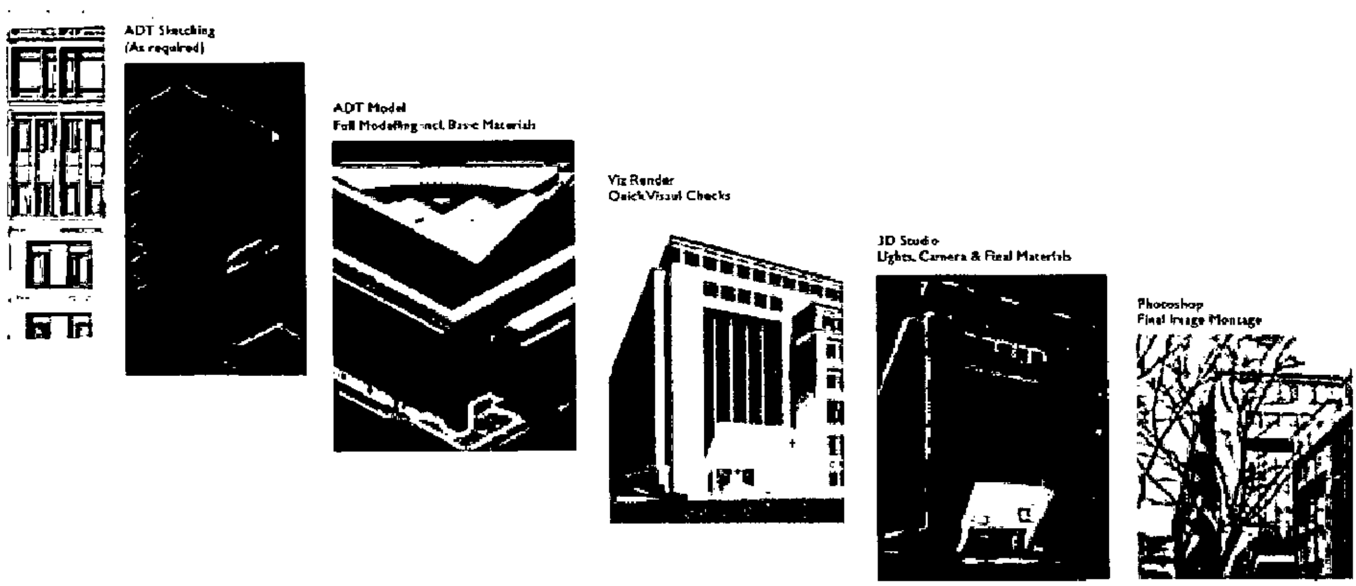


Fig 3.7 (h): Design /Modeling /Visualization

3.2. SUMMARY

The detailed case studies provided shows that the adoption of BIM is challenging but certain. The study clearly shows that BIM unequivocally improves the quality, in terms of accuracy and reliability of the documents. Fabrication and erection are essentially error free, and the effort required for checking drawings has declined drastically.

The trend towards increasing productivity from project to project is evident from the data gathered Benefits can be found in all phases in the building project ranging from the conceptual design to the realization of the building. It also seems that most stakeholders in the building process benefits from the use of BIM, but maybe the greatest beneficiary is the client. Therefore investments in BIM technology should be evaluated on the project level, sharing the costs and benefits between all stakeholders.

The next chapter is about the implementation potentials and constraints in using BIM in order to get the clear idea about this methodology before carrying out the real time analysis.

CHAPTER 4

IMPLEMENTATION POTENTIAL AND CONSTRAINTS

4.1. INTRODUCTION

Implementation and use of BIM systems requires dramatic changes in the current business practices, bring new challenges for stakeholders e.g., the emerging knowledge and skill gap. This Chapter reviews and discusses the status of implementation potentials and constraints of the BIM systems around the globe and their implications to the industry. Moreover, it will provide a guide to tackle these challenges and to facilitate successful transition towards utilizing BIM systems in construction projects.

4.2. BIM APPLICATIONS

A building information model can be used for the following purposes (*Salman Azhar, Micheal Hein and Blake Sketo, 2008)*.

- *Visualization*: 3D renderings can be easily generated with little additional effort.
- *Fabrication/shop drawings*: it is easy to generate shop drawings for various building systems, for example, the sheet metal ductwork shop drawing can be quickly produced once the model is complete.
- *Code reviews:* fire departments and other officials may use these models for their review of building projects.
- *Forensic analysis*: a building information model can easily be adapted to graphically illustrate potential failures, leaks, evacuation plans, etc.
- *Facilities management*: facilities management departments can use BIM for renovations, space planning, and maintenance operations.
- *Cost estimating:* BIM software(s) have built-in cost estimating features. Material quantities are automatically extracted and changed when any changes are made in the model.
- *Construction sequencing:* a building information model can be effectively used to create material ordering, fabrication, and delivery schedules for all building components.

- *Conflict, interference and collision detection*: because BIM models are created, to scale, in 3D space, all major systems can be visually checked for interferences. This process can verify that piping does not intersect with steel beams, ducts or walls.

4.3. BIM ADOPTION

Lack of initiative and training (Bernstein and Pittman 2004), the fragmented nature of AEC industry (Johnson and Laepple 2003), varied market readiness across geographies, and reluctance to change existing workpractice (Johnson and Laepple 2003) have been discussed as some of the reasons for slow adoption of BIM. In an industry where most projects are handled in multi-organizational teams the lack of clarity on responsibilities, roles and benefits in using the BIM approach is an important inhibiting factor (Holzer 2007). Some of the surveys conducted recently (Khemlani 2007b, Howard and Bjork 2008) suggest that collaboration is still based on exchange of 2D drawings, even though individual disciplines are working in a 3D environment and the demand for object libraries is growing. These surveys reveal that a tool preference varies with firm size, and there is a greater demand for technologies supporting distributed collaborative works across all firm sizes.

4.4. BIM BENEFITS

The key benefit of BIM is its accurate geometrical representation of the parts of a building in an integrated data environment (*CRC Construction Innovation, 2007*). Other related benefits are:

- *Faster and more effective processes* – information is more easily shared, can be value-added and reused.
- *Better design* – building proposals can be rigorously analyzed, simulations can be performed quickly and performance benchmarked, enabling improved and innovative solutions.
- *Controlled whole-life costs and environmental data* – environmental performance is more predictable, lifecycle costs are better understood.
- *Better production quality* – documentation output is flexible and exploits automation.

- *Automated assembly* – digital product data can be exploited in downstream processes and be used for manufacturing/assembling of structural systems.
- *Better customer service* – proposals are better understood through accurate visualization.
- *Lifecycle data* – requirements, design, construction and operational information can be used in facilities management.

4.5. EVOLUTION OF BIM SOLUTIONS

After the Second World War, American martial technology was applied in the civil field. The sketchpad was first developed by Ivan Sutherland. That was the root of CAD. In the beginning, the technology of CAD was not popular as in modern times. However, with the popularization of personal computers, the renowned software company Autodesk developed AutoCAD. Suddenly, all the architects in the world started to learn and use this type of software to design their project. (*Leondes, 2005*)

Entity-based modeling and Object-based modeling have been two distinct lines of products since the introduction of Computer-Aided Design (CAD) in the marketplace some twenty years ago. Although the majority of practitioners have opted for entity-based modeling, the enhancement of object-based modeling has continued. With the increasing capabilities of computer hardware and software, most CAD vendors have launched more powerful object-based CAD software in recent years. This software's are now commonly known as Building Information Modeling (BIM), Virtual Building, Parametric Modeling, or Model-Based Design. The move is considered revolutionary in the world of the construction CAD market, and would enable seamless downstream applications of the rich information generated by the model (*Tao-chiu Kenny Tse, wong, 2005)*

.Nemetschek Allplan and GraphiSoft ArchiCAD, introduced in 1980 and 1984 respectively, were the pioneers in object-based modeling in the construction industry (*Nemetschek 2004 and GraphiSoft 2004a*). In the same period, the first versions of Autodesk AutoCAD and Bentley MicroStation were also introduced (*Autodesk 2004a and Bentley 2004a*). This indicates that the development of object-based modeling and entity-based modeling began at a similar point in time.

In 1994, the top three best-selling CAD products were all entity-based models, including AutoCAD (1,000,000 copies sold), Cadkey (180,000 copies sold) and MicroStation (155,000 copies sold) (*DSC, 2000*). Practitioners did not opt for object-based modelling in the 1980s because it requires faster graphic displays, and more memory and storage

Bentley and Autodesk, who had already captured the market in entity-based modelling, began developing object-based models and launched the Bentley MicroStation Triforma and Autodesk Architecture Desktop in 1996 and 1998, respectively (*Bentley 2004a and Autodesk 2004a*).

In 2000, Revit Technology Corporation launched a new parametric model called Revit, which was acquired by Autodesk for a price of US$133 million two years later (*Graves 2002*). Nemetscheck issued the AllPlan 2003 in year 2003 (*Nemetscheck 2004*) and GraphiSoft released the latest version of ArchiCAD version 9 in September 2004 (*GraphiSoft 2004a*)

4.6. BIM SOFTWARES

The major BIM software products are Bentley Architecture, Graphisoft ArchiCAD, VectorWorks ARCHITECT and Autodesk's Revit and Architectural Desktop. This is based on quantity of installed seats. All of these solutions initially design a 3D model and then extract views, such as elevations and sections, and other information. All information's are interrelated at all times.

The software solution keep all the information about the project (models, views, sheets, schedules and so forth) in a single database file, or manage relationships between databases in multiple files. (*H. Edward Goldberg, 2005*)

Graphisoft ArchiCAD: Graphisoft ArchiCAD, introduced in 1984, was the first product among these solutions to create a virtual model. Now in its ninth version, ArchiCAD's keep all the data in one PLN file that can hold a 60,000squarefoot building including all construction documents in a 30MB file.

ArchiCAD uses the GDL (geometric description language) model creation language. GDL contains all the information necessary to completely describe building elements as 2D CAD symbols, 3D models and text specifications for use in drawings, presentations and quantity calculations. (*H. Edward Goldberg, 2005*)

Autodesk Architectural Desktop 2005: Autodesk Architectural Desktop is an object-based BIM solution based on AutoCAD. This solution uses specialized programming and routines to make AutoCAD perform as a BIM modeler (Fig 4.1). This solution that saves all information in separate DWG drawing files.

Architectural Desktop is very capable and relies heavily on the automation of entity creation. It's very productive and capable of handling the biggest projects. Because it's basically enhanced AutoCAD, using the native DWG format, it's especially capable during the construction document phase. (*H. Edward Goldberg, 2005*)

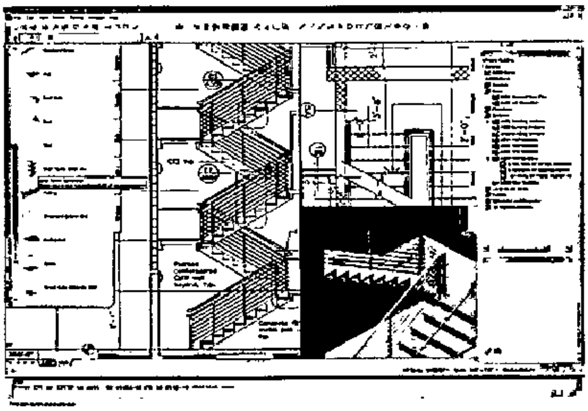


Fig 4.1.Autodesk Architectural desktop 2005

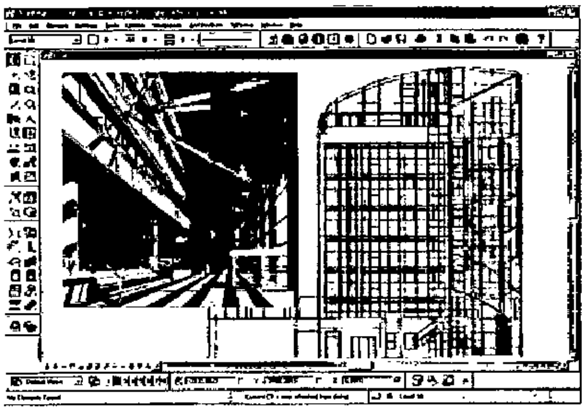


Fig 4.2. Bentley Architecture

Bentley Architecture: Bentley Architecture is the architectural application within Bentley's multidisciplinary suite of solutions. It's an object-oriented product, based on the MicroStation platform. MicroStation has the second largest number of installed seats. MicroStation or AutoCAD operators can easily become proficient with Bentley Architecture, and Bentley offers full DWG support to integrate with AutoCAD and Architectural Desktop users on mixed-platform projects.

Bentley Architecture includes full top-quality rendering and animation from within its user interface (Fig 4.2) and also provides capabilities for modeling, visualization, and reporting, schedules, cost and program analysis. It also offers a capability called 2D/3D choice, which allows users to work in either the 3D model or 2D drawing views or in both at the same time while keeping all drawings and the models in sync. (*H. Edward Goldberg, 2005*)

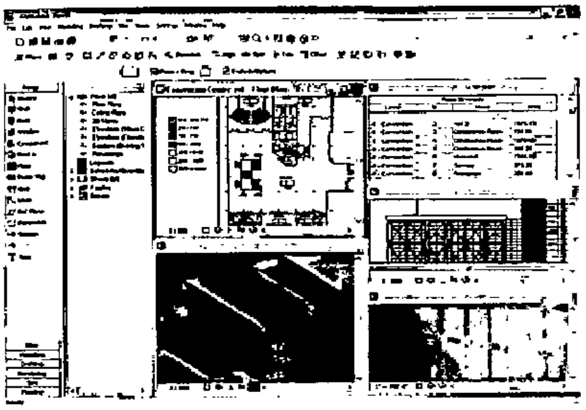


Fig 4.3.Autodesk Revit

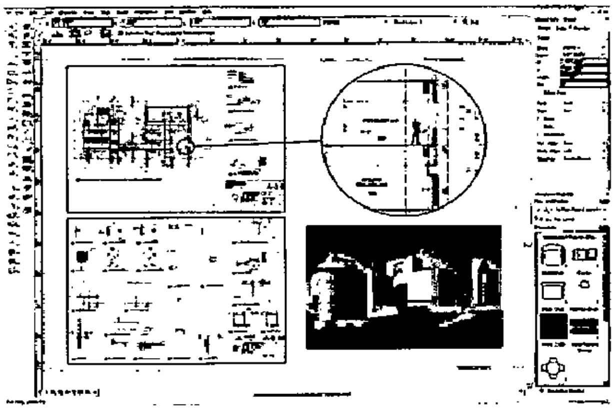


Fig 4.4. Nemetschek VectorWorks

Autodesk Revit: Autodesk positions Revit as software purposefully engineered for BIM. Revit was conceived by programmers who created 3D software for the mechanical design industry and applied those concepts to create a solution tailored for architecture and construction. Revit is four years old and in its seventh version. Autodesk updates it about every six months. Third-party plug-ins is available for energy analysis.

Many large architectural firms are doing pilot projects with this software, and SOM is using it for its 1,776-foot-high Freedom Tower project at the 9/11 site. Autodesk is expending lots of resources developing and promoting this software to the AEC community. For architects new to BIM, this software may be an excellent choice. It is, however, an excellent solution and, with the backing of Autodesk, could become an industry leader. (*H. Edward Goldberg, 2005*)

Nemetschek VectorWorks ARCHITECT: VectorWorks ARCHITECT is developed by Nemetschek North America, a wholly owned subsidiary of European developer Nemetschek AG. Like ArchiCAD, it's a cross-platform BIM program that runs on the Macintosh as well as Windows operating systems. The developer suggests that smaller, price-conscious firms may be drawn to this product, which is the least expensive of the five packages reviewed. Although this program creates an excellent 3D model, it incorporates years of 2D CAD expertise to provide drafting and detailing capabilities (Fig 4.4). (*H. Edward Goldberg, 2005*)

4.7. CURRENT ACCEPTANCE OF BIM

In some states such as Finland, Denmark, Norway, and USA, the use of BIM has been endorsed while some other states have progressed towards it. Finland as the world leader of BIM has summarized 108 projects, which has been completed. Although slow progressive changes are taking place within the UK industry and whilst many UK companies are happy to continue using traditional CAD, it is noticeable that US organizations working in the UK markets are effectively converting their processes to utilize BIM technologies (*Oakley, 2008*).

4.8. CONSTRAINTS

BIM, the potential contender for future, like any new tool, needs to be reviewed critically to explore its potential as well as limitations before using it in a different socio-technological set up like India.

The following reasons have been identified as the main obstacles that are preventing the adoption of BIM in India without any modifications:

- Investment and cost for training, preventing adoption of BIM in many companies. The relative cost for hardware and software probably would go down than ever before.

- Difference or gap between the cost for modeling buildings in BIM tools and the expected benefits for other participants in a project has to be narrowed down to start modeling.

- There is a general concern among some people that the size of a company has strong correlation with the ability to adopt BIM easily in comparison to smaller firms in US is confirmed by survey, but the result also shows that there are many large companies not following this trend. In India number of big companies is limited.

- A significant obstacle for using BIM in general is the need to redefine the work processes and roles that each player must have in a future environment in (architecture, engineering, construction) AEC, where BIM is fully integrated in all the relevant processes.

- India being one of the emerging global economies has strong potential for concentrated construction activities in coming decades. The trend is towards more sophisticated, high quality service oriented built spaces. Professionals like architects have to be equipped appropriately to execute such projects.

BIM, a very recent phenomenon in construction sector, has established its immense potential to be accepted as an important tool to resolve issues arising out of complex inter-relationships between different services, systems and technologies.

4.9. SUMMARY

The potentials and the constraints of BIM is discussed briefly, the primary constraint of BIM is it has less expertise, and the cost of the software .the main benefits are visualization which make clear understanding for AEC professional .

In the next chapter is the complete analysis of BIM potentials in India, the analysis is executed in two ways.

1. Survey
2. Hands on experience

CHAPTER 5

REVIEWING THE SCOPE OF BIM IN INDIA -HANDS ON EXPERIENCE

5.1. INTRODUCTION

BIM has captured the attention of the industry, much of the current research has moved in the direction of demonstrating the value of BIM and the inter-operability of software to make the applications more practical. Another key direction of research is identifying how the changeover to BIM will impact industry practice.

The focus of this research is to identify the differences between BIM and conventional design by comparing documentation of design outputs at the completion of the Schematic Design phase to a representation of the Schematic Design in the form of a BIM using Revit.

5.2. REVIT – THE ADOPTED BIM TOOL

5.2.1. General Introduction

Revit is the newest and most technologically advanced BIM application. Currently, a number of BIM application are on the market, although most other products in today's market, Revit was designed as a BIM tool to specifically address the problem areas of the architecture, engineering, and construction (AEC) industry.

It is the leading software package in the international market which offers the most holistic approach. Revit is a technological platform supported by a patented parametric change engine.

A parametric object is a smart object that can change its size, materials, and graphic look but is consistently the same object. For example, a single flush door can be 32", 34", or 36" (70, 75, 80, 85, or 90 cm).And most importantly, this information is always accessible, reversible, editable, and schedulable. Fig 5.1 shows the properties window of a particular single flush door which contains the construction type, materials and finishes, dimensions, identity data, etc. Fig 5.2 Shows the door family files where each door with the building industry specification which can even be edited according to the type of projects. Fig 5.3.Shows the generated door schedule, if any changes in the drawing it will automatically update in the schedule. Schedules can be generated for every element separately like for doors, walls, windows, etc.

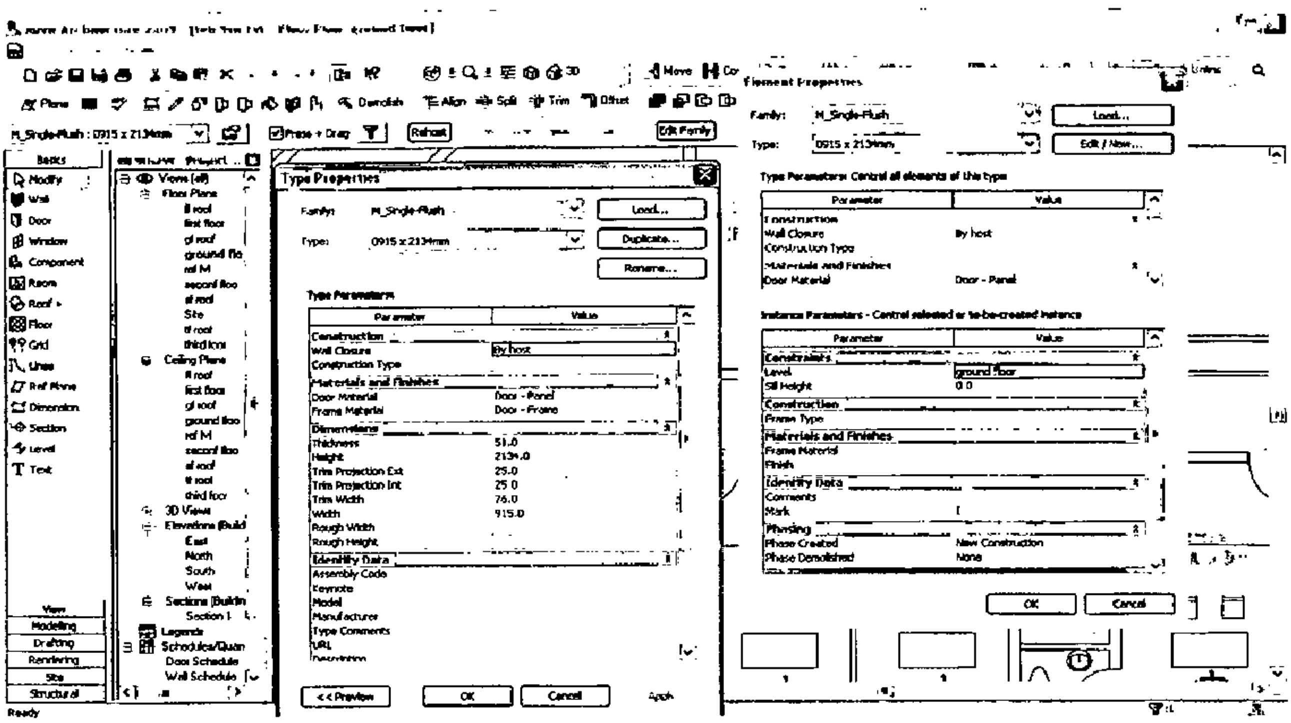


Fig 5.1 Properties window of a single flush door

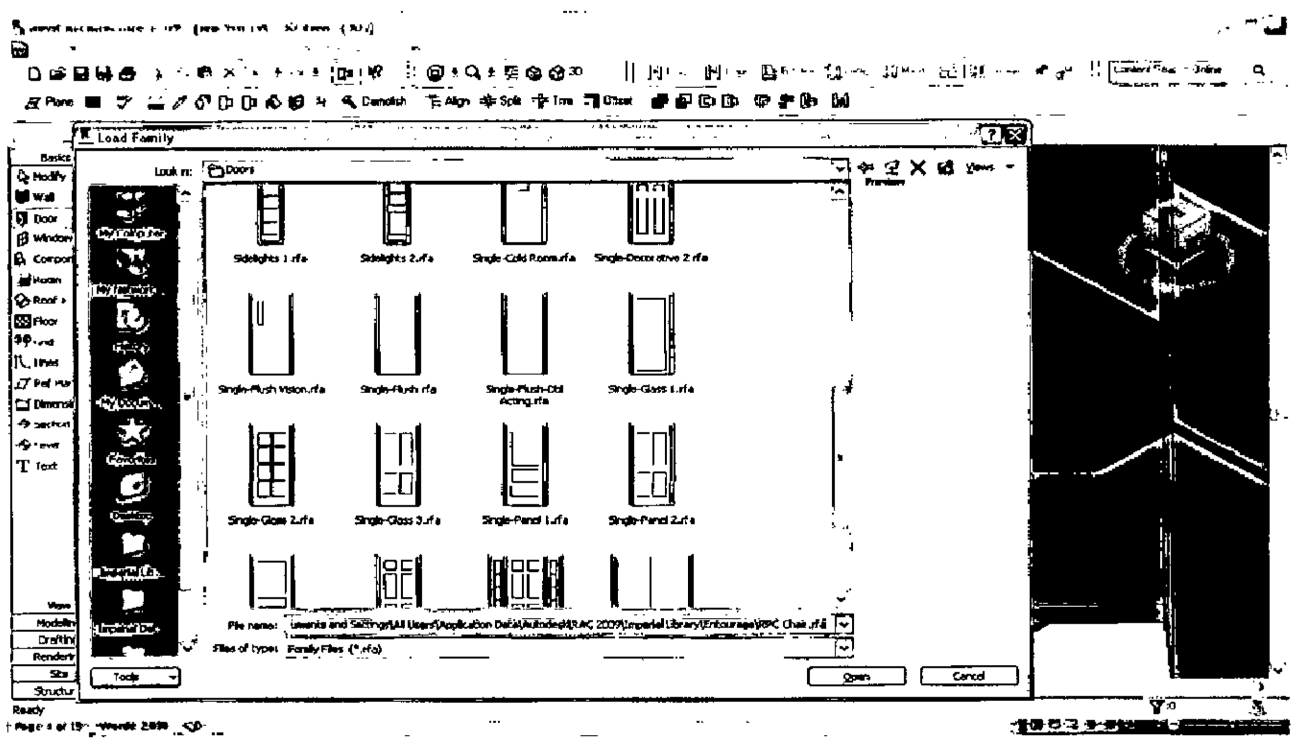


Fig 5.2 shows the door family folder

Revit has a unique ability to create relationship between objects. For example, walls can be attached to roof. If the roof changes to a new shape or size, all walls attached to the roof automatically adapt to the roof shape which is being shown in the Fig 5.4 & 5.5. This parametric engine guarantees that a "change anywhere is a change everywhere". Revit has embedded intelligent relationships among elements that are in logical relationship so that when one is affected; all related objects follow the change.

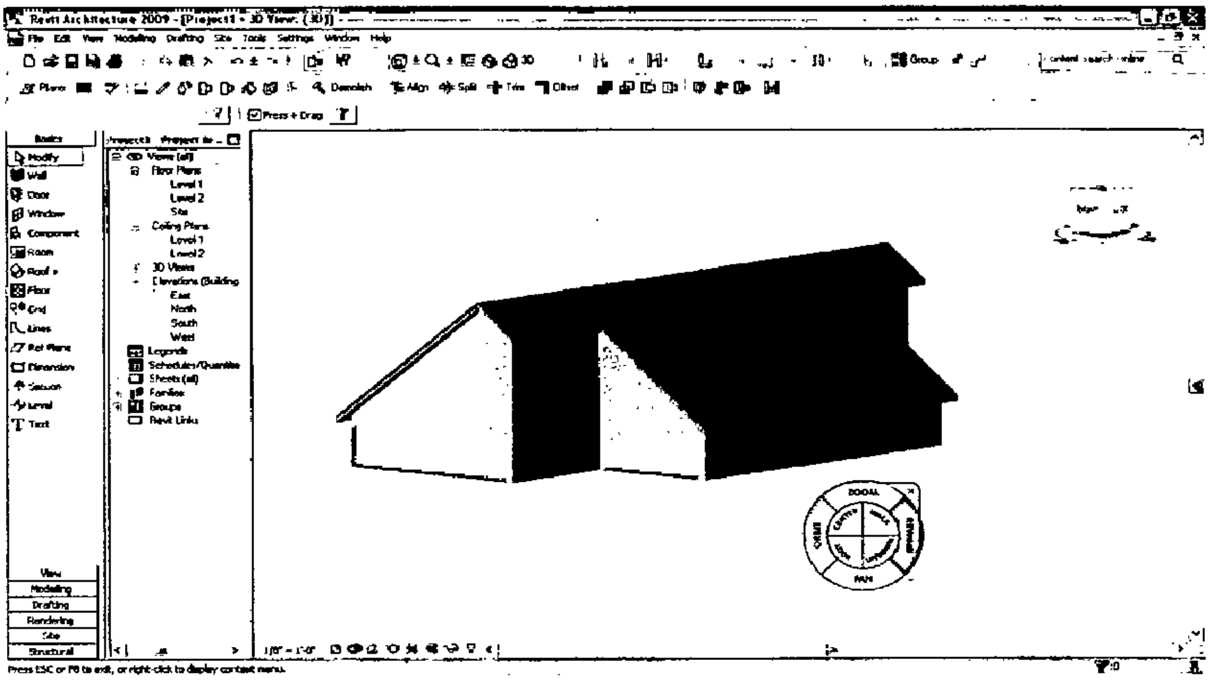


Fig 5.5 Walls attached to the roof, automatically adopt to the roof shape

5.2.2. Data organization in Revit: Revit uses a building industry specific classification to organize all the data in the model. This system of organization manages relationships among classes of elements as well as their graphical display. At the top of this organization is a fixed list of categories into which all elements are grouped.

5.2.3. Model categories: Model categories (Fig 5.6) include all representations of physical objects types that are typically found in buildings. This includes 2D elements that are used to add more detail to the model, such as floor patterns and ceiling hatch.

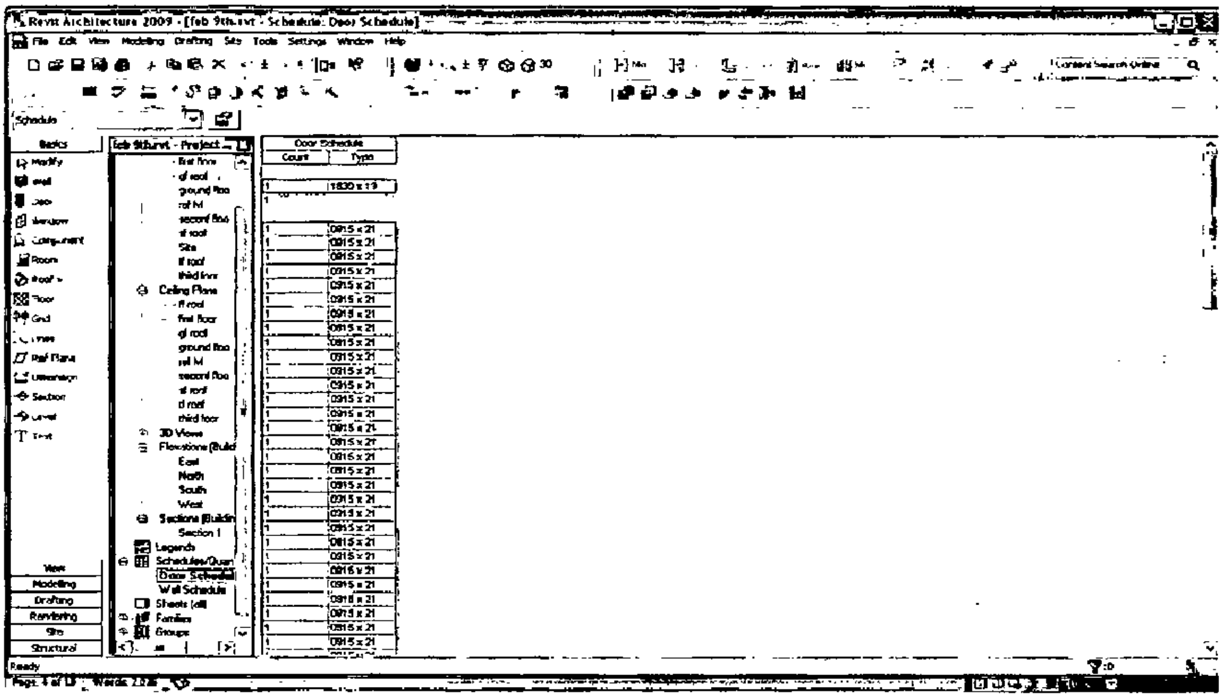


Fig 5.3 Generated door schedule

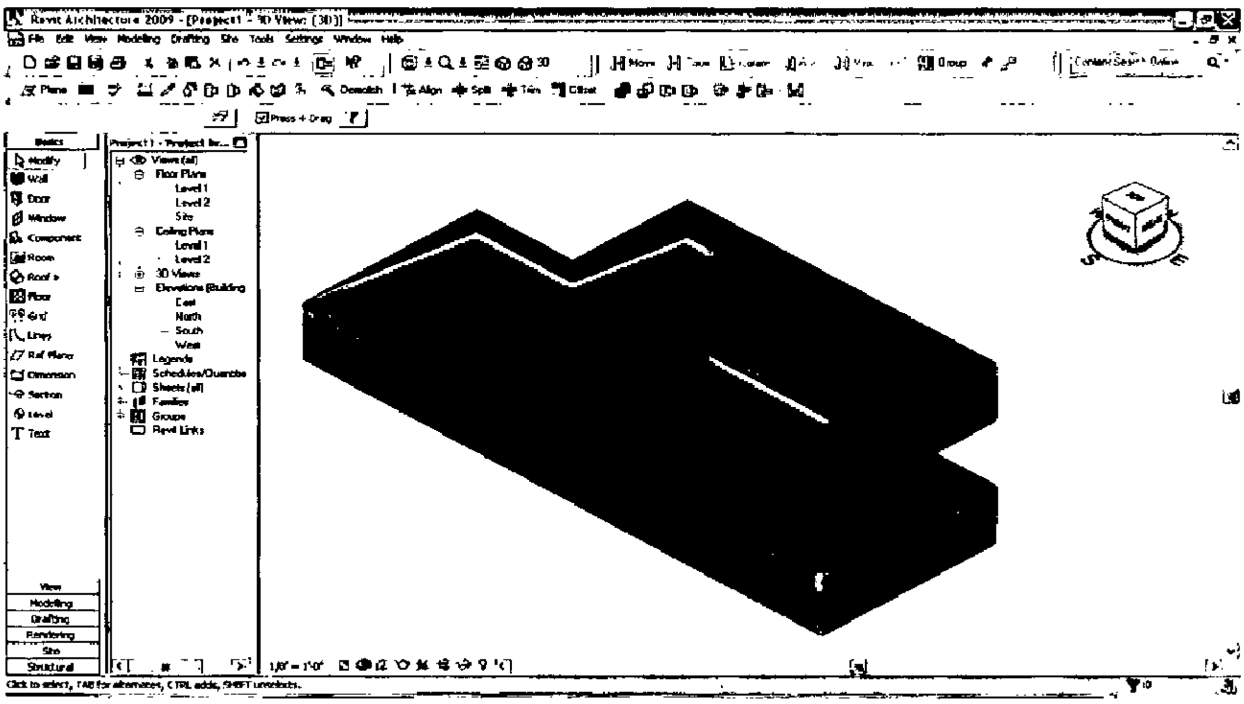


Fig 5.4 Roof structure of a model

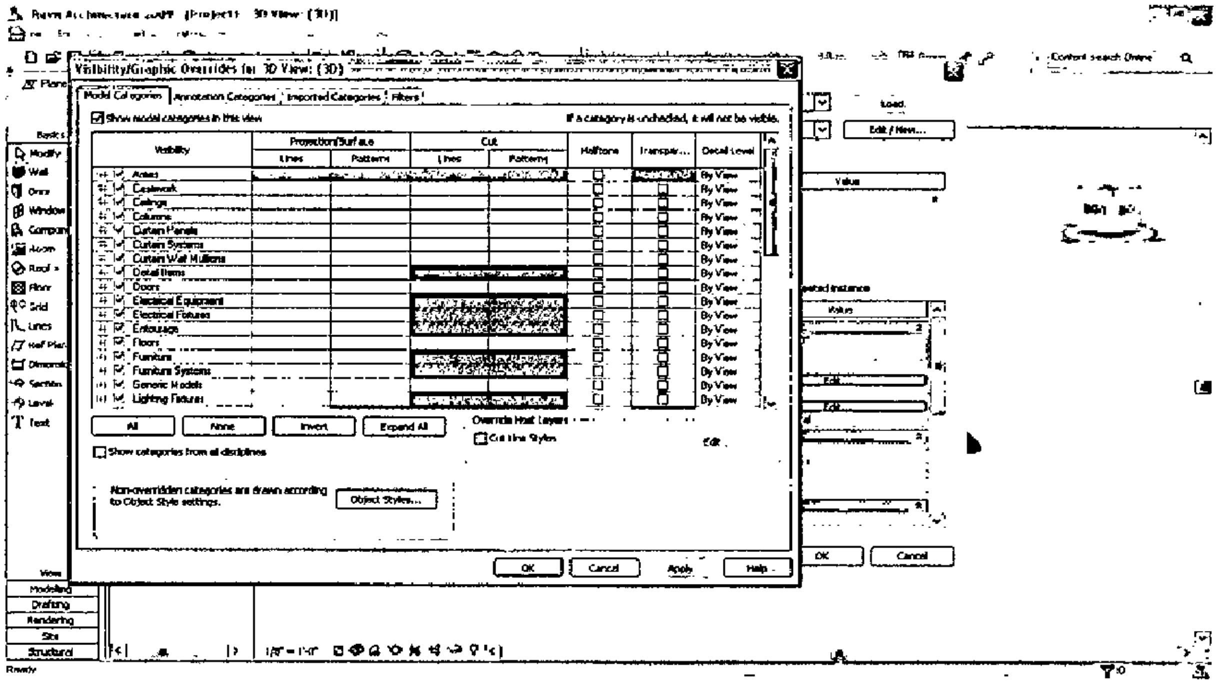


Fig 5.6 Model Categories

5.2.4. Annotation categories (Fig 5.7): These are all the annotations, symbols, and 2D data added to a drawing to describe how the building is to be constructed. These don't appear in the 3D view.

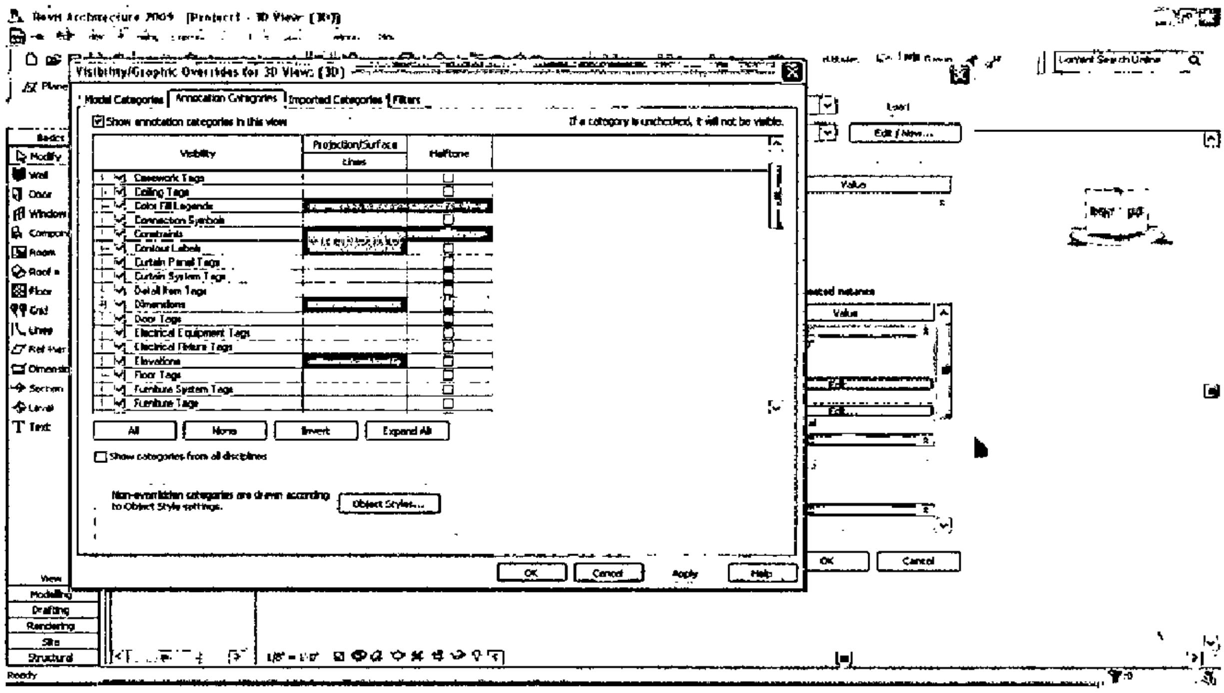


Fig 5.7 Annotation Categories

Below each category can be many subcategories. If door is the main category, the elevation swing, frame/mullion, glass, opening, panel swing, and any other user defined elements that can be made when creating the door. The beauty of this system is that you can control the visibility of each subcategory (Fig 5.8) independently.

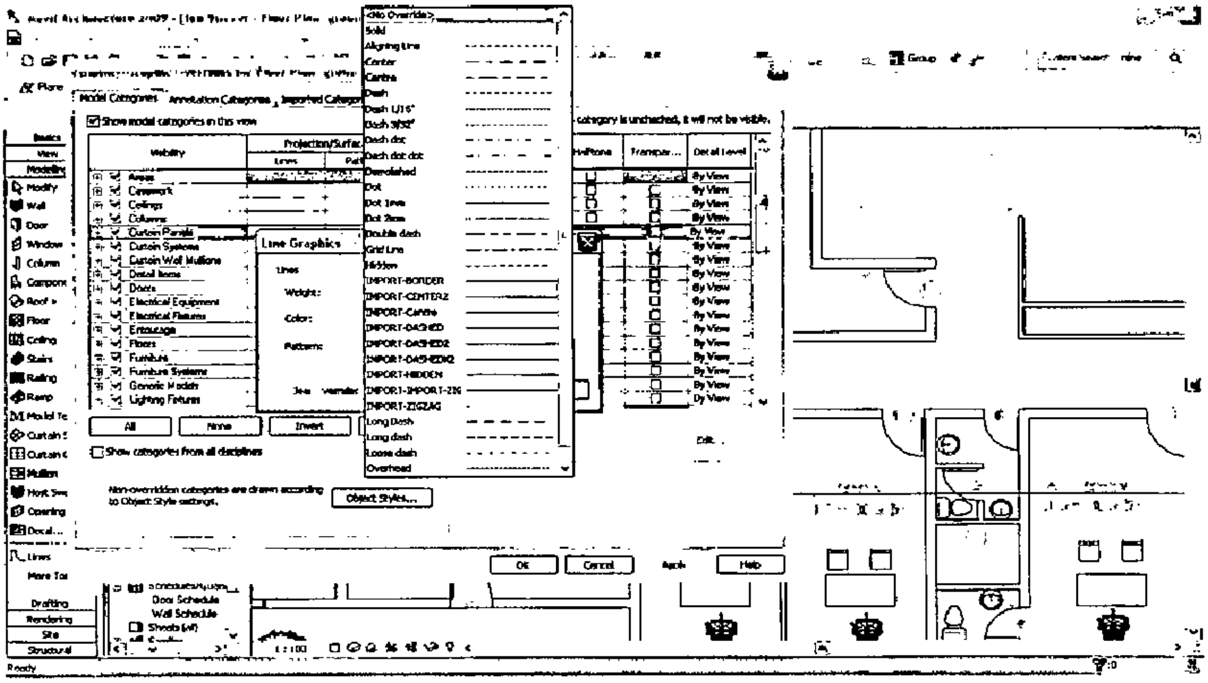


Fig 5.8.Visibility Control of each Subcategory

Revit has commands to control visibility of elements. If you don't want to show the glass in windows, doors, or curtain walls, you can turn them off in the view. Revit doesn't require you to know any programming or scripting language in order to create new smart, parametric families. Doors, windows, balusters, casework, columns, curtain wall panels, entourage, furniture, massing elements, generic objects, and plantings are all examples of standard Revit families. Revit will allow you to make major changes at any stage in the process, and maintain coordination.

In Revit, a BIM is comprised of synchronized views and schedules. The fields in each schedule have to be selected from the corresponding available fields. Additional schedules and parameters can be set in the interfaces. The data in a schedule can be exported as a delimited TXT file for downstream application (Fig 5.9, 5.10).

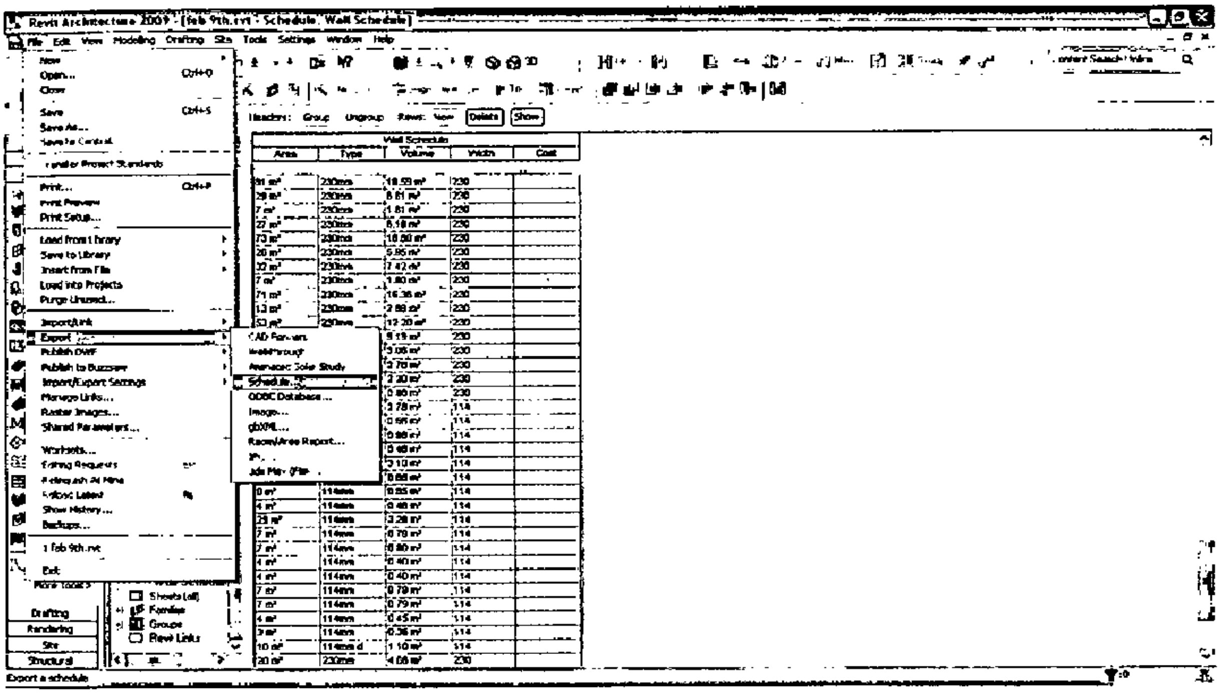


Fig 5.9 Schedule can be exported as a delimited TXT file

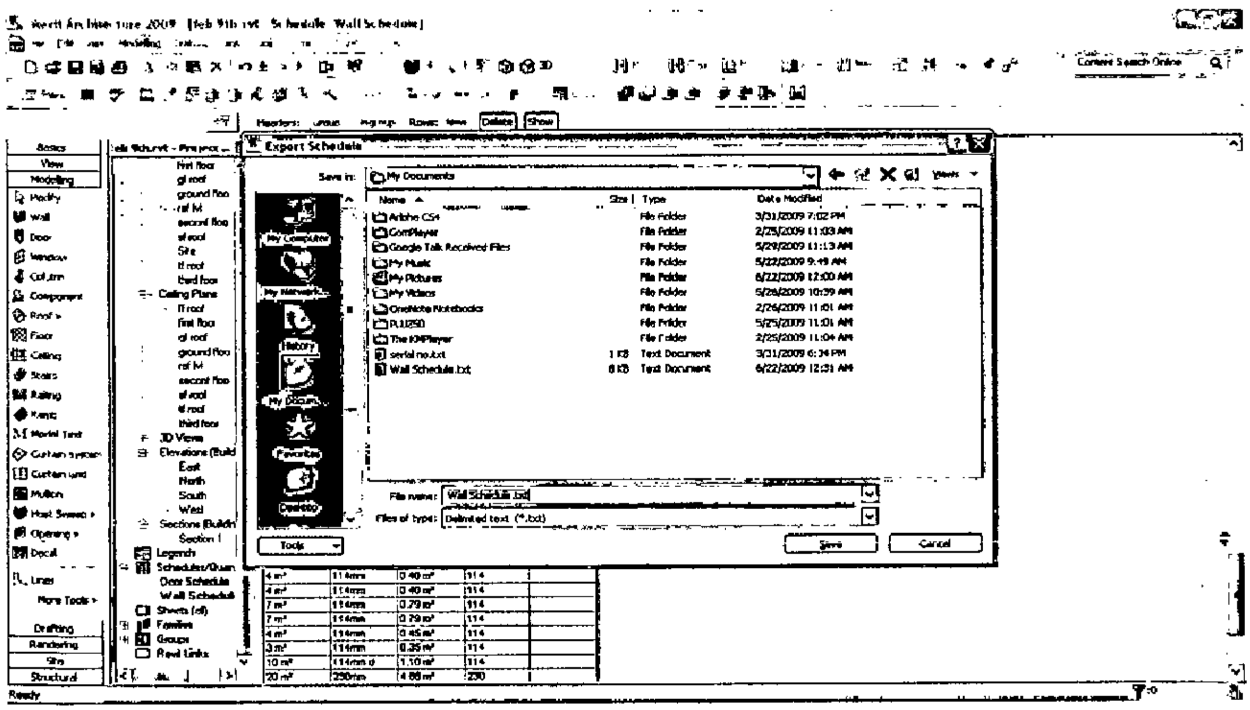


Fig 5.10 Schedule can be saved as a TXT file.

5.3. DEVELOPMENT OF PROJECT USING CONVENTIONAL CAD MODELS AND BIM MODELS

5.3.1. Project Summary Information:

Project Name:	Office complex at 33kv s/s Srinagar Garhwal
Facility Type:	Office building
Location:	Srinagar Garhwal, Uttarakhand
Client:	Uttarakhand state Electricity board
Date Completed/Occupied:	September 2008 (under construction)
Size:	916 s.m.
Design:	Prof.Shankar, IIT, Roorkee
Construction, Office:	Livin consultant, Dehradun, Uttarakhand

Model generated by using BIM supported drafting tool Revit Architecture 2009, where 3d model is been created automatically from the 2d drawing because it has a parametric interface between 2d and 3d as shown in the Fig 5.11. The Fig 5.1 shows the model created using AutoCAD 2008 which is a non-parametric model.

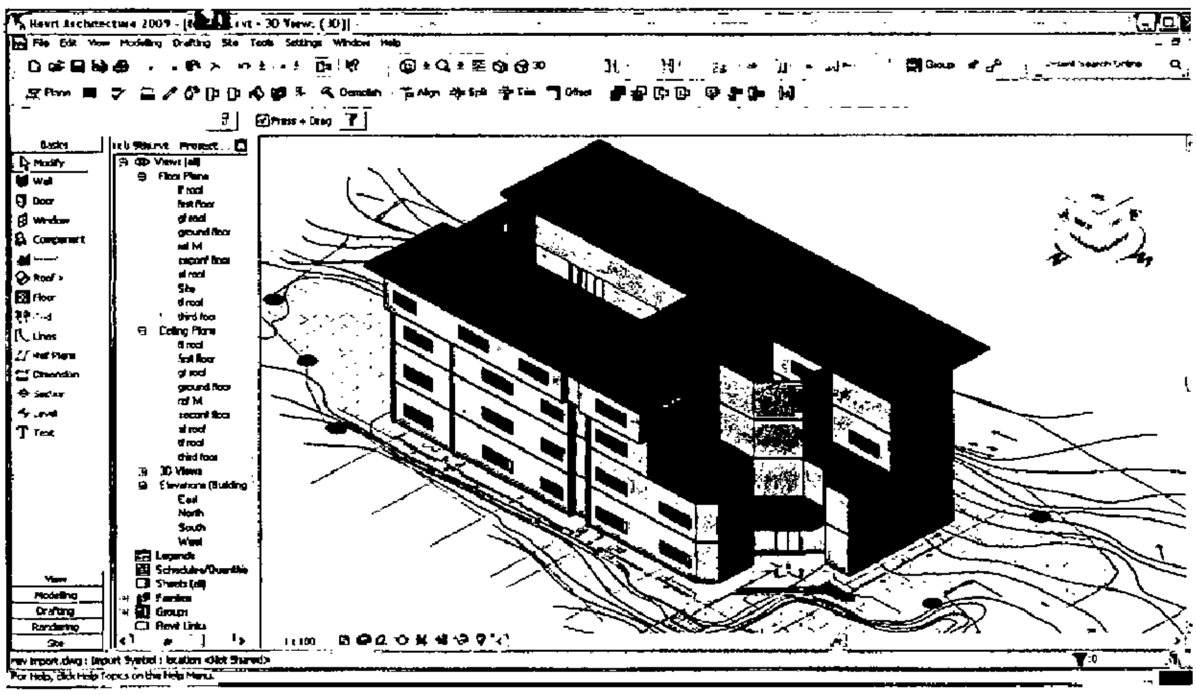


Fig 5.11 3D model generated using Revit Architecture

Model generated using Revit structure 2009 showing wireframe model of the office building (Fig 5.14). Revit structure and Revit architecture are linked and the structural objects are installed in the previously made architecture model using Revit structure 2009 and reviewed for clash detection. Fig 5.13 showing the Sectional view created using Revit. The service objects are installed using Revit MEP 2009 in the generated architecture model (Fig 5.15), in order to find the clash with other structural and architectural elements.

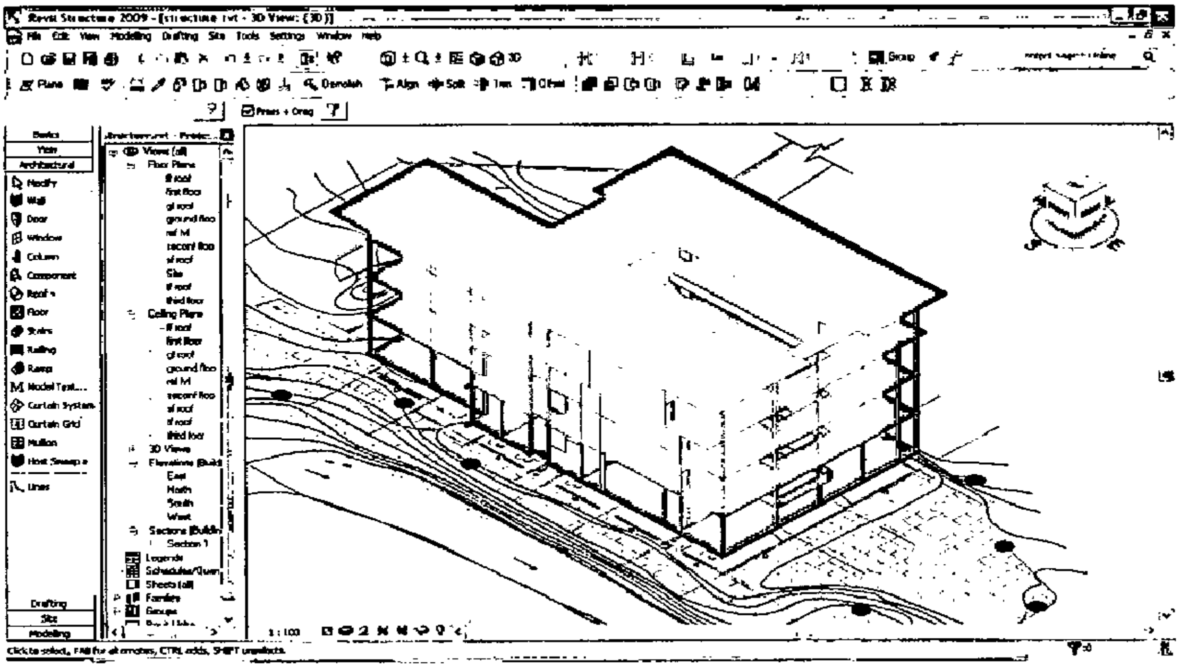


Fig 5.14 Wireframe Model generated using Revit structure 2009

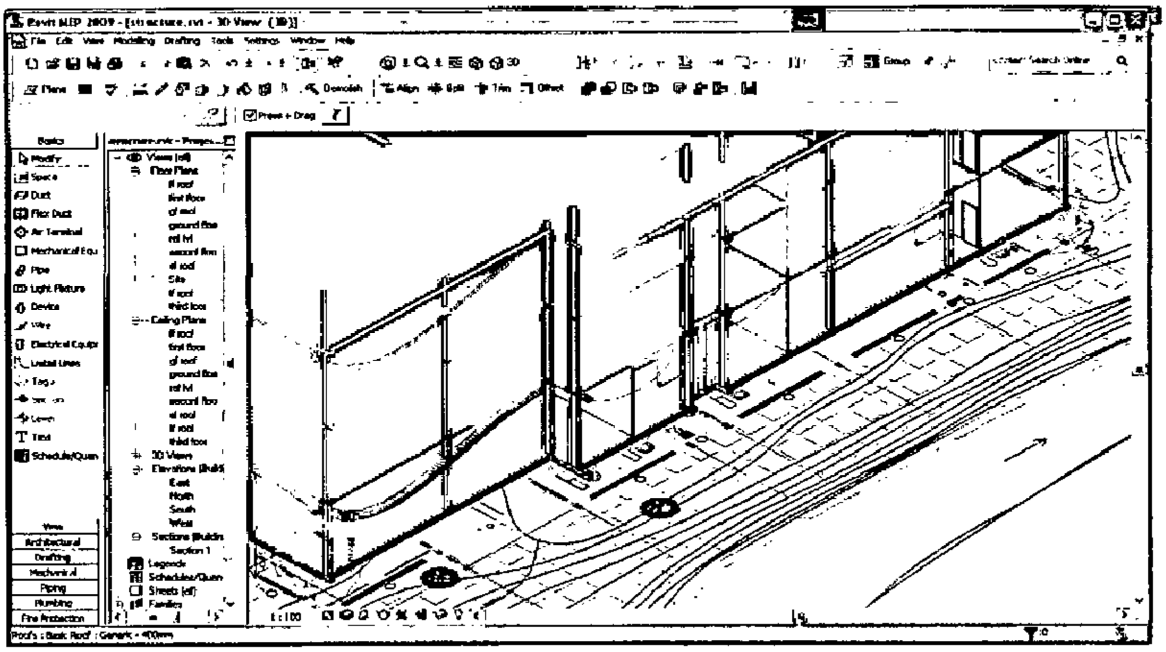


Fig 5.15 Service installed using Revit MEP 2009

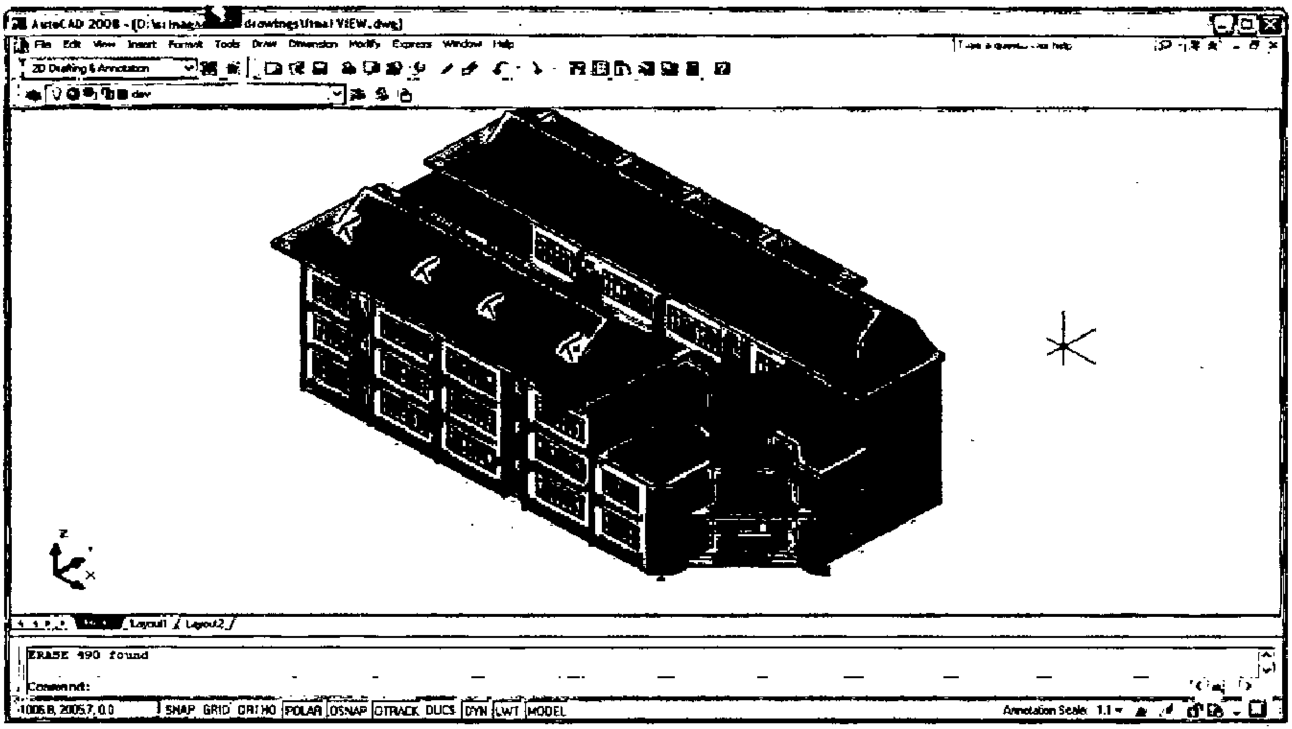


Fig 5.12 Model generated using Autocad 2008

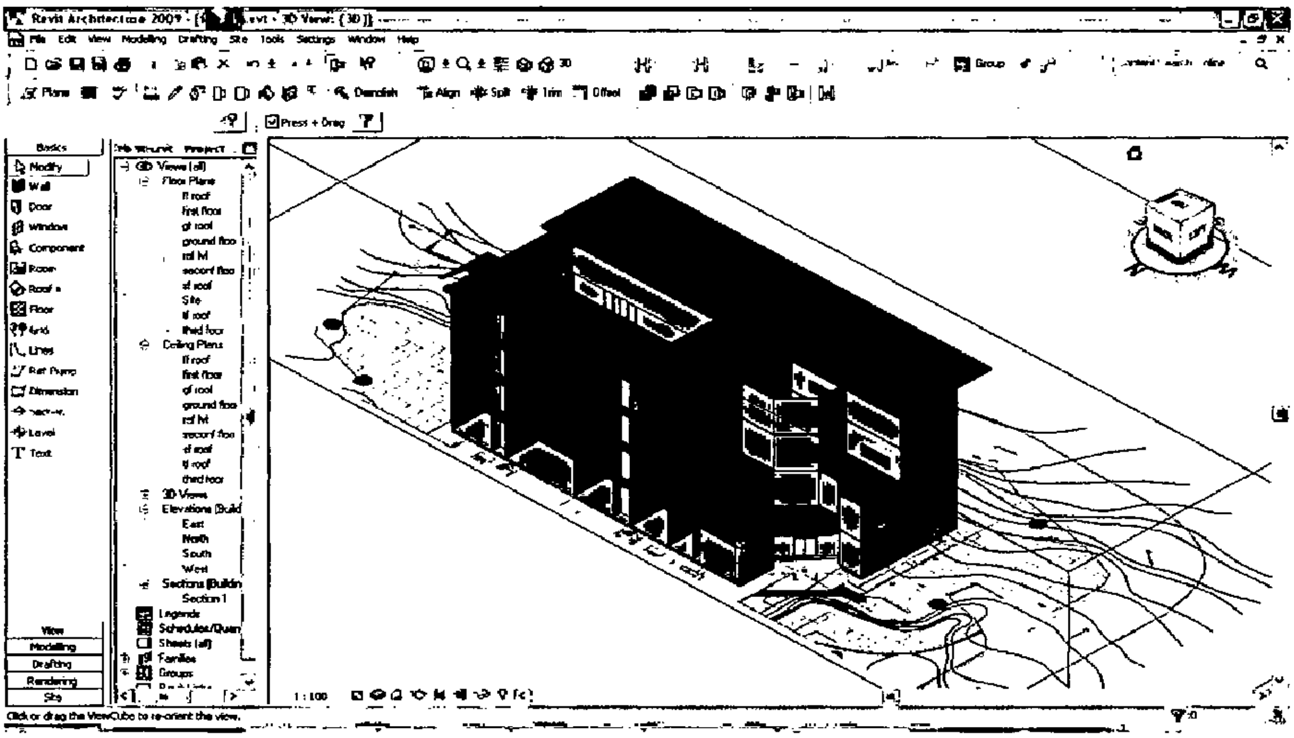


Fig 5.13 Sectional view - Revit model

In Revit, schedule can also be generated separately for all the elements in the building.

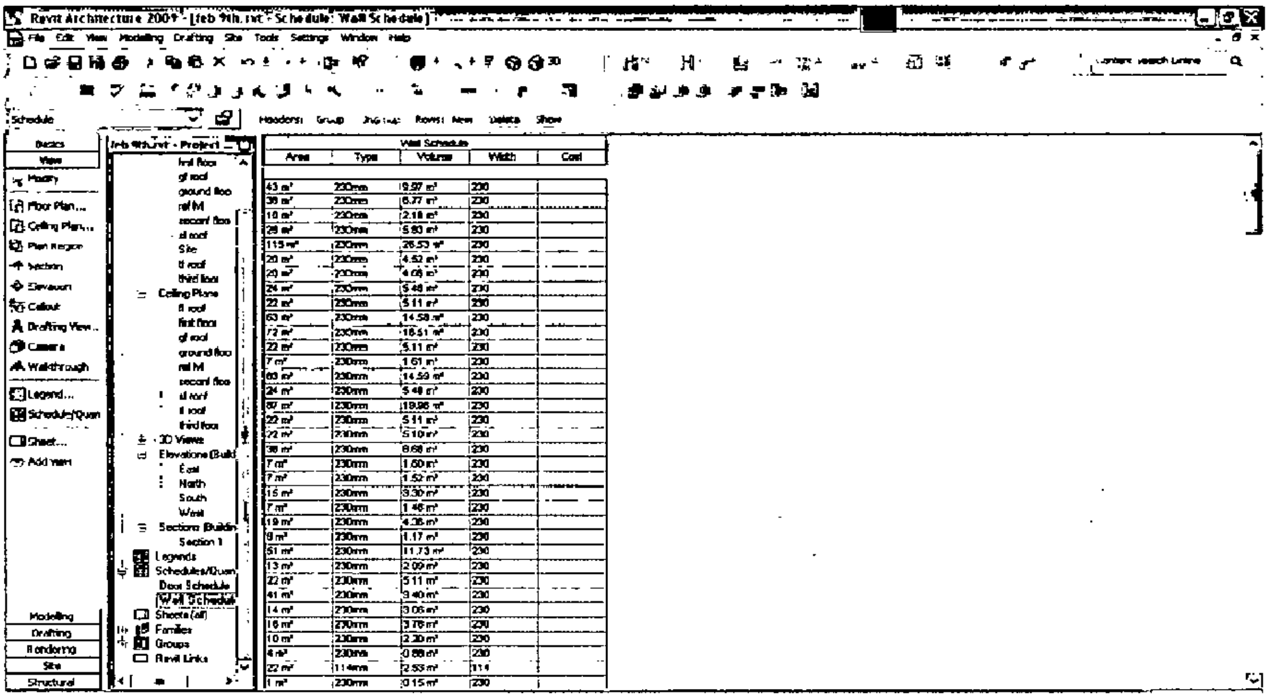


Fig 5.15 Generated schedule

5.4. COMPARATIVE MATRIX FOR CONVENTIONAL CAD MODELS AND THE BIM MODELS.

5.4.1. Comparison Criteria

The first step was to define the standard Schematic Design documentation. The standard submission requirements served as a basis for this research. In addition to specific drawing requirements, additional documented goals for the review include,

1. Constructability review
2. Spatial program verification
3. Sustainability review

5.4.2. BIM Development

A "2D Conversion" is using the CAD files and using the necessary information to incorporate the third dimension. The time and effort needed to perform a conversion changes depending on the level of detail incorporated and the experience of the modeler. When the design CAD files are available, they can be inserted into the BIM authoring software and the BIM is drawn over the original 2D plans. The use of the CAD files simplified the geometrical modeling of the project.

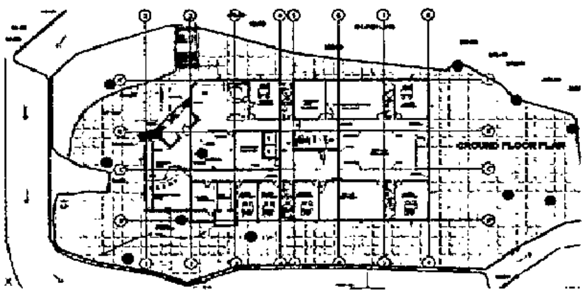
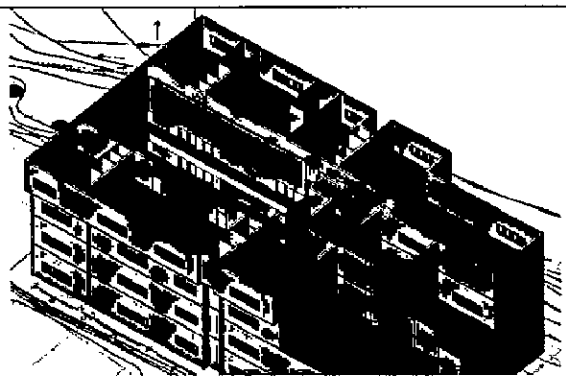
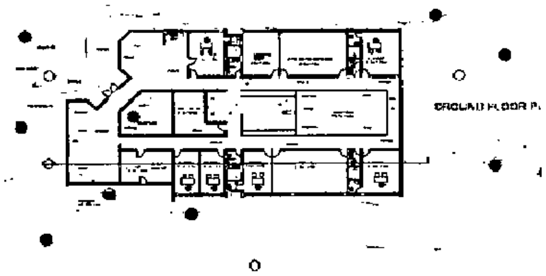
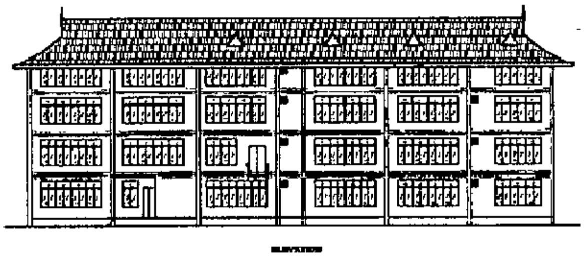
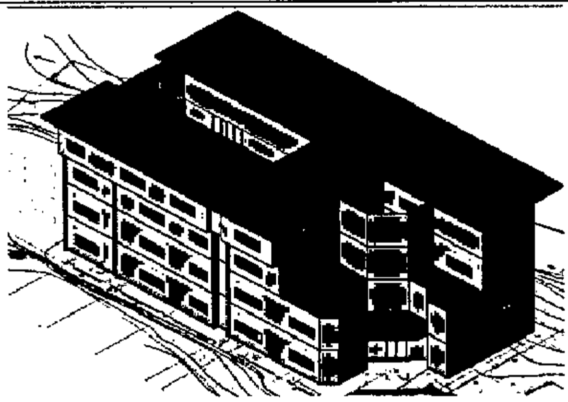
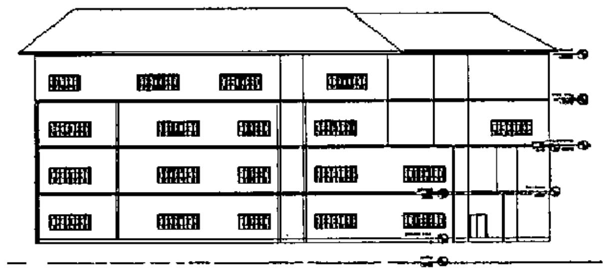
One potential value of a BIM over a conventional 2D documentation of the design is the ability to easily perform additional analysis tasks such as energy, day lighting, construction scheduling, and quantity takeoffs. To investigate this value, the model was used to perform an energy analysis using Green Building Studio (GBS 2007). Energy modeling was chosen because of the LEED goals of the project.

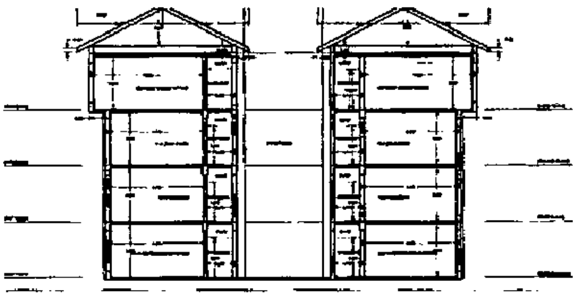
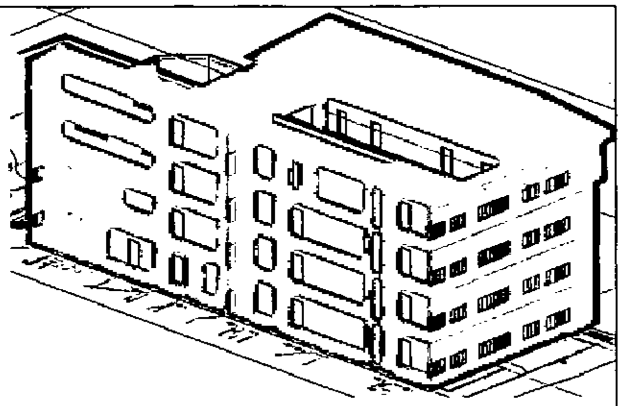
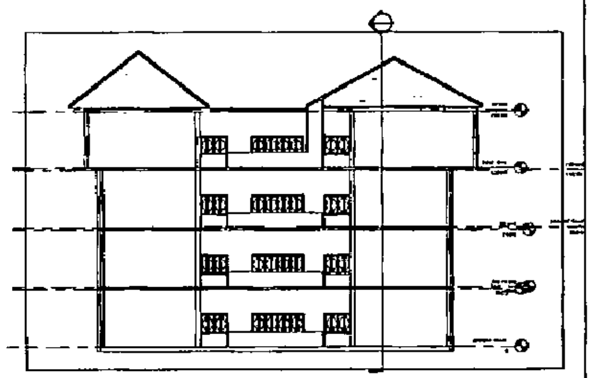
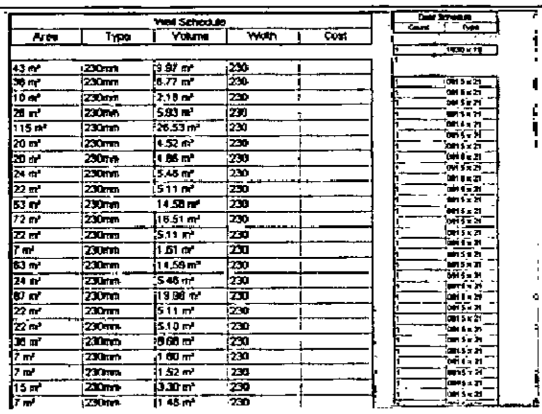
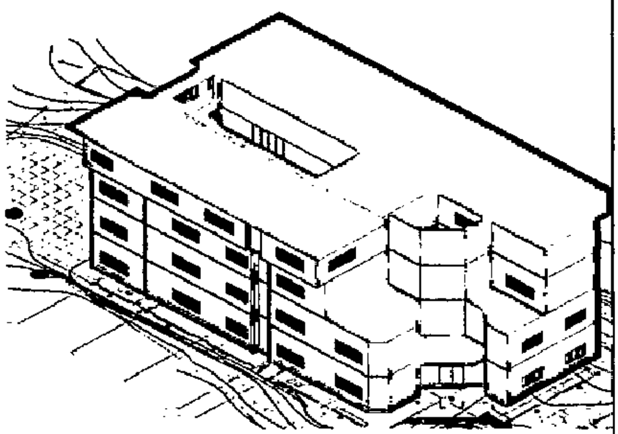
5.4.3. Identification of Differences

The identification of difference was achieved using various methods. The CAD files for the 2D design documents were imported into architectural BIM authoring software, for this project Autodesk Revit Building and Systems. Using the 2D drawings, the 3D geometrical aspects of the model is developed. The conversion of the design into a 3D model aided in the identification of geometrical challenges which do not readily present in conventional 2D documents, a detailed comparison based on submission criteria using an evaluation matrix. The first column is dedicated to the conventional design documents and was used to identify the form of the information. The second column is dedicated to the BIM which was developed.

The second set of columns focuses on the information in the BIM and aids in identifying the differences in the information and the manner in which it was obtained. The comparison of the two columns also served to identify information which was not represented in one of the two forms of media.

Table 5.1 shows the areas of the identified differences visually from the requirements matrix.

view	Conventional Documentation (CAD)	Building Information Model
Plan		 
Elevation		 

Section		 
Quantities	N/A	
Energy	N/A	

5.4.4. Differences in Visualization of Geometrical Information

One of the primary expected differences when developing the BIM was in the geometrical information; the BIM allows for multiple, and dynamic, 2D and 3D views of the building, while the traditional documents have purely predefined 2D views.

5.4.5. Differences in Obtaining Data from the Design

Obtaining data from the two design representations was also found to be notably different. With the BIM, we can open a properties window for a given element to find the aspect. Using the BIM, we can see certain properties, such as component pieces, from the plan view. We can also have the option to develop an equipment schedule by automatically generating one within the BIM software. In addition, other schedules of information can be generated from the model. An area or volume takeoff, as shown in Figure 3, can be generated to save time in the estimating process and to provide accurate area information to the owner.

5.5. SUMMARY

This Chapter has identified primary differences in design representations between traditional 2D documents and BIM for representation the Schematic Design information. A detailed review of the documents along with a comparison to BIM has been performed to identify the differences in information in each representation and the new considerations in developing design scope while using BIM. To identify the differences, a basis of comparison has been prepared. The BIM representation is developed to make a comparison to the traditional documentation for the same project. It also served to identify the perspectives of AEC industry members to better evaluate the range of issues related to the use of BIM.

Every project requires different information to be incorporated depending on the individual goals of the project and the different interests of the owners. BIM enables the incorporation of a variety of information and visualization which is not readily available in traditional 2D drawings, such as structural or lighting analyses. BIM encouraged spending more time coordinating the designs than with traditional design documents because conflicts could be more quickly and clearly identified. It would be a time saver in generating area and quantity takeoffs for the estimate. The mechanical designer would be able to more quickly develop the loads and system requirements.

The balance of time savings using the computational aspects of the model versus the added time of incorporated information beyond the practical scope of this comparison but would be a valuable area of future research. The key will be to work out for each project what is the appropriate level of detail and information to incorporate at this early stage.

The results indicate the potential for clearer communication, whether it is through better understanding of the systems, visualization of complex building geometry, or simplifying building space zoning using color coding. The true value of this comparison, however, is focused on the impact to the Design phase.

CHAPTER 6

REVIEWING THE SCOPE OF BIM IN INDIA -SURVEY METHODOLOGY

6.1. INTRODUCTION

In January 2009, survey conducted to determine the awareness, understanding, and use of BIM in India. The upshot of that survey was that few Architects were familiar with the term and even fewer of them had used BIM on some projects in their firm or organization.

The electronic questionnaire was sent to nearly 150 architecture firms whose valid email address were available from different sources. A total of 58 respondents including architects and engineers participated and recorded their views. The response rate is about 40%. Several responses contained invalid answers and were therefore disregarded.

The report captures the detailed results of the survey, which was entitled "***Evaluating the scope of building information modeling for the Indian construction industry***". The survey results in this report capture not just the consolidated feedback of all the respondents but also an analysis of the data across various segments to determine if there were any significant differences in how respondents in different categories rated the various criteria.

In addition to responding to the survey questions, many respondents took the time and the initiative to provide additional feedback on their requirements for BIM. While architecture was the predominant discipline that was represented, there were also a sizable proportion of respondents practicing engineering, construction, and facilities management and operations.

In terms of BIM solutions being used or evaluated, Revit formed the majority followed by ArchiCAD BIM solutions. Overall, the diverse background of the respondents and their solutions provided a rich context for their inputs.

6.2. ACCEPTANCE LEVEL OF BIM IN INDIA

BIM application has received different levels of acceptance in different countries. In US this is not only accepted but also made compulsory to large extent. The General Service Administration (GSA) of US has initiated a requirement in 2007 for the planners to produce a BIM model for spatial program validation as an open standard if they are applying funding for their projects, *Holzer, Dominik* . Despite being new to the Indian construction scenario, BIM has shown strong acceptance potential here. To establish this claim quantitatively, Survey methodology has been adopted. A Questionnaire with twenty one questions has been designed to be a current "status check" on BIM. The questionnaire was sent to AEC industry practitioners in different parts of India, *Lachmi Khemlani, Ph.D, 2007.*

6.3. ABOUT THE SURVEY

The main objective of this survey was to identify the most important requirements that AEC professionals would like BIM (building information modeling) solutions to fulfill. The Autodesk is currently the undisputed market leader in the AEC technology space and its Revit platform is getting the most when it comes to BIM.

This survey is conducted as a neutral and independent resource on BIM. This report has been focused on covering, analyzing, and reviewing BIM technologies, implementations, since its inception, and has reported in-depth reviews of all the leading BIM applications, including Revit, and ArchiCAD. The survey questions were based on this knowledge and the analysis of the survey results captured in this report also reflect my understanding of the core strengths, capabilities, and limitations of the Revit and Archicad platforms.

6.4. THE SURVEY QUESTIONS

The survey questions listed a number of criteria that can be used to evaluate BIM solutions. For each of these criteria, respondents were asked to indicate the degree to which it was important to them and their firms by rating it on a 5 point scale, where 1 indicates "strongly agree" and 5 indicates "strongly disagree." Respondents were requested to be as judicious as possible in using the top ratings, reserving it for only those aspects that were really critical to them. The criteria listed for this were:

1. What are your primary CAD applications in use in your office? (Mark all that are used for active projects only).

2. Which BIM application is in use in your firm? Mark none if your firm is not using a BIM product or BIM methodology (ex: using Revit Architecture 2008 but not in a BIM methodology).

3. What would cause you to start using "Building Information modeling (BIM)"?

4. Why aren't you using "Building Information modeling (BIM)"?

5. From the firm principle or firm leader's perspective, how much you are interested in using "Building Information modeling (BIM)" technology

6. From the principle or firm leader's perspective why is your firm interested in "Building Information modeling (BIM)" technology at this point in time?

7. Are you personally interested in adopting a "Building Information modeling (BIM)" workflow?

8. Do you agree with the following statement: 2D CAD is inefficient compared to a true "Building Information modeling (BIM)" workflow?

9. Do you agree with the following statement: Adopting "Building Information modeling (BIM)" in practice will lead to greater firm efficiency during the working drawing phase than 2D CAD?

10. Do you agree with the following statement: Adopting a "Building Information modeling (BIM)" workflow will lead to better and greater works of architecture?

11. Do you feel that the adoption of "Building Information modeling (BIM)" technology within the field of Architecture will lead to greater pay (salary) for architects at all levels within the profession?

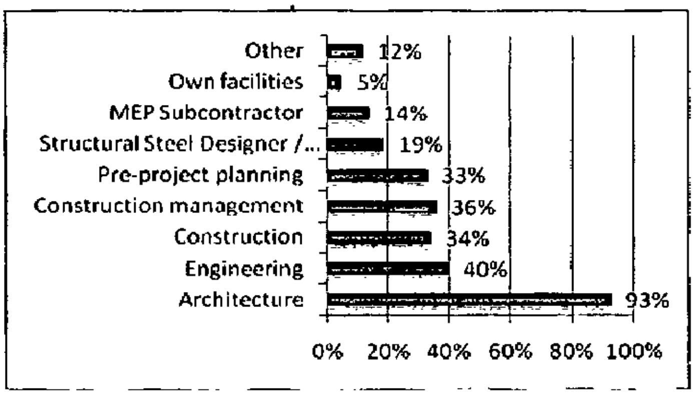
12. Do you agree with the following statement: The adoption of "Building Information modeling (BIM)" within the field of Architecture will increase society's value for architects and architectural services?

13. Do you agree with the following statement: "Building Information modeling (BIM)" technology is still too complex and should be and could be made much simpler?

14. What aspects of "Building Information modeling (BIM)" technology most appeal to you?

Respondents were requested to identify any additional criteria that were not mentioned in the questionnaire, but which were important to them. They were also given the opportunity to add any additional comments regarding the subject of this survey.

6.5. QUESTIONNAIRE RESULTS AND ANALYSIS



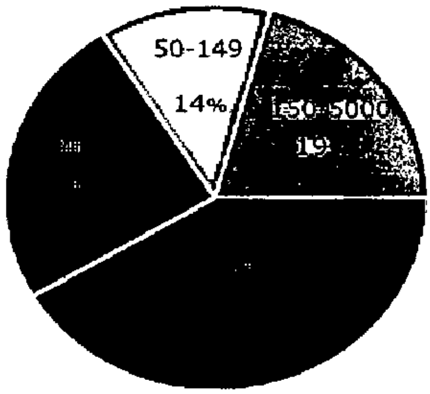
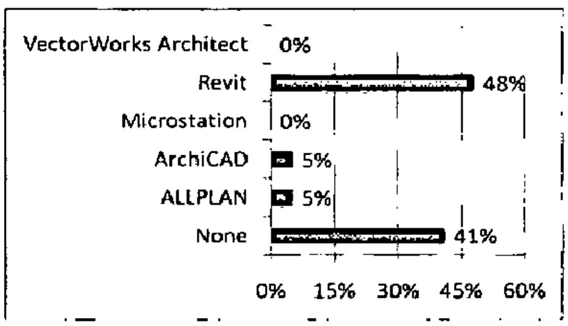


Fig 6.1(a).Disciplines practiced in the Firm

Fig 6.1(b).Firm Size of the respondents



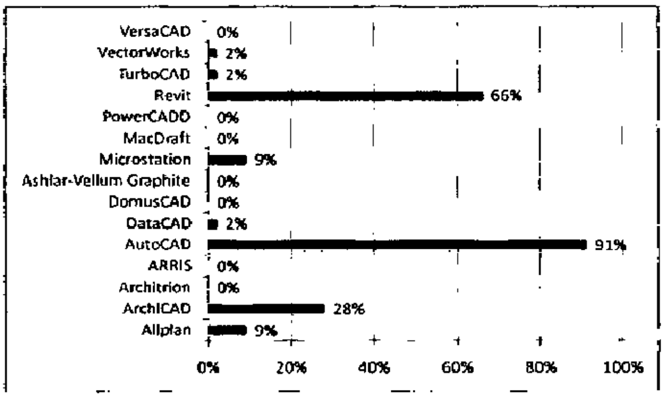


Fig 6.1(c) BIM Application used in the Firm

Fig 6.1(d) Primary CAD Application practiced in the firm

BIM is not as widely adopted as conventional CAD software. It is necessary to know the uptake of the conventional CAD software in the respondents firms. As shown in the Fig 6.1(d), the widespread of AutoCAD is evidenced. The figure shows that 91%

(53 out of 58) of respondents are using AutoCAD; this means that they were only producing 2D drawings, not real 3D building models. In comparison, 38 respondents out of 58 had installed Revit and 16 out of 58 using ArchiCAD. Vector Works, All plans, DataCAD, Microstation, TurboCAD were found in a very small number (less than 10%) of firms.

In India, the overall uptake of BIM in architecture firms is still noticeably low. Revit is not practiced widely in many firms as a primary CAD application, but it is incorporated as a BIM application. The survey reported that 48% of the respondents use Revit as a major BIM tool shown in Fig 6.1(c). Autodesk is adopting an aggressive strategy in promoting Revit. A 60-day trial version of Revit is currently downloadable from Autodesk's website.

Fig 6.2(a), (b), (c), (d), (e) and (f) provide information on reasons for non-adoption of BIM at present.

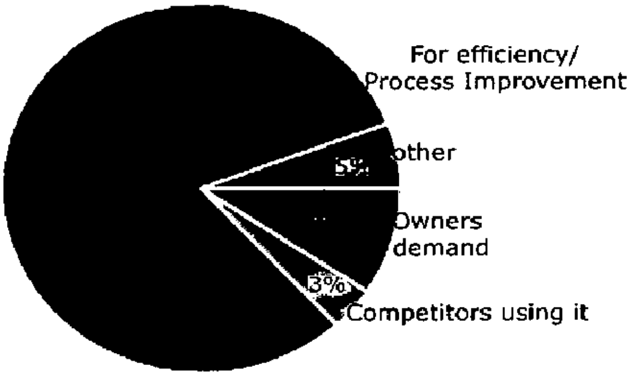


Fig 6.2(a) Causes for starting BIM

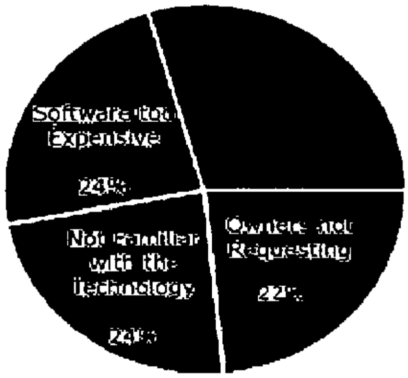


Fig 6.2(b) Reasons for not using BIM

The main reason for not using BIM here, is the lack of technical expertise.

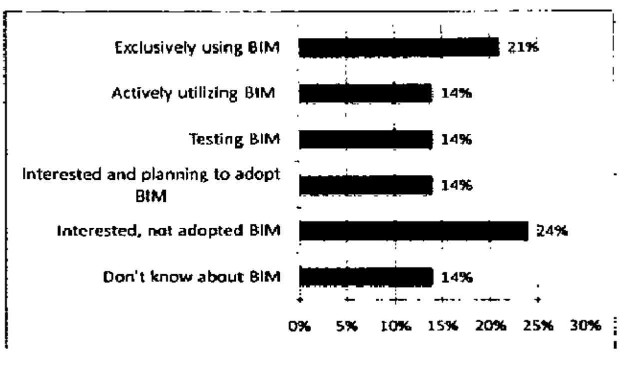


Fig 6.2(c) Firm Leaders interest towards BIM

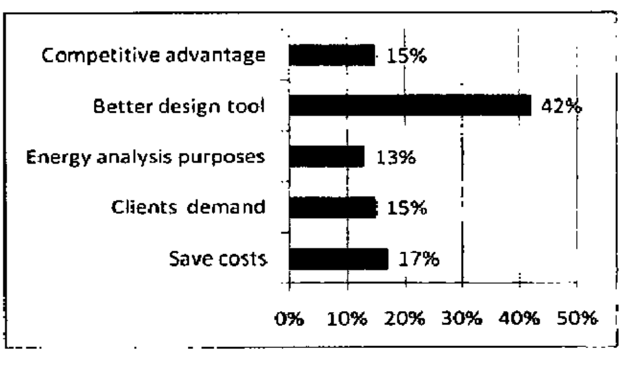


Fig 6.2(d) Reasons for the interest towards BIM

The Fig 6.2 (c) Shows that nearly quarter of the firms applied BIM i.e. 21% (12 out of 58) and about 14% were testing BIM on their projects. But the result also shows that 24% of the total respondents are not using BIM but interested to use it.

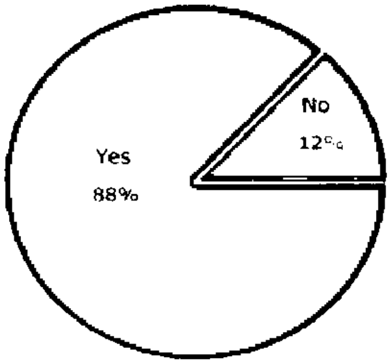


Fig 6.2(e) Interested in adopting BIM workflow

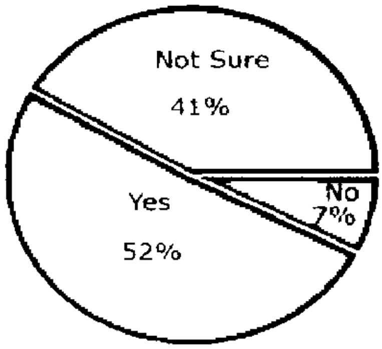


Fig 6.2(f) Adopting BIM in Architecture field leads to better pay.

The fig. 3(e) shows that over 88% of the respondents would probably move to BIM if required to by clients. While it is questionable whether architecture firms will follow the requirements set by external project parties, a large user base would be a positive driving force for the adoption of new technologies.

The result suggested that more efforts should be put into promoting the advantages of BIM over conventional entity-based CAD software, and into enabling the application programming interface as well as into promoting information interoperability.

Fig. no. 6.3.(a), (b), (c), (d), (e) and (f) provide information on BIM user's reasoning's behind the preference.

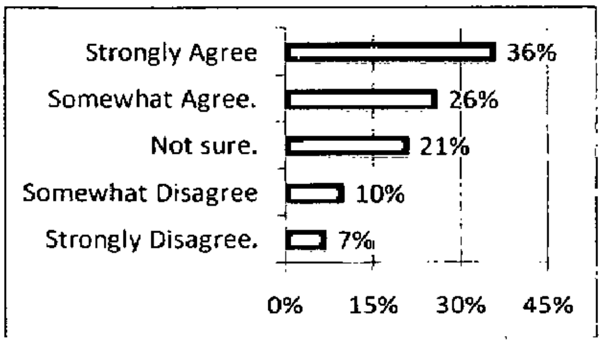


Fig 6.3(a) Adoption of BIM in architecture will increase societal value for architects.

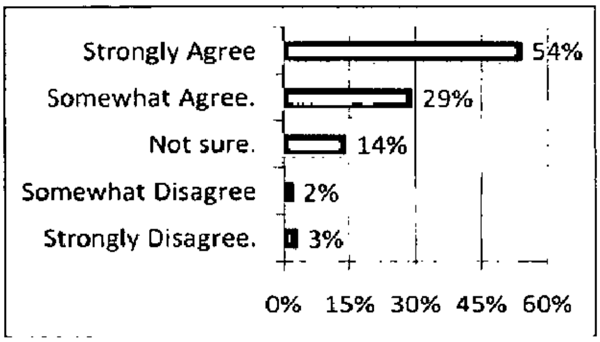


Fig 6.3(b).Adopting BIM workflow will lead to to better architectural works

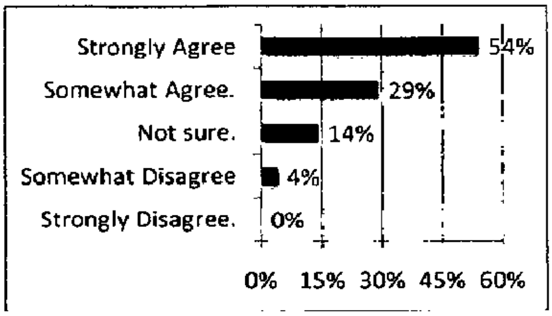


Fig 6.3(c) Adopting BIM leads to greater efficiency in the working drawing phase than 2D CAD

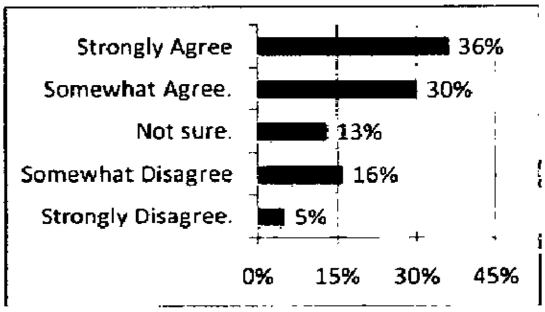


Fig 6.3(d) 2D is inefficient to true BIM workflow

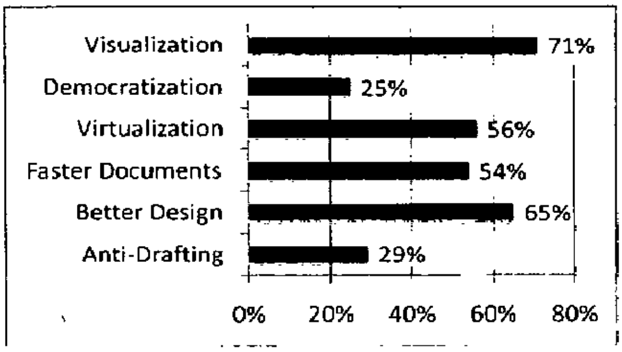


Fig 6.3(e).Aspects of BIM that appeals most

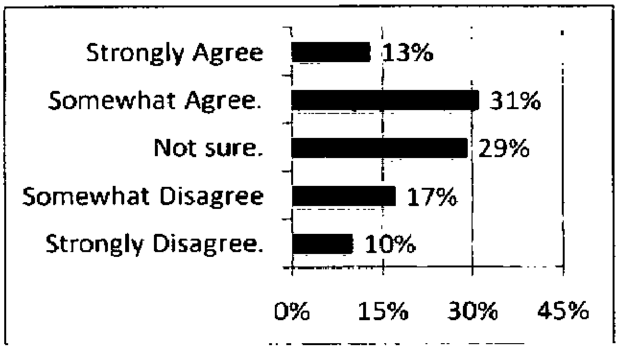


Fig 6.3(f).BIM is too complex and should make it simpler

6.6. THE FUTURE OF BIM

From results of questionnaire, only a few companies are currently using BIM to model their projects. However, the results also reflect that most of the respondents are confident that BIM will be more popular in the future. Lots of the design teams are planning to adopt BIM within 3 years and the rest are also interested in BIM.

The survey respondents also identified the barriers to incorporate BIM in their firms, like complexity of BIM, inertia to explore new technology, lack of support from clients and contractors, unwillingness to change the traditional practice, and uncertainty about BIM platform (Revit, Bentley or something else). Finally, about 88% of the survey respondents volunteered that, at their respective firms, they are interested in adopting BIM.

The results of this survey clearly indicate that the AEC industry is still very much reliant on drawings for conducting its business of designing and constructing buildings, which is why the most important requirement for BIM applications that has emerged for all categories of firms and respondents is the ability to provide full support for producing construction documents so that another drafting application need not be used. At the same time, AEC professionals also realize the power of BIM for more efficient and intelligent modeling by placing a high premium on smart objects that maintain associativity, connectivity, and relationships with other objects and the availability of object libraries.

Comparing these requirements to the BIM applications that are available, the first is currently better served by a BIM application based on a CAD platform such as Revit while the second is the strength of a BIM-from-the-ground-up application like Archicad.

6.7. ADDITIONAL INPUT OFFERED BY RESPONDENTS

Over 40 out of 58 of the respondents took the time and the initiative to provide additional feedback on their requirements for BIM. While a full, or even an extensive, discussion of their inputs is beyond the scope of this report, some of the most frequently mentioned criteria are listed below.

1. Simplicity and ease of use
2. Design freedom
3. Interference checking
4. Compatibility with other BIM applications
5. Improved link from design to fabrication
6. Support for LEED
7. Faster performance
8. Ability to make multiple changes in real time by multiple operators
9. Efficiency and speed of operations
10. Ease of use for making custom components

6.8. SUMMARY

The results of this survey clearly indicate that the AEC industry is still very much reliant on drawings for conducting its business of designing and constructing buildings. At the same time, AEC professionals also realize the power of BIM for more efficient and intelligent modeling by placing a high premium on smart objects that maintain associativity, connectivity, and relationships with other objects and the availability of object libraries. Comparing these requirements to the BIM applications that are available, the first is currently better served by a BIM application based on a CAD platform such as Revit.

BIM as a technology is still in its formative stage and solutions in the market are continuing to evolve as they respond to users' specific needs. The main requirements of users as identified in this survey are satisfied to varying extents by both Revit and Archicad, two of the leading BIM solutions available today in India. It is also clear that the extent to which a specific criterion is important to an individual user depends upon the type of organization the user is engaged in, the type and size of project, and the level of multi-disciplinary interaction required between teams and stakeholders.

The criteria identified by this study, along with their relative importance to the diverse group of users that participated in the survey, can be a useful aid for firms in evaluating different BIM solutions to determine which one to implement.

CHAPTER 7

CONCLUSION & RECOMMENDATIONS

7.1. CONCLUSION

The BIM is a new and promising approach towards documentation required for building construction industry. In India BIM is gradually gaining acceptance by owners, architects, engineers, and builders. It is believed to be a way in which construction stakeholders can extract, share and reuse the information on electronic design throughout the lifecycle of the project.

The objective of this research has been to explore the BIM capabilities when used in the field to better communicate and integrate construction information across different trades, allowing for efficient work processes and better decisions. More specifically, the study concentrated on the deployment of the model to support planning, scheduling and tracking of the job site operations in India.

The designed comparative analysis identified differences between the 2D and BIM methods for design phase which is categorized into three categories: visualization of geometric information, data availability for further analysis, and the existence of information. It clearly illustrates a difference in the way information was obtained and presented between the two media. Additional results identify the methods that contain information which is contained in one form but not the other.

This report reviewed the BIM solutions in the Indian market, with particular emphasis on the provision of built-in objects and data interfaces for third party application. The investigation has been based on a questionnaire survey conducted in India. The architects play a leading role in establishing BIM, the survey targeted mostly architects in the architecture firms. Although the survey focused on the situation in India, the findings provide a basis for comparing similar surveys conducted around the world.

Through the survey it is revealed that the uptake of BIM is still very low and that conventional entity-based CAD software remains the dependable drafting tool. The barriers to the use BIM include a complicated and time consuming modeling process, a lack of training and technical support, and the unavailability of free trial software.

The findings indicate that most architects would be more proactive in adopting BIM if they could see large gain productivity over the use of conventional CAD systems and the downstream application of the building information. According to the BIM users, the reason for using BIM is that different views and schedules can be generated and updated automatically and instantly. In the entire life-span of any built project BIM can help effectively to accommodate changes appropriately.

By contrast, slightly more than half of the non-BIM users had actually not heard about BIM. The others considered that entity-based CAD software can largely fulfill design and drafting needs and that BIM could not reduce the drafting time.

7.2. RECOMMENDATIONS

i. Good training set-up;

ii. Availability of free trial versions

iii. Survey highlights the areas that should be sensitized, enhanced, stressed or clarified when promoting BIM.

iv. The findings also substantiate the view that clients and other members of the project team can play an influential role in the use of BIM. Promotion should therefore be directed to not only to architects but also to clients and consultants.

v. It is recommended that more user friendly interfaces for embedding extra parameters into the modeling objects should be provided in the future versions of BIM based softwares.

7.3. FUTURE RESEARCH SCOPE

BIM technology is rapidly improving and a number of commercial applications supporting BIM are available in the market. Though there have been a few examples of successful use of BIM in the industry (Campbell 2007) the adoption rate has been slow.

i. New process models will need to be developed, considering new members and dynamics of the project team to include clients; new design requirements and constraints; new tools and resources and so on due to the adoption of BIM in different project stages.

ii. Since the BIM approach envisages a central database with different applications accessing and using the data, it is possible to extend the BIM usage beyond the project life-cycle and facilities management to routine functions of the built facility.

iii. Organizations need to change their work-practices, project development processes and methodologies to adapt to the BIM approach that allows benefits such distributed access to data and greater concurrency in multi-disciplinary collaboration.

iv. An integrated model of the entire project would generate a large amount of data. In order to avoid information overload innovative data representation and information visualization techniques must be used that are user friendly and effective.

v. Training modules in design schools and industry must be updated regularly to include modern technologies and tools, which are constantly improving. Educators and trainers need to train users not only in the use of tools but how they can fit in with the design process and within the team environment. In addition, training modules should not only be prescriptive but also demonstrate the pitfalls of not using the tools properly.

REFERENCE

Journals

1. Azhar, S, Hein, M; and Sketo, B, 2008. "Building Information Modeling: Benefits, Risks and Challenges", *Proceedings of the 44th ASC National Conference*. Auburn, Alabama, USA

2. Bernstein P.G., Pittman J.H, 2004. "Barriers to the Adoption of Building Information Modeling in the Building Industry". Autodesk Building Solutions. White paper on http://images.autodesk.com/adsk/files/bim_barriers_wp_mar05.pdf>.

3. Campbell, D.A. (2007). "Building Information Modelling: the Web3D application for AEC." *Web3D 2007*, Perugia, Italy.

4. CRC Construction Innovation, 2007. "Adopting BIM for Facilities Management: Solutions for Managing the Sydney Opera House". Cooperative Research Center for Construction Innovation, Brisbane, Australia.

5. Erin Rae Hoffer, 2007. "Sustainability and software - Fueling green design with BIM". The Construction Specifier, pp. 114-119.

6. Fischer, M. & Kunz, J, 2005. "Virtual Design and Construction: Themes, Case Studies and Implementation Suggestions". California, USA, Center for Integrated Facility Engineering, Stanford University.

7. Gallaher et al., 2004. "Cost Analysis of Inadequate Interoperability in the U.S. Capital Facilities Industry." National Institute of Standards and Technology. http://www.bfrl.nist.gov/oae/publications/gcrs/04867.pdf.

8. H Yan and P Demian, 2008. "Benefits and barriers of Building Information Modeling." 12th International Conference on Computing in Civil and Building Engineering, Beijing 2008.

9. Hedges, Keith, 2007. "How the Impact of Building Information Modeling (BIM) on the Cognitive Paradigm May Influence the Future of Architectural Education." Judith Bing and Cathrine Veikos (Eds.) In *Fresh Air*, ACSA Press: 461-469.

10. Holzer, Dominic, 2007. "ARE YOU TALKING TO ME? WHY BIM ALONE IS NOT THE ANSWER", Association of Architecture Schools Australasia Conference 2007, URL http://hdl.handle.net/2100/476.

11. Howard, R., and Bjork, B, 2008. "Building information modelling - experts' views on standardisation and industry deployment." *Advanced Engineering Informatics*, 271–280.

12. Ibrahim, Magdy, and Robert Krawczyk, 2003. "The Level of Knowledge of CAD Objects within the Building Information Model." Connecting: Crossroads of Digital Discourse, Proceedings of the 2003 Annual Conference of the Association for Computer Aided Design in Architecture, Indianapolis (Indiana). Pp. 173-177.

13. Ibrahim, M., Krawczyk, R. & Schipporeit, G, 2004. "A Web-Based Approach to Transferring Architectural Information to the Construction Site Based on the BIM Object Concept." CAADRIA 2004 Conference. Seoul, South Korea.

14. Johnson, R.E., and Laepple, E.S, 2003. "Digital innovation and organizational change in design practice." CRS Center Working Paper No. 2, CRS Center, Texas A&M University.

15. Leicht, R. and Messner, J, 2007. "Comparing traditional schematic design documentation to a schematic building information model." Conference Proceedings from CIB w78, IT in Construction. Maribor, Slovenia.

16. Leondes, 2005. "Intelligent Knowledge-Based Systems: Business and Technology in the New Millennium. USA". Kluwer Academic Publishers.

17. Penttilä, Hannu, 2007. "Managing the Changes within the Architectural Practice." eCAADe 24, pp. 252-260.

18. Penttilä, H Marko, R Simo Freese, 2007. "Building Information Modeling of Modern Historic Buildings Case study of HUT". Architectural Department by Alvar Aalto in proc of ECAADE 2007 (education and research in computer aided architectural design in Europe Conference) published online at http://www.ecaade.org/organisation/cumincad.html

19. Rob Howard, Bo-Christer Bjo¨rk, 2007. "Building information modelling – Experts' views on standardisation and industry deployment." Science Direct., pp. 271-280.

20. Scheer, D. R, 2008. "From an Educational Perspective: BIM in the Architectural Curriculum." www7.nationalacademies.org/FFC/david_scheer_utah.pdf.

21. Tse, T. et al., 2005. "The utilization of building information models in nD modeling." A study of data interfacing and adoption barriers, *Journal of Information Technology in Construction. Pp.*85.110.

Websites and Blogs

1. AEC (2008) AEC Magazine http://aecmag.develop3d.com 26 May, 2008, Page 2

2. Autodesk (2005), Parametric Building Modeling: BIM's Foundation, *http://images.autodesk.com/adsk/files/Revit_BIM_Parametric_Building_Modeling_Jun0 5.pdf*, Last accessed 12 Feb, 2009

3. Autodesk (2004a). *Autodesk Homepage.* Available at: http://www.autodesk.com

4. Autodesk (2004b). *Rev It Up Promotion for Architectural Desktop.* Available at: http://www3.autodesk.com/adsk/files/4624835_Rev_It_Up_Promo_for_ADT_FAQ.pdf

5. Autodesk (2004c). Autodesk Revit User Manual. Autodesk.

6. Bentley (2006), Build As One - BIM is a new way of approaching the design and documentation of building projects, *http://www.bentley.com/en-US/Promo/Build+As+One/What+is+it/*, Last accessed 27 Jan, 2009

7. Bentley (2004a). Bentley Homepage. Available at: http://www.bentley.com

8. Bentley (2004b). Bentley Architecture – User Guide. Available at http://www.bentley.com

9. DSC (2000) History of CAD. Dalton State College. Available at: http://cadlab.daltonstate.edu/historyofcad.pdf

10. GSA 01 - US General Services. BIM Guide Overview Version 0.50.[Online]www.gsa.gov/gsa/cm_attachments/GSA_DOCUMENT/GSA_BIM_02_MAIN_v09_R2C-a3-1_0Z5RDZ-i34K-pR.pdf.

11. GraphiSoft (2004) GraphiSoft Homepage. http://www.GraphiSoft.com

12. Graves, J. (2002) Press Release – AutoCAD to Acquire Revit Technology Corporation. Available at: http://usa.autodesk.com/adsk/servlet/item?siteID=452932&id=1156948

13. H. Edward Goldberg, 2005; AIA Cadalyst, AEC from the Ground Up--Software Strategy: Building Modeling Options http://aec.cadalyst.com/aec/article/articleDetail.jsp?id=141032&pageID=1&sk=&date=

14. Khemlani, L. (November 22, 2007). "Top Criteria for BIM Solutions", *AECbytes*, October issue [WWW document] URL http://www.aecbytes.com.

15. Nemetschek (2004) Nemetschek AllPlan. Available at: http://www.nemetschek.com

16. Oakley, "CAD Enough?" CAD User AEC Magazine, Vol 21 No 01 - Jan/Feb 2008.

17. Rundell, Rick. The Five Fallies of BIM, Part 1. *cadalyst.* [Online] November 1, 2007. http://aec.cadalyst.com/aec/Column:+1-2-3+Revit/The-Five-Fallacies-of-BIM-Part-1-1-2-3-Revit-Tutor/ArticleStandard/Article/detail/470107.

18. Rundell, Rick. "Calculating BIM's Return on Investment." Cadalyst. 22 Sept. 2004. http://aec.cadalyst.com/aec/article/articleDetail.jsp?id=124222.

19. Wikipedia (2007), Wiki, *http://en.wikipedia.org/wiki/Wiki*, Last accessed Dec 9,

20. 2008

21. *www.intelibuild.com/index.php/cathay-pacific-cargo-terminal*

22. *www.aia.org*

23. *www.designpresentation.com*