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Project Leader	Claudelle Taylor, Nexus Point
Research Leader	Ning Gu, University of Newcastle

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Authors	**Name**	**Organisation**
	Vishal Singh	University of Newcastle
	Ning Gu	University of Newcastle
	Kerry London	University of Newcastle
	Ljiljana Brankovic	University of Newcastle
	Claudelle Taylor	Nexus Point Solutions

THE UNIVERSITY OF
NEWCASTLE
AUSTRALIA

Contents

1. Introduction

This report presents the current state and approach in Building Information Modelling (BIM). The report is focussed at providing a desktop audit of the curren t state and capabilities of the products and applications supporting BIM.   This includes discussion on BIM model servers as well as discipline specific applications, for which the distinction is explained below. The report presented here is aimed at giving a broad overview of the tools and applications with respect to their BIM capabilities and in no way claims to be an exhaustive report for individual tools.
Chapter 4 of the report includes the research and development agendas pertaining to the BIM approach based on the observations and analysis from the desktop audit.

1. What is BIM?

   a. BIM is the process of maintaining a   repository of all the information relevant to a building or construction project throughout the different phases of the project lifecycle. This repository facilitates storing, integrating, checking and visualizing the entire data emerging through out the project lifecycle. This information can be used in combination or separately, but not in isolation, in the sense that they will alwa   ys be sub ject to some integrity and cross-checking.

      The information maintained and produced in the BIM approach includes both the geometric as well as non   -geometric data. Geometric data includes 2D   drawings, 3D models, dimensional   and spatial relationships. Non   -geometric data could   mean annotations, textual semantic relationships, reports, tables, charts, freehand illustrations, graphs, images, audio-visual data, and any other form of representing some information generated during the project.

   b. BIM implementation: The BIM implementation in general involves a client -server model. The server called the BIM Model Server does not include any application and hence apart from the regular database management operations no operations can be conducted on the data within the model server. If any discipline has to change the data the data needs to be imported from the model server onto the local application (discipline specific tools) at the clients end. Once the data has been changed it needs to be exported back into the model server.

      While this project is aimed to provide specifications and guidelines for facilitating collaboration in design teams through the use of BIM model servers, a desktop audit of BIM application tools is   also   important to und   erstand the BIM process   and functionalities.

   c. BIM Model server: A BIM model server only holds a repository of the information , and allows native applications to import and export files from the database for updating, modifying, viewing and checking of data. The model server by itsel   f has no inbuilt applications. Figure1 shows how a model server is used along with the other BIM applications that form native tools for the collaborating disciplines.
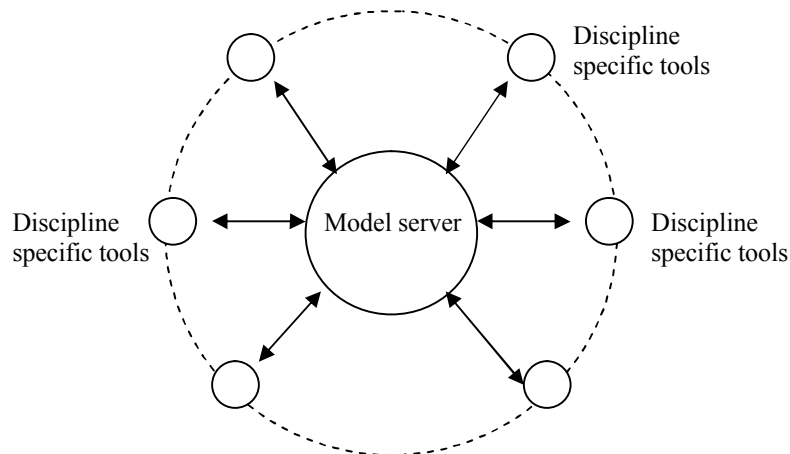
Figure1:A BIM model server allows import/export of data to BIM application tools

2. Why BIM?

a. How it is different to geometric data model? (Khemlani 2004)
   - It describes the attributes (geometric and non -geometric) of the entities in the AEC domain as well as how these entities are related to each other.
   - Gives ability to extract the relevant information from the representation that is needed for design, analysis, construction management, operation, and so on.

b. Some of the benefits:
   - BIM allows integration of all the relevant documents and data generated and required by various disciplines involved in a given project.
   - Instant, controlled and distributed access to data.
   - Facilitates easier update, maintenance and retrieval of data. Long-term programming, maintenance and operation.
   - Facilitates resource utilization by reducing rework and avoiding duplication.
   - Automated extraction and processing of data that required dedicated effort like costing, area calculation, conversions, and so on.   This can now be done at any stage of the project development.
   - Improves visualization and buildability by allowing easier transition between different representations of the same data.
   - Facilitates checking and reduction of conflicts and coordination errors.
   - Analysis and visualization of product performance over the building life cycle   . (Mitchelle et al. 2007)
   - Facilitate and smoothen legal and regulatory processes. e.g. Corenet (Tai Fatt)
   - Content development for electronic building component objects including product data and links to manufacturer Websites

3. Applications and products supporting BIM?

Since BIM aims to provide an integrated documentation of the entire project, the amount of information and the variety therein becomes extremely large. This means that it may not be feasible for a single vendor to be able to develop tools that are ca   pable of supporting the different requirements posed by the collaborating disciplines. Hence, a variety of tools and applications need to be having the capability to support generation of data for the   facilitation of BIM technology in AEC industry   (Pentilla 2007, Khemlani 2007 , Eastman et al. 2004b). The BIM tools are classified here as:

a. Preliminary Tools
- Preliminary Space Planning Tools- *e.g. Trelligence Affinity*
- Preliminary Massing and Sketching Tools- *e.g. Google SketchUp*
- Preliminary Environmental Analysis Tools- e.g.
- Preliminary Cost Estimation Tools- e.g.

b. BIM Design Tools- *e.g. ArchiCAD, Revit*
c. Structural Design Tools- *e.g. Revit Structure, Bentley Structure*
d. BIM Construction Tools- *e.g. Graphisoft Constructor*
e. Fabrication Tools- *e.g. Digital Project (Gehry Technologies)*
f. Environmental Analysis Tools- *e.g. Riuska*
g. Construction Management Tools- *e.g. JetStream Timeliner*
h. Cost Estimation Tools- *e.g. Calcus*
i. Specification Tools-
j. Facility Management Tools- *e.g. Active facility*
k. Mechanical Tools- *e.g. DDS mechanical, Bentley Mechanical Systems*
l. Model checkers – *e.g. Solibri Model Checker*
m. Product libraries- *e.g. ADSearch, FormFont*
n. Design review/ Model viewers - *e.g. JetStream Roamer, Octaga*

2. Desktop audit of commercial applications

In this report a d esktop audit of some of the available commercial tools is presented to discuss their capabilities and role in the BIM technology. There are some products with a range of capabilities while there are other products that are made for very specific applicatio   ns that support and contribute to a small aspect of the BIM approach. This audit is based on tool demonstrations, white papers produced by the vendor and literature review. Each tool reviewed is categorized and discussed in terms of:

    a. Application- service disciplines that the tool caters to and for what purposes and usage is the tool meant for.

    b. Main features

        a. Collaboration: Capabilities and features that facilitate co   -ordination and information exchange.

        b. organization

            i. Data management: how the data is handled.

           ii. Version management: how the data integrity is maintained.

        c. Modelling: 3D modelling capabilities.

        d. Viewing: Navigation, graphics and viewing capabilities.

    c. Underlying technology

    d. Add-ons/ Plug-ins

    e. Data exchange

    f. Business model: Business approach of the vendor and the target market segment.

    g. Shortcomings and limitations

Some tools may have all the categories of features applicable to them, while some may be very specific for which only few of the features can be discussed.   A summarized chart of the studied tools is presented at end of chapter 3.

2.1. ArchiCAD 11

Overview: ArchiCAD 11 uses a single 3D building model for design development, visualization, collaboration, and producing 2D documentation.

Application: BIM design tool.

Main features: (Graphisoft, CyonResearch 2003, Khemlani 2007)

- Collaboration and organization
    - Hotlink to manage linked drawings.
    - Mark-Up features facilitate communication. It allows highlighting problematic or new elements.
    - Integrated database of construction elements, acce   ssible from the Calculate menu. Can display the number, quantities and the elements' spatial disposition. Displays can be in list format or in an interactive schedule format.
    - Standard Library provided with the program. Allows access to additional Libraries, both from local volumes and through the Internet.
    - Worksheets: a dedicated environment for 2D drawings, either generated from the model, created from scratch, or imported from external files.
        - Allows parallel development of   the model and the drawings by different team members.
        - A drawing generated from a model view maintains a link to that view, allowing it to be rebuilt from the source view.

- o Workplace: similar to conventional design and drafting environments in many ways.
- Modelling, documentation and other enhancements since previous versions
    - o Complex geometries are easier to make.
    - o Various options available while choosing a module file.
- Viewing:
    - o Visual Compare feature to find the differences between model and drawing views.
    - o Virtual Trace feature
        - § Ability to display a live reference view alongside the currently active model view or drawing.
        - § Allows editing the elements in the active view
        - § Allows transfer attributes and parameters from the reference view elements to the active view elements.

Underlying technology: (Graphisoft)

Graphisoft's GDL (Geometric description language) is the technology used for object intelligence. GDL objects contain the information necessary for text specifications, 2D symbols and 3D models. In addition to material, style, and measurements, the objects can also store manufacturers' data. Key features of GDL are

- 2D, 3D and property data in one file
- Parametric: one object – many products
- Product-specific user interface
- Integrated links to external product data on the web
- Logic and behavior of the real product
- Compatible with common CAD formats in 2D and 3D
- Small file size

GDL Technology licenses tools and technology to create on -line and off -line intelligent product catalogs. Product manufacturers are now developing, marketing a nd distributing their product on the internet via GDL technology.

Add-ons and plug-ins: to be added
- Integrates with Google Earth
- Bidirectional integration with the Google 3D Warehouse. It requires downloading and installing a plug-in from the Graphisoft website.
- Inbuilt PDF support allows saving in PDF format without relying on a PDF printer driver.

BIM and business Approach:
- ArchiCAD suggests that construction models be better built from scratch rather than be based on design model.
- ArchiCAD has good 3D c apabilities but realizes that the present work practice is around 2D. With Virtual Trace feature which is a 2D feature ArchiCAD is targeting current professional practice. Thus, while attracting current market ArchiCAD is looking for a gentle transition to BIM.

Shortcomings:
- Lack of modelling constraints and lack of associativity between building elements
- Does not make a distinction between rooms/spaces as commonly defined by a single enclosure and a larger collection of spaces that can come together as a zone; its Zone tool has to be used for spaces as well.
- Model-based interference checking or clash detection is missing.

- Though it is simple to build   favourites (project directories) such as wall type, with IFC (Industry Foundation Class)   properties pre -entered the IFC properties are not included when using these. (STATSBYGG 2006)
- Several of the program's objects need more setting options for appearance and material properties. (STATSBYGG 2006)

2.2. Graphisoft Change Manager

Overview: Graphisoft Change Manag er is a new application that automates the process of checking for drawing (2D) revisions across two or more complete construction dra wing sets. It is focused on current professional practice rather than the future BIM -oriented scenario in the AEC industry.

Cons: Does not work with file formats other than DWG; works only with drawings rather than models, making its long-term viability in a future BIM world uncertain.

Application/purpose: 2D drawing checker

Main features: (Khemlani 2006)
- Drawing-based rather than model-based solution
- Automated checking for drawing revisions across complete construction drawing sets
- Works with all DWG files created by AutoCAD Release 14 and above.
- Provides three different kinds of viewing modes to review the changes made to   a drawing. All three modes involve overlaying the old version and the new version of the drawing and showing the changes in different ways.
- Review Assignments: allows all the assignments of each individual team member to be viewed to see their current sta   tus, as well as other information such as the date of assignment, assignees, and the assignment priorities.
- History commands: To know what happened to every assignment throughout the history of the project.

BIM and business Approach:
- First of its kind, with a very specific purpose.
- Target audience: AEC professional such as a contractor, sub   -contractor, engineer, or architect who often has to compare large document sets to find out what has been changed.

Shortcomings:
- Restricted to the DWG file format. As of April 2006 Graphisoft was working on adding PDF support, so that Change Manager will eventually be capable of working with both DWG and PDF files.

2.3. Graphisoft has a Virtual Construction suite comprising two products:

Graphisoft Constructor

The Constr uctor application includes the ArchiCAD modeling system for creating 3D construction models, a 4D sequencer for automatically linking the construction model to the project schedule and enabling different schedule alternatives to be analyzed, and a connecto r to the Estimator application that comes bundled with the product.

Graphisoft Estimator

The stand-alone Estimator application includes a model -based estimating system that extracts quantity information from the construction model for producing estimates   quickly and accurately, a traditional estimating system for easing the transition from manual takeoff -based

estimating to model -based estimating, a module for dividing the resources created by the estimating application in production zones and for generating procurement requirements, and a 5D reporting system that uses the construction model as the link between cost and time and produces cost-loaded schedules for financial analysis.

2.4. Revit suite and Revit Architecture 2008

Overview: Revit consists of three   discipline-specific platforms: Revit Architecture, Revit Structure, and Revit MEP. Each team member *must* be working on the same platform version and product build to effectively collaborate. This review is primarily of Revit Architecture.

Application/purpose: BIM design tool

Main functions: Parametric modelling, Quantity Take off, Rendering

Main features: (Khemlani 2007)
- Collaboration and organization
    - Ability to check interferences within a single project or linked models.
    - Each discipline creates a relationship based on their individual workflows
    - Linked models: Easy to divide up a large project into multiple linked files
    - Copy/Monitor feature:
        - Components of the linked model can be monitored for change.
        - Elements from the linked model can be copied into   the host project automatically creating a monitored relationship.
- Modelling
    - Shape editing feature for roofs and floor slabs allows subdividing its surface into parts that can slope independently.
    - Groups feature
        - Elements can be combined into a larger entity.
        - Changes made to one instance of the group can be automatically updated in all the other instances.
        - Group Edit mode greys out the rest of the model.
        - Groups can be edited independently of the project or fa mily in which they are loaded.
        - Allows conversion of groups to linked Revit models and vice versa.
- Viewing
    - Enhanced hide/isolate feature
        - Changes persist after the project is closed and also affect the printed output.
        - Reveal Hidden Elements mode allows users to see all or selected hidden elements in a view
    - Graphic overrides can be applied to individual elements to display them differently from the graphic settings associated with their categories.
    - Ability to split up a large floor plan, section, or elevation view into multiple smaller segments to place them on sheets at a readable scale.
    - Dedicated masking tool for controlling which elements will obscure other elements in a view.
    - Colour scheme enhancements
        - To create and manage colour schemes independently of applying a colour fill to a view
        - The colour scheme is now a property of a view that allows different schemes to be applied to different plan views.

Add-ons and plug-ins:
When exporting a 3D view for use with 3ds Max or VIZ, Revit retains the materials when exported using ACIS solids, as o pposed to showing only one material for the entire solid, as in previous releases.

As on June 2007 (Khemlani 2007) a link to Google Earth will soon be available to subscription members, allowing users to bring site information from Google Earth into Revit   and export a Revit model back into Google Earth with the correct geo -referencing information, so that it can be viewed on the actual site.

Shortcomings:
- Despite having many built   -in constraints that regulate the   modelling to prevent inaccuracies and erro rs, Revit continues to allow illegal operations such as overlapping doors, columns, windows, etc., which require interference checking to be used to detect them.
- Modelling non-regular building forms is difficult.
- Conceptual modelling capabilities are no t good enough to avoid the need for applications like SketchUp and form.Z.
- Built-in rendering capabilities not on par with those in other   modelling and BIM application

2.5. Bentley Building V8 XM Suite

Overview: Integrated multi -disciplinary set of BIM soluti   ons built on the MicroStation platform, and includes Bentley Architecture, Bentley Structural, Bentley Mechanical Systems, and Bentley Electrical Systems.

Bentley's vision of BIM: user need for BIM as a hierarchy of needs in following order (Bentley and Workman 2003)
- Enter/access/analyze information
- Share information
- Synchronize shared information
- Best context for information: i.e. should be able to use tools and environments related to the discipline
- Secure environment for full collaboration: IP issues and so on.

Three key aspects:
- Bentley sees BIM as a superset of CAD
- has a "federated database" approach to BIM,
- Bentley believes in "not starting over" with a new solution, and so all its individual discipline-specific BIM solutions are built on top of   its existing MicroStation platform and TriForma extension.

Main features: (Khemlani 2006)
- Organization
  - Implications of a federated database approach to BIM
    - Allows the separation of 2D and 3D objects
    - Change in the model does not automatically update the ex   tracted drawing—because of the association, the change is detected and the drawing is recognized is being out   -of-date. The user is then given the choice of updating it.
    - Project data but can be distributed across multiple files. This means

- § Project organization becomes crucial when working with Bentley's BIM applications. The project organization can be changed later if required, making the setup very flexible.
        - § The different files making up a project can be easily handled by several project members working simultaneously.
    - o Link sets can be created in the project explorer. Unlike Revit's Project Browser or ArchiCAD's Project Map, the Project Explorer in Bentley Building is an optional component rather than an integral aspect of the application.
- Modelling
    - o Gives the user the choice of four different 2D/3D design modes:
        - § Drafting, create 2D drawings only and not a 3D model
        - § Plan to Model, create 2D, but a 3D model is dynamically generated. Changes made to the model do not affect the plan
        - § Plan and Model: work either in the 2D plan or 3D model
        - § 3D Modelling, work entirely in 3D mode, and any 2D drawings can be extracted from the 3D model.
    - o 3D modelling improvements
        - § Creation of parametric 3D geometry
        - § Mesh modelling
        - § New handles for interactive editing; improved viewin g and navigation in 3D
- Viewing
    - o Task Based interface
        - § Allows the vast array of tools and commands in each application to be organized according to tasks.
        - § Possible to have multiple task interfaces open at the same time
        - § Task-based interface makes a referen   ce to a specific tool rather than physically placing in a designated tool palette, which means that the same tool can appear in multiple tasks.
    - o Better graphics with real-time interactive shading
        - § Users can work directly in shaded views
        - § Improved visualization capabilities for photo-realistic rendering
        - § New animation tools
    - o Interface improvements
        - § dialog and element transparency
        - § integration with PANTONE colours, and display priority
        - § keyboard mapping that allows each user to configure their entire keyboard as desired
- It is also possible to run all the Bentley Building applications that are installed in the same MicroStation session by using a Bentley Building Suite Icon instead of launching the individual applications.

Integration and data exchange:
- Support for 3D PDF, allowing an entire project including 3D models, 2D drawings, specifications, and other documents to be packaged in a single PDF document
- Integration with Google Earth, allowing a building modeled with the Bentley Building applications to be exported to Google Earth with the correct geo-referencing information
- Google SketchUp and the Google 3D warehouse are also fully supported.
- Anything drawn, modeled or imported into MicroStation can have BIM information added to it, allowing virtually any kind of geometry to be BIM aware.

Limitations: (Bentley Architecture)
- No tools for conceptual design tasks or space programming.
- No sketching capabilities. Sketch can be imported and used as an underlay for developing 3D massing or detailed models.
- Though very good solid and surface modeling capabilities that can be used to model any kind of regular or freeform shape, these tools lack the intuitiveness and ease of use needed for quick 3D massing found in dedicated conceptual design tools such as Google SKETCHUP.
- Does not have the capability to automatically derive the building shell   —with intelligent wall, floor, and roof "BIM" objects—from the schematic massing model.

Strengths: (Bentley Architecture)
- Extended toolset for modelling the site as well as different building components.
- Default settings are used for its type information of a newly created building element, which can be changed later when required.

Limitations: (Bentley Structure)
- The entire physical structure of the building has to be creat   ed in one model in Bentley Structural if it needs to be analyzed as a whole.

Strengths: (Bentley Structure)
- Digital model of the building structure combines both the physical model as well as the analytical model. This can be used for the different types of structural analyses engineers need to perform to design their structures, as well as to derive the construction documentation needed to build the structure.
- Structural Snaps option makes it easy to model structural elements in 2D as well as 3D.
- Has dedicated tools for creating larger structural assemblies.
- Ability to automatically create a fully associated analytical model   (optional) of the structure from the physical model, and then link it bi   -directionally to popular structural analysis tools for performing different kinds of analyses.
- Allows modifications to analytical members and physical members separately, so that the analytical model can be tweaked for correct input to an analysis program, without affecting the physical model.
- Option to choose to send the entire analytical model or only a portion of it for analysis.
- Design History makes it possible to visually review any changes that are accepted.

2.6. JetStream from NavisWorks3

Overview: JetStream from NavisWorks is a complete design review solu   tion for teams working with 3D models. It is modular in design, built around the core module Roamer with a set of powerful optional plug -ins: Publisher, Presenter, Clash Detective, TimeLiner, and RVM Reader.

Application: Design review, presentation, collaboration

Main features: (Navisworks)
- Extensive repertoire of navigation and review tools
- smooth navigation with no performance deterioration even in large projects
- Can combine multiple models into one file, synchronize them easily, and review them against each other
- Good photorealistic output, along with a wide variety of sketch styles for a hand   -drawn look
- Availability of an API for customization

- Relatively easy to learn and use

2.6.1   Roamer

Overview: Roamer is the central product of JetStream. It allows open   ing multiple files from any of the major 3D CAD design formats into a single 3D environment. One can then navigate through the 3D model in real time and use Roamer's extensive toolset to review the design.

Application: Model viewer, design review

Main features:
- Organization:
    - Reference Files - every time the model is opened the latest version of the CAD design is used but past review data is kept.
    - Database Link   - DataTools feature allow import of live data from external databases using SQL through ODBC to be displayed with the model.
- Viewing:
    - 3D File Support - Opens all major 3D design and laser scan file formats.
    - Streaming - JetStream technology allows the handling of large models and intelligently streams content from disk, enabling navigation around th   e design whilst the model is still loading.
    - Merge Models - Models can be combined together, regardless of file format, into a single unified model.
    - Smooth real-time walkthrough with a range of navigation tools
    - Full Screen Mode- with the interface hidden or on a secondary screen.
    - Stereo Viewing - Support for full OpenGL stereoscopic viewing.
- Gravity and Collision Detection
- Review Tools - Review toolkit includes:
    - Measurements - detailed measurement of distance, area and angle.
    - Viewpoints - Store, organize and share camera views of the design.
    - Comments – Notes can be added to viewpoints.
    - Redlines - Mark-up to viewpoints.
    - Section Planes - Cross sections to enable close inspection and focus on details.
    - Animations - animated walkthroughs.
- Object Properties – Allows reading intelligent data from the original design files.
- SwitchBack - Open the current model and viewpoint in the original design software with one click. (Compatible with AutoCAD 2004 and up or Microstation J and v8)
- Collaboration - Multiple us ers can share a single review session through Windows NetMeeting technology.
- API - Automate tasks or extend functionality using our extensive COM API.

2.6.2 Publisher

Overview: allows publishing model in a single, secure and compact, .nwd file. This .nwd file can be shared freely with all stakeholders who can open it in JetStream or Freedom.

Application: Model publishing

Main features:
- Organization
    - Stores the complete 3D model in a single distributable JetStream model file.
    - Security - Files can be password encr ypted, time expired, made readonly, and have authorship and copyright details attached.
- Viewing:

- o   Free Viewer - Freedom.
- o   Internet and Office support - allows the viewing of an .nwd model from an internet page or inside a Microsoft Office document, such as a   PowerPoint presentation.
- Embedded Review Data - JetStream review data from Roamer, Clash Detective and TimeLiner is stored alongside the model.
- Embedded Materials - Presenter data including textures can be embedded inside the file.
- Embedded Properties - Object properties including external databases read through Roamer's DataTools can be embedded or excluded for added security.
- Compact File Size

2.6.3 Freedom

Overview: free viewing software that can be downloaded and used by anyone to open .nwd files created b y JetStream Publisher. It allows navigation around the model and viewing of embedded viewpoints, redlining and animations.

Application: Viewer

Main features:
- Completely Free
- Navigation - Includes Roamer's full set of navigation tools.
- Review - Allows the   viewing of review data embedded in the model, including viewpoint, redlines and animations.
- Real-time display of materials and lighting added using the Presenter module.
- No Install - Available with or without an installer for users without installation privileges.

2.6.4 Presenter

Overview: JetStream plugin that allows the enhancement of 3D designs with photorealistic materials and lighting. The results can then be exported into rendered images and animations.

Application: Viewer/ presentation tool

Main features:
- Photoreal Images & Animations
- Drag & Drop Interface - Simple but powerful workflow.
- Huge Archive - Over 1000 built-in materials.
- Full Customisation - materials, lights, backgrounds, and rendering styles, everything can be configured.
- Various rendering/sketch effects
- Real World Lighting - Support for real world lighting intensity units.

Underlying technology:
- Realtime Shaders - Supports OpenGL 2. 0 shader language to provide realtime lighting and shadows.
- LWA-enabled - Presenter uses the LightWorks r   endering engine, allowing you to add additional materials available from the LightWorks user site.
- RPC - Rich Photorealistic Content allows photographic imagery such as people and trees to be dropped into a scene.
- HDRI Lighting - Powerful rendering technol ogy to provide smooth shadows and natural lighting.

2.6.5 Clash Detector

Overview: enables the identification, inspection and reporting of interferences found in 3D models.

Application: Clash detection, Model checker

Main features:
- Interference Detection - clash tests against specified geometry to find conflicts.
- Time Based Clashing   - TimeLiner can be linked with Clash Detective to catch interferences arising over the course of a project's lifetime.
- Point/Line Based Clashing - Check as-built laser scan data against 3D designs.
- SwitchBack - Open the current clash in the original design software. (Compatible with AutoCAD 2004 and up or Microstation J and v8)
- Audit Trail - Track the status of clashes as they are found and resolved.
- Reports - Export results of clash tests including comments and screenshots.
- XML import/export - Share clash scenarios with other JetStream users in XML format.

2.6.6 TimeLiner

Overview: TimeLiner is a project planning and review tool that enables 3D model data to be linked with project software for fast 4D visualization of construction schedules.

Application: Planning tool

Main features:
- 4D Simulation - Links model geometry to times and dates, then playback construction or demolition sequences to check buildability.
- Schedule Linking   – Allows importing times, dates and other task data from project management software
- Time Based Clashing   - TimeLiner with Clash Detective to catch interferences arising over the course of the project lifetime.
- Planned vs Actual - Planned and actual times t   o visualize deviations from the project schedule.
- AVI Export - Export 4D simulation into a pre-recorded avi animation.
- Customize Output - Task color and transparency, along with overlay text can all be customized.

Shortcomings:
- It is a generic, geometry   -based solution that works for any industry dealing with 3D design, rather than being a building   -specific solution like Solibri Model Checker that represents building entities, understands about concepts such as space, wall, door, etc., and can be used to rev iew the building model in a more intelligent fashion by checking for code violations, satisfaction of specified constraints, and so on.
- Lack of IFC support, an issue that is fast becoming critical from   an interoperability perspective.

2.7 Digital project (Gehry technologies)

Overview: Fully parametric tool built on CATIA. Here parts are considered as basic objects (User definable tag for BIM object) and products are assembly of multiple parts.

Applications Type: BIM Design Tools, Fabrication Tools

Main features:
- organization

- o Can store data as either a Part or Product file. A complex assembly can hold enormous amount of parts or products.
  - o Existing part and product files can be referenced from other files to increase the reusability of designed parts.
- Interoperable with Subsystems: DP can produce information for many subsystems and not only preliminary objects from the architectural design. As a BIM application it can produce structure, MEP and other manufacturing documents along with the design.
- Modelling
  - o Full parametric definition:
    - § User definable parametric geometry
    - § User definable parametric objects
  - o capability to handle complex and parametric geometry

2.8 Acrobat 3D

Application: Design collaboration tool.

Main features:
- Works with all design software and platforms.
- Can import 3D models saved in common exchange formats such as 3ds, obj, dxf, wrl, iges, and so on.
- Allows embedding 3D models in Word, Excel, Powerpoint, and InDesign documents.
Acrobat 3D is needed to create 3D-enabled PDFs, but anyone with A dobe Reader can view, interact, comment and markup the very same PDF. Complex 3D models can be emailed as PDF files.

2.9 Data Design System (DDS)- mechanical engineering

Application: Modelling and calculation tools

Main features: (STATSBYG 2006)
- Good for modelling sanitation installations
- Has its own functions for calculating pressure drop and heat requirements

2.10 Riuska energy simulation program

Application: Analysis and calculation tools

Main features: (STATSBYG 2006)
- Used to run energy simulations and annual cost calculations.
- Properties for walls and roof and load factors can be entered
- Allows quick and easy simulation of the entire building with correct sun,   weather and internal load data.
- Good for energy ca lculations, very accurate and can run various   calculations for the entire building or individual rooms.

2.11 G-PROG Calcus from NOIS

Application: For calculation of projects according to the Building Element Table.

Main features: (STATSBYG 2006)
- Calcus calculates volumes itself based on the model.
- Easy to build up the calculation by extracting priced elements and price lines from the price directory in the software.
- Building up customized directory with prices is straightforward.
- Presentation of the calculation result is very good and flexible.

- Ability to evaluate chapters, sub-projects or the total calculation.
- Can compare the project with a previously calculated project.

Import/export
- Easy to import IFC files to either an empty account list or one containing defi   ned elements.
- IFC file can be saved as a sub-project or everything can be saved under a main project.
- Price lines can be added to the elements as they are imported.
- Importing several IFC files in the same calculation is possible.
- Cannot export IFC information but can export calculations in NS3420 format and to Excel.
- Options to export the whole calculation or parts of it.

Viewing (IFC viewer)

- Marks an element in the calculation, which marks the corresponding element in the model.
- The graphics are too diffused. It is difficult to separa   te activated elements from those to be evaluated.
- Necessary functions (such as pan, zoom etc) are absent.

Shortcomings:
- Function for *export* of IFC information is missing.
- It should allow product selection directly in the model
- Non-calculated elements should be reported in the model
- Weak graphic reproduction that cannot be used for large models.

2.12 O2c_Interactive!

Application: 3D Presentation, Viewer

Main features: (STATSBYG 2006)
- Built on the highly-compressed, Internet-deliverable o2c format.
- Allows interactive navigation through 3D content online.
- Exploration and presentation of different variations of material finishes for 3D objects on the fly.
- Scope is mostly limited to exploring material alternatives for a design project.
- Generate high-resolution photorealistic renderings of selected.

2.13 Solibri Model Checker

Overview: To detect potential problems, conflicts, interferences, or design code violations, and ensure the integrity of the model to downstream building analysis applications.

Application: Model checker, Clash detection

Main features: (STATSBYG 2006)
- IFC format
- has a good visualization interface, allowing viewing and walk through of the model
- Enables parametric constraints for checking that can be configured to desired standards.
- Requires a little training to make use of its potential.

2.14 QuadriSpace Presenter

Overview: Tool for creating interactive multimedia presentations combining navigable 3D models, animation sequences.

16

Application: 3D publishing and presentation solution

Main features:
- Ability to record animation sequences in 3D models and include these sequences in the presentation
- Ability to synchronize a 3D model and the corresponding 2D vector drawing so that the position in the floor plan can be monitored during navigation th rough the 3D model, and collision detection in walkthrough animation.

2.15 Octaga

- **Octaga viewer**
  - Pure viewer able to read IFC files
  - Easy to use and seems to be stable, even with large files.
- **Octaga Modeller**
  - Works well with model server, good colour schemes and visualization
  - simple user interface

2.16 Trelligence Affinity

Overview: Is an architectural programming, space planning, and schematic design application that extends BIM to the pre-design phase of building projects.

Application: Preliminary design tool

Main features:
- Customizable questionnaires that can be used to capture
  - Project and client requirements
  - Spaces and their areas
  - Spatial relationships, finish details, and size/cost constraints.
- Can create schematic designs base don requirements
- Data analysis engine allows requirements validation as the design is developed.
- Facilitates bi-directional integration with Autodesk Revit and Graphisoft's ArchiCAD.

Export
Finalized schematic design can be exported to any CAD or BIM application for further development. Relevant project information can also be exported to cost estimation and project management tools if required.

Add-ons-Plug-ins
Available as a stand -alone application or in two   other versions that integrate either with ArchiCAD or with Revit.

2.17 ADSearch from Architectural Data Systems

Overview: ADSearch, an attribute -based search engine tool that allows users to find products from the growing ADS library of over 1000 manufacturers' catalogs.

Application: Product library

Main features:
- Provides multiple product results in one search , and thus eliminates the hassle of browsing several sites.
- ADSearch-Green feature is dedicated to finding building products that are eligible for LEED credits.

Add on/ Plug in:

ADSearch can be integrated within Revit, Au toCAD Architecture, and AutoCAD, in addition to being available online. Free plug-in available from the ADS website. Once this is installed, it allows ADSearch to be activated from within the Autodesk applications listed above.

2.18 Tectonic BIM Library Manager and Quantity TakeOff

2.18.1   BIM Library Manager

Overview: Specifically designed for the organization, management, naming and selection of Revit object families used in the creation of Revit building models.

Application: Product library

Main features:
- Comes with an extensive collection of parametric families of 2D and 3D objects such as doors, windows, cabinets, plumbing, lighting, etc., which Revit users can include in their models.
- Simple interface for collecting, organizing, and presenting content in families.
- Supports drag and drop from the interface to Revit.
- BIM Library Manager can reside on individual computers or on a firm's network.   Plans of making them available to customers through a link on their website.

Add-on/Plug-ins: Tectonic QTO

2.18.2   Family Content Publisher

Overview: Works as a companion product to BIM Library Manager.   Plugs into Revit Architecture 2008 to automate the process of adding the Revit family files that come with the application, or are obtained from other sources, into the BIM Librar   y Manager content management system.

2.18.3   Tectonic QTO

Main application: Quantity Take Off application

Overview: Works by segregating those Revit families that are used in a project and associating unit line items from line item databases to the Revit elements . Includes an assembly editor and unit line item calculator to describe constituent products of Revit families that aren't represented explicitly in Revit and rules to calculate their quantities.

2.19 BIMWorld

2.19.1   BIMLibrary

Overview: Focused on developing buildi ng product manufacturer -specific BIM content as well as generic 3D product models in its BIMLibrary resource.

Application: Product library

Main features:
- Over 18000 objects including 2D drawing files, image texture files, and 3D models.
- These objects ca n be used in Google Sketchup, Autodesk Revit, Graphisoft ArchiCAD, Bentley Architecture, AutoCAD, and other applications.
- Free for users.

2.19.2   BIMContentManager

Overview: intended to serve as a content management solution for Autodesk Revit and AutoCAD DWG files.

Application:

Main features:
- Allows managing Revit family (RFA, RVG) files on   local computer, company network and optionally publish them to the Web for sharing and collaboration.
- Features an interface where content can be viewed as thumbnails in a g   rid display with the ability to dynamically resize thumbnails using a slider
- Provides the ability to sort families by any number of fields, including Supplier, Uniformat, Masterformat, Path, Filename, Cost, etc
- Ability to associate custom images and multiple URLs to families.
- Users can manage products specified inside of each Revit project —allows content to be managed at a project-by-project level with the creation of custom project libraries.

2.20 Form Fonts

Overview: Web-based subscription service that provid es professionally -created, low polygon count 3D models and textures for a low monthly fee.

Application: Product library

Main features:
- Over 26,000 objects in various file formats, including GDL (ArchiCAD).
- For corporate subscribers an   enterprise-level co ntent management solution, the EdgeServer is provided, which is installed on-site and
  - Provides exclusive access to a sharing and collaboration platform that Form Fonts has established called SharedNet
  - Allows exchanging virtual building objects and other d   igital assets either on a one-to-one or one -to-many basis. The content is exchanged server -to-server, so that each firm has a local copy of the shared content on their respective server.
- Allows firms to meet their content demand in three ways:
  - Accessing the Form Fonts content library
  - Sharing their own content on a peer-to-peer basis
  - Contracting Form Fonts to develop custom content on demand.

3. BIM model servers

This review is based on product demonstrations, whi te papers and product brochures. Though this report discusses only two of the model servers there are a few more available in the market.

3.1. ActiveFacility

Overview: A web based model server to support hosting of a unified building model for enhanced and effective facilities management.

Application: Model server for facilities management

Main features: (ActiveFacility 2004)
- No local computational requirement. Everything happens at the server end.
- It uses natural language interpreter for making queries to the database.
- Site specific glossary can be developed as per the customer requirement.
- Organization:
  - There is a separate website for each customer and each project. Thus, the access is provided through a web application.
  - Active facility team builds the Unified Building Model once the data is prov ided by the client. The object relationships are identified and references are made.
  - It is like any other DBMS where information is manually loaded.
  - The database is hierarchically organized based on the IFC specifications.
  - Object description comes from IFC specifications. This classification is done in the parent model development tool based on object attributes and these cannot be over-written in the model server.

- Active Facility is a service provider that manages the project data for the client.
  - Supports import and export of data
  - Supports viewing of data in both graphical and non-graphical form
  - Interface to systems used at client side is possible. This allows automatic update of the data in Active Facility system based on changes made on those system s. In turn changes made to data on Active facility system may trigger changes in another system.
- Viewing:
  - GUI is customized to meet the client requirements.
  - On the client side SVG viewer needs to be loaded for graphic support.

Underlying technology:
- Built around Oracle relational database technology, which
  - Supports XML messaging as native datatypes within the database.
  - Provides an object layer as part of its relational technology.
  - Provides a spatial module that allows geometry to be stores directly.
- Microsofts.NET architecture allows high level of development and integration possibites, and acts as the technology interface between the user and the data.
- Uses Microsoft English query, which allows natural language processing.

BIM and business Approach:
- Web based model server
- No investment on client side on hardware and infrastructure.
- Business process outsourcing. Helps client better organize and manage their building data.

3.2. EPM suite

Overview: Offers a wider range of tools to allow a full range of mo del export/imports, partial or full model exchange, access rights and role definitions, querying, analysis, visualisation etc.

Application:

Underlying technology:
- EPM is based on a native IFC database.
- Model driven architecture. Models are instances of IFC specifications.

Main features: (Bengtsson, K: 2005, EPM Technology 2004)
- The database has a hierarchical structure, where project is at the top, which is the model.
- Supports the IDM   - information delivery manual based on definable processes that specify the data (objects & content) necessary to support model collaboration transactions.
- There are two types of associations in the model: (1) data associated (2) back/ inverse relationships.
- The model server has checks before drawings can be merged. Sync   hronization of the models from different disciplines is what is checked.
- Model server has a global administrator who is basically the database manager.
- Model server has multiple ways of data in and out.
- Check-in and check-out allows for version management.

3.2.1.   EDMServer™

Overview: Enables product data to be effectively managed, exchanged and shared across radically different systems, independent of location, type or network design.

Application: Product Model server, Data management

Main features:
- Modular by design tha t allows mix and match of the products and desired options.   This allows expansion or update of the system as needs change and as the standard continues to evolve.
- Native support for any standard data model like   IFC and   STEP (Standard for The Exchange of Product Model Data)
- It allows access to the data throughout the project life cycle.

Underlying technology:
- Unified database system
- Model driven architecture. These models are created and defined in EXPRESS, the information modelling language specified in STEP.

3.2.2.   EDMmodelMigrator™

Overview: Supports migrating data from a legacy data system to a different product data support environment, such as a PLM and BIM systems.

Application: Web-enabled client-server solution

Main features:
- Enables multi-user operation
- Addresses the need for a gap analysis between the legacy data model and the target data model.

- Mapping Analysis Tool assists the user in the production, management, and follow -up of this gap analysis.
- Internet browsers serve as graphical user interface.
- All data is managed by an EXPRESS database management system on the server.

3.2.3. EDMdeveloperSeat™

Overview: A comprehensive package of tools for users of the EXPRESS data modelling language who are working to develop, implement or maintain applications or systems supporting the international standards for product data representation and exchange.

Application: Application development toolkit

Main features:
- Includes a database designed specifically for storing and manipulating data modelled and described in EXPRESS.
- Fully supports and significantly expands the scope of the Standard Data Access Int erface (SDAI).
- Includes powerful functions for database supervision and management, data queries, and user convenience.
- Multi-user access for data sharing. Allows   several processes or applications to have controlled access to the same data at the same time.
- EDMI can be used as a linkable library providing access to the   EDM database and all EDMdeveloperSeat™ functions except those specific to EDM's own graphical interface.
- Application data can be isolated from the application for long-term archiving.
- An EXPRESS schema and data can be presented in HTML format, automatically creating links that make it easy to examine the source in a Web browser and correct errors.
- Has an in-depth help system includes complete, clear documentation.

Underlying technology:
- EDM's EXPRESS compiler makes it possible to validate any EXPRESS schema with respect to syntax and consistency, regardless of the source or system.
- It is also possible to store the results as a dictionary model in the SDAI without any loss of information and begin populating it immediately.

3.2.4. EDMvisualExpress™

Overview: For creating and visualizing data models based on the graphical notation EXPRESS-G.

Application: Visualization tool

Main features:
- Fully supports EXPRESS-G
- Makes it possible to visualize the objects in a data model that are not possible to display using only EXPRESS -G. These objects are basic to all data models and are essential for accomplishing any serious tasks in EXPRESS:
    - Global rules
    - Where rules
    - Uniqueness rules
    - Derived attributes
    - Functions Procedures
- Includes a documentation feature allow displaying comments as part of the graphic data model or print them as independent text, as well as publish the data model on the web.

- Facilitates moving quickly and easily between the representation of the model in the graphic view, the structure of the model in the object navigator, and the actual EXPRESS source code.
- Gives immediate feedback as a data model is created or modified, giving notification.

3.2.5.   EDMmodelConverter™

Overview: Uses EXPRESS-X to convert data from one EXPRESS schema to another.

Application: Data conversion

Main features:
- Facilitates developing translators to any database system as well as any advanced data - warehouse application.
- Makes it easy to maintain translators
- Allows defining the mapping for data exchange
- Provides a fast, reliable path for any bulk conversion that may be required.
- Enables easy handling of data described by multiple schemata.

Underlying technology:
- Includes an EXPRESS -X compiler to validate the mapping schema and set up a dictionary model which is the definition for the actual conversion process.
- The data model that results from the conversion is saved automatically in the EDM database. It can be exported as a STEP physical file and, thus, used by virtually any system.

3.2.6.   EDMmodelChecker™

Overview: Validates a data set and ensures that it conforms to all rules and constraints defined in one or more EXPRESS schemata.

Application: Model checker.

Main features:
- Errors can be quickly and easily identified before importing any data to the database.
- Validation possible all at levels.
    o Complete model in one call.
    o Check all entity instances of a particular type for all applicable rules and constraints.
    o Entity instance can be checked against one specific rule or constraint.
- Continues the validation process until everything is checked according to specifications.
- A detailed error report is generated as a text file. EDM allows examining the STEP physical file of the model in HTML format and use a Web browser to easily examine the violations.
- Provides the high standard of quality assurance and active control.

EPM's BIM and business Approach:
- A range of products supporting building information integration.

Categorization of main BIM tools: Table 1

Table 1: Indicative summary of main BIM tools (refer report for detailed review)

Application	Type	Approach	Purposes	Features and strengths	Limitations	Comments
BIM APPLICATION TOOLS (DISCIPLINE SPECIFIC)						
Acrobat 3D	Standalone		Design collaboration tool	Very good viewing capabilities Light files, easy to share	Functions limited to viewing and annotating	Can be used with Adobe reader, hence easy access
ArchiCAD	Suite	Integrated database	BIM design tool Architecture/ construction	Object intelligence Visual compare Hot-linked drawings Trace features	No conceptual design support Lacks modelling constraints	Wide recognition for its BIM approach.
Revit	Suite	Integrated database	BIM design tool Architecture/ Structure/ MEP	Object intelligence Linked models Relationship based workflows Interference check Rich product library and plug-ins	No conceptual design support Allows many illegal operations Not easy to make non-regular geometries	Rapidly growing market share and product capabilities.
Bentley	Suite	Federated database	BIM design tool Architecture/ Structure/ Mechanical/ Electrical	Object intelligence Very useful for large projects Inherits the strengths of Microstation	No conceptual design support Needs greater effort on project organization	Widely used in large projects
Navisworks	Suite		Design collaboration, BIM integration and visualization tool	Clash detection Exploration/design review Conflict resolution Accepts data in most formats Very good integration and visualization capabilities	Conceptual design support	Very useful for coordination
BIM MODEL SERVERS						
ActiveFacility	Standalone Model server	Relational database	Design collaboration, BIM integration and visualization tool	Coordination Data management Reference data Share project data No infrastructural requirement (web-based)	Data hosted by a third party	Service provider
EPM	Suite	Object oriented database	Design collaboration, BIM integration and visualization tool	Coordination Data management Conflict resolution Model check Reference data Share project data Web-based range of Products available for licence		Service provider and product supplier

4. Discussion on BIM:

This section discusses some of the theoretical and research issues related to the BIM approach. Literature and the trend in BIM application development suggests that the pri   me enablers of BIM approach are:

- o Technology and tools
    - o Distributed access and sharing
    - o Import/ export
    - o Management
    - o Operations
    - o Control and validity
    - o Coordination
- o Data associativity
- o Common platform for data exchange (e.g. IFC)
    - o Format
    - o Terminologies (vocabulary) (e.g. IFD-International Framework for Dictionaries)
- o Specification
    - o Relevance (minimum and sufficient data) (IDM- Information Delivery Manual)
- o Customizability and flexibility
- o Comprehension and legibility
- o Multi- modal representation

4.1. IFC (Industry Foundation Classes)

Why do we need IFC?

a.   Provides open data exchange format required to deal with issues of interoperability
b.   Facilitates smooth and efficient workflow across different tools
c.   Provides guideline to determine necessary and sufficient information to be given

What is IFC? (Khemlani 2004, IAI)

- Another object-based building data model. However, it is non-proprietary.
- Being an open data exchange format that captures building information, it can be used by the commercial building-model based applications to exchange data.
- IFC model represents not just tangible building components li   ke walls, doors, etc., but also more abstract concepts such as schedules, activities, spaces, organization, construction costs, etc. in the form of entities All entities can have a number of properties such as name, geometry, materials, finishes, relationships, and so on.

Key aspects of the IFC model that enhance its flexibility and extensibility are (IAI):

- **Property sets:** If an entity has a property that is universal and unambiguous, such as the U-value of a wall or the cross -sectional area of a beam, that   property is hard -coded into the model as an   *attribute*. On the other hand, if a property can be seen differently by different parties, it is defined in a separate   *property set* that can be attached to the model and behaves just like attributes.
- **Proxies:** It is also possible for software implementations working with the IFC model to create altogether new entities that have not been defined in the IFC model. These are referred to as   *proxies*, and can be defined with geometry and property sets just like regular IFC entities.

Since IFC model is not designed to work with one particular application, it is deliberately abstract. There are no direct relationships between entities.

IFC and Data exchange:
- Since the file size of any file format is related to how the dat   a is structured in its data model, the size of an IFC file would generally be larger than a native ArchiCAD or Revit file carrying the same project data.
- Data loss can happen both in importing from and exporting to the IFC format.

Is IFC the only way?
- Apart from IFC there are other methods of data integration that allow individual applications to communicate with each other, such as APIs (Application Programming Interface), other data -oriented export formats such as ODBC, XML for Internet   -based applications, and so on. (Khemlani 2007)
- IFC might not be the best interoperability solution under all circumstances.
- Seamless integration of a suite of commercial applications based on the IFC format has not yet been demonstrated, except for carefully modelled test projects.

However, IFC's integration capabilities and collaborative benefits can go a long way towards eliminating the inefficiencies and waste in the building industry.

Issues with certification of IFC compatible applications
At present the IAI's certi fication of IFC compatible applications is not stringent. The criteria for IFC certification are that the application should be able to import IFC data. Since, outputting IFC data is not a criertia for IFC certification most of these applications fair poor   ly in generating IFC data and in some cases the errors can go as high as 40%.   This is a very serious concern for managing an integrated database at the model server in the form of IFC files.

4.2. IDM (Information Delivery Manual)

The Information Delivery Manua l (IDM) provides a state of the art approach to connecting building information   modelling methods with business processes. It provides exchange requirement definition that is (Christensen and Gruppen 2005)
- Easy to understand for different groups
  - Managers
  - Project people
  - SW developers
- Useful for
  - Interoperability
  - Software development
  - Contractual interface
  - Knowledge management
  - IFC model extension
  - Process understanding
  - Transaction messaging
  - Model server queries
  - Data quality assurance
- Recursive, enabling re-use and re-combination at many levels

4.3. Observations from desktop audit:
As the desktop audit suggests a wide array of applications are being developed to facilitate the BIM approach. Within these itself different kinds of approaches are being adopted that ne ed to be analyzed. Some of the issues yet to be resolved in BIM implementation include:
- Design model –construction model: what is the best approach?

- Model size vs distributed database. Is distributed database the best approach? What are the co -ordination a nd maintenance issues there?   What are the ty   pes of database technologies used? For a discussion on database technologies adopted see (You et al. 2004).
- How much intelligence is good? Modelling constraints vs flexibility   (Eastman et al. 2004b, Khemlani 2007)
- 2D world to 3D world! Transition and data exchange. (Eastman el al. 2004b)
- Richness of detail. Resolution
- Is there a role change for the involved professions? (Eastman et al. 2004a)
- One critical omission in the repertoire of most current architectural BIM solutions is a set of dedicated tools for programming, space planning, conceptual sketching, and quick 3D massing that work in an integrated fashion with each other and also tie in intelligently and efficiently with the subsequent design development phase. (Khemlani 2007)
- And finally work practice, and the resistance to change. (Eastman et al. 2004a,   2004b; Autodesk)
- Procedural measures and standard work practices in terms of 3D model validation, data ownership and information handling practices need to   be developed to facilitate organizational and legal issues of changing work practice and process change.

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Useful online resources:

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