THE DIVERCITY PROJECT

Divercity

Contents

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The Aim of This Handbook

This handbook provides an overview of DIVERCITY, a toolkit for construction briefing and design.

DIVERCITY allows users to visualise building projects and run computer simulations of various aspects of their performance during the briefing, design and construction phases. In particular, the software enables collaborative working between groups of project stakeholders in separate locations.

Who should read this?

This handbook has been written specifically for construction project leaders and business managers.

What can DIVERCITY achieve?

- Improved communications with the client;
- Design of better facilities;
- Improved collaboration and communication across the supply chain.

Executive Summary

Construction projects usually involve a large number of direct and indirect stakeholders.

Current methods of communicating building design information can lead to difficulties. Typically, these include incomplete understanding of the planned construction, functional inefficiencies, inaccurate initial work or clashes between components.

By resolving the above difficulties, integrated software solutions based on visualisation and simulation technologies can bring significant improvements and cost reductions to the construction industry.

The DIVERCITY project has secured funding from an EU Commission to explore new, cost-effective solutions for the construction industry.

DIVERCITY has developed a toolkit of six software applications, which allow users to visualise and simulate aspects of a project during briefing, design and scheduling. The six applications are:

- Client briefing;
- Acoustics simulation;
- Lighting simulation;
- Thermal simulation (i.e. energy consumption);
- Constructability simulation (titled Visual Product Chronology); and
- Site Analysis.

These applications can be used independently, or simultaneously. They are also suitable for collaboration between end users who may be in different geographical locations.

This handbook provides more detail on the DIVERCITY toolkit. If you are interested in using any part of DIVERCITY on your construction projects, please visit www.e-DIVERCITY.com.

DIVERCITY applications are currently available for use on a consultancy basis. In the light of strong interest from construction companies, the applications will also be developed as off-the-shelf packages in the future.

Using Divercity tools during the tendering stages of “prestige” projects, and in particular for communicating with clients, can improve your company's tender success rates and its image. As the tools become more established, and your business learns how to use them, they can also improve productivity in design and construction.

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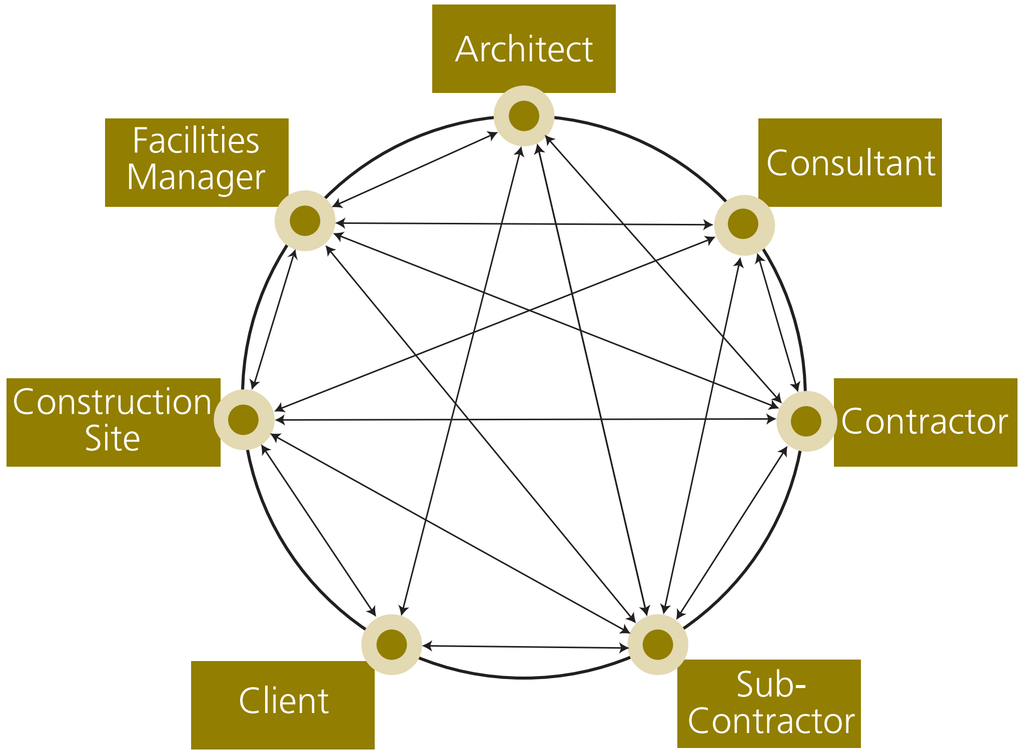
The Construction Industry

The European construction industry accounts for approximately 11% of the region's GDP.



Excessive numbers of documents during construction projects results in processing errors and problems with information management

Around 2 400 000 companies employ 8.8 million people directly and 26 million people indirectly. Small and medium-sized enterprises (SMEs) account for 83% of the region's total construction turnover (Brussels 1997).

In the past decade, construction companies have invested a great deal of effort and resources in improving their business processes.

Responding to ever-growing pressure to complete projects on time and to deliver high quality buildings, construction companies have adopted new forms of innovative project management which utilise recent IT developments.

Construction has become an information-intensive industry. In fact, the process of managing project information has led to the emergence of a new discipline: information management.

But despite the interest and effort of leading companies, information management in the construction industry is still in its infancy.

Construction projects involve a large number of direct stakeholders (e.g. clients, professional teams, contractors) and indirect stakeholders (e.g. local authorities, residents, workers).

There are significant barriers to communication between stakeholders, as shown in the figure. Many researchers have acknowledged the limitations of current approaches to project information management. For example:

- Large volumes of project information are stored on paper as drawings and written documents. These tend to be unstructured, difficult to use and easy to lose or damage (Construct IT 2000).
- In a typical project thousands of documents are shared, leading to significant human errors in managing the versioning of these documents.
- This leads to incomplete understanding of the planned construction, functional inefficiencies, inaccurate initial work or clashes between components.
- The individuals responsible for collecting and archiving project data may not always understand the specific needs of the people who will use it, such as building maintenance teams.
- The data is usually not managed as soon as it is created, but is instead captured and archived at the end of the construction stage. Individuals who know about the project are likely to have moved on to the next project by this time, so their input is not captured.
- The specific lessons learned are not properly organised or highlighted, and are buried in the details. It is therefore difficult to compile and disseminate useful knowledge and best practice for other projects.

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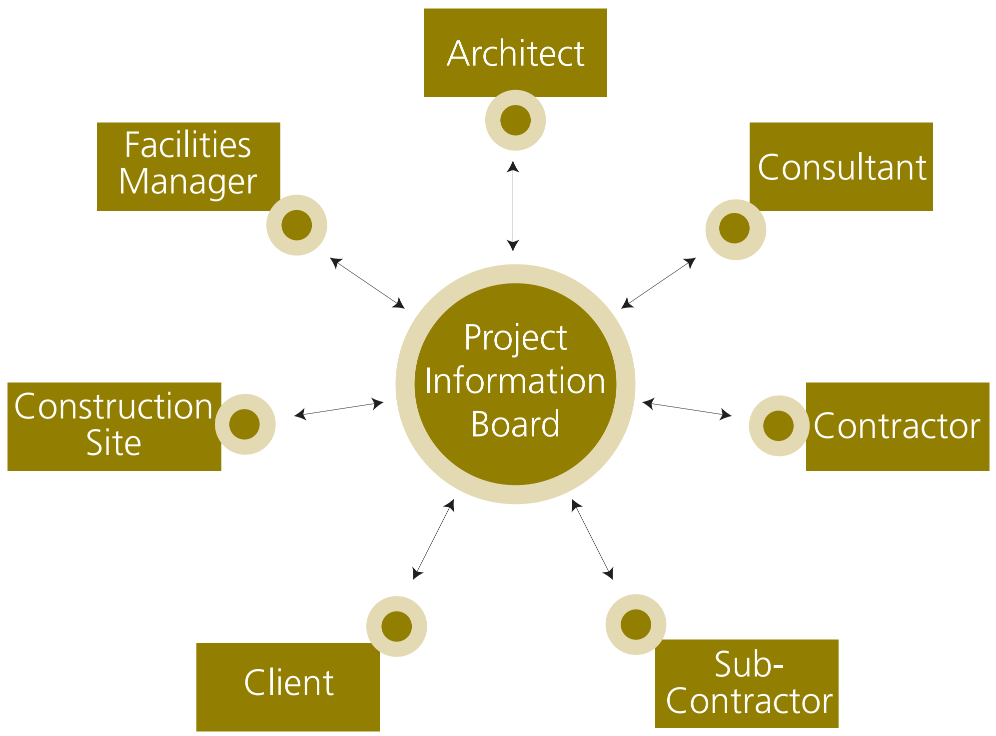
Vision for Future ICT Solutions

Visioning can assist in the development of a new generation of Information and Communications Technology (ICT) for the construction industry.



An electronic project information board can intergrate the information from stakeholders. Users can pull up the latest version of any information on demand

Imagine a scenario where all stakeholders produce relevant project information and post it on an electronic "project information board", as shown in this figure (Sarshar 2000). Each user has appropriate access rights and can manipulate information on demand. Researchers have termed this vision construction "integration".

Now, imagine that the users of this information board are no longer reliant on their computers and office networks for connections and access. Thanks to advances in communications technologies, users can manipulate information in any format, and in any geographical location. This is termed construction "collaboration".

Construction Integration

Currently, construction project information is captured in documents and 2D CAD drawings. Often, the various parties in a construction project share these documents and drawings in an electronic environment. But problems arise when the volume of documents and drawings and their versions increases. (Sarshar 2002).

The "project information board" approach is a means of sharing project information via a shared conceptual model that includes both products and processes. Information is entered once and once only, and is used by all stakeholders in a project.

The benefits of the integrated approach include:

- Much of the project information can be presented in a visual format rather than as text. This facilitiates communications and information sharing.
- Many aspects of the proposed building can be computer simulated to improve client briefing and design reviews.
- Interactive technology can be used to consider life cycle issues such as environmental impact, space planning, facilities management, emergency evacuation, security and constructability. Findings can then influence subsequent design reviews. The integrated approach facilitates concurrent engineering by involving clients, planners, architects, designers, civil engineers, contractors, facility managers and security personnel.
- It also makes it easier to use past project knowledge and information for new developments.
- A major barrier to implementing this integrated vision has been the lack of information standards in the construction industry. An international industry body, the International Alliance for Interoperatability (IAI), was set up in 1995 to address this issue. More information about the IAI can be found later in this handbook.

Construction Collaboration

Construction Collaboration explores how the supply chain can access and manipulate the "project information board" in a virtual project workspace, irrespective of the geographical location of stakeholders.

DIVERCITY has adopted the following definition for a Virtual Workspace (Christiansson 2001):

'The Virtual Workspace, VW, is a new design room, which facilitates new and existing design processes. VW uses mixed reality technologies.

The VW will host all project partners from the conception of a project. It provides appropriate access and visibility (for persons and groups) rights, during the different phases of a project lifecycle.

VW promotes the creation of shared values in a project. It thus acts as a communication space, providing project information in the right format. VW co-ordinates access to general and specific IT-tools '

cont.

Based on this definition, the shared virtual workspace will have the following features:

- Advanced administration tools for repositories of personal, team, and project information;
- Access to virtual building models and collaborative environments through wireless networked technologies and low cost virtual reality environments;
- Appropriate security levels for sharing information via the Internet or over intranets;
- Process and workflow management tools to support variations in working practices between different projects;
- New generations of ICT tools to facilitate collaboration and communication with end-users.

DIVERCITY has created a virtual workspace for construction which includes some of the features listed above. The details of DIVERCITY's Collaborative Workspace are discussed later in this handbook.

Achieving Construction Integration

Implementing construction integration has proved complex.

It is becoming increasingly clear that integration will not be achieved through a wholesale re-eningeering of the industry, but in small evolutionary steps.

Two of the critical steps towards achieving integration are (i) 3D modelling; and (ii) the use of IFC standards. This section discusses these issues.

From 2D Drawings to 3D Interactive Design

Currently, CAD is the main application used to produce construction drawings. CAD generates 2D representations of a building's elements, highlighting their size and position. But despite being in common usage, 2D CAD models are not efficient at capturing and communicating building information.

3D CAD technologies are available, but are not used in most construction projects. 3D models require more detail early in the project, while the benefits of the up-front effort accrue gradually through the project's life cycle. However, the industry has not yet embraced these models on a large scale, and many project managers are not convinced that the extra time and effort needed to produce 3D models will benefit the project down-stream.

3D CAD modelling, which facilitates visualisation as well as the simulation of project information, is a pre-requisite for making the transition to integrated construction environments.

However, difficulties may arise when projects need to share 3D information across the supply chain, since each company is likely to use different IT packages and work to different product standards.

Construction therefore needs a set of industry standards which all the participants in a project will adhere to.

International Alliance for Interoperatability (IAI)

In 1995 an international industry body, the International Alliance for Interoperatability (IAI), was set up to develop information standards which would allow integration between construction applications.

The IAI has produced a set of standards called Industry Foundation Classes (IFCs).

IFCs basically specify how the 'things' in a constructed facility (both tangible items such as doors, walls and fans, and abstract concepts such as space, organisation or processes) should be represented electronically (IAI, 2002). Each "thing" defined in IFCs is given specific attributes, such as width, height and opening direction.

The use of IFCs enables interoperability among Architecture Engineering Construction (AEC)/Facilities Management (FM) software applications. IFCs are therefore the main platform for the construction industry to establish real integration between project stakeholders.

For more information on IAI, see http://www.iai.org.uk.

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Industry Example

The construction industry is beginning to realise the potential benefits of IFCs. Until now, the industry has collaborated with academia to produce prototype integrated solutions. But recently, real trials and implementations of these solutions on live projects have begun. The Helsinki University of Technology (HUT) Auditorium Complex is one of the early examples.

This was a small project to extend the main building of the Helsinki University of Technology in Otaniemi, Espoo, near Helsinki. The gross area of the extension was 1,130 m2. The estimated cost of the project was EUR 4.3million (excluding audio-visual equipment). The project involved integrating a new 600-seat auditorium into the existing main building in terms of architecture, functionality and traffic flow. The project was successfully completed on time, on the 15 February 2002.

The project provided a collaborative environment for all major stakeholders (figure below). YIT was the contractor and construction manager. Olof Granlund was the main services consultant.

The building was designed using IFCs within a single project model. The project team experimented with various aspects of IFCs such as 3D virtual reality, the 4th dimension (i.e. linking 3D information with time and scheduling data), sustainability, life cycle costings and computational fluid mechanics analysis.

The project goals were: (i) to help the owner, designer and construction team improve their performance; and (ii) to demonstrate the practical benefits and limitations of IFCs and using an integrated suite of product model-based tools.

For more information visit http://www.tkksali600.net/site_eng/esittely.asp . Alternatively http://www.stanford.edu/group/4D/projects/calvin/PM4D.shtml provides some useful information.

IFCs Modelling in (HUT) Auditorium Complex (Source: 4D CAD Research)

Barriers to Integration

The construction industry is constantly seeking to improve productivity and reduce inefficiencies in the supply chain. IFC-based modelling permits the integration of CAD with other applications, and facilitates communications across the supply chain.

However, there are still major barriers to the implementation of IFC-based drawings in the construction industry. Some of these barriers are listed below:

- The entire project must standardise on 3D, IFC-based design. Several CAD packages currently on the market are compliant with IFCs (e.g. ArchiCAD, AllPlan , AutoCAD) . The project must use a CAD package which has been fully certified by the IAI.

- The key project stakeholders must be aware of this need and buy into the idea from the outset of the project. However, there is currently a lack of awareness amongst many senior construction managers.

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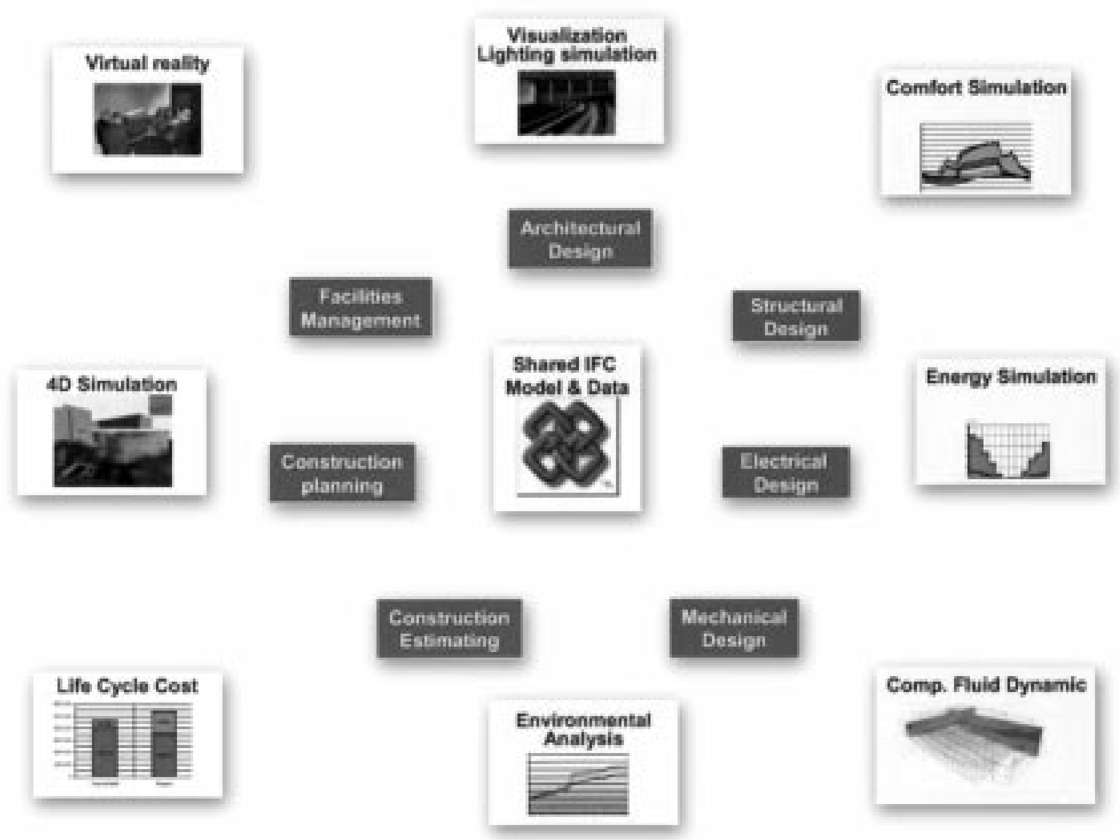


IFCs Modelling in (HUT) Auditorium Complex (Source: 4D CAD Research)

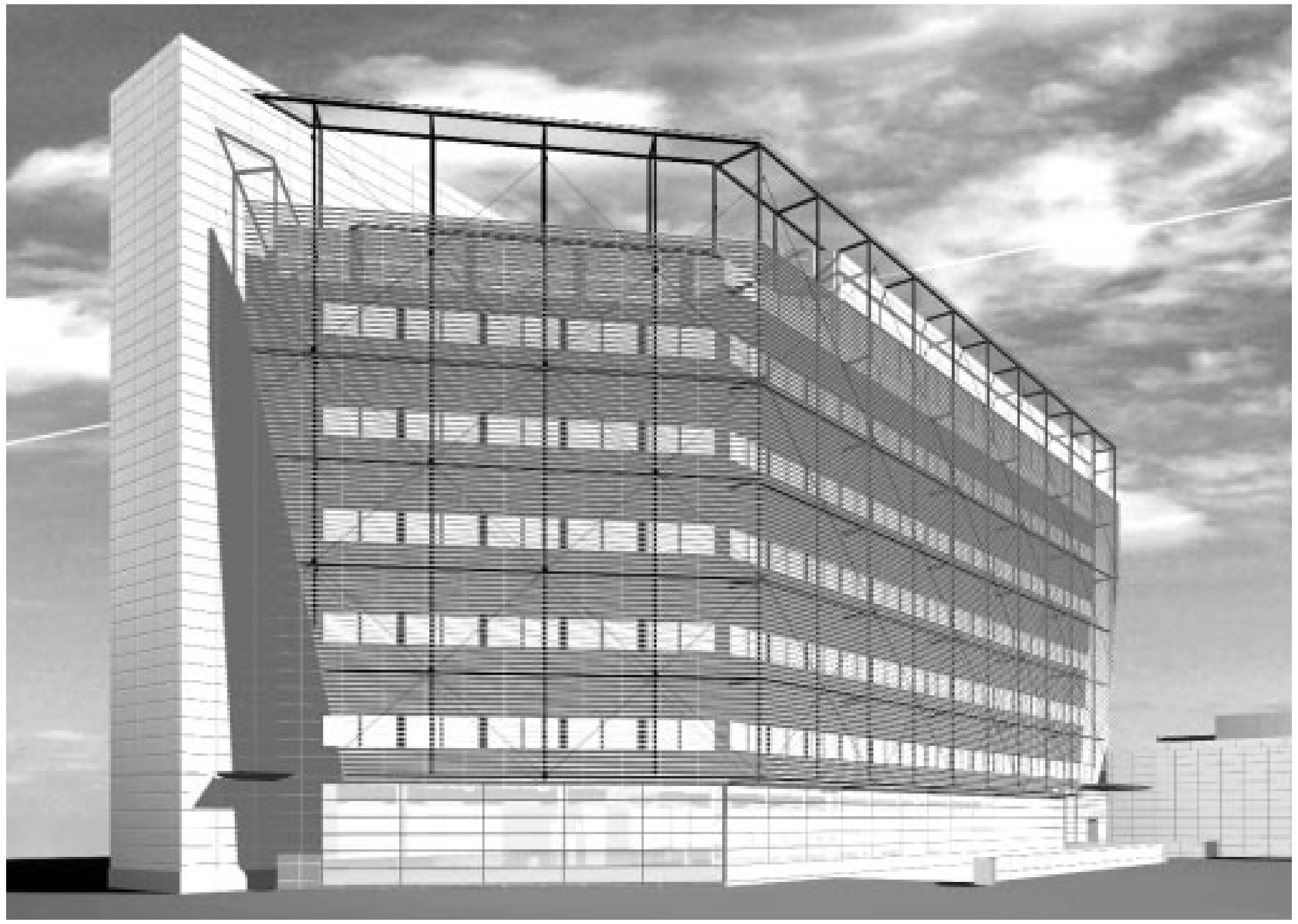
- IFCs cover a large amount of information: from design to construction management, from thermal calculations to material characteristics. To reap the benefit of using IFCs, somebody (usually the architect) must enter the relevant data into the drawings. However, this requires extra working hours early in a project. Financial arrangements must take this into consideration.

- The project owners need to be aware of this issue, and apportion project costs appropriately.

- The learning curve is lengthy. The industry needs appropriate training programmes.

The Divercity Project

The project used IFCs in order to develop a toolkit for collaborative virtual briefing and design in the construction industry.



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DIVERCITY is an EU funded project. This toolkit allows construction companies to conduct client briefings and design reviews, to simulate "what if" scenarios, to test the constructability of buildings, and to communicate and co-ordinate design activities between teams.

DIVERCITY has developed virtual workspaces (i.e. software applications based on virtual reality) that improve communication and collaboration.

DIVERCITY has focused on three construction processes: (i) client briefing; (ii) design reviews; and (iii) site operations and constructability.

DIVERCITY allows users to produce designs and run performance simulations in a virtual environment. The designs are IFC-based and can be viewed by all stakeholders within the project team.

DIVERCITY uses a distributed IT infrastructure and enhances concurrent engineering during the briefing and design phases. It also allows teams based in different geographical locations to collaboratively design, test and validate shared virtual projects. **DIVERCITY** comprises of six applications:

- Client Briefing: This supports clients and designers during the briefing process. It provides tools for capturing a project's strategic and spatial requirements, and allows users to experiment with alternative spatial layouts in a visual format.
- Acoustics Simulation: This application automatically reads IFC-format CAD drawings and allows users to substitute different building materials on-line, in an interactive manner. The user can then “listen” to the building's acoustic qualities, and change the design or materials to achieve desired noise levels.
- Thermal Simulation: This application automatically reads IFC-format CAD drawings and allows users to alter building materials on-line, in an interactive manner. This means users can simulate the energy consumption of the building, or individual rooms, and select appropriate materials for energy efficiency.
- Lighting Simulation: This provides a realistic simulation of lighting. Users can change and move objects or lights in the building and study lighting simulations in an interactive manner.

One novel characteristic of this application is the mathematical algorithms used for simulation.

Standard lighting simulations generally take several hours. In most cases, DIVERCITY algorithms allow real time simulation and only take a few seconds. This facilitates interactive and collaborative simulation.

- Site Planning: The site planning and analysis application evaluates safety and the use of space on the construction site, and generates enhanced construction site layouts based on time and safety criteria.
- Visual Product Chronology: The Visual Product Chronology application provides visualisations of various types of data and their interdependencies. In these visualisations, the "time" aspect is crucial.

The application links appropriate building components and their data with "time tags". This allows users to generate visualisations of the status of the building and its components at selected points in time.

These six applications collaborate via a communication layer (an additional application), which operates without the user being aware of it. All applications are designed to be IFC-compatible. This provides a further dimension of integration among the DIVERCITY products. There are also provisions to plug-in third party IFC-based products.

A pre-requisite for using DIVERCITY is the use of an IFC-compliant CAD package, and standardisation on 3D modelling during the project.

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A more detailed explanation of each application is given below.

Client Briefing

At the moment, architects communicate outline designs to clients via hand-drawn sketches. These are time consuming to produce, and it is difficult to analyse sketch designs against the client's initial requirements objectively. The client cannot walk through the sketches and fully understand the implications of the design.

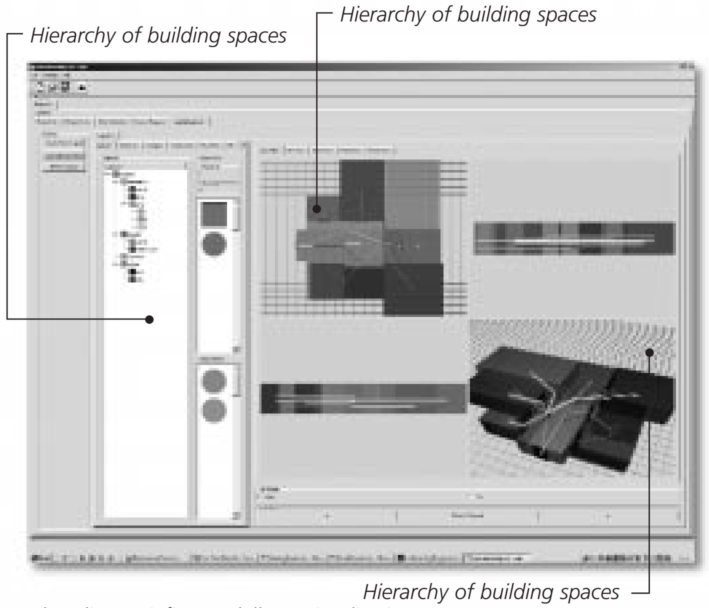
The Client Briefing application provides a tool for clients and designers during the crucial briefing process. The application captures the project brief, identifies strategic and spatial requirements, and allows clients and designers to experiment with alternative spatial layouts.

The application includes analysis tools to compare how well the proposed spatial layouts match clients' requirements on quantifiable issues.

The briefing application allows the client and designer to define the building's spatial form before detailed design commences. In this way it can improve the briefing process.

The Client Briefing application contains the following elements:

- Project definition: This records project information. When users create a new project, they enter high-level information such as Project Title, Client, Cost Description, and Project Description.

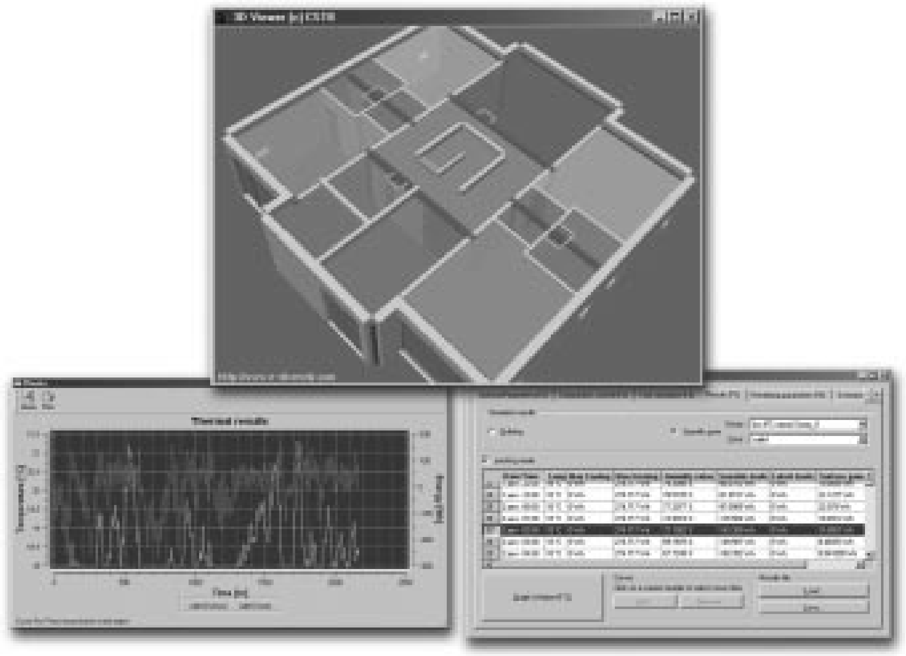


The Client Briefing toolallows visualisation & feasibility of building layouts

- Space Program: This allows the users to define space requirements for the building graphically. Users can also define the relationships between spaces. A 'drag-and-drop' interface allows the user to specify space definitions within the building, and arrange them in a hierarchy that corresponds to the building's function.
- Spatial Layout: This allows the users to define alternative spatial forms for the building layout, in an interactive 3D environment. Users can perform space analysis calculations and establish the local and global accessibility of the building layout.
- Building Layout Analysis: This allows the users to calculate the distances between different spaces in the building. For example, users can stipulate that the bedrooms should be as far as possible from the kitchen or the games room; or that all bedrooms should be close to fire exits.

Thermal Simulation

This application allows users to simulate conditions in the building in order to assess both ***energy consumption & thermal comfort***.



Engineers can calculate the energy consumption of a building with respect to different architectural choices (for instance, its glazed surface area or orientation) and the technical solutions under consideration (for instance, the type of HVAC system).

Thermal comfort calculations can check that comfort conditions are met throughout the building. Comfort conditions are represented in 3D, using colour coding. Hot zones are coloured in red and cold zones in blue.

The main features of the thermal application include:

- changes in weather conditions;
- changes to building materials, e.g. walls;
- options for fine or coarse simulations, e.g. hourly, monthly;
- options to control the precision of the thermal simulation should be;
- splitting the building into zones and allowing different heating activity levels for each zone;
- viewing different results, e.g. temperature, humidity ratios, energy consumption, energy gains, and cost in use values;
- viewing the results in virtual reality

Information is input via an IFC-based CAD drawing. The application uses "rough cut" algorithms rather than the detailed engineering calculations conducted by HVAC engineers. The purpose of the application is to reach initial decisions with the client before the HVAC engineers start detailed calculations.

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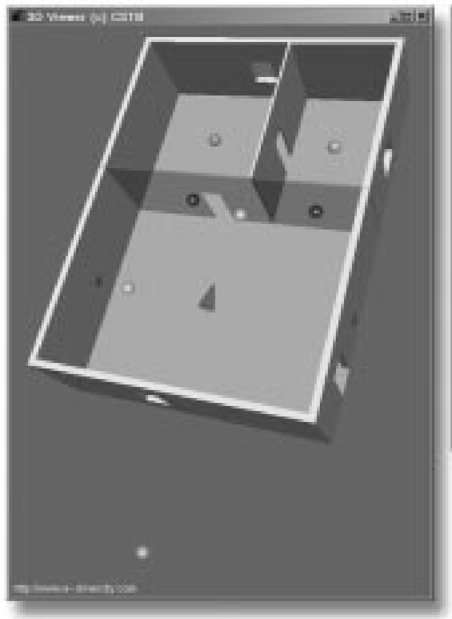
Acoustics Simulation

The acoustics application simulates the effect of sound within a building.



The listener and sound sources can be moved, as required

The acoustics application positions a listener in the building and simulates the effect of the surrounding sounds

Designers and engineers can make alterations to the building's materials on-line, in order to achieve the desired level of soundproofing.

This application is particularly useful for designing hotels or industrial facilities, where soundproofing has a critical impact.

The simulation is in virtual reality, and can be shared over the Internet by architects and engineers in different locations. It allows a quick "first cut" sound calculation, which can be shared with clients in a user-friendly manner.

Here is a short summary of how the application works:

- The application receives IFC-based drawings from a CAD application.
- It automatically adds acoustics information about the listener; the sound sources; and the acoustic properties of the walls.
- It simulates sound transmissions in a VR environment.
- If noise transmission is too high, the designer can change the thickness or material of the walls and ceilings on-line.
- A further simulation can be performed in real time to observe the impact of changes.

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Features of the application include:

- The listener can "move" into any space within the building;
- The sound sources can be changed and moved, in real time, as required.
- The sound volume can be changed.
- Doors and windows can be opened or closed.
- The sound can be heard via speakers attached to the computer. However, headphones provide a more accurate simulation.

The algorithms used in this application are fairly simple acoustic models, which can simulate sound: (i) inside a space; (ii) in adjacent spaces, and (iii) in the external space. However, the algorithms cannot simulate sound for a concert hall, for example, which would need more sophisticated calculations.

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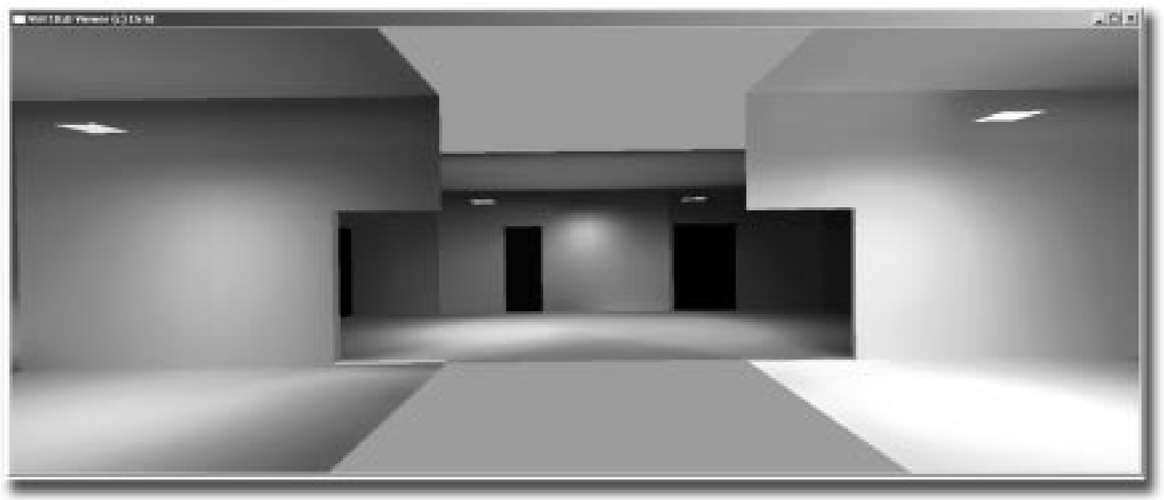
Lighting Simulation

The lighting simulation enables lighting engineers and experts to find the right solution to illuminate a building.



Real-time lighting simulation of SAS offices, near Helsinki Airport, Finland

This simulation is build around the radiosity method, which provides realistic ambient light simulation. However, radiosity calculations are extensive, and to date all lighting simulations have been off-line, taking several hours to run.

A major contribution of the DIVERCITY framework is that it provides an interactive lighting simulation in near real-time. The user can manipulate furniture and lights, update lighting properties and view the results in less than a few seconds.

The lighting application can be shared between different stakeholders in real time. For example, the client and the lighting engineer can be in different locations. The lighting engineer can display the lighting simulation, receive client feedback and update the solution on-line. The results are displayed immediately on the client's computer.

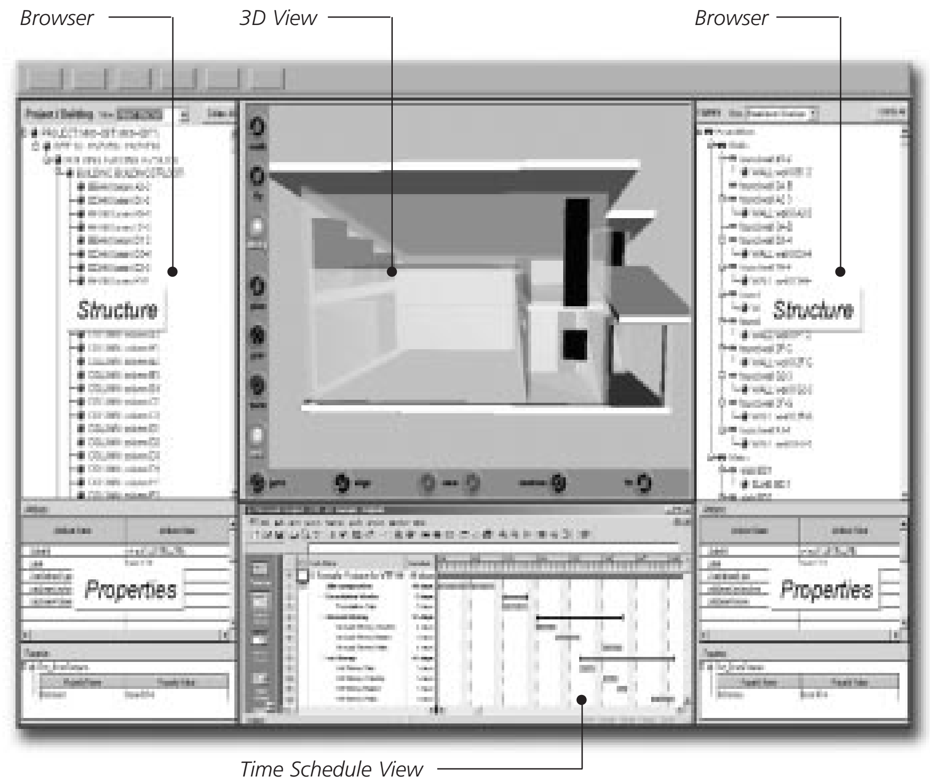
The results can be stored on disk for future use, or displayed via a web browser.

This new technology improves collaboration across the supply chain, and speeds up the design process.

The lighting simulation receives its input from an IFC-based CAD package. Output can be saved in a VRML format and then posted on the web.

Visual Product Chronology

This software creates simulations of the building schedule so that day by day progress on the construction site can be seen on the computer display.



If the workplan contains mistakes, these can be quickly identified in the visualisation sessions. The software comprises the following modules:

Linker is used to combine the 3D building model in IFC 2.0 format with project schedules originated in MS Project. It also automatically changes time data whenever the schedule is updated. After linking the 3D model with the fourth dimension (i.e. time), the resulting 4D model is then saved in the IFC 2.0 format.

The linker module can also be used as a tool for preparing schedules. The user can show the sequence of construction by selecting the building's components from the 3D visualisation, which clearly enhances understanding of the detailed sequence of construction operations. This user interface is composed of four main parts:

- IFC Object browser
- Property window for viewing detailed data on selected IFC objects
- Schedule object browser
- Property window for viewing detailed data on components and objects for the selected schedule

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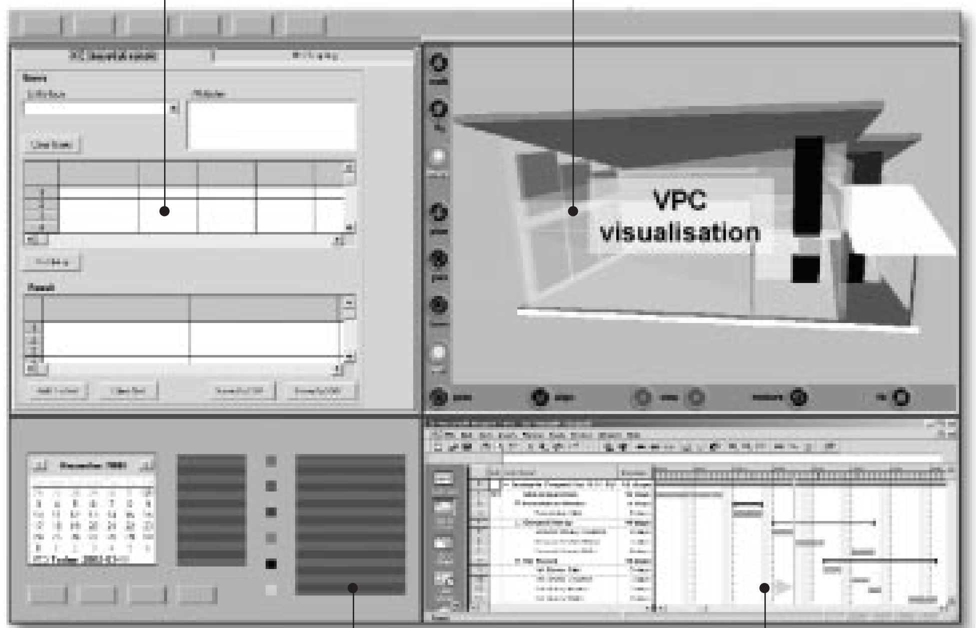


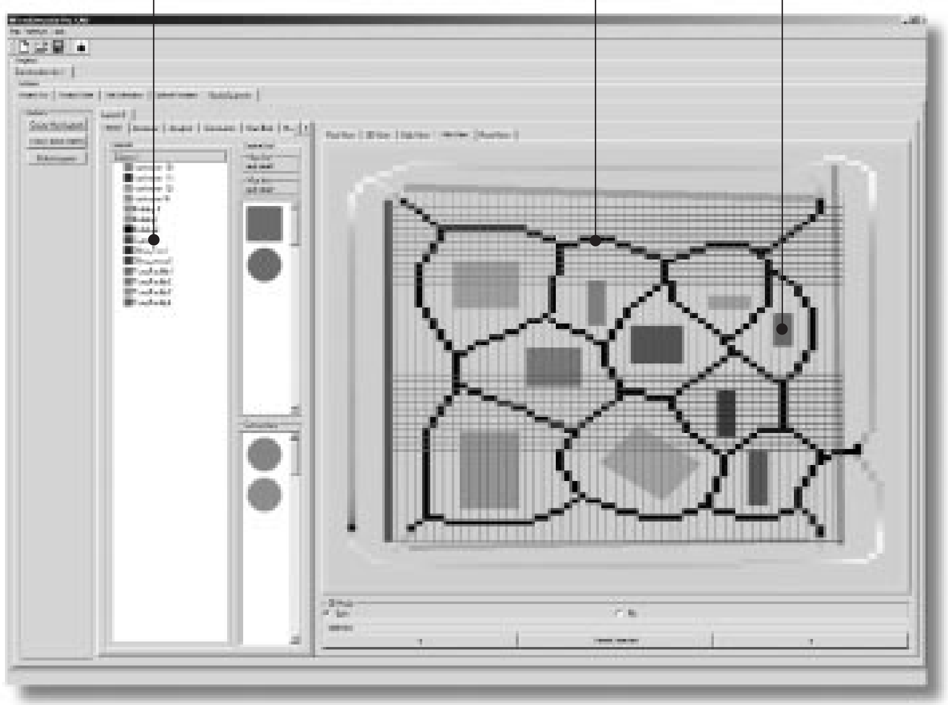
- Interactive 3D viewer for displaying selected components
- Time schedule viewer for displaying the schedule in barchart form
- Visualisation configuration for selecting options for viewed components and processes.
- Schedule viewer for displaying the schedule in barchart form

4D Viewer is a toolkit of interactive tools that can be used for accessing appropriate data from the building product model and for visualising it in a format defined by the user. This user interface is composed of four main parts:

- 3D viewer for displaying components and processes, and for relating features of interest
- Query dialogue for retrieving data from the product model database

Site Planning Simulator

The site analysis and planning application simulates and analyses the layout of the construction site



Site Planning application identifies best path layouts during construction

It provides an IT tool for site planners and managers to improve site efficiency and safety.

The simulator's purpose is to provide space and quality information on construction site layouts, in terms of visibility, accessibility and risk. The application uses 2D space analysis and hazard zone algorithms.

The simulator can model temporary facilities layouts, and detailed movement paths. Users can conduct "what if" scenarios, and change spatial dimensions in order to evaluate the site layout at different stages of construction. Users can export the 3D site models to VRML and then view them using standard tools.

This application is particularly useful for health & safety training on site.

The main functions of the site planning and analysis application are:

Site layout initialisation: This allows the user to set the site dimensions and boundaries, and then introduce objects onto the virtual site (e.g. buildings, vehicles and temporary facilities). Once the site boundary and initial layout have been set, the user can perform four types of analysis: (i) visibility; (ii) accessibility; (iii) hazard zone definition; and (iv) facility layout optimisation.

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- Visibility analysis shows which parts of the site have high or low visibility. It provides guidelines as to where to place security cameras, or where to position staff rooms or temporary facilities.

- Accessibility analysis can assist in determining the route of site paths during different stages of construction. The software can recommend layouts based on visibility and safety considerations.

  The user can also select path layouts based on several additional criteria, for instance the shortest travelling distances, the lowest risk in terms of health and safety, or the highest visibility.

- Hazard zone definition is used to highlight hazard zones for specific objects on the site, such as cranes. It is particularly useful in health & safety training. The software shows the hazard area surrounding a space and the degree of hazard across the space. Site managers can generate a map of high-risk areas so that they can restrict access, or train new staff in hazard awareness.

- Facility layout optimisation works out the best possible location for temporary facilities (TFs). The user can specify the relative importance of various factors, for instance the minimum distances between TFs, or the maximum distances from cranes. The software then generates a layout solution taking these factors into account.

Communication within DIVERCITY

Any third party application can share data with DIVERCITY or add new information.

E-viper 'Distribution Manager' handles access to the workspaces and projects

This can be achieved at several levels, from a building's end-users using a simple GUI interface, to software developers providing a high-integrated solution.

This new technology represents a significant advance in communications. It allows all kinds of data exchange, whether asynchronous (where information is simply distributed) or synchronous (where information is distributed then worked on collaboratively).

DIVERCITY's communications layer, called "eViper", eliminates firewall or proxies issues in a way that is transparent to end-users. eViper is built around a client/server architecture. The server is called the 'Central server' and the client side is known as the 'Distribution manager'.

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Central Server

The central server provides a centralised space to store data and control data exchanges. It provides the following features:

- **Source control** of the stored data using a versioning tool. This stores different versions and keeps a history of what happens on a project.
- **User profiling** identifies people connected to the system or trying to connect. It manages users' access rights on a project.
- **Security and integrity of information** are permanently controlled by the server. The server manager can set and validate the security policy on any project.
- **Messages management** is one of the most important features of eViper. It controls the information exchanged between users, and manages different priorities. Thanks to this feature, software developers using eViper can build collaborative as well as distributed applications. This feature is an open mechanism that allows any authorised third party users to access the data.

Distribution Manager

The distribution manager is the client (user) side of DIVERCITY's communication layer. It can be included within an application, or can be run as a stand-alone application, controlling the data exchange between the user and the central server.

The distribution manager is not dependent on a particular platform.

It provides all necessary functionality to send and receive messages from the server. It also offers a simple way to plug any third party application into eViper's central server.

Project Participants

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