

# SUSTAINABLE BUILDING DESIGN – A SYSTEMATIC APPROACH

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Atkins are developing a strategic plan to exploit collaborative working techniques, specifically object based modelling of buildings, with the initial investigation centred on early stage design. As part of this they are currently developing tools to evaluate environmental impact of building proposals in terms of materials use and energy consumption. Cost comparisons will also be made for the various solutions analysed. The assessments will use IFC2x schema to hold both the proposed designs and also the Atkins library of Construction and Material properties. An integrated ICT enabled approach will allow all designers to assess their buildings and inform design decisions. A materials evaluation tool will apply the BRE developed EcoPoints methodology, initially using data published in the Green Guide for Specification. IES Virtual Environment will be used to assess energy consumption, Autodesk Architectural Desktop and SketchUp will be used for creating the building models. A live project case study is used to demonstrate the business impacts of introducing a clearer, systematic approach to early stage building design.

Keywords: Collaborative design, IFC, integrated early stage design

## INTRODUCTION

This research proposal is part of a larger rolling programme of integrated ICT enabled design, construction and facilities management Atkins are undertaking.

It is closely aligned with two large current construction industry research projects, namely Avanti and mBOMB. The Avanti Programme addresses ICT enabled collaborative working for design, procurement and management of a building throughout its life. The mBOMB model based operation and maintenance of buildings project focuses on interoperability of software applications. Both are funded via the DTI Partners in Innovation PiI mechanism.

This research focuses on the early stages of building design as outlined in the RIBA Plan of Work, feasibility and concept design. In order to be able to build more sustainably, designers need to quickly grasp the main economic, environmental and social issues associated with a particular building on a particular site.

Collaborative design has been identified as a means of arriving at more robust solutions. There are various ICT tools available that aid individual disciplines in completing their tasks within the design process. The most common include AutoCAD and Microstation, which are mainly used for draughting, StruCAD for structural design analysis, Hevacomp for HVAC (Heating, Ventilation and Air Conditioning) system design. However, they are not generally used collaboratively.

The proposed research offers a systematic approach to building design and builds on ten years of R&D within Atkins aimed at improving processes and product. As one of the largest engineering consultancies in the world Atkins has an excellent portfolio of world class projects and is well disposed to implementing new and innovative work processes. It is anticipated that adopting the ICT enabled collaborative working approach will add value to the built product as well as streamlining processes within the company.

## **BACKGROUND**

Materials used in construction of buildings currently account for 40% of natural resource use, 30% of CO<sub>2</sub> emissions and 40% of waste and are used in buildings taking up 45% of the UK's energy use. Reducing emissions has become a major policy issue, the government's goal of a 20% reduction in carbon dioxide emissions by 2010 (compared to their 1990 level) is much more ambitious than the UK's international legal obligation under the United Nations (UN) Kyoto Protocol of a 12.5% reduction in greenhouse gas emissions. More ambitious still is The Royal Commission for Environmental Pollution 60% reduction in greenhouse gas emissions by 2050.

It has been well documented that the way buildings are designed and constructed is a very fragmented process and solutions to streamline the various processes and improve the built product are currently being developed throughout the industry.

## **SUSTAINABLE DESIGN**

The construction industry is central to the process of sustainable environmental, economic and social development, improvement is vital in terms of

- Minimising energy consumption during construction and operation
- Most efficient use of natural resources, reducing mineral extraction
- Minimising environmental impact e.g. disruption of habitats
- Regeneration of housing, revitalisation of town and city centres
- Planning to reduce transport impacts
- Streamlining Construction

The government is increasing the drive towards Sustainable Development with initiatives such as Accelerating Change, and the Movement for Innovations Environmental Performance Indicators for Sustainable Construction.

The key target relevant to this research project is that by the end of 2004, 20% of construction projects by value should be undertaken by integrated teams and supply chains, increasing to 50% by 2007.

It is very difficult to measure the sustainability of different building solutions. There is a wide range of issues relating to economy and environment which must be considered. Within the main issues there are subsets of further considerations. There is information explaining what constitutes sustainable design but there are few tools available to quantify it. The following list outlines some of the main and sub headings that should be included in the evaluation of any building project from a sustainable perspective.

“Sustainability reflects an understanding that we must meet the needs of the present without compromising the ability of future generations to meet their own needs.”

- Site Features
- Daylighting
- Building Envelope
- Renewable Energy Technologies
- Energy Efficient Lighting and Electrical Systems
- Energy Efficient Mechanical Systems
- Building Materials, Products and Systems
- Water Conservation
- Recycling Systems and Waste
- Transport
- Commissioning, Operation and Maintenance
- Eco Education

## **SUSTAINABILITY MEASUREMENT TOOLS**

The BRE Environmental Assessment Method is a recognised means of evaluating the sustainability of a building. It is concerned with Design and Procurement, Operation and Management as well as Performance. It addresses the triple bottom line of sustainability i.e. Social, Economic and Environment, the main headings are

- Transport
- Energy
- Health and Wellbeing
- Pollution
- Water Conservation
- Ecology
- Land Use
- Management
- Materials

Envest is a tool developed by BRE and is used to measure environmental performance of buildings. It provides a useful means of comparing methods of construction e.g. steel frame versus concrete structure and the main elements of a building, however it is not ideal for calculating energy consumption, there are more comprehensive tools which should be used to do that. The user simply inputs the building dimensions, window areas and selects construction types for each element e.g. floors, walls, roof etc. Envest identifies which elements have the greatest environmental impact and gives an overall ‘Ecopoint’ rating for the selections made. The design team can then investigate the influence of changing construction types. An ‘Ecopoint’ is derived by

BRE and equates to the total impact on the environment of one UK citizen over a year.

The Movement for Innovation Sustainability Working Group Report 'Environmental Performance Indicators for Sustainable Construction' published in July 2001 provides a simple means of evaluating environmental impact of building projects. The initial proposed suite of indicators addressed are:

- Operational Carbon Dioxide emission (kg CO<sub>2</sub>/m<sup>2</sup>/year)
- Embodied Carbon Dioxide (kg CO<sub>2</sub>/m<sup>2</sup>)
- Water (m<sup>3</sup>/person(equivalent)/year)
- Waste in the Construction Process (measured in m<sup>3</sup>/100m<sup>2</sup> floor area)
- Biodiversity (under development)
- Transport

#### Thermal Modelling

IES Virtual Environment ([www.iesve.org](http://www.iesve.org)) is an integrated suite of software focussed around an Integrated Data Model IDM. It is used within Atkins to advise design teams on passive building systems design, energy consumption, internal comfort, solar shading. It can also be used to perform Life Cycle Analysis and to test drive building heating and cooling systems. It is a very powerful tool in providing the design team with the opportunity to test drive buildings. From experiences on the case study and other projects the difficulty in designing sustainably comes when the focus is expanded beyond energy performance to materials and renewable energy technologies for example

## **INTEROPERABILITY**

Interoperability is defined as being able to move data from system to system without translation, or data loss. In terms of the single data model once the information is created it is used in various applications automatically without re-entry, modification or interpretation. The benefits are time saving and reduced margin for error.

Key characteristics of interoperability are common language (semantics), the ability to maintain relationships between different elements e.g. window in particular wall and finally that transfer is automatic, there is no need for manual intervention.

There have been various demonstration projects focussed on Interoperability and collaborative working. These highlighted the need for fewer formats and techniques of data transfer that are straightforward and help speed up the process. With so many different platforms in use on any project there are numerous gaps where information can be lost.

The International Alliance for Interoperability (IAI) was set up in 1995 with the aim of developing information standards that would allow integration between construction applications.

The Industry Foundation Class (IFC) object model is a representation of the content and structure of data to be exchanged. It covers real building elements e.g. wall, floor, windows and abstract elements such as space, project organisation and process. The various parties involved in the design can share current information in different

software applications with no inefficiency or loss of data. The major CAD vendors i.e. Autodesk, Bentley, Allplan have built IFC translators into their CAD packages.

## **RELEVANT INDUSTRY RESEARCH**

The Avanti Programme: ICT – Enabled Collaborative Working

The objective is ‘to deliver improved project and business performance through the use of ICT to support collaborative working’. It is an international project led by ‘be’ (formerly Reading Construction Forum and the Design Build Foundation), working with a number of industry partners, the International Alliance for Interoperability IAI, Teamwork and DTI. The timetable is July 2003 – June 2006 (government funding) and July 2006 – June 2008 (industry/product funded). DTI funding is £750,000, matching an industry ‘in kind’ contribution and ‘leveraged’ funding from 3<sup>rd</sup> parties gives a total equivalent value of around £5M in the first 3 years.

## **THE RESEARCH**

The Systematic Approach builds on what is already being done or has been done. This research aims to develop a rapid, efficient means of producing and interacting with the information required for strategic design at the earliest stages of projects, enabling the elements of Sustainable Building Design to be investigated, conveyed to and understood by all relevant parties. By combining emerging technologies in human computer interface design with best practice in environmental design and Whole Life Costing within the context of real building projects the research aims to develop a pragmatic and practice driven approach to overcome some of the major obstacles to achieving sustainability in construction.

The obstacle is the lack of data on sustainable materials alternatives, the inflexibility of current design processes and use of software against the background of increased time, cost and competitive pressures in the construction process and the industry as a whole. Modular design and standardisation of solutions can help achieve efficiency gains with respect to some aspects of a design, but not in others. By using collaborative work processes, 3D and object modelling, interoperability and databases modules of accommodation e.g. a typical classroom, toilets, sports hall can be easily configured and reused on subsequent projects to produce layouts for costing and analysis very quickly. This frees up more time to examine several solutions during the same timescale in the context of the particular site.

On design projects the more solutions that are worked through the more value is added to the product and its through life considerations. Due to increased time and budget constraints and increasing expectations designers tend to have to go with what they know will work just to meet deadlines. As a result more sustainable solutions are often shelved because they are perceived to be too costly, risky, unworkable or because there simply is not enough time to design and cost them. Testing of solutions and informed feedback to the design team needs to be speeded up for projects to become more sustainable.

Multidisciplinary working can speed up the design process. Making data easily available and interpretable across disciplines facilitates decisions. The intelligent common object model has been canvassed to enable this approach, but difficulties have been found in populating the database with every type of material and component for every possible solution. Possible solutions to this problem exist using a common data model, allowing libraries of data to be constructed from various

projects, providing a rich data source transferable between projects. A second issue this research proposal aims to tackle concerns the quality and format of outputs for interpretation by different parties from different disciplines. Using innovative interface design both human-computer and software-software it is proposed to explore means of ensuring that communication is eased.

Ultimately the vision is to construct a virtual building that can be queried and analysed in any number of ways in real time and one that is completely interactive. This virtual building model would be used during the operational life of the building. Whilst the technology is becoming available and virtual buildings are being used to assess spatial layout and people movement, there is still a long way to go before it is possible to develop a fully intelligent model for energy and environmental design coupled to whole life costing on everyday projects. All of the components exist but bringing them together in a usable form presents a challenge.

The aim of the research is to develop a prototype process linking applications that will allow quick design iteration and 'optioneering' at early design stages and will easily convey results to people from a variety of backgrounds.

### Aims and Objectives

- Comprehensive review of existing literature and software including research papers, industry journals, trade magazines, Internet articles and in-house data.
- Examine how simulation results could be linked to the Whole Life Cost model, the CAD model and a VR model.
- Test Industry Foundation Classes as a means of transferring building data between software applications.
- Develop a materials sustainable alternatives database complete with capital and maintenance cost data, environmental impact
- Identify key communication bottlenecks to achieving sustainable design.

### Methodology

- Specify and Identify a suitable Atkins building project.
- Familiarisation with the IFC Model and Property Sets.
- Develop a list of Sustainable Elements which will be evaluated at early design
- Identify existing Property Sets within the IFC model that could be used.
- Create new Property Sets as necessary.

## **CASE STUDY: REDHILL LEARNING AND COMMUNITY CENTRE**

The Avanti proposal was accepted in September 2004 and registered on the programme as a satellite project which means that one or two aspects of ICT enabled collaborative working are focussed on rather than trying to address all aspects.

Redhill Learning and Community Centre is the project selected as the basis for the research. It is to be procured under a Design and Build contract therefore the client, Surrey County Council, employs Atkins to produce an Architectural; Structural and Servicing concept. Through a tendering process the successful Design and Build contractor will take the basic design information and develop the detail.

The project is interesting from a number of aspects. It is a bespoke building, in which Surrey is bringing together five different facilities into one building. Each of these facilities has different requirements due to the nature of the users and the different services/activities that each department offers. The five different facilities include:

- Day Centre
- Adult Learning
- ISIS
- OASIS
- CTPLD and Childcare
- Family Centre

There are also some shared facilities including multi-purpose hall, music and drama, café and hydrotherapy pool. In order to generate revenue these and the Adult Learning department will be made available for community use at evenings and weekends.

The building is bespoke in terms of the fact that there are no similar buildings elsewhere and the fact that the stakeholder team is extensive, with professionals and parents representing all of the user groups. The project has quite a high profile within Surrey and they are keen to set some new precedents with it in terms of sustainability and attractiveness from a user point of view.

The Avanti satellite project aims to measure the potential impact of introducing Environmental Impact into the early stages of design. The metrics for the project are as follows:

#### People issues

- Awareness of the impact of early design decisions on Whole Life Costs and environmental impact
- Awareness of IT generally in the design process.

#### Process and Efficiency Issues

- Costs of developing a 3D object model
- Value of Whole Life Cost and evaluation tools
- Develop guidelines on early stage design.

#### Improved delivery and project benefits

- Design cycle time – more options, added value
- Whole Life Costs information for maintenance regime and budget
- Measure and manage environmental impact throughout the life of the facility
- Client perception.

The Avanti deliverable will include a protocol for using early stage design tools e.g. Sketch Up and ADT, and a methodology for delivering early stage design information in the IFC format. A tool will be developed which will allow users to connect to a database and use the information stored to evaluate their design. Evidence of skill,

process and product improvement will be captured using questionnaires, timesheets and the evaluation tool itself.'

## **BUSINESS JUSTIFICATION**

The main business justification for introducing the new process and prototype tool proposed by the research is to improve performance of design teams at the crucial early stages of design.

It will allow teams to integrate and investigate more solutions within a shorter time the result of which is more robust solutions over the long term. This is where the benefits of Technical Differentiation are capitalized on.

Whole Life Costing Adds Value. A simple statement, which has been well proven. The systematic approach means that WLC can be carried out at early stages without incurring a major time penalty or a large additional fee. It will be able to be more easily integrated into the whole process.

The financial investment required to implement these changes on a large scale throughout the company has not been calculated at this stage. This will be the subject of discussions with various Directors in order to judge the appropriate scale of the roll out in the short and medium term.

The benefits of the systematic approach are investigated at concept and scheme design stages. Ideally we would want to carry the model developed then right through the design, construction and operating phase of the facility. This would lend more weight to the concept of completely changing the way things are done.

There are other major barriers besides investment in technology which have been identified including culture, many designers, quantity surveyors, and engineers are not comfortable with using computer software no matter how simple and user friendly it is and experience thus far with the Avanti project highlights a considerable amount of resistance. Within Atkins the integrated approach is gaining popularity however for the most part disciplines continue to work in isolation.

The cultural technological and business barriers to adopting a new and different approach have led to Atkins waiting for things to change in the industry before they follow suit. At one time Atkins was recognised as an early adopter and indeed developer of new technologies and techniques. The benefits of this relate to perception of the company as much as actual savings on projects or sales of technology. From an interoperability point of view it is the large vendors who have the responsibility of adopting new standards and enabling interoperability this does not have to be transparent for the user. The least disruption to working practice is desirable. However beyond that in the realms of integrated, collaborative working and sustainable design these are issues which Atkins must address for itself rather than follow the herd. Better even than being an early adopter Atkins should be setting the example for others to follow. Already we are falling behind some of our leading edge competitors.

## **BUSINESS CASE**

Atkins have employed 3D modelling tools for a number of years, CAD and Visualisation for Architectural Design, Structural analysis tools, environmental analysis, lighting design tools.

The company is currently moving towards Integrated 3D design where one model contains all information from all disciplines on the Autodesk platform, using ADT.

The research proposal is aimed at investigating how we can use a common language and the power of databases to improve the intelligence of these 3D models, so that they can be evaluated in terms of cost and environmental impact at various stages of development.

As far as the users, designers/modellers are concerned they will build their models as normal but it will be possible to link to a database and an evaluation tool to get feedback on Whole Life Costing etc.

The anticipated benefits are summarised as follows;

- Improving end product quality
- More informed decisions early in the design process
- Added value
- Innovation
- Empowering designers to give more strategic advice

## CONCLUSIONS

Construction in the UK creates large amounts of waste every year. Collaboration during design and construction can reduce the amount of waste generated and result in more sustainable buildings. More robust integrated processes, seamless data exchange on projects can lead to better coordination and increased accuracy of design information which presents a clearer picture to the Contractor. The use of Common Data Environments or Single Data Models enable teams to share data which reduces time taken up by data re-entry and reduces the margin for error due to data lost in the process. Object modeling enables evaluation of one design against another at the earliest stages and enables the design team to make informed decisions from a whole life perspective. The research examines the current situation with respect to ICT enabled collaborative working and the business case, opportunities and barriers, to pursuing this approach in one of the largest engineering consultancies in the world.

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