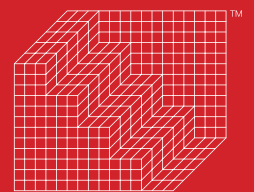
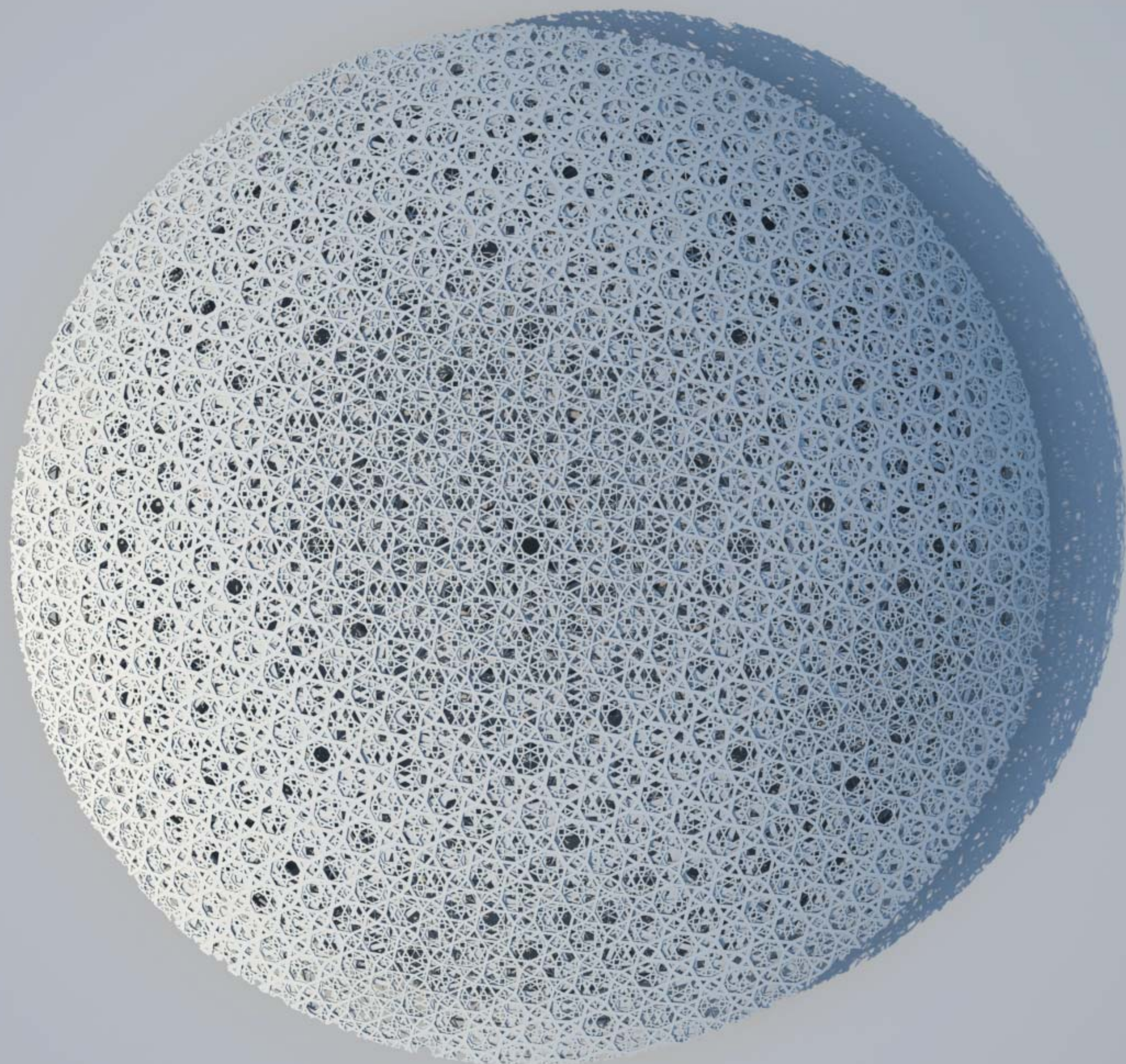


SMART Software Solutions
Capability Statement 2011



Buro Happold



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Introduction to Buro Happold



Ted Happold



Image copyright: Zumtobel



Buro Happold Bath Office

Buro Happold is a world class, multi-disciplinary engineering consultancy, operating out of an international network of offices.

We provide comprehensive general and specialist engineering services for complete developments, buildings and their infrastructure.

Buro Happold was founded in Bath in 1976 by the late Professor Sir 'Ted' Happold as a traditional partnership. In 2007 Happold LLP was formed as a limited liability partnership employing over 1700 people worldwide.

As engineers our role is to listen, understand and advise. We believe our sharply focused approach of integrated design, blended with proven fast track experience allows maximum financial return on developments.

Our vision is to become the world's best integrated multi-disciplinary engineering and strategic consultancy for the built environment.

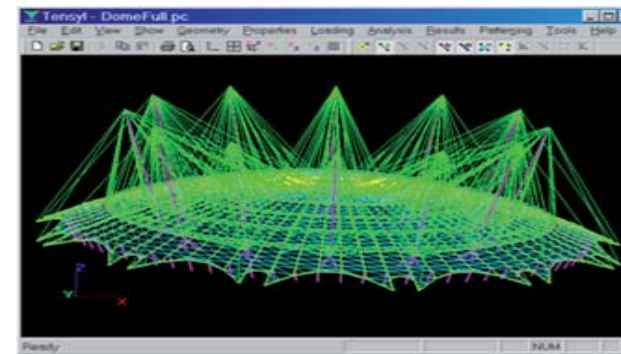
Broadly, the objectives of Buro Happold are:

- To achieve value in our engineering design and complete commissions both to cost and to programme
- To provide easily constructed design solutions responsible to the environment, efficient in their use of materials and energy, and deliver value for money
- To integrate sound engineering principles into the total design. To present clear, concise and relevant drawings and documentation or tendering and construction
- To manage the process so that it is timely, efficient and co-ordinated with the processes of the architect, quantity surveyor and other disciplines, and with the needs of the client and end users.

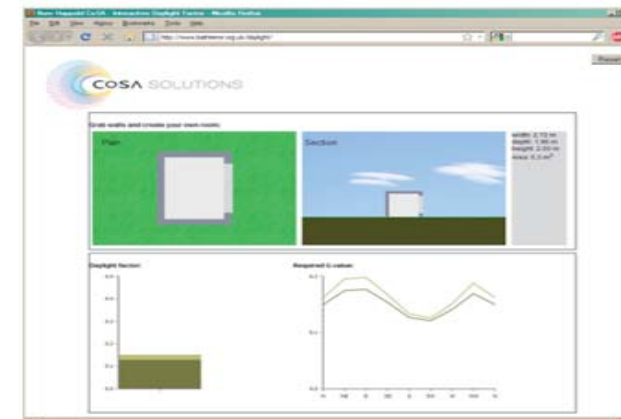
We have offices in Bath, Belfast, Birmingham, Edinburgh, Glasgow, Leeds, London, Manchester, Abu Dhabi, Berlin, Boston, Chicago, Copenhagen, Dubai, Hong Kong, Pune, Los Angeles, Munich, New York, Riyadh, San Francisco, Toronto, Warsaw. We also have representation in Cairo, Jeddah, and Kuwait.

SMART Software Solutions

Innovative software solutions for the built environment



Professional applications: SMART Move and Tensyl



Bespoke software: interactive excel and web based tools

Buro Happold is continually developing new technology to ensure we deliver efficient solutions for the built environment and beyond. SMART Solutions, our team of developers with strong analytical capabilities, has been instrumental in enabling this.

SMART uses a combination of existing tools and specialised in-house software developments to find solutions related to a wide variety of problems. We are also capable of developing new professional 3D graphical applications as well as simple plug-ins for commercial CAD or CAE software or Microsoft Office and interactive web tools

SMART Form

Digital prototyping software for real-time generation, manipulation and optimisation of complex forms and structural grids.

Tensyl

Our flagship nonlinear form finding and analysis software. Applied to several complex structural projects, including the Millennium Dome.

SMART Sizer

An innovative one-step structural optimisation tool to size members selecting from a database minimising the target deflection and meeting stress and buckling criteria.

SMART Move

Rapid simulation of people movement through buildings and urban network. Network based micro-simulation – highly scalable and capable of analysis as well as design optimisation.

SMART Particles

Simulation of wind flow around buildings of a complex shape, particularly flexible structures.

SMART Sight

Enables sightline assessments. Design and analysis of raked seating based on sightline requirements.

Bespoke Tools

In addition to fully-fledge applications, SMART routinely develop unique tools customised to the needs of specific projects. Examples include an Excel-based environmental planning tool for a major UK-wide retailer, and a simple web-enabled tool for solar shade design.

SMART Form

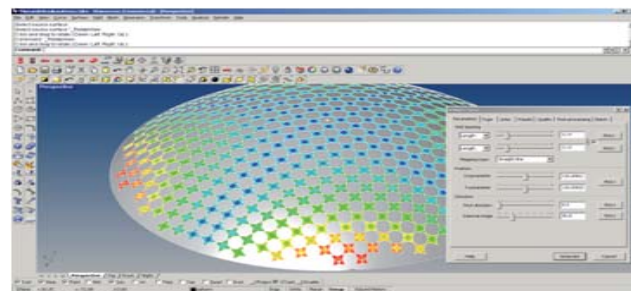
Real-time Geometry Optimisation Software

Note: A light, architectural version of this tool can be downloaded from www.smart-solutions-network.com

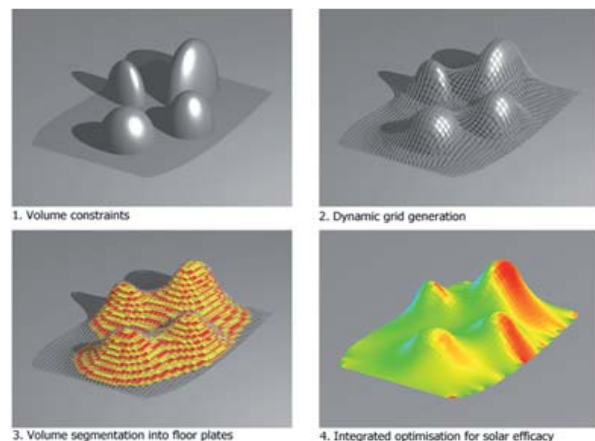
An increasing number of modern architectural designs have complex 3D forms that require an element of 'smartness' in the design of the structure. Buro Happold's structural experts have worked on many such projects, including glazed canopies, grid shells and greenhouses.

In order to create optimal structural solutions for these complex doubly curved geometries, Buro Happold developed SMART Form, an in-house digital prototyping software for real-time generation, manipulation, and optimisation of complex structural forms.

Using our in-house geometry processing software, it is possible to generate a smooth surface from discrete faceted geometry. Any given complex surface can be analysed and if needed rationalised to facilitate its subdivision into planar cladding panels. The manufacturing schedule of the members and panels can subsequently be processed automatically. The process of geometry characterisation, relaxation, structural analysis and fabrication is integrated to allow an iterative evolution to an optimal form.



Complex Pattern Mapping

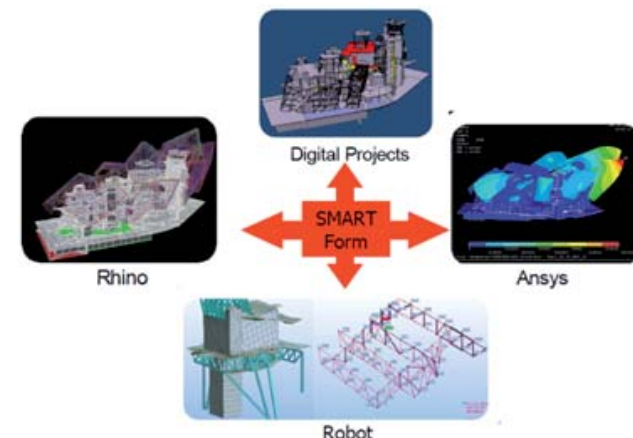


Integrated formfinding to optimise structure and environmental response

SMART Form can analyse a 3D surface for the various characteristic curves and then use these curves to map various arch shapes, membranes, and panels with special properties:

- Subdivide a complex, doubly curved surface comprising entirely of four-sided flat or singly curved panels
- Optimise the grid layout and sizes for structural performance
- Constrain the grid to form a net of equal-sized links so that the same element can be used throughout the structure
- 'Relax' the grid in order to achieve uniform distribution of members for optimal performance or visual appearance
- Parameterise geometry/relationship between structural elements
- Produce FE mesh for structural analysis in Robot / Ansys
- Create digital fabrication information for direct CNC cutting.

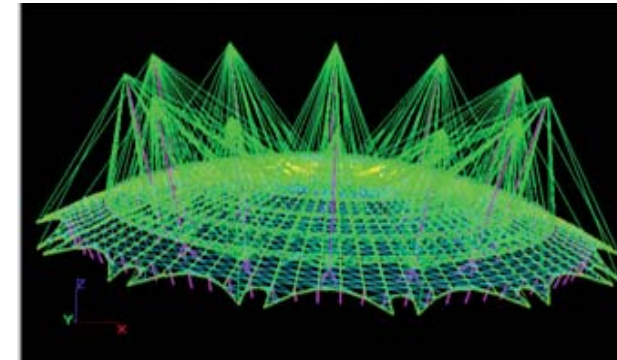
SMART Form is integrated with the Rhino 3D interface and works with analysing tools such as Ansys, Robot and Tensyl. Work is underway to produce the next generation version of SMART Form that can be used for optimising structural grids for a combination of architectural, structural and buildability considerations.



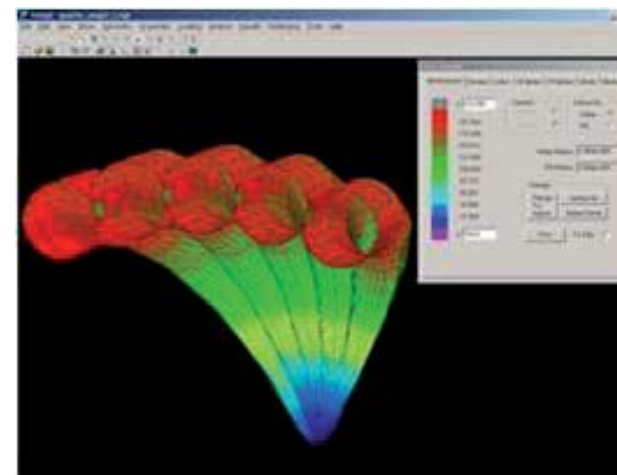
SMART Form links with CAD and analysis tools

Tensyl

Nonlinear Formfinding Software



Tensyl model of the Millenium Dome



User interface of Tensyl



Hanging chain model for Scunthorpe Gridshell

Form-finding is a process by which the most efficient form for a structure can be determined. Think of a metal frame being dipped into a soap solution; the resulting 'soap film' equates to that shape's minimum surface area. This is an optimum shape for both tensile fabric structures and compressive shell structures, where bending moments are minimised.

Over the past 20 years Buro Happold's expertise with structural formfinding has been used to develop our in-house computer program Tensyl, which models the form-finding process for membrane and cable-net structures. The software is capable of determining the most effective form for fabric, cable-net, pneumatic, and non-linear structural system under given constraints. Tensyl is available on a PC platform and boasts a 3D virtual reality-style interface, which allows the user to build, analyse and interrogate models. The latest version was released in 2008.

The software has been used on a number of high profile projects, including the form-finding of Millennium Dome O2 Arena roof, and design of highly efficient concrete shell structure for the geometrically complex Stuttgart21 railway station.

Tensyl has post-processing functions that allow a graphical display of all forces within elements. In addition, results can be exported as text or video files and there is full integration with third-party programs such as Excel and CAD.

SMART – Buro Happold's team of innovators behind Tensyl are continually developing and supporting Tensyl to enable solutions on a wide range of complex structures. We also customise the software to suit the project needs. Be it an interoperability issue, new solution constraints, or model generation routines, Tensyl is constantly evolving to solve the new and diverse range of problems that tomorrow's buildings require.



Scunthorpe Academy

SMART Move

Rapid, sophisticated crowd flow simulations

Note: A light, architectural version of this tool can be downloaded from www.smart-solutions-network.com

SMART Move is a visual simulation tool for analysis and design of circulation spaces. It brings together the strengths of network modelling and agent-based simulation technologies to offer a fast, flexible and visual tool, with significant functionality for integrated modelling of people, transport, and baggage. Its integration with 3D CAD, ease of data input, and rapid simulations and design-mode capability make it a unique design optimisation tool.

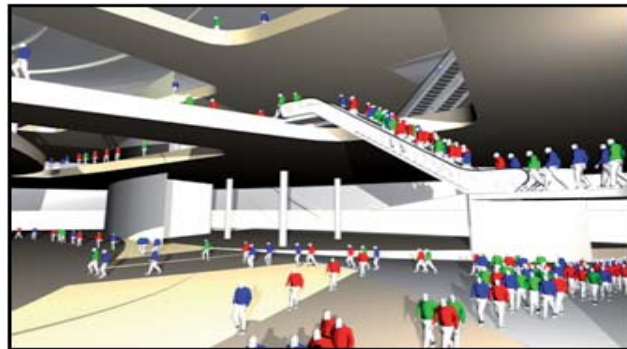
SMART Move allows detailed simulation of people movement through a given space. The software is highly scalable and capable of analysis as well as design optimisation of circulation routes through an office floor, school, high rise building, sport stadia and urban spaces alike. The software's static network analysis capability is used for conceptual design and analyses of spaces, while the dynamic simulation capability allows testing of complex interaction of hundreds of thousands of people in scenarios such as day-to-day circulation, mass arrival/exodus, and emergency evacuations.

SMART Move's statistical modelling, sensitivity analysis, and design optimisation capability enables various design variables and management measures to be tested thoroughly to achieve the desired levels of comfort and safety criteria, while minimising costs.

SMART Move capability is complemented by our team's powerful data capturing and analysis methodology for the understanding of population behaviours and movement patterns. We have developed EventCounter software that allows rapid analysis of video data to generate statistical information on walking speeds, queuing behaviour, service times, limiting flow rates, etc. This data can be superimposed on a circulation network to obtain visual flow paths and congestion map.

The software, integrated with Rhino, provides fully immersive 3D virtual simulation of the circulation space in operation, making it an invaluable selling tool for the designers and developers to prove the feasibility of the scheme.

The team behind the software is SMART Crowd Flow Solutions – Buro Happold's specialist circulation modelling consultancy service. It therefore benefits from innovations brought out from the team's years of experience on the work on several landmark buildings and projects, including: Ascot Racecourse Redevelopment, London 2012 Media Centre, Liverpool King's Waterfront development, Jeddah Airport Hajj Terminal (Saudi Arabia), DY Patil Management School (India), etc.



Cairo Expo City Simulation



London 2012 Media Hub



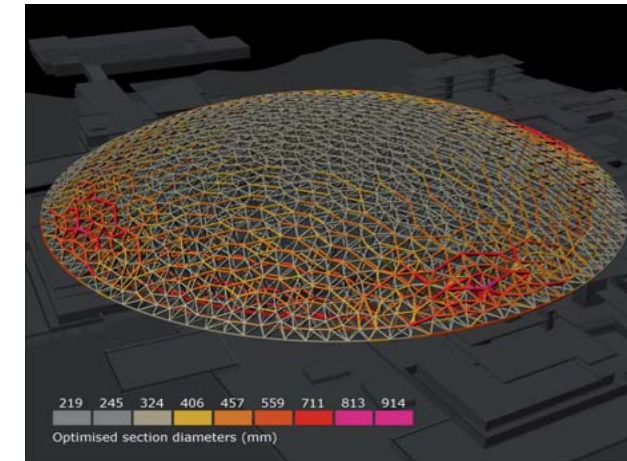
Baggage hall models: London City Airport



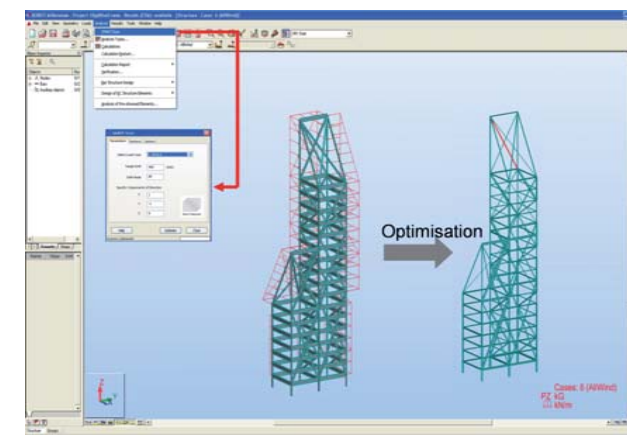
Lord's Cricket Ground exit simulation

SMART Sizer

A member size design optimisation tool



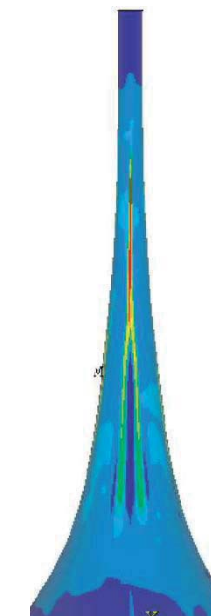
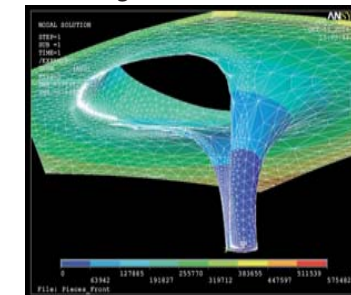
Optimised roof model: Louvre Abu Dhabi



One-step optimisation of a tall building



Form and depth optimisation for Stuttgart Station



Smart sizing on Beacon Tower

Buro Happold's engineers strive for efficiency in their designs, and SMART Sizer has been developed to address this need. Using a combination of direct and iterative algorithms, the program can help optimise tall buildings and long-span structures, with rectilinear or complex 3D forms.

SMART Sizer has the following underlying capabilities:

Virtual work (VW) based one-step optimisation

A quick and powerful concept design tool, it delivers deflection based optimisation in 1-step.

A novel integrated VW-DR optimisation

Combining the virtual work principles with our flagship dynamic relaxation (DR) engine a novel progressive optimisation technique has been developed which uses distinct strength, stiffness, and buckling criteria for a dominant load case, whilst additionally ensuring compliance to multiple further load cases.

Use of principal stress grids

Quite simply, this approach suggests aligning the structural members along the lines of the stress flow, thereby delivering maximum efficiency.

Genetic algorithm (GA) based multi-objective optimisation

By dividing the surface form into a set of regions that have relatively few design variables, these methods seek to minimise total weight of the structure for a given outcome. One can also combine 'objectives' so we can e.g consider simultaneously maximum buckling loads and minimum deflections.

Topology optimisation

This method's key strength lies in its ability to derive optimal grid placement and sizing at the same time. By covering the building (or the roof) envelope with all possible combinations of structural members, the technique seeks to find the optimal solution by iteratively upsizing or adding material where stresses are high and downsizing or removing material as required. The optimal structure evolves through the subsequent iterations.

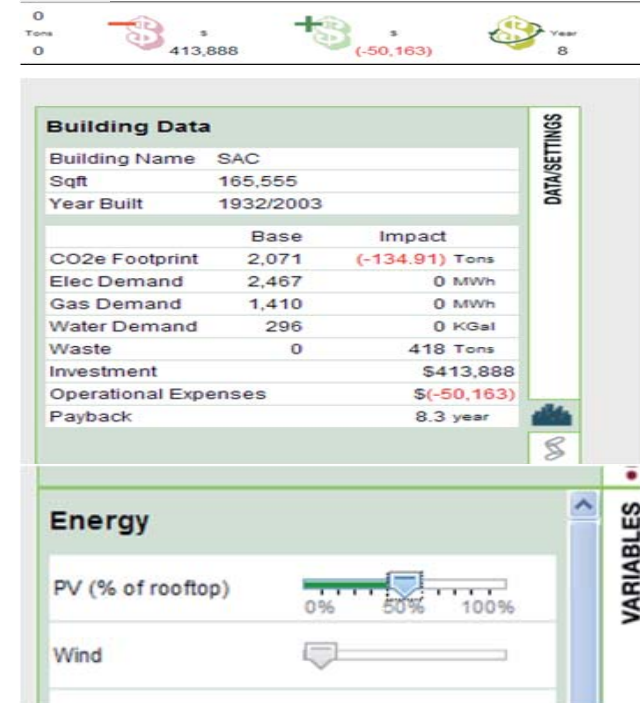
SMART City Viz

3D City Performance Visualisation and Analysis

SMART City Viz, a collaboration between Buro Happold Los Angeles, Chicago and SMART Solutions, is a web-based 3-D city performance visualization and analysis program. It is an interactive dashboard of portfolio performance and conceptual strategy development.

SMART City Viz visualizes large amounts of building/portfolio performance data and creates an intuitive interface for manipulation by exploring options for retrofit. The tool not only serves to further clarify the client brief, but also creates the ability to quickly compare a variety of solutions to drive conceptual decision making. The alpha version is now live and can be found at <http://www.smartcityviz.info>.

The dashboard allows a portfolio to be filtered by performance based on user defined metrics, visually identify the poor-performing buildings against specific client objectives. The complexity and accuracy of the tool is constrained by the quality and quantity of data provided. The number of options are intended to scale with the level of data captured. A full energy and utility audit of the selected portfolio will result in the highest level of accuracy and most comprehensive suite of retrofit options. Likewise a simple site resource analysis will result in the lowest accuracy and limited suite of options.



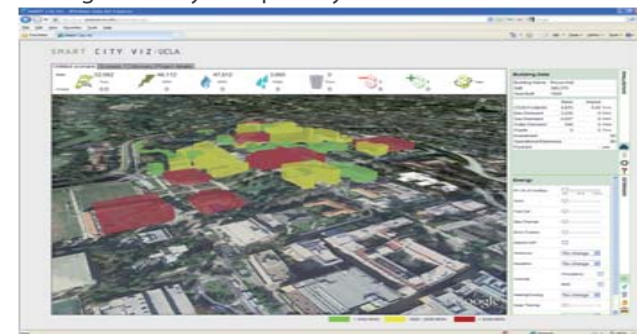
Quick impact assessments

The software platform is open and extendible, is web-based and uses the Google Earth engine for an intuitive and familiar user experience.

The program is currently in an alpha version. The front end of the tool is fully functional, allowing for dashboard application today. The database structure and algorithms driving the retrofit impact will continue to be developed in order to achieve full functionality. The current alpha version has 3 functioning retrofit options: 1) PV, 2) Lighting Upgrade to LED, and 3) Density Change.

The application of the tool is extremely open. We have designed it with the needs of cities, property investor/managers, architects, and universities in mind.

The development strategy ahead will involve the core development team: SMART Solutions and specific representatives from BH LA office. We encourage all offices to apply this tool to projects as they see a fit. We would expect real projects to drive the future developments, with SMART and BHLA working as part of the project teams, while the tool matures to a point the tool can be released throughout BH. We have also begun to explore collaborations outside of Buro Happold to expand the accuracy and computations driving the analysis capability.



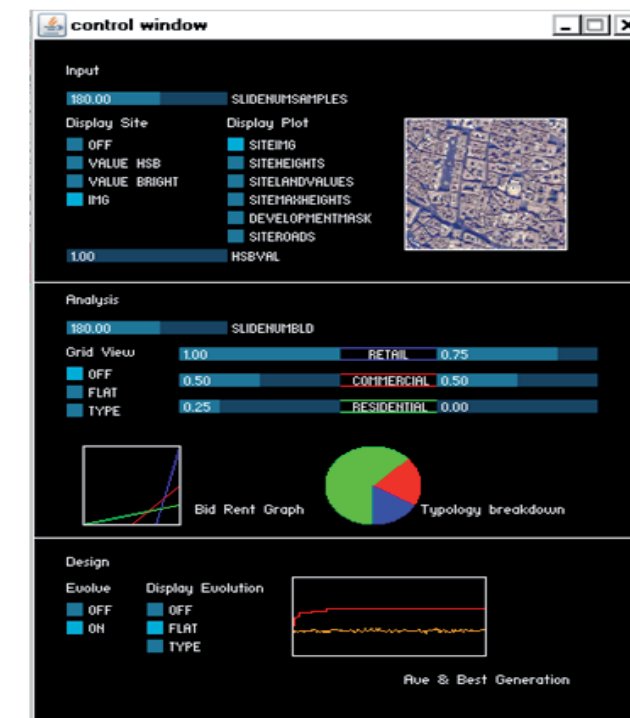
Analysis of geographically connected sites



Analysis of geographically distributed sites

SMART City Designer

A Concept Stage Masterplan Design Tool



Buro Happold's engineers strive for clarity in master planning design decision making, and SMART City Designer has been developed to address this need. A collaboration between the strategic consultancy and urban designers at Happold Consulting International and computer simulation experts in SMART Solutions teams, SMART City Designer is a rich graphics environment for visualising, analysing, and optimising city and site scale masterplans.

Part of the SMART City suite of software, SMART City Designer can be readily customised to the individual projects requirements. Allowing it to adapt to the concerns of the design team as well as simultaneously offering a controllable environment to present an impact of decisions to technical designers as well as clients.

SMART City Designer has the following underlying capabilities:

Data Visualisation

The software utilises raster data provided by GIS and other sources and efficiently displays it in a custom interactive visual output. This can include site topography, mixtures of building typologies, and specialised information (pollution plots, land value etc). The tool is currently being integrated to our City Designer to visualise the output on Google Earth based web link for quick deployment and sharing.

Analysis

SMART City Designer allows superposition of site information and computationally driven analytical capabilities to produce bespoke decision metrics. Advanced geographic, geometric, economic and social parameters can be applied and modified with real time feed back on the overall site performance.

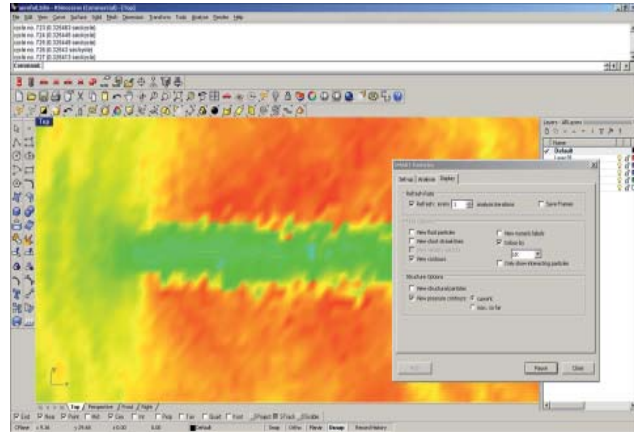
Design Optimisation

Using artificial intelligence techniques the software iterates through thousands of possible designs and land utilisation derived by the input data and user agreed fitness criteria to converge on optimum design solutions.

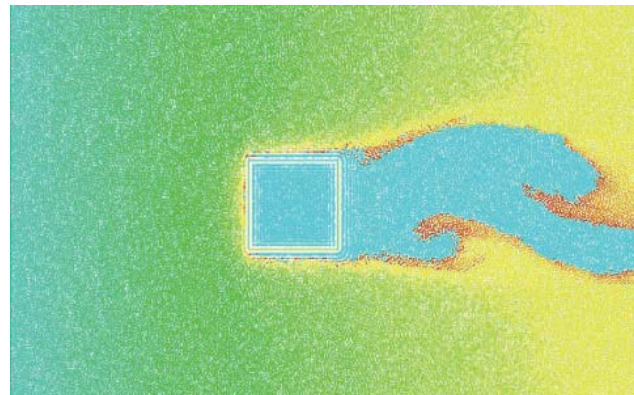
Simple interface, rapid analysis, and real time visual feedback make the tool an ideal concept design tool for masterplanning.

SMART Particles

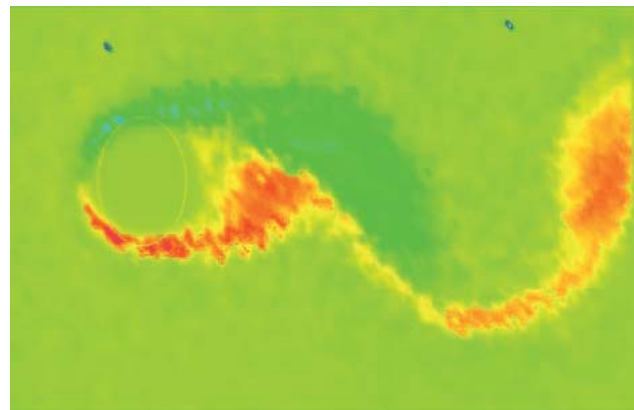
Fluid Structure Interaction Modelling



SMART Particles working within a familiar interface in Rhino



Wind flow around a square shaped building



Flow around a cylinder, showing contour plot of velocity magnitudes

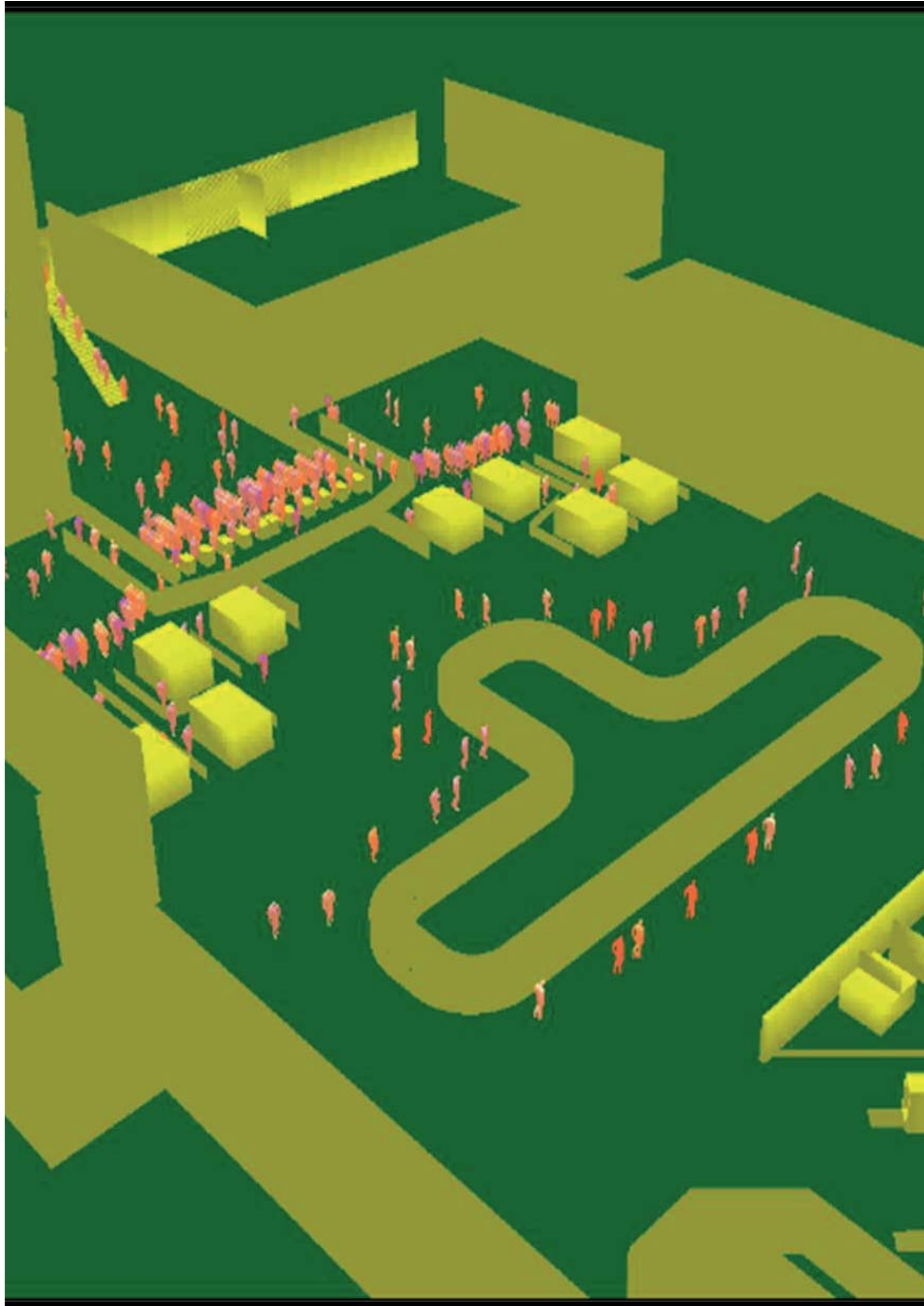
Prediction of wind loads is difficult when dealing with complex building forms, such as those inherent to contemporary architecture and lightweight engineering structures. SMART Particles is a new computational fluid dynamics (CFD) application developed to model the wind flow around surfaces of freeform geometry forming an enhancement of Buro Happold SMART's Tensyl software. The innovative engine is based on a meshless particle based model.

SPH, or Smooth Particle Hydrodynamics is a technique for modelling fluid flow. Although it falls under the umbrella of CFD (computational fluid dynamics) modelling, it is distinct to the conventional mesh-based techniques (such as those used in commercial CFD software Ansys CFX, Fluent, etc), in that it uses particles rather than volumetric meshes to represent fluid. Each particle can be modelled in 2D or 3D with properties such as velocity, pressure, etc and a shape function that determines its influence on the neighbouring particles. Depending on the modelling accuracy desired and computing resources available it is possible to use a smaller number of bigger particles or with a large number of smaller particles.

The software is integrated with and runs within the familiar interface of Rhino 3D CAD, making it easy to analyse buildings of complex forms. The software is also meant to interact fully with Tensyl, which too is being integrated with Rhino.

Using a simple and intuitive interface, it only takes a few seconds to setup a full-scale analysis. As the analysis progresses the fluid velocities, pressure, as well as the forces and pressure on the structure is plotted. The visual plots as well as the trace of these parameters can also be saved for reload or visualisations later.

Apart from detailed fluid-structure interaction modelling, key applications of SMART Particles are in building shape optimisation to accommodate wind effects and visual effects animations



Key People



Shrikant Sharma - Associate Director

BEng MTech PhD CEng MIMechE

Shrikant leads SMART - Buro Happold's specialist modelling and analysis team that provides innovative solutions to complex engineering problems in the areas of advanced FE analysis, dynamics, blast modelling and crowd flow simulations.

He has developed innovative software tools such as SMART Move – a dynamic network simulation tool to model complex scenarios of people movement through a 3D network, and EventCounter – for crowd flow data collection and analysis.

Shrikant is actively engaged in the advancements in the crowd flow simulation through rigorous ongoing research and development. He is currently steering the development of Smart Cities – a multi-consortium project for intelligent design and management of urban scale crowd management.

Al Fisher – Senior Analyst

MEng, PhD



Al's research is in the field of numerical modelling and generation of complex geometries, with applications in the definition of arbitrary architectural geometries. As a structural engineer with this

background in computational design and analysis he has interests covering a range of specialist problems including form-finding, geometric rationalisation, optimisation, parametric design and non-linear structural analysis.

Since joining Buro Happold he has worked on developing a number of novel tools to generate rational structural geometries from arbitrary forms. Al is also developing software to model wind flow around surfaces of free form geometry. This shall have an immediate application in the wind loading analysis of tensile structures where complex doubly curved geometries are intrinsic to their design.



Rob Hart – Senior Analyst

MEng, PhD

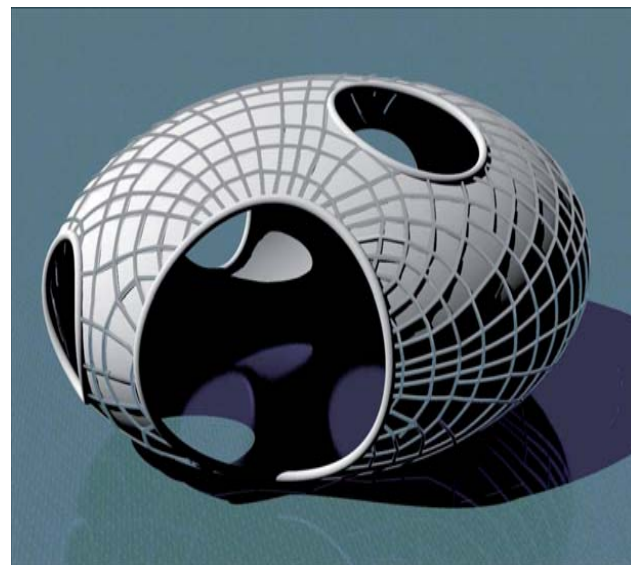
Rob is an engineer and analyst with a strong background in software development and modelling techniques. Having completed a PhD in 'Numerical Modelling of Tunnel Fires and Water Mist Suppression', he now

leads the Software Modelling Analysis and Research Technology (SMART) group for the London office.

He enjoys applying computerised methods to problems ranging from complex geometrical and structures to those of environment and finance.

Rob leads a team of developers working on a range of in-house packages including SMART Move, SMART Form and Tensyl, as well as numerous bespoke tools to meet project-specific needs.

Rob is experienced with many programming languages including C++, Visual Basic, Perl and Javascript and modelling techniques including Genetic Algorithms, Monte Carlo simulations, Finite Element and Finite Volume analysis and Dynamic Relaxation.



Panopticon, Earth Centre



David Williams – Senior Analyst

MA(Oxon) MSc DPhil

David is a member of Buro Happold's advanced analysis and simulation team - SMART (Software Modelling Analysis Research and Technologies). The team provides innovative

solutions to complex engineering problems in the areas of numerical analysis, dynamics, blast modelling and crowd flow simulation.

After his mathematics degree in Oxford in 1991, David completed a Masters in Nonlinear Mathematics at Bath University before returning to Oxford to study for a doctorate in Earthquake Seismology. His subsequent career in mathematical modelling has seen him apply his skills in a wide range of fields, including structural dynamics, stress, fatigue, fracture mechanics, fibre-optics and air-traffic control.

David has an ability to develop specialist software applications from first principles, as well as detailed knowledge of proprietary numerical analysis tools such as Matlab, Simulink and Mathematica. One of his particular strengths lies in finite element modelling, where he has developed complex models of aircraft components for static stress analysis in Patran/Nastran and for dynamic/impact analysis in LSDyna3D as well as detailed models of blast events in ANSYS Autodyn.



Sochi Stadium, Russia

Colin McKinnon – Innovations Director

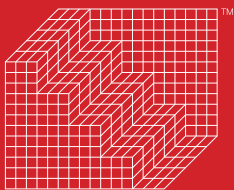
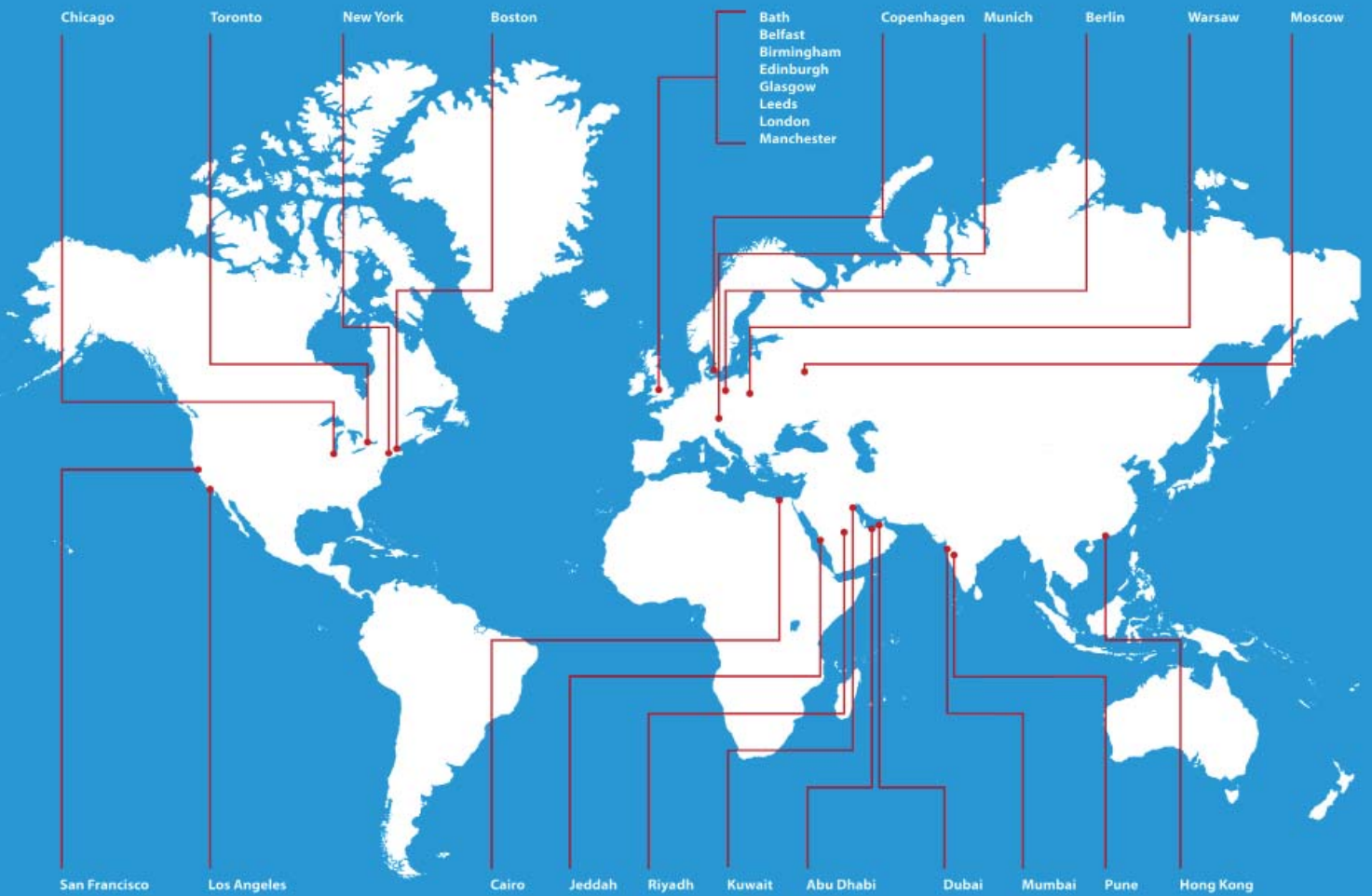
BA, MPhil

Colin sponsors, advises and helps co-ordinate Research, Development and Innovation (RDI) activities across the company. As well as initiating

new contacts and partnerships, RDI also advises on potential sources for funding, helps staff in exploiting new ideas, looks at the business cases for new services and manages our internal and external knowledge networks.

Colin's investment in innovation has led to the development of a suite of in-house software tools which helps Buro Happold better model the ever more complex scenarios faced by our clients. Examples are :

- SmartMove, an agent-based dynamic visual simulation tool that generates thousands of random scenarios to detect cross-flows and bottlenecks in crowd movement
- SmartForm, a complex geometry modelling software
- SmartCam, a CCTV camera placement optimisation software
- Vulcan, an integrated analysis tool for structural behaviour under fire.



Buro Happold

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