SMART Crowd Flow Solutions

Capability Statement 2012

Buro Happold

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About Buro Happold

Buro Happold is a world class multi-disciplinary engineering consultancy operating out of an international network of UK offices (Bath, London, Birmingham, Edinburgh, Glasgow, Leeds, Manchester), Europe, North America, Middle East and India. Founded in Bath in 1976 by the late Professor Sir 'Ted' Happold, Buro Happold is now a limited liability partnership, providing a comprehensive exemplary engineering consultancy for complete developments, buildings and their infrastructure.

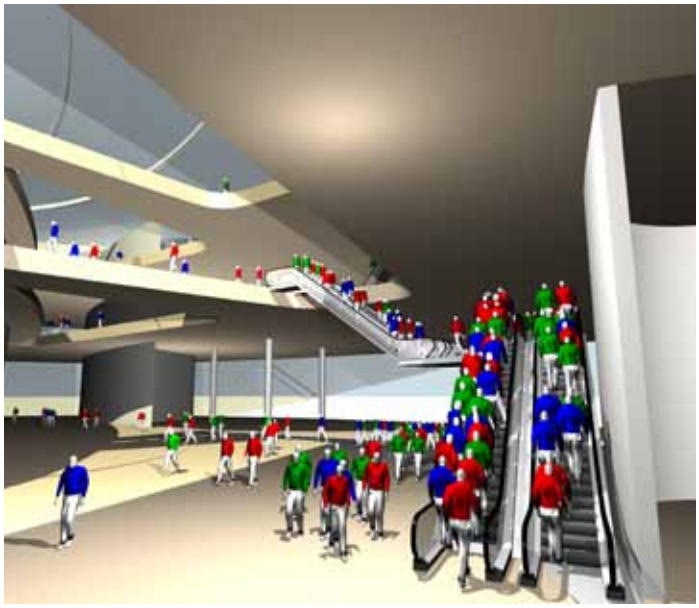
Our aim, on behalf of our clients, is to achieve maximum value in our engineering design. We provide design solutions that are elegant, easily constructed, responsible to the environment, efficient in their use of materials and energy and that deliver value for money. To achieve this, our design approach often has to be innovative in nature.

The best practice and innovative approach used is individually customised to the project requirements. Buro Happold expects its engineers to work to the highest level in all our design work in order to ensure the quality of output and to manage costs. We think imaginatively and inventively about construction and we make the design experience enjoyable. Our role, as engineers, is to listen, understand and advise. We believe our sharply focussed 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.

Our engineers work as members of design teams with architects and other professionals, providing either assistance in specific disciplines or the total engineering input. Our multi-disciplinary approach enables us to assist effectively across every stage of design, from the important early stages through to final implementation and subsequent operation and maintenance.

Together with our proven core service capability in structural, mechanical and electrical engineering, we offer specialist services including pedestrian planning, crowd management, fire engineering, accessibility, wind effects, security, transport, and environmental engineering.

SMART Crowd Flow Solutions is one of our key specialist disciplines backed by a world class team of professionals with an impressive portfolio and focus on innovation and delivery.



About SMART Crowd Flow Solutions

Buro Happold believes in designing built and urban spaces that put people at the heart of the design process: quality environments where people feel comfortable and secure, and which are convenient and accessible to everybody.

SMART Crowd Flow Solutions is Buro Happold's specialist circulation modelling consultancy service, helping architects, transport planners, airport planners, urban designers, regulators, developers, fire engineers and security advisors to understand and optimise space layout, design and management. It provides a modern approach to how buildings and urban spaces are designed and managed – from the user perspective – with a focus on comfortable, safe, and efficient environment for effective people movement.

Our key aim is to help develop a design that is vibrant, comfortable and safe, and works with the minimum of operational intervention.

We take into account potential social, cultural and community users to provide an inclusive environment suitable for diverse user groups. Where a single design solution cannot accommodate all users, our aim is to provide as much choice and flexibility as possible.

Our consultants are well practised in applying the principles of static and dynamic people movement modelling in a wide range of projects, from large-scale urban infrastructure schemes and transport systems to residential/office buildings, hotels, museum and exhibition spaces, retail malls and public buildings.

In collaboration with the client and the design team we will establish appropriate application of good practice standards, including guidance on policies, practices and procedures.

The resulting designs are therefore extensively tested with a minimised risk of undesirable and/or unsafe congestion. It is also usual to achieve cost savings through the optimisation of design.

Benefits include:

- Improving visitor experience
- Saving design costs through increased efficiency
- Saving operational costs through more effective and reduced management
- Optimising normal and emergency operations
- Maximising retail revenue and profit
- Improving accessibility

Our people movement consultants have significant experience in informing the design and management of a multitude of environments. Our expertise reflects a team of highly qualified professionals, who understand and regularly inform state-of-the-art applied research on crowd safety design, together with human behaviour in fire and emergency evacuation scenarios.

Apart from the rigorous experience in the applications of commercial modelling tools such as Legion, Vissim, Aimsun, etc. our team has to its credit sophisticated data capture tools such as EventCounter, and static network analysis tools such as SMART Network – used for conceptual design and analysis of spaces. The team has also developed a dynamic simulation tool SMART Move, which can model thousands of occupants circulating around and evacuating from the built environment. The software has an in-built design optimisation capability which allows us to explore multiple design options with ease.

Our team's extensive crowd flow design and management modelling and research has been successfully applied to:

- London 2012 Olympics Media Centre
- Millennium Dome
- St. Giles Urban Realm development
- Liverpool Kings Waterfront
- Lord's Cricket Ground
- Ascot Racecourse
- London City Airport
- Cairo Expo City
- Winspear Opera House, Dallas
- Barcelona Rail Terminals
- Jeddah Airport Hajj Terminal
- Sochi Stadium
- Birmingham International Airport
- Thomas Deacon Academy
- DY Patil University Mumbai

Our Approach to Crowd Flow Consultancy

We provide a holistic input to the design and management of buildings: influencing the architecture, building environment and thereby the visitor experience. Working with the relevant stakeholders and consultants, we offer an integrated solution that accounts for the distinct and often conflicting requirements of transport, pedestrian movements, fire evacuation and accessibility.

We have developed a thorough approach to designing buildings and urban spaces from the visitor perspective. Our methodology involves three key stages, tailored to suit specific project and client needs.

A. Desk study - Flow pattern prediction

In order to analyse flow patterns around a pedestrian space it is firstly essential to have a robust understanding of pedestrian behaviour in the specific environment. We have an extensive database of behavioural information for multiple building types and we continually supplement this with information gathered from the client team and also from field surveys, questionnaires etc. In addition we use the most appropriate techniques to gather flow data specific to the project so a thorough understanding of flow patterns is gained. This understanding helps us identify the critical scenarios for the project, forecast the likely 'demand' for each scenario and arrive at acceptance criteria for 'levels of service'.

B. Modelling - Performance analysis

The next step in the consultancy process is to map the demand levels and flow patterns for each identified scenario onto the proposed design and use appropriate modelling techniques to predict performance. These modelling techniques will be appropriate for the project in question, often including dynamic network modelling, fine grid modelling, and spreadsheet analysis. The modelling carried out is stochastic in nature and always includes appropriate sensitivity testing in order to fully understand the performance achieved by each building. The predictions made help the consultant understand where, and to what extent, there is over-design or a high risk of queuing/congestion. At this stage, further modelling is usually undertaken to determine multiple approaches to optimising the building and minimise risk.

C. Design and management optimisation

The final step in the consultancy process is to inform the design team of the analysis results and provide optimisation advice. Multiple solutions can be developed between the consultant and the design team and the design re-modelled to ensure appropriate/ optimal performance. Additional scenarios such as emergency evacuation are also covered at this stage.

Footfall map of an urban venue in Abu Dhabi.

A. Desk study
- Demand forecasting
- Scenario planning
- Data Capture surveys
- Flow patterns
- Performance targets

B. Modelling
- Flow pattern mapping
- Spatial network analysis
- Dynamic simulations
- Statistical analysis
- Flow visualisations

C. Optimisations
- Sensitivity study
- Design optimisation
- Management recommendations
- Evacuation & emergency advice
- Operational advice

Our Contributions Within the Design Process

Our consultants work as members of design teams with architects and other professionals, providing either assistance at one of two possible levels:

1. Short term one-off study at any stage of design
2. Ongoing consultancy during design developments

1. Short-term desk based study

This study involves a review of the proposals at any stage of the design, with a view to saving costs, improving performance and providing confidence in the design. It involves a desk study to review all inputs and design, highlight pinch points in the circulation spaces, establish worst case scenarios and macro-modelling to make recommendations.

2. Ongoing consultancy to support design developments at the following stages

Concept design: This stage includes a desk based study together with a detailed client briefing and data gathering exercise. The aim is to inform the architectural concepts and align them to key circulation strategies, while integrating with transport, fire and accessibility strategies. This minimises costs, reduces rework and ensures confidence in the design at an early stage. The work includes demand forecasting, data capture surveys, and use of high level flow diagrams and network modelling for illustrations of various scenarios.

Scheme design: Using the background work from the concept design, we perform detailed macro and micro modelling of the whole design with assessment of all key pinch points and circulation areas; for comfort and safety during all circulation scenarios. Using the available circulation design, management parameters and flow data, models are set up for the scenarios identified. Analysis will comprise of an appropriate combination of spreadsheet calculations, static network flow models, and dynamic simulation models. Continued support is provided through regular design workshops. Additional data surveys are carried out as necessary.

Detailed developments: We support the detailed design developments to ensure the final designs are thoroughly tested and optimised for best performance. Using network density maps and queuing times, we carry out a detailed sensitivity study to determine optimum design and management solutions. The key deliverables are the final optimised design, a summary report with drawings, sketches, management recommendations, and video animations of the functioning building in operation.

Subsequent support during construction, and liaison with operations and Post Occupation Evaluation is also available.

Arrival to Lord's Cricket Ground by London metro. Our consultancy extends from capturing the extent of current performance to predicting and optimising the future design and operations.

Winspear Opera House

Distinct Capabilities

Crowd Flow Modelling

Design and Planning for Emergencies

Spatial Network Analysis

Crowd Flow Surveys

Crowd Flow Modelling

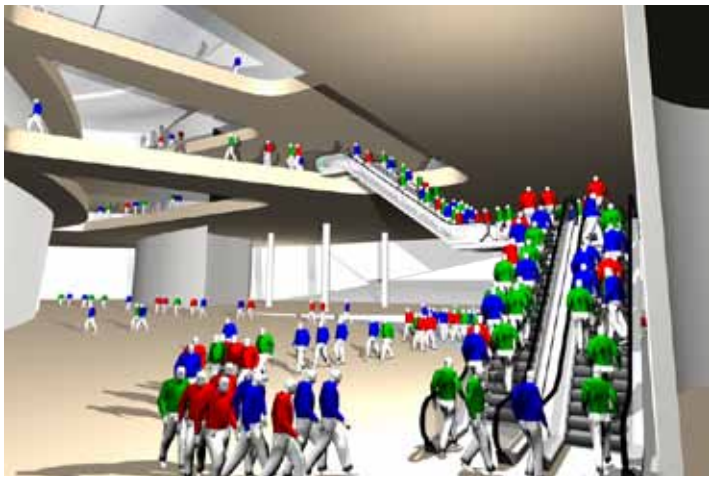
Crowd flow modelling is a powerful tool to predict, analyse, and visualise how a built or urban space will operate. It enables testing the impacts of designs in order to help our clients realise their desired intent. Through the forecasting of movement and activity patterns, pedestrian flow modelling informs design and management in order to optimise the use of built and urban spaces and enhance user experience.

We employ a wide range of spreadsheet based, network analysis, and dynamic simulation tools, covering a wide range from high level to detailed assessments.

Network modelling allows visual assessment of architectural design using pinch point assessments and mapping of travel distances, footfalls, density maps, mean flow rates, etc. It also provides a powerful sensitivity analysis tool for quick assessment of the circulation space without a need for detailed simulations.

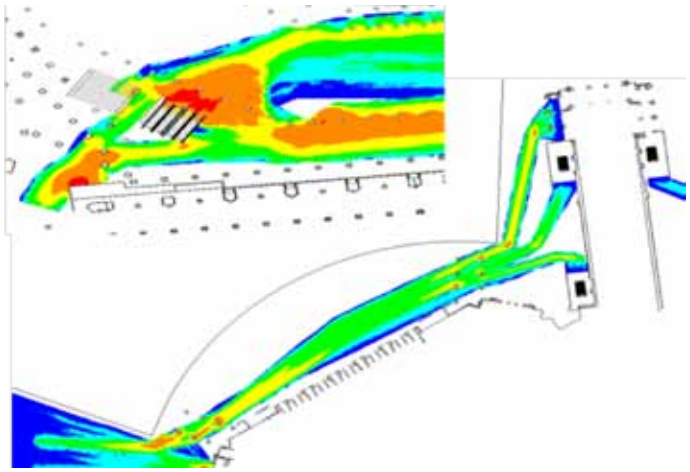
We are experts in the use of commercial simulation tools e.g. Legion and Exodus, and SMART Move – our in-house crowd flow modelling software. SMART Move's capability for rapid modelling of people movement is particularly valuable for early stage assessments and design optioneering. Legion is a sophisticated simulation tool for later stage validations of design against complex movement scenarios. Exodus is particularly suitable for the testing of design in emergency evacuation scenarios. SMART Move is additionally suited to model interactions with traffic (e.g. at transport terminals) and bags (e.g. in airports).

Our depth of modelling capabilities, fully integrated with modern data surveying/analysis techniques allow us to provide an efficient assessment of even the most complex flow network, such as those present around external urban spaces as well as within sports stadia, entertainment venues, educational establishments, mixed use facilities, etc.



Car park simulation in SMART Move - inter-modal people movement

Transport interchange simulation in SMART Move



Legion Modelling of the Holy Mosque in Makkah

Design and Planning for Emergencies

People flow analysis is a vital element in fire engineering design and emergency evacuation procedures. 3D computer models are used to predict crowd behaviour in emergencies and to design smooth evacuation procedures.

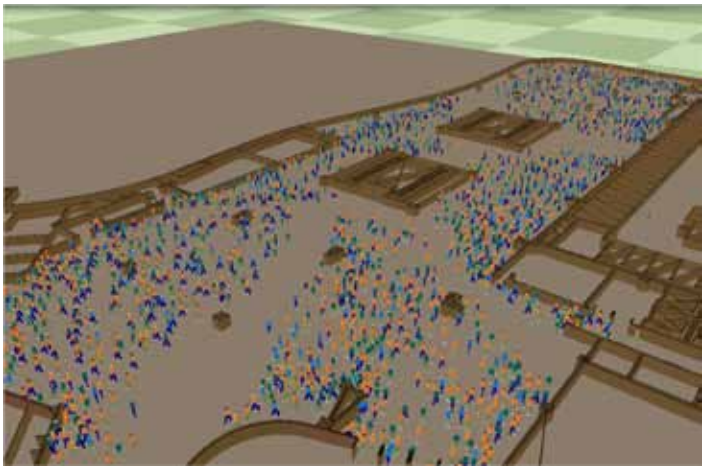
In line with Buro Happold's multi-disciplinary approach to consultancy, SMART Crowd Flow Solutions advise fire engineers, security planners, transport modellers and masterplanners, who rely on us for analysis of crowd flow in emergency conditions.

Design and planning for emergency is a logical extension to our people movement services. Taking the design proposals, occupancy levels, and any fire/security procedures in consideration, our team establish worst case scenarios for evacuation, accounting for:

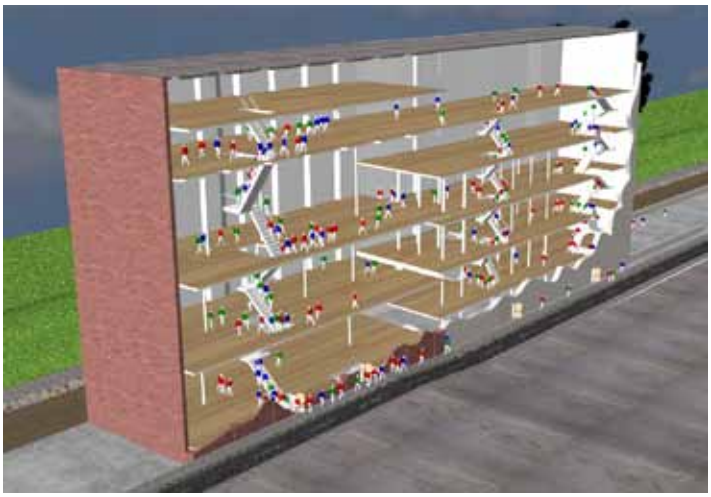
- Location of threats and areas affected
- Discounting of key exits and stairs
- Nearest/safest/assigned exits
- Human behaviour
- Emergency management procedures

Our solid project and research experience base enables us to provide next generation solutions that provide safe and secure solutions in the built environment. Risk assessment is a key aspect of our emergency evacuation consultancy services. Using our in-house software SMART Move's statistical modelling and sensitivity analysis capability we are able to assess a range of scenarios and associated threats. SMART Move has rapid turnaround times, it can therefore do rapid sensitivity analysis with regard to the effects of particular links in the network, widths of links, deference behaviour, number of service desks, security desks, etc.

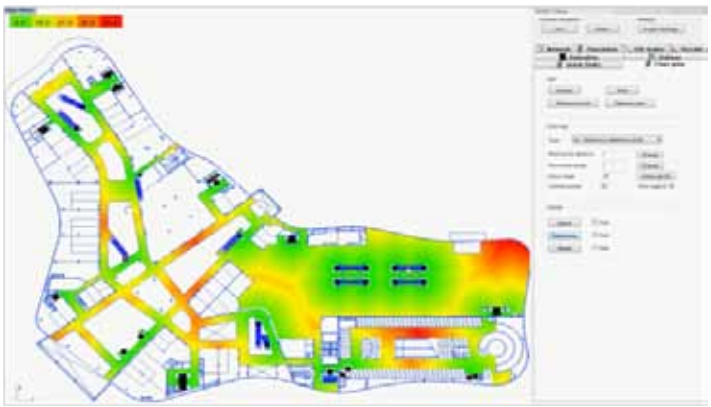
Our applied research on crowd safety design and management; human behaviour in fire and emergency evacuation; modelling of people movement and multi-modal flow at transportation nodes has contributed to the designs of many successfully completed projects.



Evacuation of a large retail mall



Office building evacuation simulation



Travel distance mapping tool for evacuation

Spatial Network Analysis

Our sophisticated data modelling capability is coupled with a network modelling approach to analyse flow between nodes. We combine the two effects together using graph-theory based analysis that provides quick assessment of the circulation space without a need for detailed simulations.

SMART Network is Buro Happold's indigenous software based on our novel technique that integrates the graph-theory based network analysis with an origin-destination matrix model. The model analyses space based on connectivity of nodes, superimposed with the origin-destination matrix of population to provide valuable information such as footfalls, density maps, as well as quasi-static parameters such as mean flow rates.

For each of the design proposals considered, various scenarios can be assessed that enable optimisation of the circulation and pedestrian walkways in and around the ground. These include ingress, egress, and emergency movements.

SMART Network is fully integrated with the 3D CAD package such as Rhino, thereby allowing rapid testing of architectural models for various space-synatax based performance criteria such as:

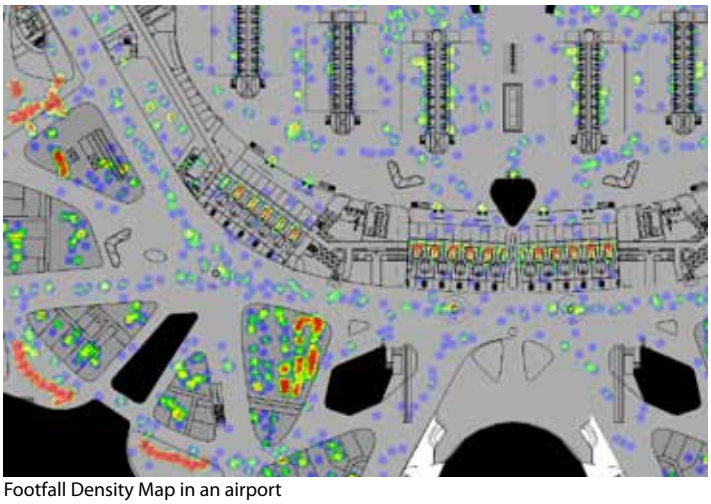
- Connectivity
- Spatial integration
- Visibility
- Footfalls

The spatial network analysis capability, integrated with 3D CAD modelling packages, makes SMART Network a powerful design tool. Using this capability we have been able to optimise the design of the whole spatial network of Thomas Deacon Academy, as well as synthesize the whole shape of a bridge in Dubai (picking the least effort combination in the space, sing continuous ramps and avoiding the need for steps).

SMART Network is fully scalable, making it effective for analysis of multi-modal movements at urban scales.

Copenhagen - Footfall Map

Density map in Makkah pedestrian corridor



Footfall Density Map in an airport

Crowd Flow Surveys

Crowd flow assessments help the architects, planners, and operational managers to answer two very fundamental questions about the design of routes and spaces:
1. How do people move through pedestrian routes and spaces?
2. How can we design spaces and walkways to optimise the use of space and enhance user experience?

The answers are obtained by capturing, analysing, and modelling crowd behaviour and movement patterns, and then mapping the conclusions onto the spatial layout, so as to optimise design and management strategies.

SMART Crowd Flow Solutions uses powerful data capturing and analysis methodology for the understanding of population behaviours and movement patterns. We have developed SMART Counter software that allows rapid analysis of video data to generate statistical information on walking speeds, queuing behaviour, service times, limiting flow rates, etc.
Our state of the art software Blue Counter can track movements using Bluetooth technology and can perform the most challenging task of automatically capturing dwell times and overall journey times.

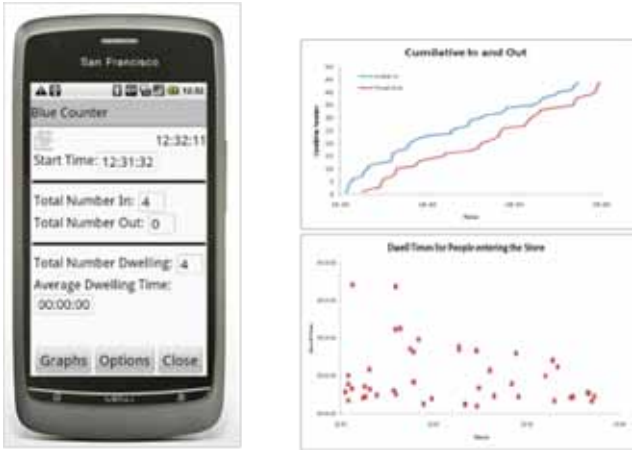
There are several methods and techniques for capturing, analysing and presenting complex people movement patterns for large rail/airport terminals, stadium, and entertainment and shopping venues. The following are some of the techniques available, one needs to pick the most appropriate based on the purpose and their features and limitations:
- Automated capture of dwell times using bluetooth
- Automated capture of flow rates from video
- Semi-Automatic video based data capture
- Break-beam gate counters
- RFID tagging & people tracking
- Manual head counting

Our sophisticated data modelling capability is coupled with a network modelling approach to map the observed flow to visually represent flow volumes and densities.

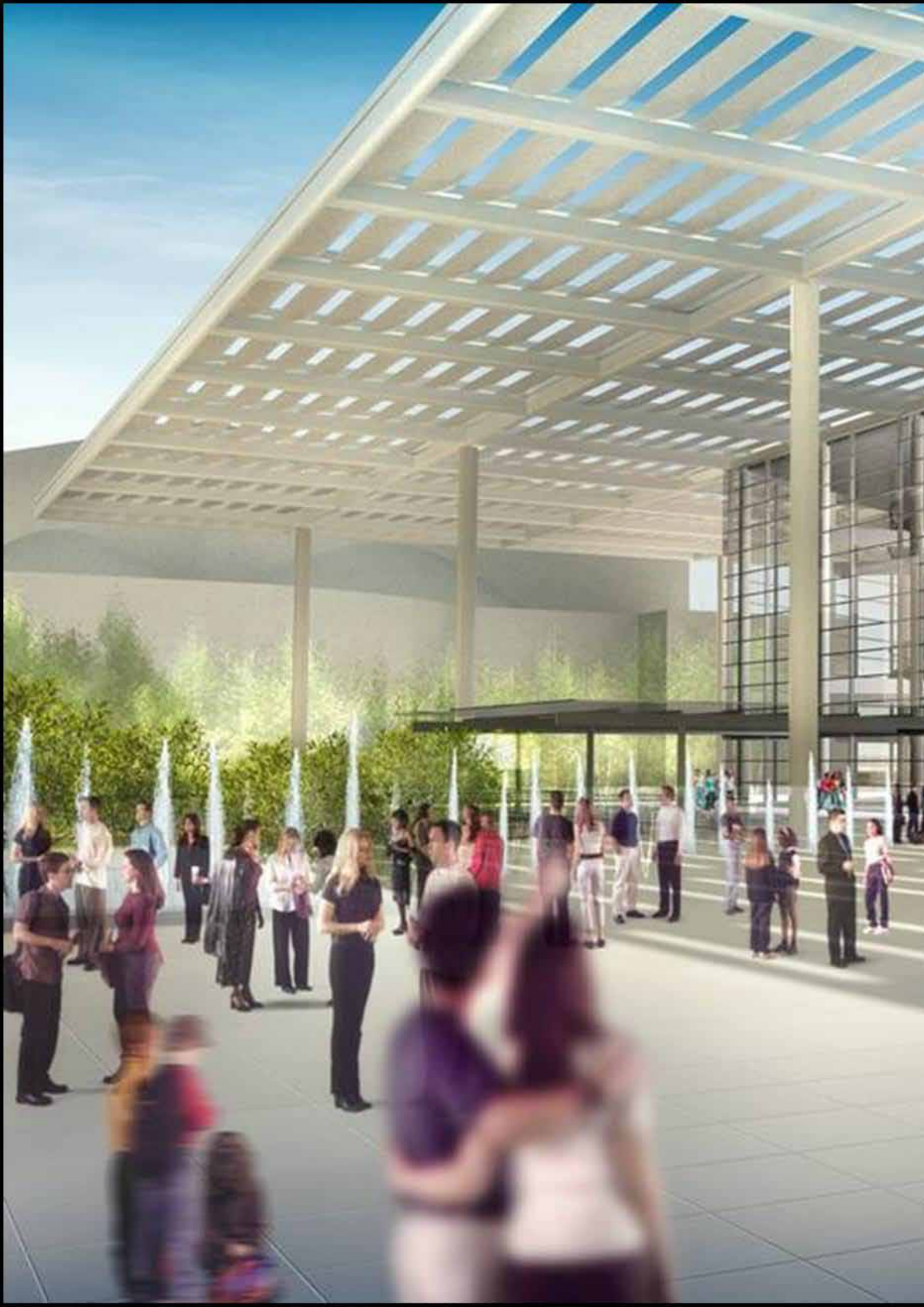
We have wide experience in conducting video and non-video based surveys across a number of venues, including urban/masterplanning sites, offices, retails, education buildings and rail/airport terminals.

Rail terminal survey – London City Airport

SMART Counter - automated video analysis



Blue Counter - a mobile app for automated capture of dwell time data



Sector Experience

Urban and Masterplanning

Aviation

Rail

Sports

Cultural and Civic

Education

Retail

Urban design and masterplanning

Optimising urban design for comfort and safety

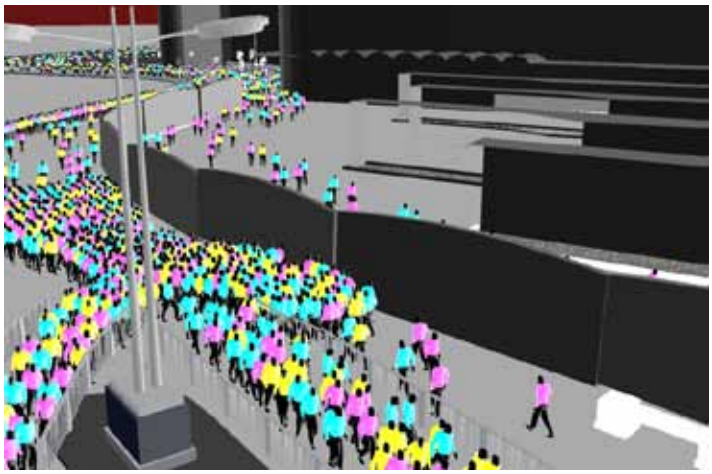
Urban planners often ponder over the ways in which people will move through their designs, interact with the environment and with each other, and utilise the spaces provided. Our People Movement Consultants enable a better understanding of the impacts of designs. Through the forecasting of movement and activity patterns, tailored to the specific use, pedestrian flow modelling informs design and management in order to optimise the use of urban spaces and enhance user experience.

Combined with effective utilisation of pedestrian and vehicular desire lines, a strategy to encourage footfall through the new developments can be formulated. The approach greatly aids the provision of adequate counter measures to deterring factors such as distance, access, fear of crime, wayfinding and signage. In addition, it allows us to optimise the placement of activities – for example, placing retail in areas where the most footfall is expected; identifying appropriate spaces to locate other social activities; etc. Such analytical foresight makes people movement consultancy a powerful tool in all stages of design, and a valuable resource when dealing with client meetings and public consultations.

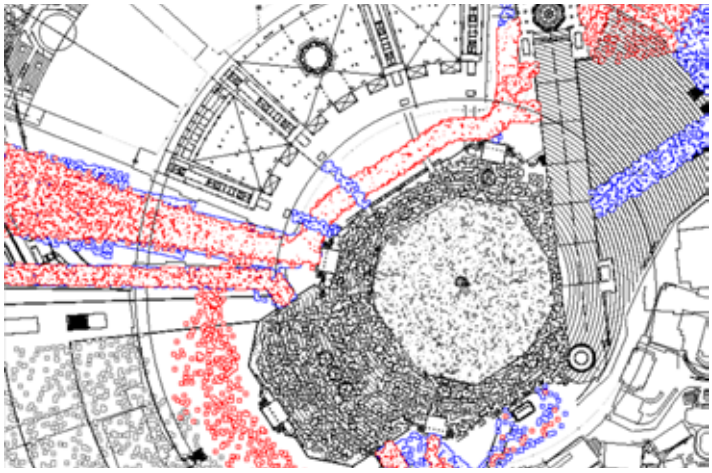
We can also help clients better understand existing activity patterns and/or visitor preference, useful insights to optimise management strategies and inform on possible building improvements. Our portfolio spans many prestigious projects, including masterplanning, sports, airports, museums, and the education sector. In each case, our aim is to enable more user-oriented, comfortable designs, entailing both commercial benefits and good reputation for our clients.

Accurate modelling provides a basis from which to assess potential risks and implement counter measures to negative factors such as poor access, fear of crime, inadequate parking facilities and lack of signage. Because people are fundamental to the creation of vibrant public spaces, pedestrian monitoring can be used to evaluate whether urban masterplans achieve the aims of sustainability and inclusive access.

Cultural quarter in Abu Dhabi



Cardiff city centre after match day



Flow around Holy Mosque in Makkah

Buro Happold

Airport design and passenger flow simulation

Enhancing visitor experience

The efficient processing of passengers and baggage is crucial for airline and airport operators alike. This process affects the operation, security and punctuality of airport and airline operations where turnaround times are key.

Buro Happold has the ability to develop solutions for the smallest and least complex operations through to international hubs. Our experts have extensive experience drawn from their roles as airport and airline clients, consultants, systems integrators/manufacturers and contractors.

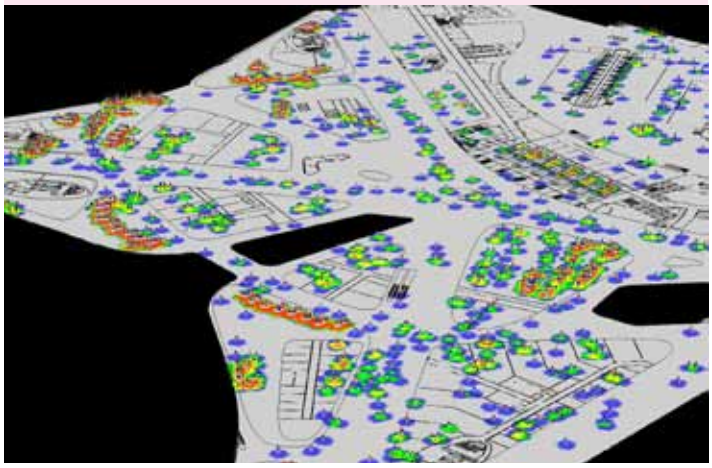
We assess and model the whole airport planning, passenger flow modelling, and baggage handling process and its interdependencies with the handling of the passenger and aircraft movements to ensure the right design and management solutions are developed. Our passenger flow modelling capability has been effectively used on several projects including London City Airport, Birmingham International Airport, Baku International Airport, Beijing Airport, King Abdullah International Airport Hajj Terminal, and Glasgow Prestwick Airport with respect to terminal redevelopment projects.

With a focus on improving passenger experience, our studies can look at all aspects of airside and landside airport design, including master planning, check-in provisions, security, immigration, baggage reclaim, retail, walkways and stair/escalator/lift requirements, ticket barriers, security X-ray units, ticket machines, multi-modal transport links, etc. Design decisions are driven by multiple what-if scenarios and sensitivity analyses against various design, operational, and population parameters.

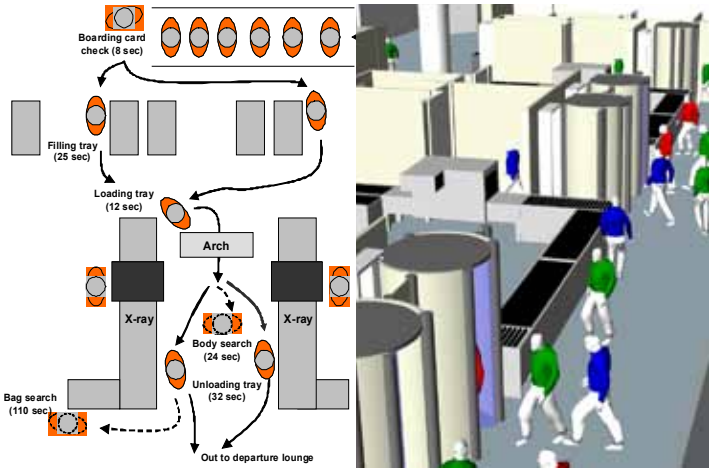
We work closely with the architects, terminal developers, and security advisers. Our capability for integrated passengers, baggage and traffic flow modelling has been particularly valuable on several projects.

We have also been working with the UK Border Agency and London City Airport on evaluating the impact of joint immigration and customs controls on passenger processing and waiting times.

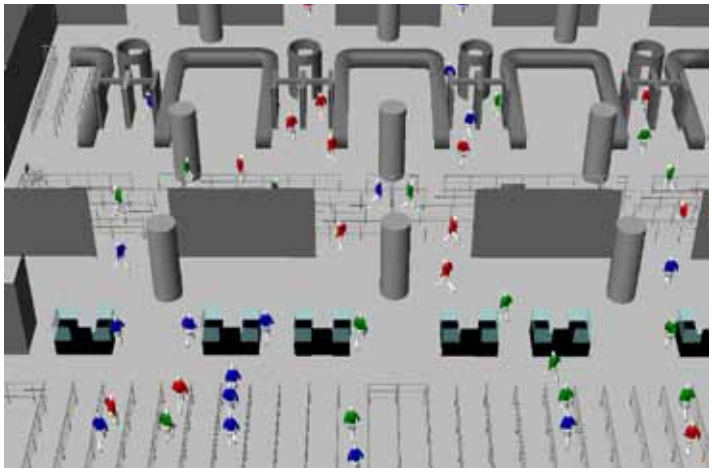
Our depth of experience means we can provide extremely quick but thorough one-off assessments on an existing design, and also ongoing support from concept to detail design stages and beyond.



A major airport in China



Birmingham International Aiport - Mircro-modelling of flow through security



Baku International Airport

Rail terminal design for passenger flow
Enhancing visitor experience

Historically the rail transport infrastructure design has been led by aesthetics and prescriptive regulations. This can pose problems in passenger intensive operations, where space is premium and terminal performance and passenger comfort are major issues. Efficient processing of passengers affects the operation, security and punctuality of terminal operations where turnaround times are key.

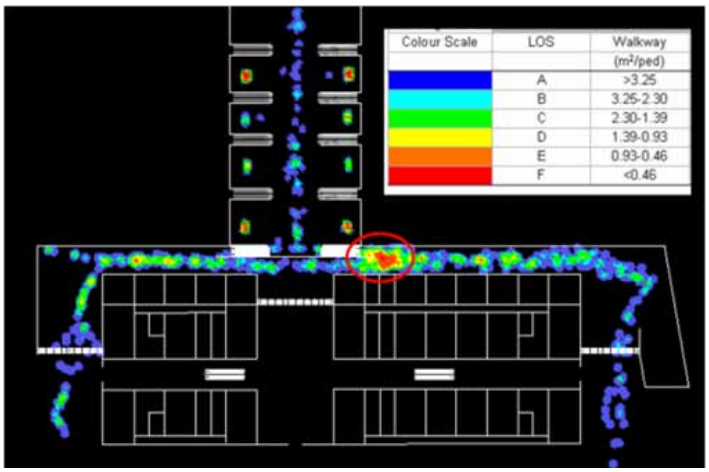
Our crowd flow consultants have the ability to develop optimised design solutions for the smallest and least complex operations through to international hubs. With a focus on improving passenger experience, our study can look at all aspects of stations design, including platform width, stairs/escalator/lift requirements, ticket barriers, security X-ray units, ticket machines, multi-modal transport links, etc. Design decisions are driven by several what-if scenarios and sensitivity analysis against various design, operational, and population parameters.

Our team's major expertise in rail terminal design is derived from over ten years of research including a multi-consortium research project focussing on detailed analysis and modelling of passenger movements at train stations.

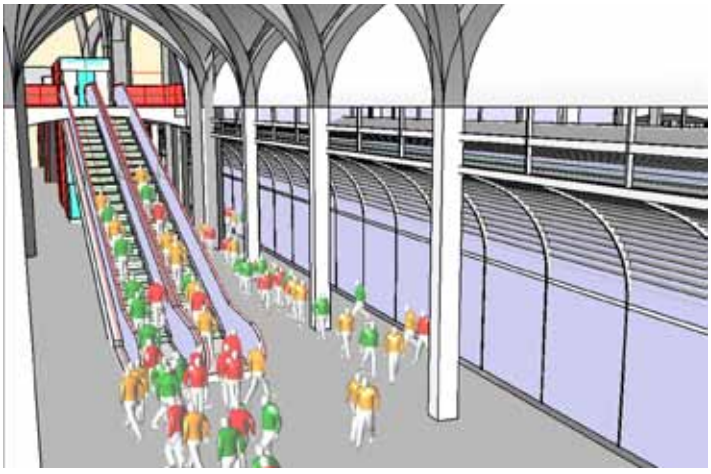
We work closely with the architects, terminal developers, and security advisers on micro as well as macro assessments of design for passenger movements.

Advanced simulation tools such as Legion, Exodus and our in-house tool SMART Move help us assess the functioning of transport hubs in diverse critical scenarios e.g. embarkation, disembarkation, waiting, shopping, transiting to onward transport modes, and emergency evacuation. Testing of the design against real-world scenarios helps optimise the design by maximising throughput with available space and appropriate management. SMART Move's capability for rapid modelling of passenger flow is particularly valuable for early stage assessment and design optioneering. Legion is a sophisticated simulation tool for later stage validations of design against complex movement scenarios. Exodus is particularly suited to the testing of design in emergency evacuation scenarios.

Haramain Makkah-Madina High Speed Rail



Kurskiy Station, Moscow



Platform arrivals modelling

Buro Happold

Sports Stadium Design

For smoother, safer crowd movement

Design for efficient and effective crowd flow at sports venues is crucial to the experience of the spectators and also to revenues and profit.

SMART Crowd Flow Solutions, Buro Happold's specialist circulation consultancy team, has expertise in all areas of stadia circulation design: covering demand forecasts, capacity planning, circulation design, and operational planning of the venue. We help architects, developers and clients during all stages of a project to design and manage sports venues.

The benefits of our services are:

- Saving design costs through efficient circulation optimisation
- Saving operational costs through effective management
- Improving visitor experience
- Optimising normal and emergency operations
- Maximising revenue and profit
- Improving accessibility

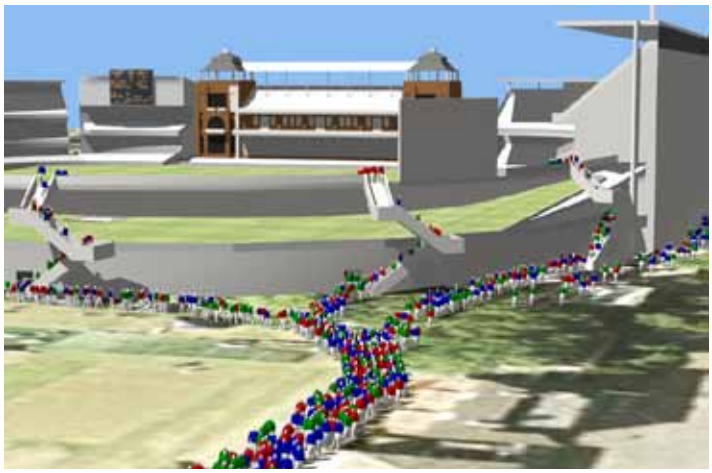
Using sophisticated commercial and in-house modelling tools we have developed a modern approach to how sports venues are designed and managed – from the spectator's perspective – with a focus on comfortable, safe, and efficient environment for effective crowd flow. The resulting designs are therefore extensively tested with a minimised risk of undesirable and/or unsafe congestion. It is also usual to achieve cost savings through the optimisation of design. Our work also enables planning approval and promotion using high quality visualisations of crowd flow.

Our depth of experience means we can provide extremely quick but thorough one-off assessments on an existing design, and also ongoing support on projects from concept to detail design and post-occupancy evaluation.

Our range of experience includes Ascot racecourse, Lords stadium masterplanning, London 2012 Olympics Media Centre, Sochi Winter Olympics, and Abu Dhabi National Stadium.

New Stadium, Abu Dhabi

Ascot Racecourse Redevelopment



Lords Cricket Ground

People Movement in Cultural Venues
Enhancing visitor experience

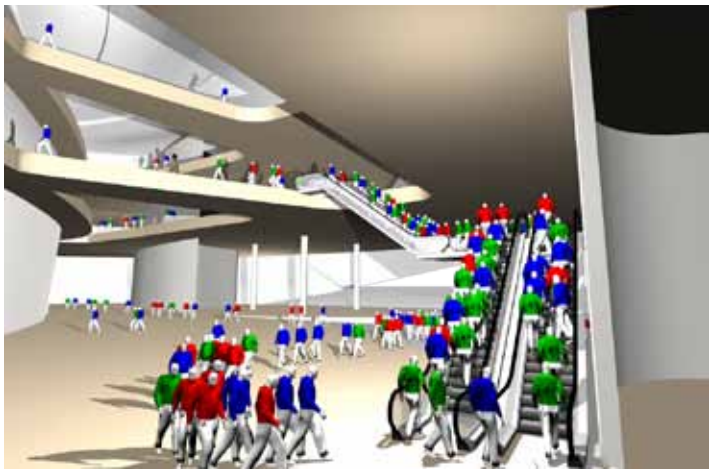
Buro Happold believes in designing buildings and spaces that put people at the heart of the design process: quality environments where people feel comfortable and secure, and which are convenient and accessible to everybody. The result is an efficient and effective circulation space that is crucial to the experience of the visitors and also to revenues and profit.

Working closely with architects, we devise elegant and economical solutions that meet the needs of visitors while providing best value for our clients. Our local, national and international projects range from exciting new arts centres, galleries, libraries and theatres to the refurbishment of existing and historic cultural buildings.

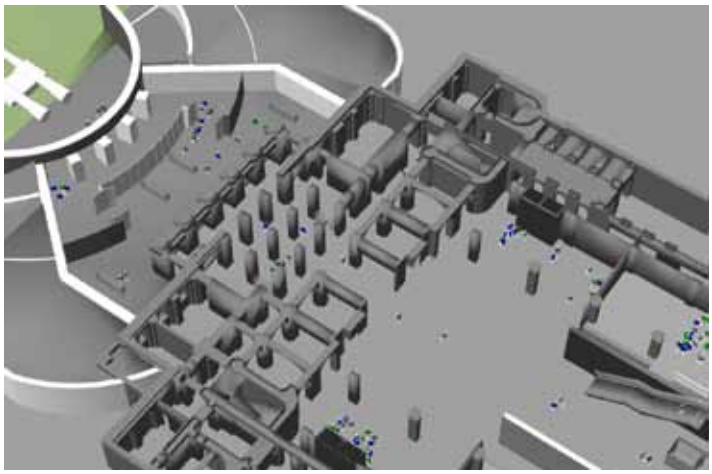
Our key aim in the design of cultural venues is to help develop a design that is vibrant, comfortable and safe and works with the minimum of operational intervention. It will also help ensure that flexibility in operation can be planned and designed in. To deliver the most efficient design we utilise a number of our specialist technical services. Data produced by our people flow, disability design and security teams is fed back into the overall design to optimise circulation and create a safe, controlled environment for all visitors.

Using latest people movement simulation technologies our work focuses upon checking and informing the circulation provisions in the venue (layout, circulation widths, stairs/escalators, door locations/widths, mobility assistance, toilet provisions/locations, etc) in relation to crowding levels, queuing and comfort. We take into account potential social, cultural and community users to provide an environment suitable for diverse user groups.

Our range of experience in the cultural sector includes Imperial War Museum London, Cairo Expo City, Kings Waterfront Liverpool, Hotel America, Dubai, and a major cultural district development in Abu Dhabi.



Expo City convention centre, Cairo, Egypt



Imperial War Museum, London, UK

Winspear Opera House

Design of schools for efficient circulation
Enhancing the learning environment

Learning environment in school and colleges has a direct influence on the performance of the students. Efficient layout and congestion-free circulation design, integrated with lighting and environment control has a major influence on the learning environment. Circulation modelling enables the design team to identify potential problems in terms of space provision and saves cost by optimising the design for comfort, safety and management.

Buro Happold's people movement consultants have extensive experience in the analysis and modelling of pupil movement within new-build and renovated school and educational buildings. By forecasting activity patterns and flow rates, our consultants can optimise the provision of routes, entrances, exits and stairways to improve ease of circulation and reduce congestion - all of which enhance the performance of the school in the long term.

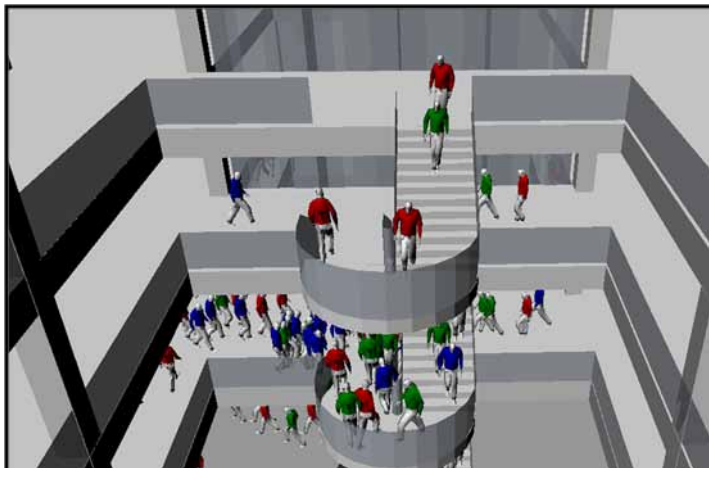
By considering how pupils move through the building and utilise the spaces provided, our simulations enable the design team to assess the consequences of a proposed layout for safe pupil circulation under routine and emergency evacuation conditions. We work closely with the developers, architects and the schools management bodies to enable assessments that account for factors such as architectural design, operational strategies, resource provision, structural and service design and security.

Our depth of experience means we can provide extremely quick but thorough one-off assessments on an existing design, and also ongoing support on projects from concept to detail design and post-occupancy evaluation. Our state-or-the-art simulation tool SMART Move enables us to assess and optimise a number of design options under different scenarios.

Our range of experience includes Thomas Deacon Academy, Corby Academy, Essex BSF, Luton BSF, Thomas Clarkson Community College, Exeter University, MMU Business School, London School of Economics and DY Patil Management School Navi Mumbai. Our people movement consultancy on the Thomas Deacon Academy fed back the following comment from Foster+Partners: "Buro Happold's people movement consultancy has been very good...most innovative".

Thomas Deacon Academy - Peterborough

Data capture for stair congestion



Manchester Metro Uni Business School

Retail design
Enhancing visitor experience and footfalls

The physical design of the retail space has an enormous influence on the mood and behaviour of shoppers. The decision to buy or not to buy is affected by the spatial layout, quality, and ambience of the environment. Design for efficient and effective circulation space is crucial to the experience of the shoppers and also to revenues and profit.

In a large retail complex the success is often in the detail. Easy navigation through the centre, strategically placed rest and eating areas and interactive information points are all conducive to extended shopping. By carefully monitoring people flow and dwell times we can show how design changes can affect footfall and shopping patterns.

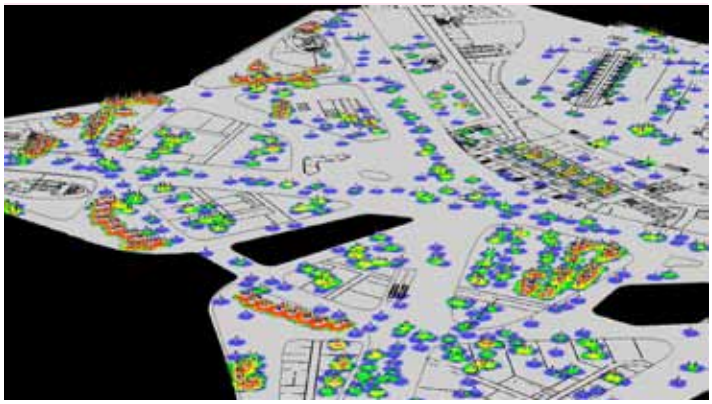
Our people movement consultancy focuses on an integrated approach to optimising the circulation space, working closely with the architects and linking with a number of related disciplines such as natural and artificial lighting, landscaping and acoustics. We integrate our assessments with the infrastructure and transport planning to ensure shoppers can park easily and have a good first impression on arrival. Departure should be equally smooth, with clear directions and collection points.

Optimised space layout with adequate management can:

- Increase footfall
- Ease wayfinding
- Maximise retail revenues
- Facilitate safe movement
- Meet the requirements of busy and quiet areas, night and day
- Minimise the need for management (reduce running costs)
- Enable value engineering

Using latest people movement simulation technologies our work focuses upon informing the circulation layout and provisions in the venue (layout, circulation widths, stairs/escalators, door locations/widths, mobility assistance, toilet provisions/locations, etc) in relation to footfalls, queuing and comfort. We take into account potential social, cultural and community users to provide an environment suitable for diverse user groups.


Retail Mall, Zibo


Airport retail footfall density map


Cultural quarter in Abu Dhabi


Food Court at Lords Cricket Ground


TOSHIBA
TDK
KODAK

Project Experience

Urban and Masterplanning
Makkah Region Pedestrian Corridor Masterplanning
St Giles Circus, London
King's Waterfront, Liverpool
Makkah Khandama Masterplanning, Makkah
Two Iconic Structures, Dubai, UAE
SM Retail, Zibo, Shandong, PRC

Aviation and Rail Sector
Kurskiy Interchange Moscow Redevelopment, Russia
London City Airport
King Abdullah International Airport, Saudi Arabia
Birmingham International Airport
Al Haramain High Speed Rail, Saudi Arabia
AVATARS, EU Project on Rail Terminal Modelling

Sports Sector
Ascot Racecourse Redevelopment, Berkshire
Lord's Cricket Ground, London
The New Stadium, Abu Dhabi, UAE
Central Olympic Stadium, Sochi, Russia
Media Hub, London

Cultural and Civic
Maghrabi and Diyafah Hotels, Saudi Arabia
Imperial War Museum - Spatial Masterplan, London
Expo City Cairo, Egypt
Winspear Opera House, Dallas, USA
Hotel America, Dubai, UAE

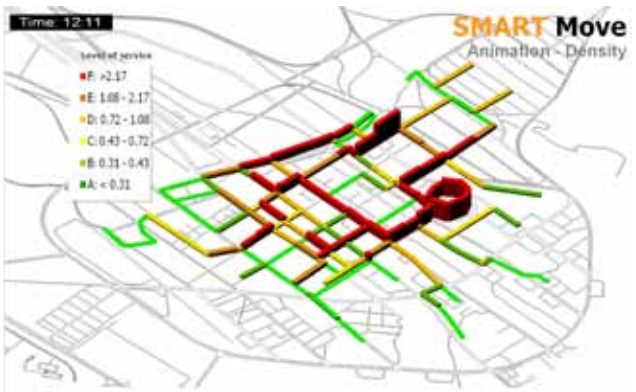
Education Sector
D. Y. Patil University, Navi Mumbai, India
University of Exeter
Thomas Deacon Academy, Peterborough
Manchester Metropolitan University
Thomas Clarkson College, Cambridgeshire
Ealing Schools PFI, London
Camden BSF Swiss Cottage Lift

Makkah Region Pedestrian Corridor Masterplanning
Makkah, Saudi Arabia

The Hajj pilgrimage is one of the biggest gatherings on earth, with very significant numbers every year that continue to increase: safety and comfort is crucial to make sure that visitor's time during Hajj and Umrah is comfortable and safe during this unique spiritual experience.

Details of this project are confidential. The broad remit of the study was to assist the authorities in improving the design and management of the 20km long pedestrian corridor (Masha'er) in and around the city of Makkah, to enhance the experience of the pilgrims. Buro Happold's crowd flow consultancy team's role was to assist the architects Gensler by providing design development and appraisal advice with respect to pedestrian movement, capacity, comfort and safety.

Working closely with the teams at Gensler and Booz Allen Hamilton, we provided high level as well as detailed input to optimise the route layouts, bridges, corridors, as well as the operational management and control of the crowd. Our work informed the high level strategies and design as well as rigorously tested and optimised the detailed solutions.



The real challenge on the project was How to model 5 millions+ pilgrims? We chose a combination of tools the team had to their armory:

1 Demand model – to perform rapid assessment of demands and flows within various "zones" in the network.

2 Novel network simulation tool (SMART Move) – The inter-zone flow data from the demand model was converted into network path assignment model. This enabled rapid testing of detailed pedestrian networks with different design options and flow scenarios.

3 Microsimulation of hot spots – used sparingly, microsimulation was utilized in testing the detailed interaction at hot-spots.

The choice of modelling tools combination above enabled us to perform sensitivity assessments for optioneering and optimization of the design as well as management conditions.

Key project information

Client	Ministry of Higher Education, Saudi Arabia
Architect	Gensler

Services provided by Buro Happold

Crowd flow modelling, transportation, sustainability.

St Giles Circus
London, UK

St Giles Circus (also known as Denmark Place) is a large mixed-use development/refurbishment site within the Central London area. The project constitutes an iconic building arrangement organised around a public space. The key strengths of the site are:

- Its highly accessible Central London location, close to Tottenham Court Road Underground Station.
- Denmark Street, which has become renowned as a home of the UK popular music industry.
- The rich and diverse collection of listed buildings.

Initial feedback from London Borough of Camden on the proposed masterplan indicated that the circulation arrangements for the site are a key concern, particularly given the close proximity of the Southern entrance/ exit of the Tottenham Court Road Underground Station. Tottenham Court Road will be a Crossrail station in 2016 as well as continuing to serve the Northern and Central Lines.

Buro Happold's crowd modelling team has been appointed to assist the design team by mitigating the council's concerns and to inform the design process.

Circulation and pedestrian flow input is an integral part of the design process, particularly in a heavily populated area with multiple connections and diverse user requirements. The objective of the pedestrian movement analysis is to:

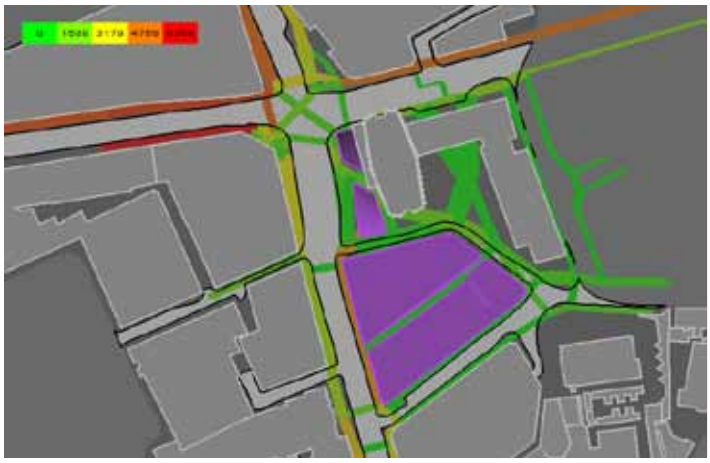
- Identify 'eyeball' expectations to determine likely (advertisement) revenue
- Use network modelling and currently available data to understand:
  - Existing level of congestion (capacity assessment
  - Impact of the proposed development
- Support design development to minimise impact of the project on surrounding crowd movements, addressing the concerns of the local council.

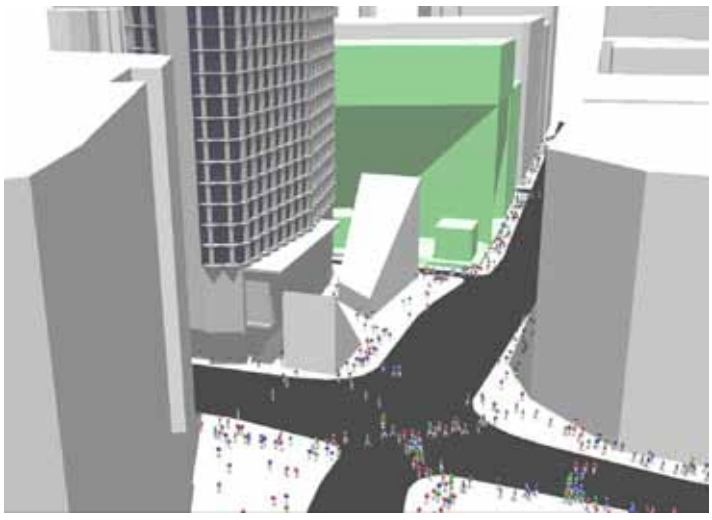
Key project information

Client	Consolidated Developments
Architect	ORMS
Dates	Ongoing

Services provided by Buro Happold

Crowd flow consultancy





King's Waterfront
Liverpool, UK

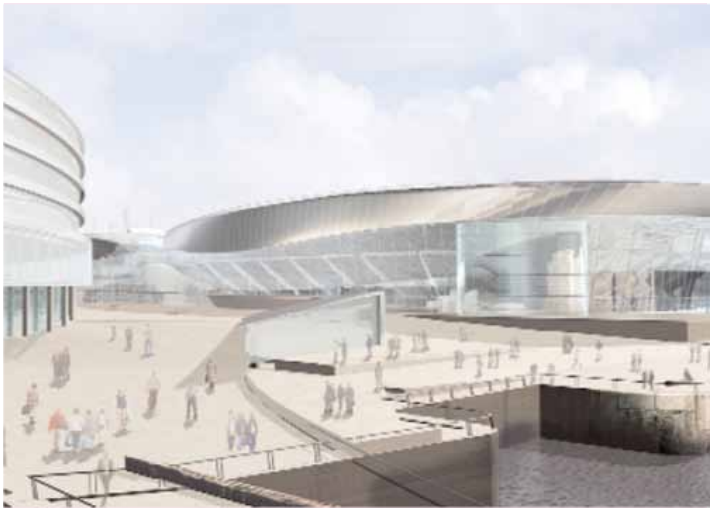
The development provides a 10,000 seat arena, while the convention centre adds a 1,350 seat auditorium, multi-purpose hall and exhibition space. With the ability to accommodate events from concerts to ice shows and sporting events, the facilities have been designed to be extremely flexible.

The form of the arena and seating bowl are presented as a horseshoe, configured around the footprint of the 30m x 60m ice floor. Its open end allows good access at arena floor level through to the hall, allowing for shared exhibitions between the two spaces.

Our crowd flow consultancy included modelling of pedestrian usage scenarios for the Kings Waterfront development site. After outlining the parameters and critical assumptions, two worst case scenarios of pedestrian usage of the site were modelled and visualisations produced.

The background data used in this study was taken from the Transport Assessment. From this we gained information on such as tram operations on the site, together with the likely modal split associated with the arena visitors; proportion of visitors using a tram, taxi, bus, car, walking modes of transport. Additional data was also gathered from a survey at the 10,000-seat Sheffield Arena and discussions with stakeholders.

A report was produced that presented a detailed account of the crowd level around the area and the impact of the development on the site. The analysis also informed the bridge width required across the docks and the circulation provisions around the arena; stair locations and widths, walkways, free space for statues in the piazza.



Key project information

Client	Liverpool City Council
Architect	Wilkinson Eyre Architects
Dates	Completed 2008

Services provided by Buro Happold

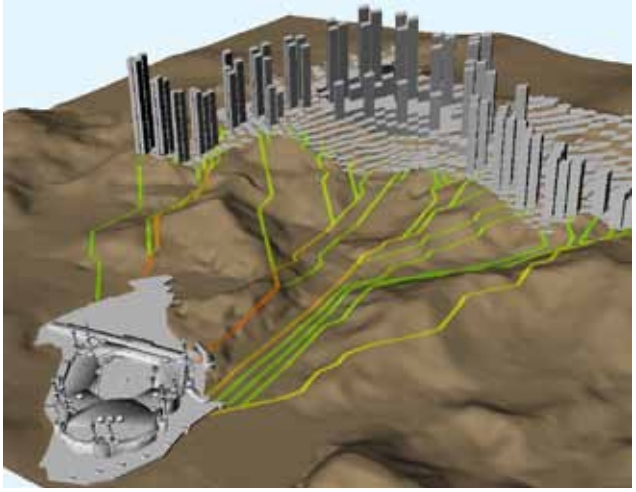
Crowd flow consultancy.

Makkah Khandama Masterplanning
Makkah

Mount Khandamah area is considered one of the most rugged mountain areas of Makkah. Some peaks reach the level of 615 meters above the sea and the goal of this project is to develop this area despite the constraints represented by the arduous rugged land and make it the urban frame connecting the Holy Mosque and the Mina Areas. The development will consist of mixed use land including residential, commercial, facilities, hospitality, etc.

The ultimate goal remains to develop and structure urban growth and achieve a sustainable conversion of this natural area within the urban connective structure of the Makkah city. The total study area is about 91 Hectares.

The aim of our pedestrian movement study on the project is to inform the circulation routes design to create an urban development area perfectly integrated in the Makkah urban fabric. One of the biggest challenges is to ensure 20 minute travel time for x100k Hajj pilgrims from the site to the Holy Mosque for prayers.

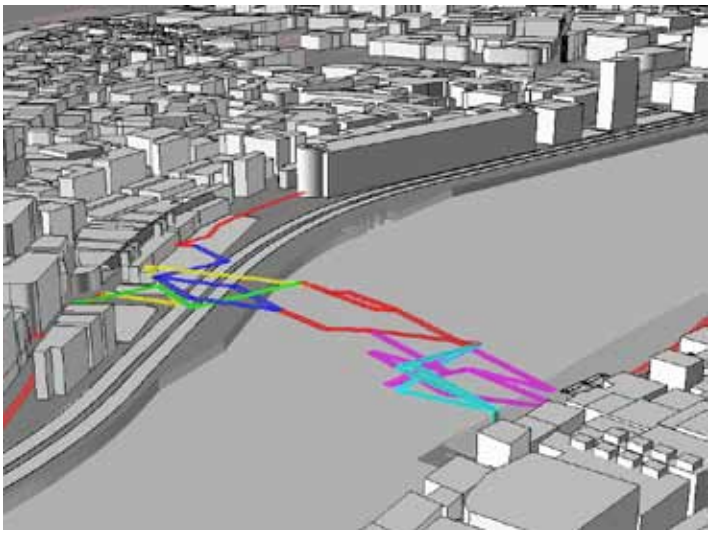


Two Iconic Structures Across Dubai Creek
Dubai, United Arab Emirates

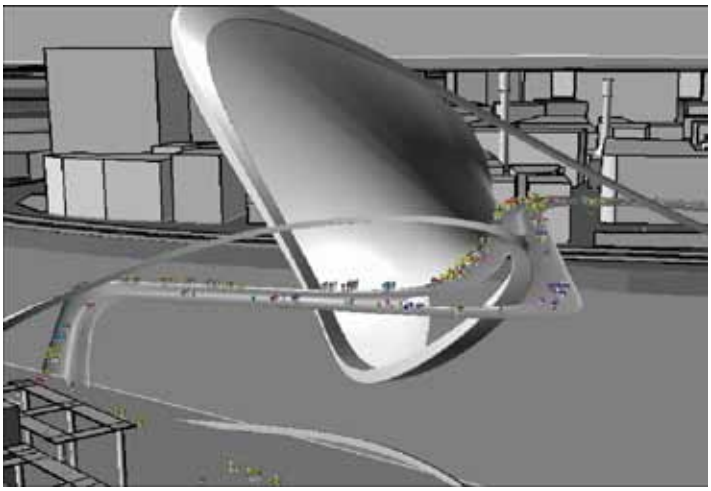
Zaha Hadid Architects were invited by the Dubai Municipality to develop a proposal for two Iconic Bridge Structures, crossing the Dubai Creek. The bridges are intended to significantly improve the usage of the Dubai Creek as a Waterway to access the large scale developments further down the creek, substituting the transversal boat traffic across the creek by permanent links to improve lateral water traffic flow along the creek.

The alignment of the bridges along the existing movement patterns plays a key role in designing the footprints and the integration of the landing zones into their local urban context. Buro Happold's specialist modelling and analysis team SMART were asked to perform a form finding exercise to determine the most optimal crossings for one of the bridges.

SMART used a novel optimisation technique to design the bridge route and ramp orientation - by applying Buro Happold's in-house people movement software SMART Move. The emergent shape of the bridge is based on movement of people starting from either side of the bridge, taking into account their preference for least effort (quickest route which accounts for the slope of all possible routes) and architectural constraints (e.g. ramp inclinations). The model used to derive the bridge shape incorporates a full 3D grid based network allowing thousands of possible routes from which the optimal one is chosen by agents. In this way the solution is fully emergent.



SMART Move people flow simulation



SMART Move people flow simulation with bridge

Image courtesy of Zaha Hadid Architects

Key project information

Client	Dubai Municipality
Architect	Zaha Hadid Architects
Dates	Completed 2008

Services provided by Buro Happold

Crowd flow consultancy.

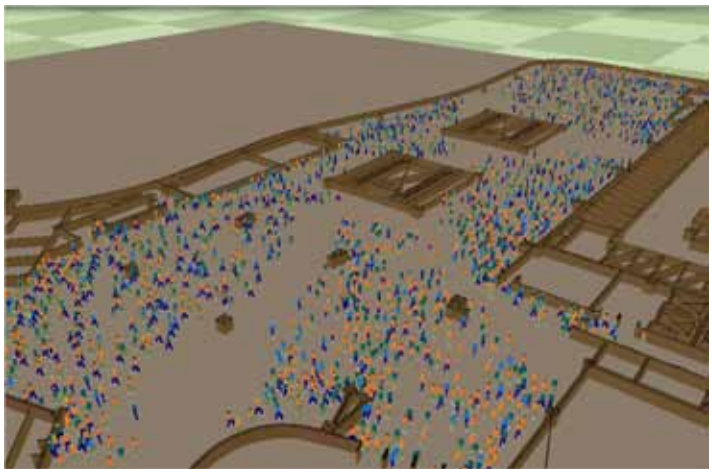
SM Retail Mall
Zibo, Shandong, PRC

The project consists of a new build retail development of approximately 120,000m2 GFA in Zibo, Shandong, PRC. Buro Happold was appointed to provide specialist engineering design input in order to increase the overall building space use efficiency.

A key role in undertaking this was dynamic people flow modelling during building evacuation. Using coordinated data from multiple disciplines, a dynamic people flow model was constructed using EXODUS. This was done in combination with SMART Move our network analysis software to assess static measures such as distance and travel times to nearest exits.

Utilising density heat maps and distance mapping, effective evacuation times were derived in association with the project fire engineers. The study was effective in reviewing and optimising the efficiency of space use within the building.

The evacuation modelling work was undertaken in close coordination with the architectural, environmental and fire engineering consultancy.



Key project information

Architect	Arquitectonica Architects
Dates	Ongoing

Services provided by Buro Happold

Services provided: environmental engineering, fire engineering, evacuation modelling

Kurskiy Interchange Moscow Redevelopment
Moscow

In December 2011, the Buro Happold Crowd Flow Solutions team was appointed by Weston Williamson to undertaken passenger flow modelling on the concept design of Kurskiy Station in Moscow. The modelling included passengers interchanging between the suburban terminating platforms, long-distance through platforms, multiple metro entrances, buses and taxis as well as local retail and the proposed development being designed as part of the project.

The main aims of the project were to confirm that the design would operate at appropriate levels of service during peak movements, both base case and with the addition of the future development proposals. Sensitivity tests were undertaken on the retail centre attached to the station complex, simulating it being open or closed, as this provided different passenger routes to be assessed.

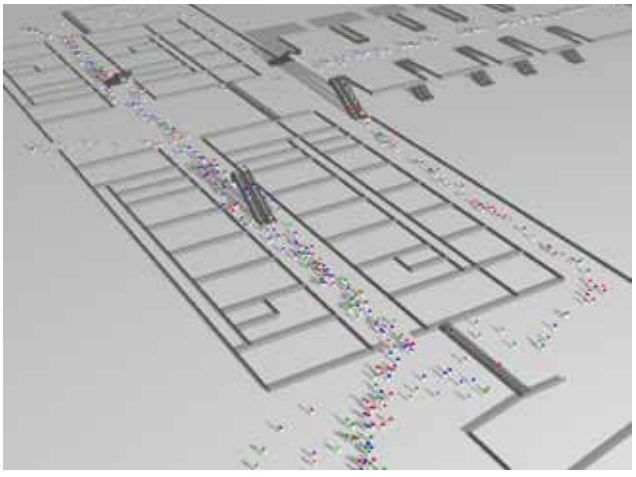
The key outcomes of the work were passenger density and flow maps and analysis to determine the appropriate widths for key corridors, stairs and escalators as well as the volumes of people utilising waiting areas in the concourse. Analysis on retail footfall and the interaction of the different land uses fed into the architectural design of the station.

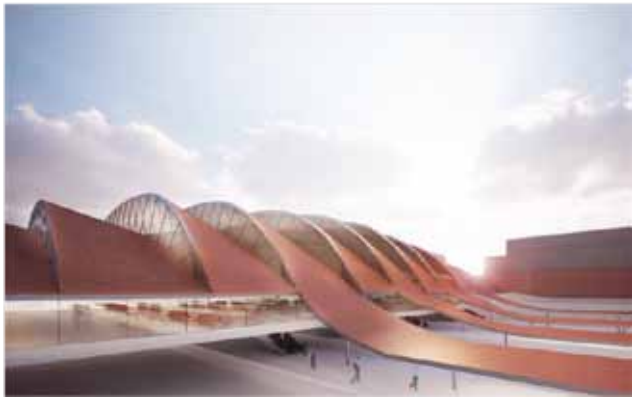
Key project information

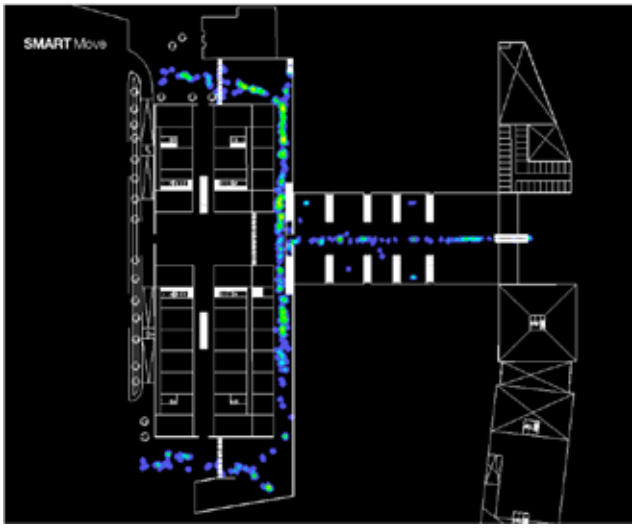
Architect Weston Williamson
Dates December 2011 - February 2012

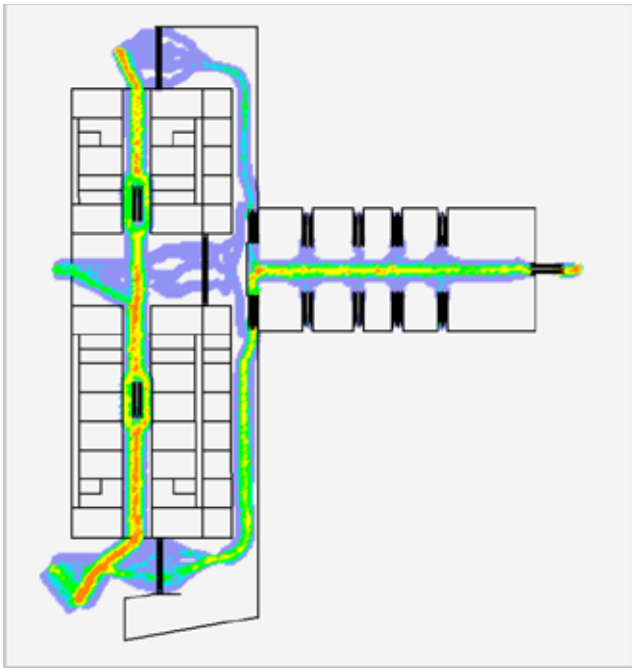
Services provided by Buro Happold

Crowd flow modelling, transport consultancy.









London City Airport
London, UK

London City Airport's Master Plan sets out a major growth and development plans through to 2030. It was developed in response to the Government's Aviation White Paper, 'The Future of Air Transport', which requires specified airport operators to outline their vision for growth up to 2030.

Buro Happold crowd and baggage flow consultancy team were invited by London City Airport to support the design and operations team on the stage C and stage D of passenger flow modelling for the proposed Terminal Development Project. The scope of works covers modelling the passenger flows within the reconfigured Terminal and proposed expansion elements – principally the new departures and arrivals areas.

Working closely with the operations and security teams at LCA, our people movement specialists carried out detailed assessments of transport related parameters such as modal splits and rail expansion plans, design parameters such as number of automatic check-in stations, operational parameters such as immigration staffing, as well as security parameters. Our work enabled optimisation of the locations, orientations and numbers of CUSS kiosks, as well as the immigration desks, baggage hall and central search facilities.

Comprehensive data capture surveys of the existing operations informed the study which involves a detailed dynamic micro-simulation of arrivals and departure scenarios for the 2010 and 2030 operations of the terminal. A combination of static network models and detailed dynamic simulations were carried out to perform sensitivity analysis of the parameters on terminal performance.

A significant contribution from our consultancy team was a collaborative work with UK Border Agency and LCA on the implementation of the Single Line of Intervention. The work involved a trial and survey at London City Airport to guide the feasibility testing through a series of what-if and sensitivity analysis of the impact of moving immigration desks on queues and densities in the baggage hall.

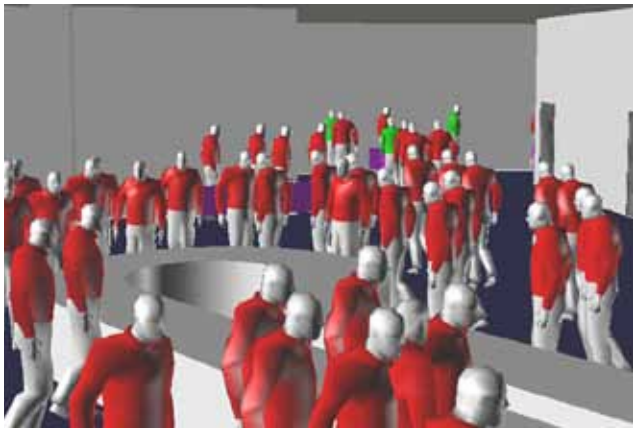
Services provided by Buro Happold

Passenger flow consultancy, Baggage handling and Structural engineering.

Key project information

Client	London City Airport
Architect	Allies and Morrison Architects
Dates	2007-2009

Departure hall simulation



Modelling of baggage hall densities

Integrated baggage/pax modelling of Single Line of Intervention at London City Airport

King Abdullah International Airport
Saudi Arabia

This major redevelopment work at the King Abdulaziz International Airport involved modernisation and capacity expansion of the Hajj Terminal, the world's fourth largest air terminal. Buro Happold provided a full suite of privatisation transaction related due diligence services on this build, transfer and operate (BTO) scheme which is at the forefront of Saudi Arabia's private sector participation programme for its civil aviation sector.

Passenger flow modelling at transport terminals such as Airports and Rail Interchanges enables design and management teams to assess the suitability of design proposals and space/management provisions in relation to crowd congestion, safety, security, comfort, and footfalls.

The work went hand-in-hand with the design development process, advising and optimising on space and resource provisions within the terminal. It was carried out in two parts. The first step was to do a desk study to analyse the space and resource provisions within the IATA guidelines and minimum technical requirements, and substantiating it by using simple flow models and spreadsheet based analyses. This stage also focused on identifying the key realistic scenarios for detailed dynamic simulation. During the second stage detailed agent based simulations were carried out on these key scenarios to test the design against passenger waiting times and densities.

Overview of the terminal

Internal view

SMART Move simulation of people movement within the terminal

Key project information

Client	El Seif Al Aziza Consortium
Architect	GMW
Dates	Completed 2008

Services provided by Buro Happold

Structural engineering, building services engineering, civil engineering, acoustic consultancy, security consultancy, bomb blast analysis, fire engineering consultancy and IT consultancy, crowd flow consultancy.

Buro Happold

Birmingham International Airport
Birmingham, UK

The Commonisation Project at Birmingham International Airport involved infilling the double height space in the link building that connects Terminal 1 and Terminal 2 with a new floor plate, allowing the creation of a centralised arrivals and departures facility. The scheme also entails significant reconfiguration of the existing facilities.

Buro Happold were appointed by D5 Architects to test the design of the PSA within the proposed terminal design in relation to agreed passenger comfort levels, as well as to test the scalability of the design.

The scope of this study covered specifically the Passenger Search Area (PSA) within the proposed terminal design. The aim is to test the design to achieve agreed passenger comfort levels, as well as to test the scalability of the design. A combination of static and dynamic simulation models were used to assess the latest design proposal with regards to the passenger movements within the PSA, modelling the detailed but realistic ingress rates, services times, etc.

As part of this study two scenarios were considered:

1. Target demand peak hour modelling: to test the proposed developments against a target demand.

2. Limiting point peak hour modelling: to test the scalability of the proposed developments. Target demands were incrementally increased until system breakdown (throughput time and spatial capacity exceeding acceptable levels).

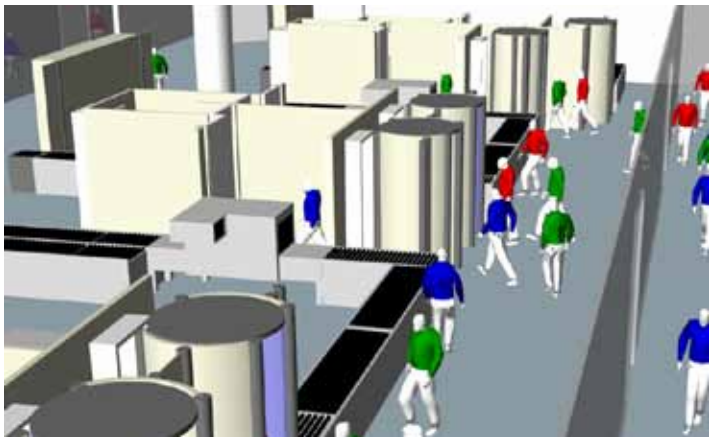
Additional to the detailed modelling task looking at the queuing levels and throughput times of the PSA and boarding pass checks, a high level review of the layout was carried out. Based on the architectural drawings provided, a 3D network model was been built to represent the circulation and queuing regions through the PSA – including the boarding pass check and AMDs. Several detailed simulations of a number of scenarios were performed.

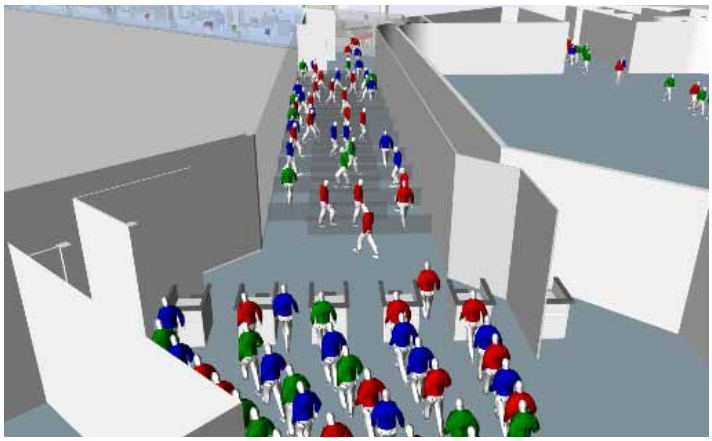
Key project information

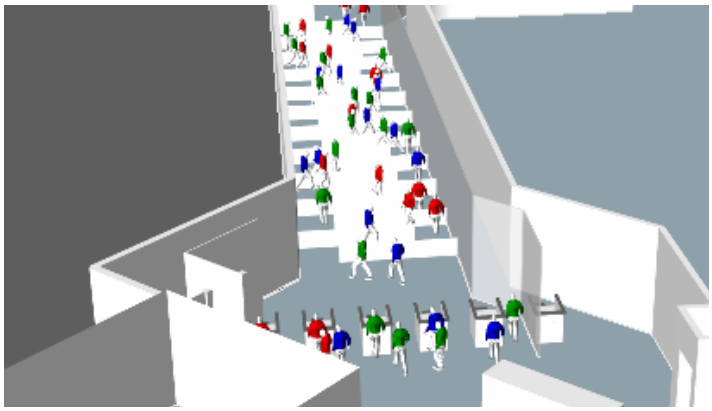
Client	Birmingham International Airport
Architect	D5 Architects
Dates	2009-2010

Services provided by Buro Happold

Passenger flow modelling, Structural engineering, building services engineering, civil engineering, acoustic consultancy, security consultancy, bomb blast analysis, fire engineering consultancy and IT consultancy.







Al Haramain High Speed Rail
Saudi Arabia

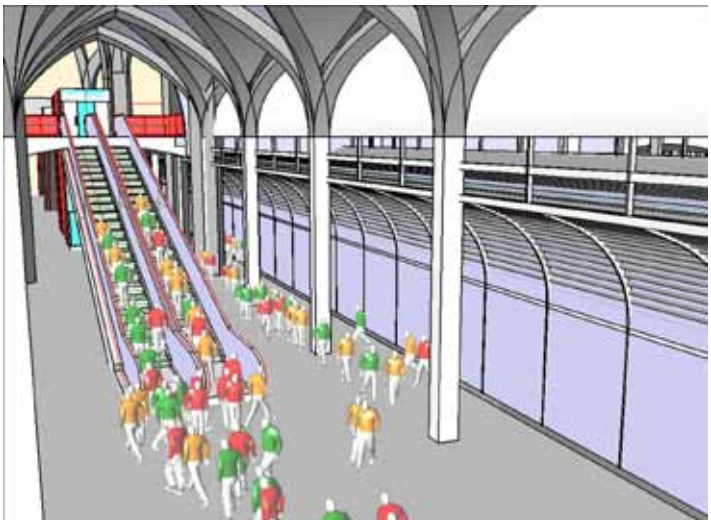
The Haramain High Speed Railway (HHR) between Makkah, Jeddan and Madinah will be a very important step in improving the transportation needs along this busy corridor, with the additional benefit for foreign pilgrims, who travel to the Kingdom of Saudi Arabia to visit the holy places.

Buro Happold's people movement consultancy team are working with Fosters & Partners to inform the current station design layout and plans for a typical platform plan, assumed to correspond to the busiest station on the network proposed. We are engaged at two levels:

1. High level assessments including demand forecasts, transport appraisals, and preliminary design advice on such as station planning, platform widths, etc.

2. Detailed assessments and detailed design advice for the stations.

With a focus on improving passenger experience, the study is looking at all aspects of stations design, including platform width, escalator and lift requirements, ticket barriers, security X-ray units, ticket machines, multi-modal transport links, etc. Conceptual design decisions are driven by several what-if scenarios and sensitivity analysis against various design, operational, and population parameters.



Key project information

Client	Saudi Rail Organisation (SRO)
Architect	Foster + Partners
Project value	£1.2b
Dates	ongoing

Services provided by Buro Happold

Structural engineering, MEP, specialist consulting including crowd flow analysis and simulation.

Buro Happold

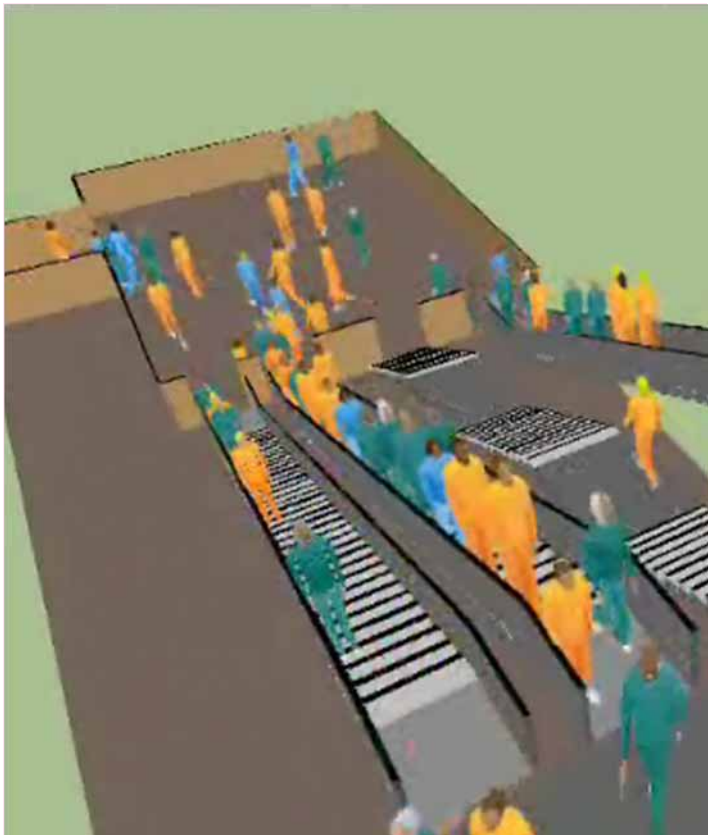
AVATARS
EU Project on Rail Terminal Modelling

AVATARS is an ambitious project to produce design guidelines and next generation software tools that allow the testing and validating of rail terminal designs by using models to simulate the circulation movements of passengers within rail or metro stations.

AVATARS will create a software tool to simulate the circulation movements of passengers in a rail terminal environment. The software will allow designers to analyse the movements of people during emergencies, as well as normal embarkation, disembarkation, waiting times, shopping and meeting onward intermodal transport. AVATARS will develop technology to allow rapid generation and visualisation of complex, real-world scenarios to maximise testing efficiency which will provide an invaluable tool for designers, operators, safety managers and regulators, as well as providing a variety of commercial benefits.

Buro Happold have provided the valuable design and simulation advice to the consortium. We have also provided a project steer to enable accurate data capture and analysis, identification of worst case scenarios, passenger surveys, behavioural model development, and case study definition and evaluation.

The evaluation of the developments is carried out under a series of case studies, developed throughout the project. These take real-world information from operating terminals and trains and produce complex, multi-event scenarios capable of evaluating the abilities of the AVATARS software.



Validation of passenger flow simulation at escalators, Barcelona FGC train stations

Key project information

Client EU Sixth Framework Programme

Consortium BMT Ltd, FSEG University of Greenwich, FGC, Ferrocarrils de la Generalitat de Catalunya, ATM, AUtoritat del Transport Metropolita, University of Salford and Buro Happold

Services provided by Buro Happold

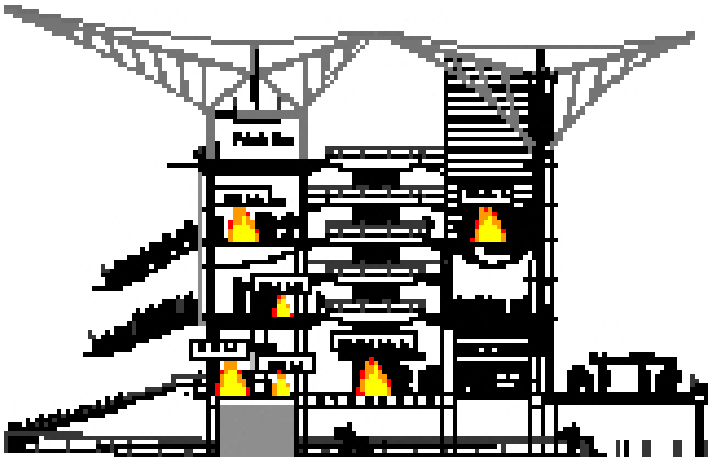
Crowd flow consultancy.

Ascot Racecourse Redevelopment
Berkshire, UK

Ascot is arguably the world's most famous race venue with Royal patronage dating back to 1711. It hosts a number of premier events including the famous Royal Ascot meeting in June. The Ascot Authority's aspiration to redevelop Ascot as 'the finest racecourse in the world', will provide spectators and visitors with world class racing and viewing facilities. The project entailed a thorough reorganisation and rebuilding of the facilities at Ascot.

The project comprised two main components: the enlargement of the current site and the construction of a new grandstand. The enlarged site was created by relocating the existing 'Straight Mile' track 42m to the north. Two major road underpasses provide the track with permanent crossings to an existing road, as well as serving as access routes to prevent traffic congestion on race days.

Circulation inside the 80,000 capacity grandstand was a key aspect of the design. Using SMART Move, our in-house dynamic network based crowd flow simulation software, Buro Happold used to optimise the placement and sizing of stairs, escalators and walkways for the building. The work also involved assessment of crowd movement at the entrance, betting areas, parade ring and cafes.



Fire engineering case study

Key project information

Client	Ascot Authority (Holdings) Ltd
Architect	HOK SVE
Project value	£125m
Dates	Completed 2006

Services provided by Buro Happold

Structural engineering, building services engineering, crowd circulation modelling, contamination consultancy, geotechnical engineering, civil engineering, transport planning, fire engineering and crowd flow consultancy.

Lord's Cricket Ground
London, UK

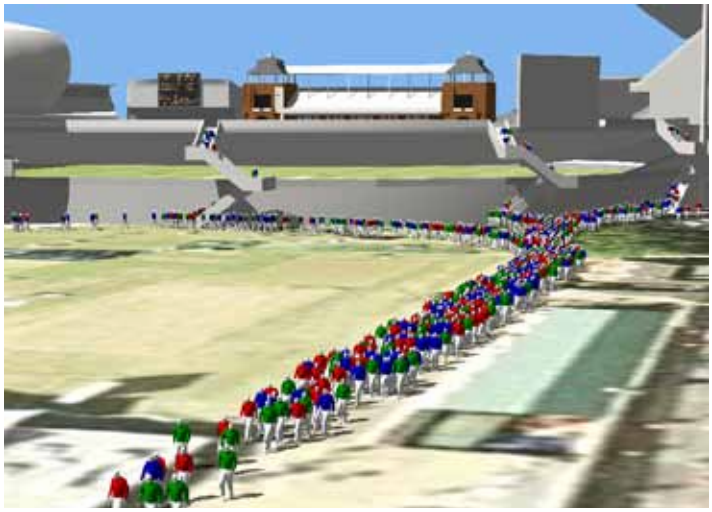
Dubbed as the 'home of cricket', Lord's Cricket Ground is renowned as the most famous and historic cricket ground in the world. The MCC (Marylebone Cricket Club) is now formulating a masterplan for future development at Lord's, with various options involving a capacity increase to somewhere between 35,000 and 40,000. The current capacity is approximately 28,500.

The study investigated the arrival and departure profiles, movement patterns during the breaks, qualitative/ quantitative data about transportation modes and quantitative flow parameters that define queues and congestion spots.

Using state of the art data capturing and analysis tools and methodology the study yielded valuable information on crowd behaviour at cricket grounds, visitor preferences for circulation routes in relation to the arrival mode of transport and destination seating areas and service times at key points in the network.

Working closely with the operations and security teams at Lord's, our people movement specialists carried out detailed quantitative assessments of design parameters such as turnstile counts and circulation widths, operational parameters such as flow balancing on various gates, as well as security parameters such as baggage search.

The study produced guidance for masterplanning as well quantitative data that is useful for detailed modelling of development at Lord's for safe, comfortable and efficient crowd circulation.



Above: Departure simulations created with SMART Move

Actual crowd flow at entrance to cricket grounds

Key project information

Client	Marylebone Cricket Club (MCC)
Architect	HOK SVE
Dates	Completed 2008

Services provided by Buro Happold

Crowd flow consultancy and simulation.

The New Stadium
Abu Dhabi , United Arab Emirates

The New Stadium is the centrepiece of a new sporting complex known as the Sports Hub. The complex forms part of the Capital District Masterplan to the East of the main Abu Dhabi Island. The main intended use of the stadium is hosting sporting events (primarily football and rugby), with a maximum seating capacity of 65,000 spectators. Additionally, the stadium will be used for hosting a variety of events such as concerts and exhibitions.

From a crowd flow point of view the stadium design can be considered as two linked elements, namely the stadium itself and the podium. The stadium itself comprises a natural grass pitch, a seating bowl consisting of three main tiers and a movable roof. The podium forms the external public concourse directly around the stadium. It provides pedestrian access from street level to the stadium entrances and circulation space around the stadium perimeter.

The aim of this study was to assess whether the design of the venue is operable given the anticipated visitor numbers. The design was assessed against all its potential uses, to ensure that it is capable of operating safely and comfortably in all foreseeable modes. From a crowd flow perspective, this involves ensuring that the venue has adequate capacity to accommodate expected crowd flows at agreed target densities.

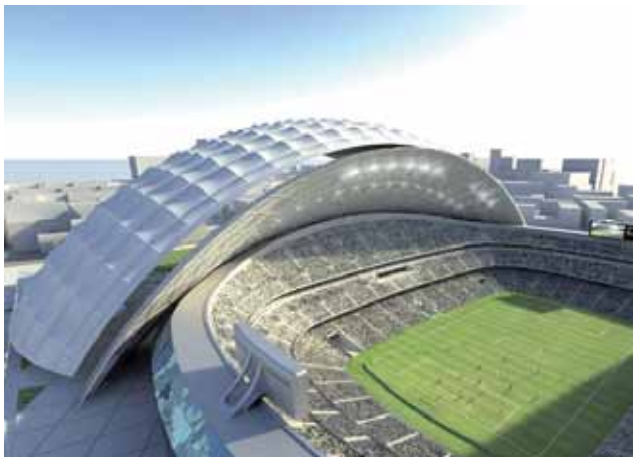
The study included a review by Buro Happold of the two people movement reports produced by Arup. This review considered the design approach adopted, identified the safety and comfort outcomes of the proposed design, and highlighted where further crowd movement assessment would be of most benefit.

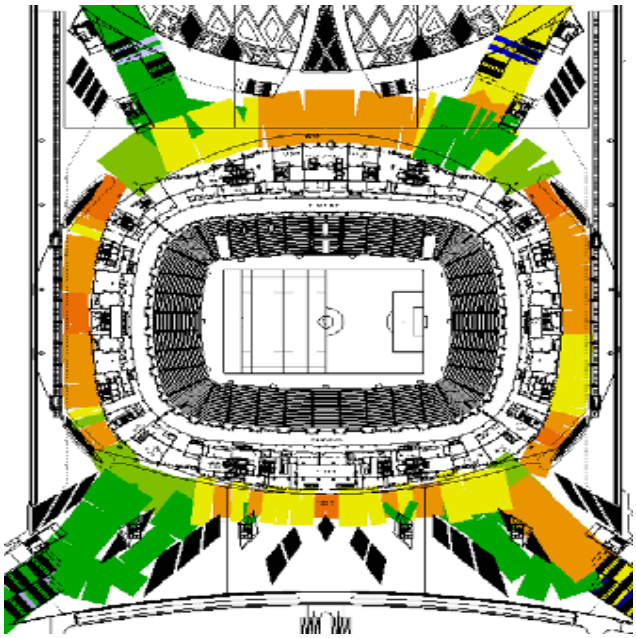
Key project information

Client	Bouygues Construction
Architect	Arup Sport
Dates	Ongoing

Services provided by Buro Happold

Structural engineering, MEP, specialist consulting including crowd flow analysis and simulation.





Central Olympic Stadium
Sochi, Russia

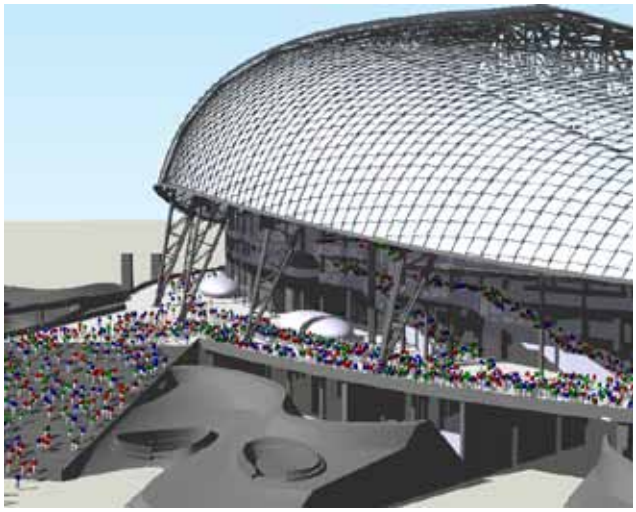
The comfort and safety of the visitors to the Sochi stadium, in all modes of operation, is a vital factor in the success of the events held there, and of the stadium itself. A design sympathetic to visitor comfort during circulation is possible if all aspects of people movement are taken into consideration. Buro Happold's team of experts have been engaged on the project with this aim in mind.

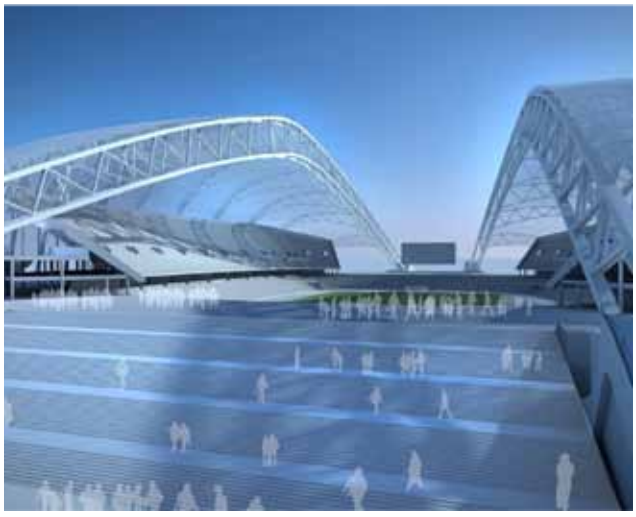
The Sochi Stadium will be designed for three main modes of operation, namely

- Olympics mode: the stadium will be used for the opening and closing ceremonies of the 2014 Olympic Winter Games, capacity 40,000 people.
- FIFA World Cup mode: the stadium will be used as a venue for the 2018 FIFA football World Cup, capacity is 45,000 people.
- Legacy mode: the stadium will be used at a reduced capacity as a domestic football stadium, capacity of approximately 25,000 people.

The study involved a detailed qualitative review of the architect's drawings with respect to circulation, simple desk study calculations and detailed flow simulations of the critical egress.

A key part of the project consisted was assisting the architects and clients with interpreting and assessing the impact of differences between Russian and international codes relating to crowd flows (e.g. acceptable density levels for enclosed sport venues).





Key project information

Client	SC Olympstroy
Architect	Populous
Dates	Ongoing

Services provided by Buro Happold

Structural engineering, MEP, specialist consulting including crowd flow analysis and simulation

Media Hub
London, UK

Crowd flow consultancy is being provided by the Buro Happold SMART team on the design of the 2012 Olympics Media Centre and associated multi-storey car park (MSCP). Through data gathering, desk studies, detailed analysis and modelling work, this advice is helping the design team to enable comfortable conditions are achieved for all media staff as they make their way into and out of the Olympic Park. The crowd flow analysis therefore considers in detail the arrival phase as media staff come into the MSCP, pass through the security accreditation zone, and make their way to the main media centre or straight out to venues within the park. It also includes the departure phase at various times within the day/night and consideration for the times of greatest counter-flow between staff entering the olympic park and those leaving.

Based on pedestrian arrival and departure predictions for the project, the SMART team are using specialist dynamic simulation software to forecast queueing levels and comfort levels around the site. Based on this work, advice is continually provided to the design team on areas where it is likely for uncomfortable and undesirable conditions to be achieved. Advice is also provided on the provisions necessary to better enable the desired levels of service for media clients.

The SMART team are testing and advising on a multitude of facilities including platform design, pedestrian crossings (width, waiting space, crossing times etc), security provisions (x-ray/metal detectors and waiting space), egress and ingress door dimensions, pavement widths, stair and escalators provisions and much more.

SMART Move simulation of crowd movement from transport hub

SMART Move simulation of crowd movement through security systems

Key project information

Client	Olympic Delivery Authority
Architect	Allies and Morrison
Dates	Ongoing

Services provided by Buro Happold

Crowd flow consultancy and structural engineering.

Maghrabi and Diyafah Hotels
Makkah, Saudi Arabia

Buro Happold Crowd Flow Solutions were invited by YALJ to analyse the pilgrim movements within the Maghrabi and Diyafah hotels. These hotels are located approximately 2-3km from the Holy Mosque in Makkah, KSA. Peak hour scenarios when the hotels are expected to be at full capacity of 18,000 – 21,000 pilgrims were modelled. Pilgrim movements were analysed between the hotel and Holy Mosque during evening meal time, afternoon peak during the last day of Hajj as well as during an evacuation. Dynamic modelling using SMART Move and Exodus was undertaken.

Knowledge gained by the team from previous projects completed in the region of Makkah was invaluable to understanding the operations of the hotels. Combined with demand provided by the wider design team, peak hour demand scenarios for these hotels were generated to feed into the analysis.

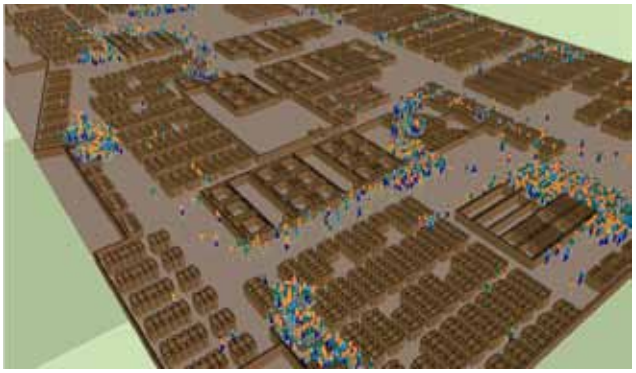
Detailed static and dynamic analysis of the lobby level, pedestrian crossing from the bus bay, dining hall level and vertical transportation elements was carried out. Our assessment reviewed visitor experience, comfort and peak hour density in the hotel. This analysis allowed conclusions to be drawn concerning pilgrim movements, optimum operations in the dining and concourse areas, as well as obtaining maximum efficiency in the bus terminal.

Key project information

Client	Yousef Abdul Latif Jameel Co. Ltd (YALJ)
Architect	CBT Architects (Maghrabi); Michael Graves & Associates (Diyafah)
Dates	November 2011 - December 2011

Services provided by Buro Happold

Crowd flow modelling.



Imperial War Museum – Spatial Masterplan
London, UK

Buro Happold Crowd flow team was appointed to review the Imperial War Museum Masterplan. With the aim of lowering the main entrance of the museum to provide step-free access, Architect Foster & Partners developed different schemes for the phased construction of the Museum. Our people movement team was involved in reviewing the final masterplan as well as several interim schemes and additional circulation options.

A site survey of pedestrian movements was undertaken, with particular focus on the museum entrance procedures and utilisation of visitor facilities. Additional data was collated to supplement information provided by the client team in order to develop key scenarios and drivers for the design.

The museum occupancy for the peak hour was over 1,000 people modelled as individuals and also in groups of varying sizes. Detailed static and dynamic analysis of the schemes with temporary deck, temporary stairs and alternative entrance passages were tested and recommendations were fed into the final masterplan design.

The museum consists of various gallery spaces, shops and cafes. Vertical movement to the various galleries on the different levels of the museum is via the lifts, stairs and ramps. Our assessments reviewed visitor experience, comfort and space optimisation in the museum, particularly focussing on museum entrance and security arrangements as well as general circulation.

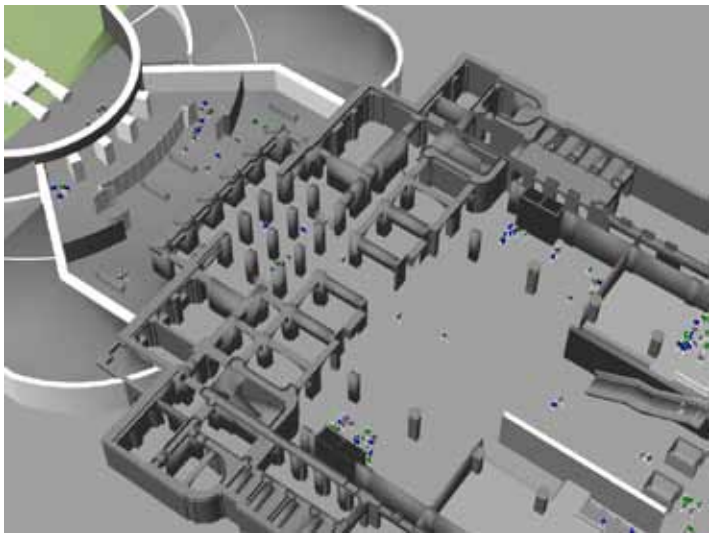
Our services were offered at both levels: rapid initial assessments to evaluate the major design options, followed by an ongoing design advice to refine and optimise the circulation provisions during design development phase.

Key project information

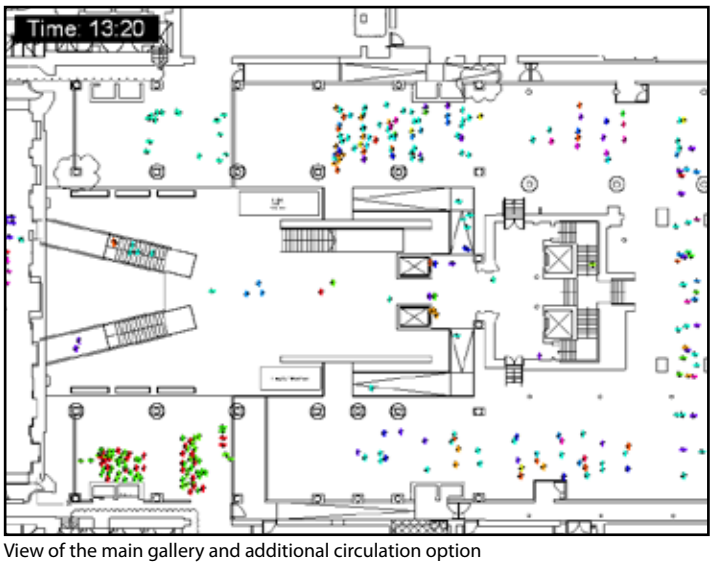
Architect Foster & Partners
Dates Ongoing

Services provided by Buro Happold

People movement consultancy, fire engineering consultancy, building services, structural engineering, sustainability, ground engineering.



Final Master Plan - View towards the main entrance



View of the main gallery and additional circulation option

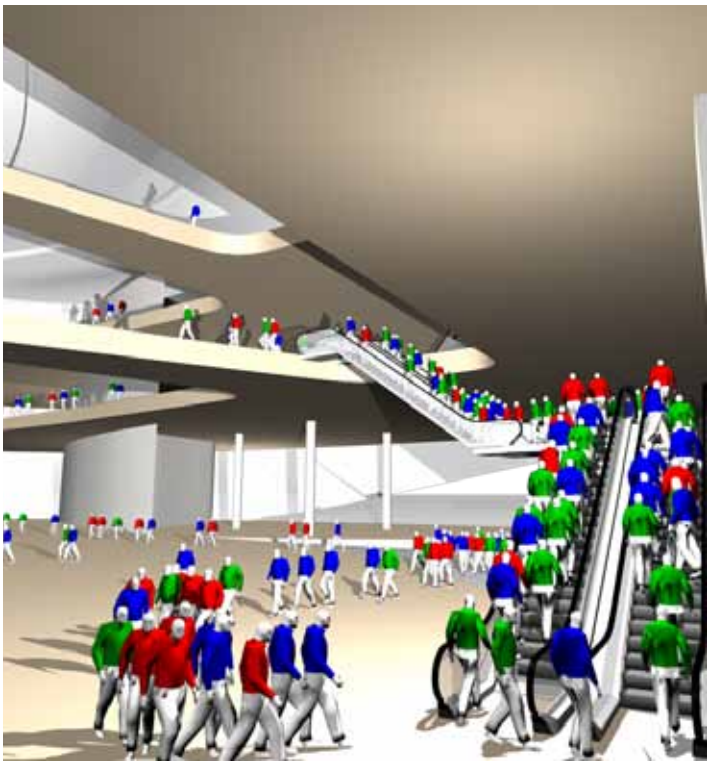
Expo City
Cairo, Egypt

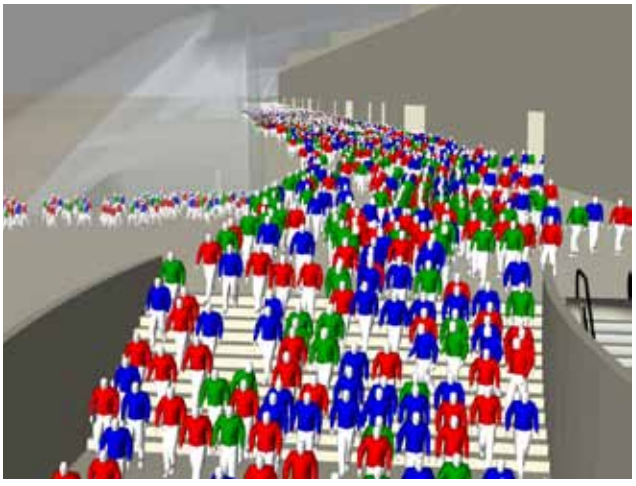
The Cairo Expo City (CEC) development is designed to reinstate Egypt, and it's capital, to being the leading convention and exhibition venue in North Africa and the Middle East. The site comprises a multipurpose Convention Centre to accommodate more than 5,000 delegates and an exhibition centre of over 60,000 capacity, two hotels with 1 000 rooms and office space in two 33 floor blocks. Huge underground garages, a new metro station and overhead monorail provide transport facilities.

The aim of the people movement study on the project is to design the optimum circulation routes within the development, accounting for the pedestrian demands associated with the metro link, the monorail link, and the private transport links. We are advising on the space planning and sizing of the connections to these nodes between the buildings (macro modelling) and within the buildings (micro modelling). The work is being carried out in close collaboration with the related disciplines of fire engineering, security and infrastructure, as well as the exhibition and theatre consultants. We are advising on the sizing of corridors, stairs, escalators, doors and service desks. The assessments include reviews of toilet provisions, bars and restaurant areas.

Key project information

Client	General Organization for International Exhibitions and Fairs (GOIEF)
Architect	Zaha Hadid Architects
Project value	$450m
Dates	Ongoing





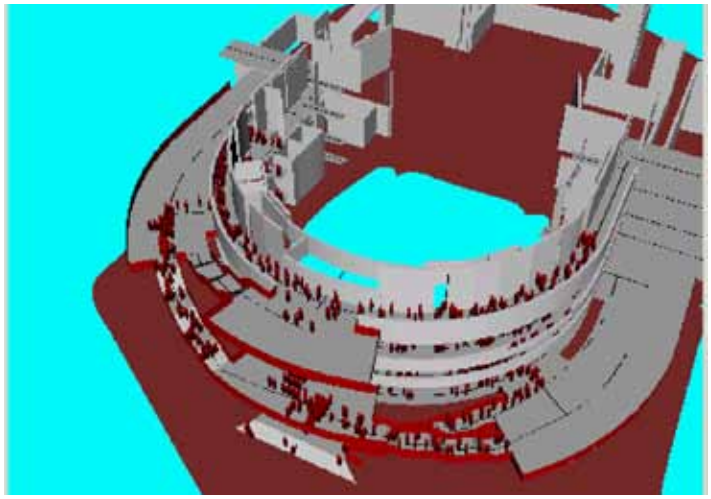
Winspear Opera House
Dallas, USA

Winspear Opera House will form part of the Dallas Center for Performing Arts on a 6 acre site in Downtown Dallas. The 2200 seat Opera House is being designed with Foster + Partners and Theatre Projects Consultants and has a projected completion date of 2009.

We worked closely with the Architect and the other members of the design team to develop the structural design and propose construction systems for the whole Winspear Opera House development.

During the scheme design phase the orchestra level structures (including the orchestra pit) were co-ordinated with the needs of the Theatre Consultant and the design of the stage walls co-ordinated with the architectural and acoustic needs of the project. The auditorium roof structure was co-ordinated with the layout of the auditorium below and the design updated to allow for a cantilevering screen around the perimeter of the roof.

Buro Happold also provided people movement study for the key circulation scenarios in the opera house: arrivals, interval, and end-of-performance scenarios. Through rigorous data collection and analysis from a survey at the Royal Opera House in London, visual simulation models were built to investigate the assessment of circulation in terms of queues, congestion, waiting times and comfort at the reception, restaurants, toilets and stairs and corridors.



Key project information

Client	Dallas Centre for the Performing Arts
Architect	Foster + Partners
Project value	$108m
Dates	Completion due 2009

Services provided by Buro Happold

Structural engineering, ground engineering, facades and crowd flow consultancy.

Hotel America
Dubai, United Arab Emirates

Buro Happold's specialist modelling and analysis team SMART is helping the design of the Hotel America car-park to achieve the desired capacities and comfort levels. The aim is to assess the sufficiency of car parking spaces (and comfort levels in terms of distance to travel / time to park), and interaction of pedestrians with cars (and comfort levels in terms of frequency of interactions and length of wait). Using the team's extensive understanding of crowd behaviour patterns and microsimulation tools such as SMART Move the work is implementing novel approaches to car park layout design.

The network modelling technique provides static as well as dynamic representation of movements of people within an enclosed or open space. A 'static' network model is first built to get an overview of the flow past various circulation spaces within the space. Detailed simulation can then be carried out using SMART Move, a dynamic visual simulation tool for the modelling of people movement. SMART Move models individual agents with random behavioural characteristics and allows rapid and accurate simulations of multiple scenarios, thus enabling an optimised design with a defined level of confidence.

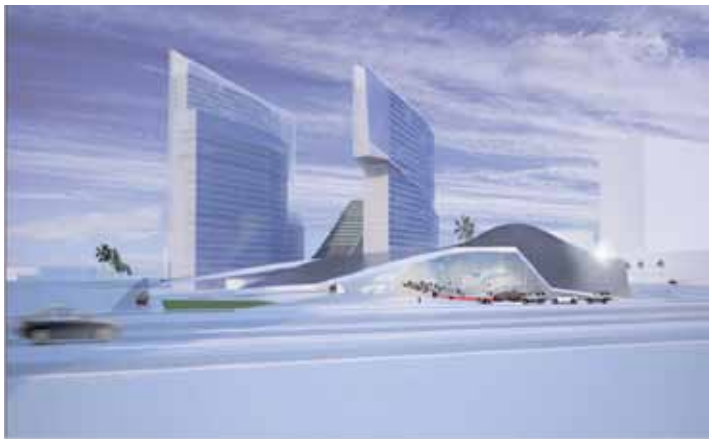
The key objective of this ongoing work is to produce multiple simulations of the car park with varying scenarios, population, occupancy levels and origin-destination matrices. The analysis output is in the form of number of interactions between people and cars, and the times people take to find a car parking space and from there to exit to their destinations. This measure provides an estimate of the level of service experienced by the car park user. This measure is used to investigate the effectiveness of various car parking layout options and to optimise the layout.

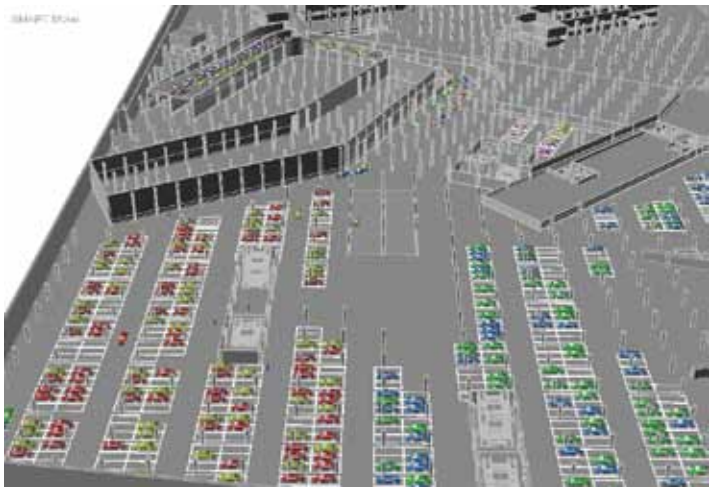
Key project information

Client	ED Harris
Architect	GRAFT
Dates	Ongoing

Services provided by Buro Happold

Crowd flow consultancy.





Birds-eye view of pedestrian and car flow

SMART Move's modelling of inter-modal movements

D. Y. Patil University
Navi Mumbai, India

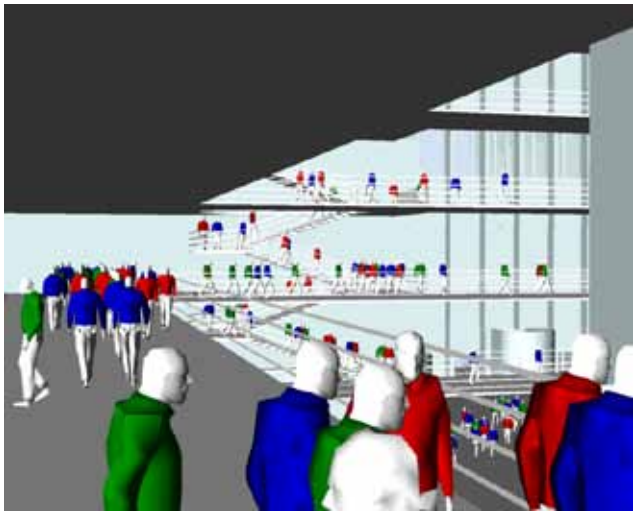
Dr. D. Y. Patil University is intending to develop a School of Management at their faculty in Navi Mumbai. The client has engaged Foster + Partners as architects to design the project. Buro Happold is providing various professional engineering services, including people movement.

The project is located at the existing site of the Padmashree Dr. D. Y. Patil University in Navi Mumbai, India. The total gross area of the project is approximately 64,000m^2 and will provide a teaching faculty block at lower levels, residential units at higher levels and a basement car-park.

The people flow study assessed the design of the DY Patil University School of Management with respect to its key circulation scheme, focusing on the smooth passage of students and staff throughout. The includes a full dynamic assessment of a limited number of scenarios (i.e. arrivals, class changeovers and departures) using Buro Happold's SMART Move software.

Finally, the impact of the lunchtime movements were assessed.

We worked closely together with the architect to improve the design and to impress the client with how well the design works in terms of people flow. As part of the project a number of impressive animations were produced to show the movements of students throughout the building spaces. These animations and the analysis results were presented to the clients at various stages of the project, who were impressed with the work



Key project information

Client	Dr. D. Y. Patil University
Architect	Foster + Partners
Dates	Ongoing

Services provided by Buro Happold

Structural engineering, MEP, specialist consulting including crowd flow analysis and simulation.

Buro Happold

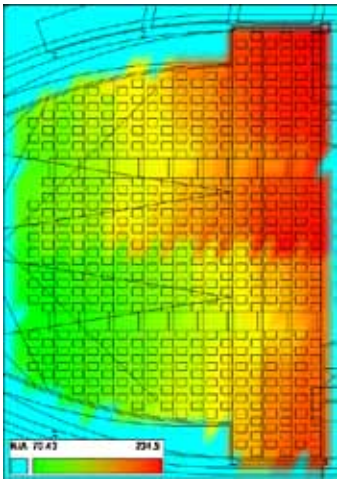
University of Exeter
Devon, UK

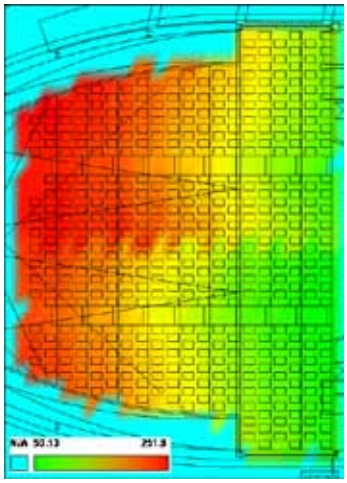
Wilkinson Eyre was appointed by the University of Exeter after winning an invited design competition in October 2008 to develop a scheme for the new Forum & University Reception Building.

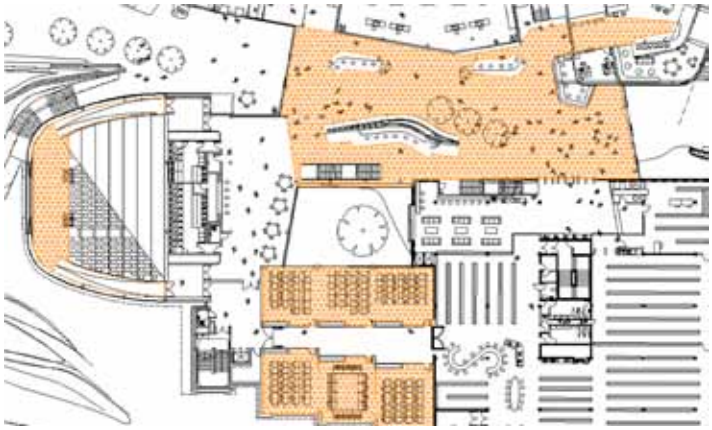
The buildings will house a university entrance and foyer space, flexible mixed use teaching areas for use by all departments within the University, a new student services centre, refurbished library and food court, all to provide a new cultural hub for the university. The brief included a 'state of the art' 400-seat auditorium combined with an equal provision of break-out seminar spaces, which will offer significant out of term time conferencing facilities.

The people flow study assessed the design of the university buildings with respect to its current circulation scheme, focusing on the smooth passage of students and staff throughout. It included people flow simulations to assess the performance of the circulation provisions within the design, including stairs, corridor and entrances.

The study looked at issues such as safety and comfort during horizontal and vertical circulation as well as at assembly points adjacent to the lecture hall and auditorium entrances. Congestion issues were considered during critical scenarios such as meal break times or lecture theatre changeover.







Key project information

Client	University of Exeter
Architect	Wilkinson Eyre Architects
Dates	Completed 2009

Services provided by Buro Happold

Structural engineering, building services engineering and crowd flow consultancy.

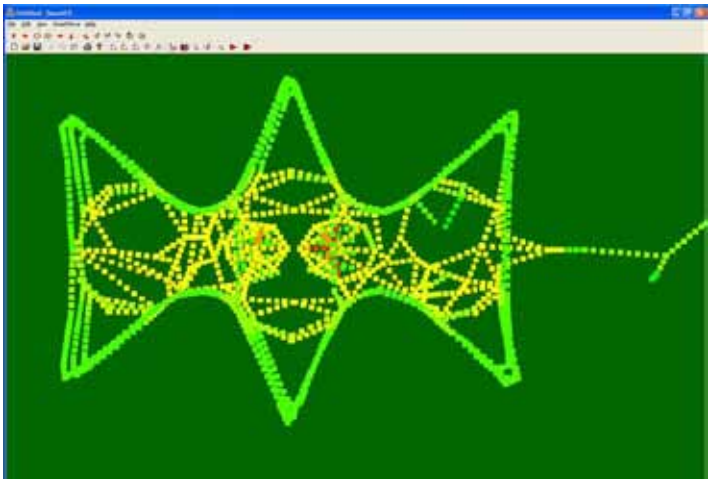
Thomas Deacon Academy
Peterborough, UK

The proposed academy is intended to provide a 2,200 pupil secondary school which will replace three existing schools as part of Peterborough Education Authority's reorganisation of secondary education across the city and will include new and improved sports and arts facilities.

Pupil movement – a fundamental but often overlooked element in the design of schools and academies was key in the design optimisation of this modern school. Using dynamic simulation tools developed in-house, our specialist pupil flow team was able to predict pupil and staff circulation patterns and congestion 'hotspots' based around the timetable and the proposed layout.

The work involved advising on the design optimisation of the circulation space as well as management measures for the safe movement of over 2200 students and staff. Issues such as stairs and corridor congestion during tutor group changeovers were successfully addressed in liaison with the design team and other stakeholders. Careful analysis of flow patterns enabled us to guide the proposed design and building management procedures, which results in substantial cost, time and efficiency savings during the lifetime of the building.

Foster and Partners reported on our work on the Thomas Deacon Academy as: "Buro Happold's people movement consultancy has been very good...most innovative…"



Key project information

Client	DfES/The Thomas Deacon Trust
Architect	Fosters + Partners
Dates	Completed 2007

Services provided by Buro Happold

Structural engineering, building services engineering, civil engineering, geotechnical engineering, planning supervision, fire engineering, crowd flow consultancy and transport consultancy.

Manchester Metropolitan University
Manchester, UK

The purpose of the study is to inform the design and management of the business school with regards to people circulation, by predicting over, and under, used areas that are not optimal to the performance of the school, and thereby provide recommendations to amend this.

The study involved an assessment of how the Hub area works from a safe and efficient student/staff/visitor circulation viewpoint. It focused on the area from the Main Entrance through to the two Hub atria at Ground Floor level, plus the Student Services and IT Drop-In levels on Mezzanine levels which make up the Student Hub. The Hub is was expected to cater for 7,000 students.

As part of the initial study a survey was carried out the existing Business School at the MMU on 6 December 2007. The first part of the study focussed on the Student Hub in the new MMUBS. This part of the study involved an assessment of how the Student Hub area works from a safe and efficient student/staff/visitor circulation viewpoint. It focused on area from the Main Entrance through to the two Hub atria at Ground Floor level, plus the Student Services and IT Drop-In on the first floor which make up the Student Hub.

The second part of the study investigated the people flow circulation provisions on the upper floors (floor 3, 4, 5 and 6) of the Business School. This study focussed on running worst case scenario simulations and looking at queue levels and design widths for the main corridors on the upper floors, staircases and area around the lifts.

Key project information

Client	Manchester Metropolitan University
Architects	Feilden Clegg Bradley Studios
Dates	Completed 2008

Services provided by Buro Happold

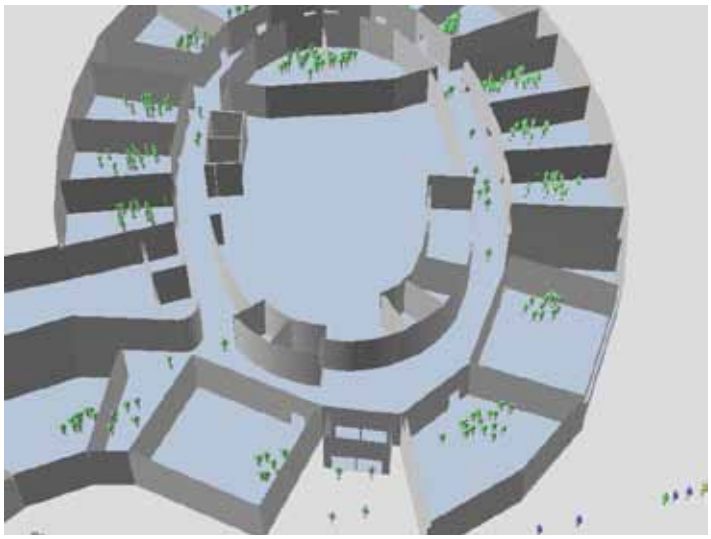
Crowd flow consultancy.

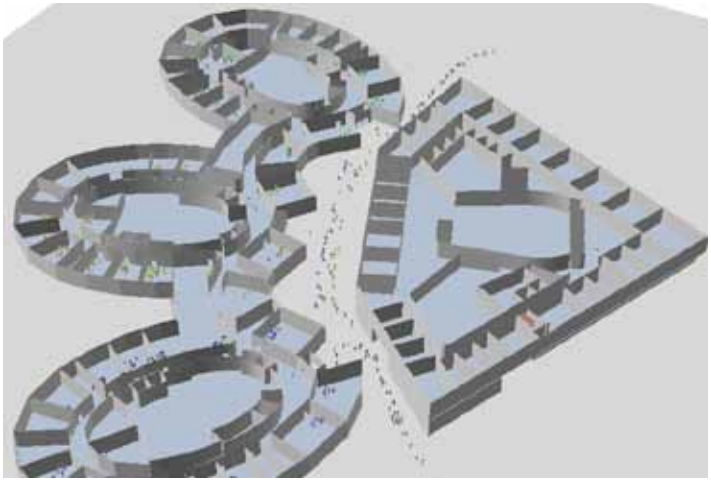
Thomas Clarkson College
Cambridgeshire, UK

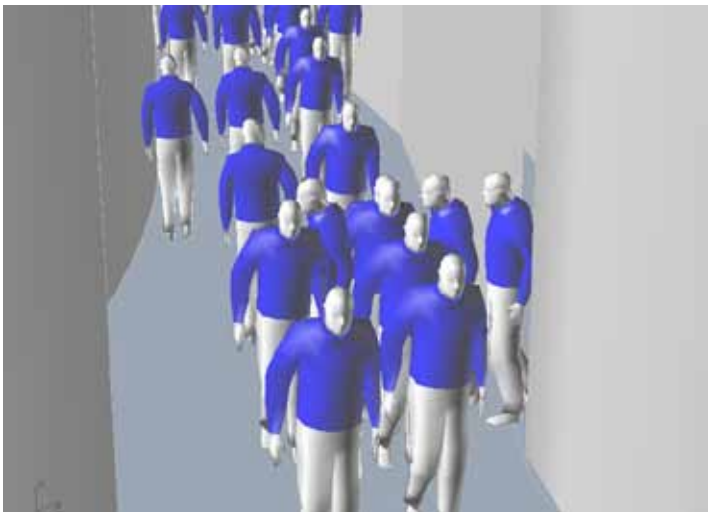
Balfour Beatty Construction Northern Limited appointed Buro Happold to carry out an assessment on the pupil movement aspects of the new design for Thomas Clarkson Community College in Cambridge. The work has been carried out in close consultation with BDP Architects and the education consultant for the project.

The Thomas Clarkson Community College reflects the operational and curriculum structure of a new school. The school design is extensively laid out over a single floor, including three oval shaped Learning Communities. Each Learning Community will contain a central semi-covered garden that can be used for pupils to eat packed lunches etc. There is also a two storey diamond shaped Hub building containing classrooms, staff facilities, the dining hall and main hall. There is a further two storey block containing the sports hall, DT rooms, and construction classrooms. The school is designed to cater for 1950 pupils.

The areas of main focus within the study were the entrance doors for each Learning Community and the Hub, the corridors and toilets within each Learning Community and the Hub, and finally the stairs within the Hub and the building containing the sports hall. Each of these areas was considered in detail within the analysis in order to assess whether there is a likelihood for significant queuing or for the corridors to become highly congested, with pupils coming to a standstill while they wait for the corridor ahead of them to clear.







Key project information

Client	Balfour Beatty Construction Northern
Architect	BDP Architects
Dates	Completed 2009

Services provided by Buro Happold

Crowd flow consultancy.

Ealing Schools PFI
London, UK

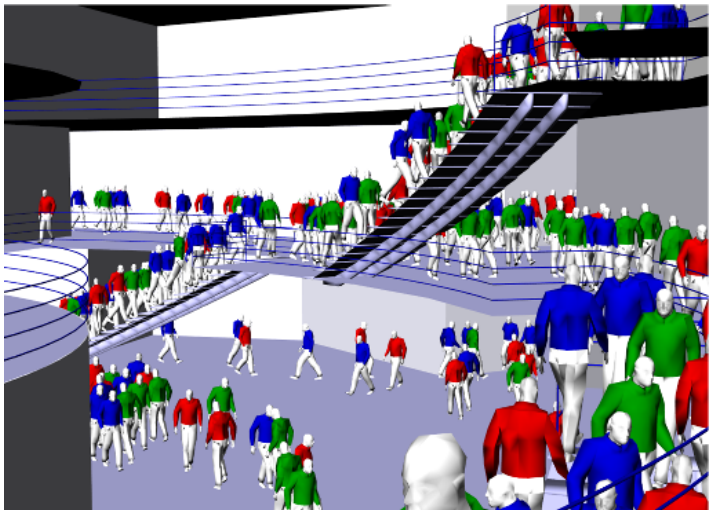
QED Education Environments (Wates Group Limited) appointed Buro Happold to carry out an assessment on the pupil movement aspects of the new design for Cardinal Wiseman School and Dormers Wells High School. Both school developments form part of Ealing's BSF programme.

The aim of Ealing's BSF programme is to transform the borough's secondary and special schools by rebuilding and refurbishing 14 schools and building one new school. Building will begin at Cardinal Wiseman and Dormers Wells high schools in 2010 with the entire programme of work expected to be complete by 2015.

Cardinal Wiseman School is designed to cater for approximately 2000 pupils. It currently consists of a number of mostly non-interconnected buildings. As part of Ealing BSF programme, the Cardinal Wiseman School will undergo new construction work, plus remodelling and refurbishment of existing buildings and an ICT upgrade. The architects of this school are HLM Architects.

As part of Ealing BSF, the Dormers Wells High School will be completely rebuilt. The planned capacity of the school is 1,450 pupils. Dormers Wells High School is designed by KSS Group architects.

Buro Happold's crowd modelling team worked closely together with both architecture firms and our client (QED Education Environments). For both schools multiple iterations of the pupil movement analysis were carried out to support the bid on Ealing BSF.



Key project information

Client	QED Education Environments (Wates Group Limited)
Architect	HLM Architects & KSS Group architects
Dates	Completed 2010

Services provided by Buro Happold

Crowd flow consultancy

Camden BSF Swiss Cottage Lift Analysis
London, UK

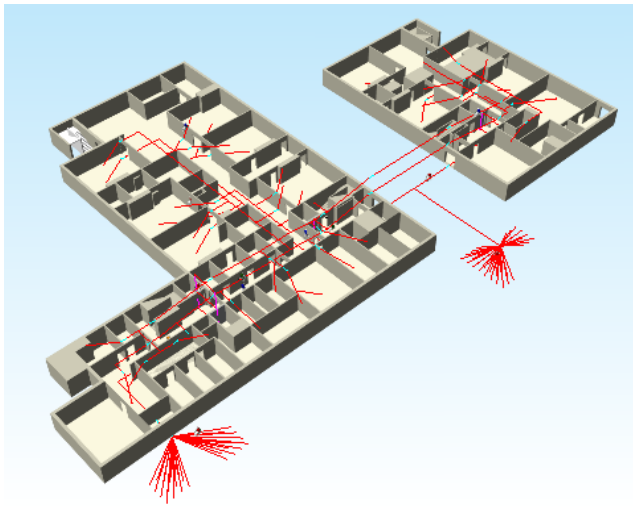
The proposed design of the Swiss Cottage Specialist SEN School within Camden, London includes a four storey building, catering for approximately 232 pupils, split over three schools. The school development is part of the Camden BSF programme.

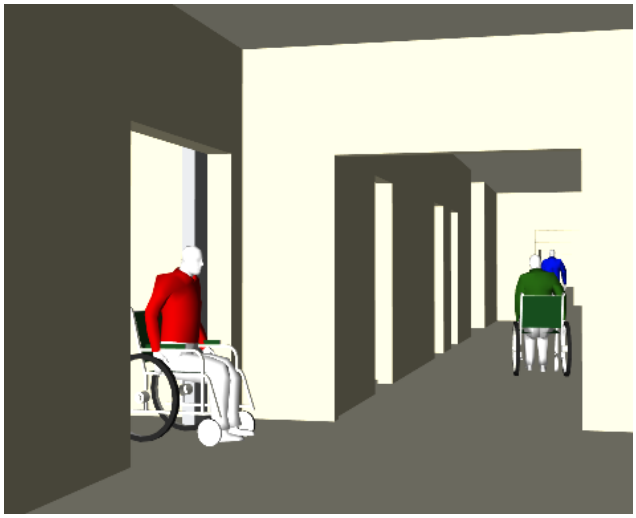
Buro Happold was appointed to carry out an assessment on the performance that is likely to be achieved by the proposed lift provisions for the development of the Swiss Cottage School.

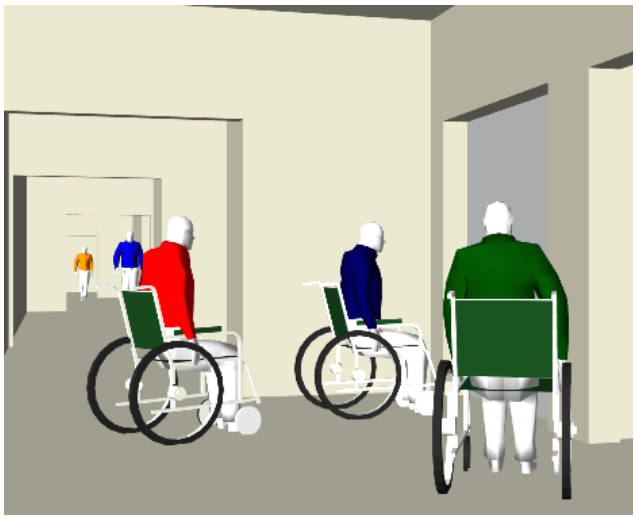
A key feature of this study was the number of disciplines (people movement, vertical transport, inclusive design, fire engineering) that had an influence on the work and a close collaboration was needed to assist with that.

Using all of the co-ordinated data, a SMART Move model was developed and multiple sensitivity tests were carried out.

Based on the people movement study the client was able to understand the maximum queuing levels (time and length) achieved at each lift for each of the critical scenarios. Appropriate design and management recommendations were included.







Key project information

Client	BAM Construction Ltd
Dates	Ongoing

Services provided by Buro Happold

Structural engineering, MEP, specialist consulting including crowd flow analysis and simulation.

Key People

Shrikant Sharma

BEng MTech PhD CEng MIMechE

Shrikant leads SMART Crowd Flow Solutions - Buro Happold's specialist circulation modelling consultancy service, helping architects, transport planners, airport planners, urban designers, regulators, developers, fire engineers and security advisors to understand and optimise space layout, design and management. It provides a modern approach to how buildings and urban spaces are designed and managed – from the user perspective – with a focus on comfortable, safe, and efficient environment for effective people movement.

Shrikant is a leading consultant on people movement and has led several major crowd flow consultancy projects, in sectors ranging from sports stadia to aviations and masterplanning. He has played a major role in the development of Buro Happold's people movement modeling capability. He has developed innovative software tools such as SmartMove – 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.

David Brocklehurst

BEng MSc DEng CEng MIFE PGCE

David has over ten years of consultancy experience working as a people movement consultant for Buro Happold. As both a skilled crowd flow consultant and long established fire engineer, he has extensive experience in designing for both normal and emergency conditions.

He also believes that good crowd flow modelling and consultancy necessitates a strong understanding of pedestrian/crowd behaviour in differing environments (stadia, schools, offices, shops etc) and under differing conditions (night time, where there is alcohol involved etc).

In order to maximise his understanding in this field, whilst disseminating knowledge to the wider community, David undertook doctoral research into circulation modelling at Loughborough University, gaining an Engineering Doctorate and winning the ICE Safety in Construction Medal for his research. His publications (focusing on flow rates, stadia modelling, and schools modelling) provide a valuable resource for other researchers and analysts. He has led people flow consultancy on many high profile projects such as Ascot & York Racecourses and the Kings Waterfront master-planning and continues to work in many sectors.

Jonathan Hall

BEng, MSc

Jonathan is a senior consultant in Buro Happold's SMART Crowd Flow Solutions team. He has 8 years experience in the fields of transport and people flow, having worked for local government and consultancies both in the UK and New Zealand.

Jonathan combines a strong project management background with multi-sector experience in people flow. His notable projects include the London 2012 Olympic Paralympic Games, for which he worked for over 4 years on numerous aspects. This included working on several venue design teams, design of the Olympic Park and overlay, Stratford stations management and operations and links between event ticketing and crowd flow.

Jonathan's key skills revolve around his practical problem solving ability, combined with a strong analytical approach. He is fully versed in several pedestrian modelling packages including Legion.

Jonathan also has extensive experience modelling transport interchanges, including Crossrail Custom House station, North Greenwich Station and Bank Underground Station.

Jon Dare-Williams

BEng (Hons) Civil Engineering MSc Transport

Jon has produced a wide variety of reports including an Interim Transport Plan, Transport Assessments for development, Travel Plans, accident analysis reports, policy guidance notes, committee reports and community transport studies. Jon has attended the full RoSPA Accident Investigation and Prevention course. As part of the planning process Jon has been involved in Section 106 and Section 278 negotiations.

Technically, Jon is proficient in the use of industry modeling packages such as TRANSYT and LINSIG and has a working knowledge of SATURN, Micro-simulation and PEDROUTE and has developed spreadsheet transport models for major masterplanning developments. Jon has designed and implemented a variety of transport management measures including traffic calming schemes, signalised and priority junctions, bus priority, pedestrian and cycle schemes. This has also included attendance at public consultation and design of associated consultation material.

Buro Happold

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