BURO HAPPOLD

FIRST-CLASS AIRPORT ENGINEERING

CAPABILITY AND EXPERIENCE

AVIATION

Buro Happold understands the complex demands and commercial realities of the air transport sector. We have the global experience and knowledge to take any airport project from its initial masterplanning and forecasting phases - through passenger terminal design or expansion, baggage handling systems and air traffic control centres – to its internal transport links and car parks, offices and retail areas.

02

With a focus on enhancing passenger experience, our designs always put people first. This approach applies whether we are optimising people flow through the buildings, creating a comfortable internal environment or improving safety and security.

terminal building is an important part of the journey. Accordingly, we strive to create inspirational spaces that are functional and navigable. Offering light and airy column-free designs, our new terminals often achieve iconic status while our expansions involve creative solutions to minimise disruption.

making extensive use of premanufacture

and architect to make that sure that we understand their priorities. Ultimately, we provide design solutions that not

Gibraltar International Airport, Gibraltar, Architect: 3DReid/bblur, Image: bblur/Hufton + Crow

OUR EXPERIENCE

Buro Happold's work in the aviation sector is seen at every stage of the air travel experience. From the approach roads and car park to the first-class travellers' lounge and control tower, our engineers design airport buildings that make flying a straightforward and comfortable process. Our experience in the aviation sector means that we have expert knowledge of how airports operate, and understand the best ways to meet client goals. From the design of new terminal buildings at large international airports to our work at smaller, private facilities, our priority is to help clients to improve their business.

This expertise extends to scheduling construction to minimise disruption for travellers and maintain business continuity.

From creating distinctive landmark structures to extending existing facilities, our engineers apply the same level of skill and care to deliver airport facilities that are functional, sustainable and efficient.















THE KEY ISSUES

An overview of our problem-solving capabilities in the aviation sector.



<u>08</u> OPTIMISING CAPACITY Optimising space and operations to support a growing airport community

<u>10</u> PROVIDING CERTAINTY, ASSURING VALUE Design solutions that reduce exposure to risk

<u>12</u> PASSENGER EXPERIENCE Integrating intuitive design and elegant engineering to ensure a seamless passenger journey

<u>14</u> SUSTAINABILITY Delivering sustainable, energy-efficient, world-class facilities that don't cost the earth

<u>16</u> CONNECTIVITY AND PLACEMAKING Realising a vision and delivering an identity

<u>18</u> SECURITY Appropriate application of security measures to provide a frictionless environment for business and operations

<u>20</u> MODULAR CONSTRUCTION Improving quality and speed of construction while minimising disruption to operations

<u>22</u> LONG SPAN STRUCTURES Enabling the architectural aesthetics that redefine passenger experience

<u>24</u> SEAMLESS INTEGRATION Airport facilities that connect effectively and efficiently with the networks around them



OPTIMISING CAPACITY

From masterplanning to terminal redevelopment and expansion, we advise clients of the best ways to increase capacity and improve operational efficiency with immediate effect. We develop and integrate the latest dynamic planning tools to create intelligent, safe, compliant systems that incorporate the means to support future growth and development.



01 HOLLYWOOD BURBANK AIRPORT Los Angeles, USA

The airport is working with the community and neighbouring cities to build a safer, modern, 14-gate Replacement Passenger Terminal (RPT) that meets current FAA safety standards and seismic performance standards. It will preserve the convenience and easy access that air travellers enjoy while providing new amenities. The goal of the report was to determine feasibility of the RPT and support facilities, and provide enough information to prepare a cost estimate.

Our design charrettes explored: maintaining the celebrated ease of accessibility and use of the current airport; emphasising local climate, character, and culture; minimising energy and water demands; health and wellbeing strategies; and providing a flexible structure that can be adapted for future change.

We determined that the proposed RPT can accommodate growth compared to current operations without increasing the current number of gates. The site layout, programme, and functional areas are determined to be generally adequate to provide an "optimum" level of service.

Client: Burbank Glendale - Pasadena Airport Authority Image: WikiCommons



02 PHNOM PENH INTERNATIONAL AIRPORT

Cambodia

We are providing the full suite of planning services up to tender design stage on terminal, security and logistics for a 10m PAX international airport building. This includes capacity and demand analysis, flight schedule review, peak hour definition, planning parameters and assumption definition.

Our planning team is preparing Basis of Design documentation, the programme of requirements and the facility planning for the whole terminal, including logistics and security. We are providing airside interface design, fixed links, and passenger boarding bridges design and specification. Working alongside the lead architect, we are implementing scheme design development including stakeholder engagement and alignment with a parallel masterplan study.

Client: Confidential



04 HEATHROW TERMINAL 5 PASSENGER FLOW SIMULATION & CAPACITY STUDY

London, UK

Heathrow airport is carrying out a partial refurbishment of its Terminal 5 to accommodate the growing passenger numbers. Heathrow and its contractor, MACE, asked Buro Happold to provide an assessment and review of this new process.

Using our bespoke simulation tool, Airport Analytics, we analysed various aspects of the departures security check, including

<u>03</u> THE RED SEA PROJECT AIRPORT

Saudi Arabia

Our scope on this project included airport development site selection (including setting the site selection criteria and option assessment), runway orientation, masterplanning, and terminal concept development. The team addressed noise footprint and impact analysis, obstacle limitation surface com-pliance and airspace integration impacts.

Stakeholder engagement was an important consideration for this project. We developed a strategy to manage the project approvals timeline, taking the civil aviation and aerodrome licensing protocols into consideration along with client and stakeholder recommendations.

In addition, our airport planning team prepared demand forecasts, benchmarking, peak hour demand analysis, future capacity requirements and phasing strategy for the terminal and airfield facility sizing to enable the development concept terminal design.

Client: The Red Sea Development Company

passenger management, circulation and queueing space required.

Following the successful completion of the initial project, we were engaged by MACE and Heathrow to carry out a comprehensive analysis of the terminal processors, including check-in, security, transfers and immigration. The study compares the capacities of the different options under consideration of the project team, and visualises their impact using a dynamic simulation tool.



Client: Heathrow Airport Limited Architect: Mace Image: Buro Happold

PROVIDING CERTAINTY, ASSURING VALUE

Buro Happold's experience means that we are able to foresee risks early on, while the design is still agile, preventing exposure of our clients. Our early and effective stakeholder engagement, internal communication and rigour, and clear explanation to contractors all come together to avoid costly surprises during construction. Regular workshops and visualisations keep our clients informed and capture their visions and views.

Our dependability earns us regular repeat work, including 300+ projects over 25 years at Heathrow Airport.



05 FLIGHT CONNECTION CENTRE

Heathrow Airport, London, UK

This project sought to improve the operational effectiveness of the Flight Connection Centre (FCC) while keeping it functional throughout the construction period. We rose to the challenge to deliver a design that mitigated the risks to existing operations and provided a construction methodology congruent with the live operations.

We undertook a careful examination of the building and site we were working on - surveying foundations, analysing placement, and checking existing structures – and produced engineering solutions that would not compromise the day-to-day working of the existing FCC. By planning around these constraints and incorporating them into our methodology, we were able to extend the FCC and enhance its operational efficiency with minimum disruption to all users, to both the logistical and financial benefit of our client.

Client: Heathrow Airport Limited (HAL) Architect: 3DReid Image: Buro Happold



06 TAG FARNBOROUGH

Farnborough, UK

Our client wanted us to come up with a design for a new triple-bay (300m x 50m) hangar for light maintenance and plane storage that could compete with the price quoted for an off-the-shelf design and build solution. It was important to deliver an aesthetically pleasing building that would fit with the stunning TAG terminal and ATCT we had already created for them.

We responded by going back to first principles. It was decided that the most efficient structure we could use to span the hangar would be an arch. Our specialist team considered the whole hangar in this form in order to achieve maximum usable space as well as elegant design. This concept required 40% less steel than a conventional design, minimising both the surface area of cladding needed for the building and its volume. This approach yielded the benefits of immediately reducing the cost of materials required while lowering heating bills and energy use in the long term.

Client: TAG Aviation Architect: 3DReid/bblur Image: Buro Happold/Adam Wilson



07 KILO APRON DEVELOPMENT CAT 3 CHECK

Heathrow Airport, London, UK

Our geotechnical and structural engineering teams undertook the Category III check for the Heathrow T2 Kilo Apron Development substructure. The basement is 190m x 100m x 13m deep, comprising raft slab, diaphragm walls, and steel-framed with concrete roof. A full and independent finite element analysis was undertaken of the structure/ground interaction. We were then appointed to optimise the basement raft slab structure.

Our work saved 47kg/m² reinforcement, generating savings of 600 tonnes of reinforcement for the entire structure and hundreds of thousands of pounds for our client. We have a strong culture of internal review within the practice while delivering complex multidisciplinary projects. Our designs are subject to rigorous checking to ensure that our teams work together to deliver the best value solution.

Client: Heathrow Airport Limited (HAL) Image: Buro Happold



08 MANCHESTER INTERNATIONAL AIRPORT TERMINAL 2 EXPANSION

Manchester, UK

We are providing multidisciplinary services for the £600m development of Manchester Airport Terminal 2 for Laing O'Rourke. Construction of this project - the largest aviation project currently on site in the UK – is on programme.

Working with the client and design team, we defined the technical performance requirements of the external envelope of the Terminal 2 Extension project based on the concept design.

Through collaboration with the structural engineers and MEP engineers, the requirements on primary structure and heat/cooling loading were agreed at an early stage. This unlocked the design of those packages, meeting the tight design programme. With our expertise in facade engineering, we were able to provide optimised envelope design solutions and highlight risks where certain performances may lead to significant cost uplift, such as the high acoustic requirement on the airside.

These risks were either budgeted for early on in the project or mitigated through an agreement whereby the client could relax the performance based on informed decisions. We were also able to challenge contractor's proposals and avoided unnecessary design requirements to the primary structure. This led to an optimised whole-building system design.

Client: Manchester Airport Group (MAG)

PASSENGER EXPERIENCE

We aim to mirror the fast, intuitive connectivity driven by the use of SMART technologies within airports by providing cutting-edge, unique terminal environments. By exploring new technologies, we develop tools that improve passenger experience and couch them within our extensive aviation experience. We combine creative thinking with engineering excellence to produce terminal designs that transcend aviation authority criteria. These solutions anticipate, respond to, and fulfil the total range of passenger needs.



09 LONDON CITY AIRPORT London, UK

To support London City Airport's major growth plan, our team undertook passenger flow modelling for the proposed Terminal Development Project. We analysed the passenger flows within the reconfigured terminal and proposed expansion elements, principally the new departures and arrivals areas.

We carried out detailed assessments of: transport-related parameters, such as modal splits and rail expansion plans; design parameters, such as the number of automatic check-in stations; operational parameters, such as immigration staffing; and security parameters.

Our work enabled optimisation of the location, orientation and number of CUSS kiosks along with the immigration desks, baggage hall and central search facilities.

Client: City Airport Architect: Allies and Morrison Architects Images: Buro Happold



10 HAMBURG AIRPORT

Hamburg, Germany

We appraised several design options for a new retail area and circulation space at Hamburg Airport. The aim was to develop a scheme that would be most effective in terms of space utilisation, passenger comfort and retail visibility. A combination of static and dynamic simulation models for rapid design testing and comparison was developed using our in-house people flow simulation software, SmartMove.

All of our designs were informed using a scenario that considered a normal peak hour with arrivals and departures passengers passing by the new facilities. As a further optioneering exercise engaging the design team, a new option was proposed to maximise retail visibility and enhance passenger experience, potentially leading to better revenue opportunities.

Client: Hamburg Airport – Flughafen Hamburg GmbH

Architect: GMP Architekten, Image: Wikimedia/Medvedev



11 HEYDAR ALIYEV INTERNATIONAL AIRPORT

Baku, Azerbaijan

By 2011, capacity at Baku's only international airport was already being stretched. Azerbaijan Airlines (AZAL) proposed an extensive expansion initiative that would see the airport increased by 150% to accommodate up to three million travellers each year.

In a joint venture, we teamed up with the architect to produce a design and build fast-track programme for AZAL that would provide a new terminal and distinguish the airport with an iconic new access route.

Using the latest in computer modelling technology, the team came up with a striking design that both negotiated the difficulties of the airport's location in a seismic region and complied fully with international ICAO and IATA standards. This included developing a smoke ventilation and fire engineering strategy that met Euro codes, and integrating an intelligible public address and voice alarm system into the central fire and security system.

Client: Azerbaijan Airlines

Architect: Woods Bagot



12 BIRMINGHAM INTERNATIONAL AIRPORT Birmingham, UK

We were appointed by D5 Architects to test the design of the Passenger Search Area (PSA) within the proposed terminal design in relation to agreed passenger comfort levels, as well as to test the scalability of the design. A combination of static and dynamic simulation models was used to assess the latest design proposal with regards to the passenger movements within the PSA. This modelled

the detailed, but realistic, ingress rates and services times. Based on the architectural drawings provided, a 3D network model was built to represent the circulation and queuing regions through the PSA, which included the boarding pass check and AMDs. Several detailed simulations of a number of scenarios were performed.

During the study, the team assessed the proposed design against target peak hour demand. Demand was increased until throughput time and spatial capacity exceeded acceptable levels, providing valuable data on the peak hour limiting point.



Client: Birmingham International Airport Architect: D5 Architects Image: Buro Happold



SUSTAINABILITY

We consistently deliver cutting-edge sustainable designs. Our strong record of accomplishment has informed our appreciation of the operational requirements of an airport and the regulatory context in which development takes place. We aim to deliver a balance between social, environmental and economic value, using sustainable design to deliver measurable improvements in the performance and quality of airport facilities.



13 OSLO GARDERMOEN INTERNATIONAL AIRPORT Oslo, Norway

We embedded sustainable and energy-efficient design throughout our work, providing a range of integrated services for this major airport expansion. Doubling the size of the existing building, this project realised the greenest airport terminal in the world.

One of the key goals was to deliver an improved terminal that cut energy demand by 50% against the existing building. This was no small task, given that the old terminal was already one of the most energy efficient in the world.

We undertook careful modelling and analysis of the building's design and orientation to develop a curved extension complete with panoramic window, which works with the skylight that runs along the length of the pier to promote passive solar heat gain and temperature control.

By taking a holistic approach to sustainability, our engineers were able to work with the wider project team to realise the first BREEAM Excellent rated terminal and establish a new benchmark for sustainable aviation.

Client: Gardermoen Airport Architect: NSW Image: NSW



14 TERMINAL MODERNISATION PROGRAM AT PITTSBURGH INTERNATIONAL AIRPORT

Pittsburgh, USA

By providing a new landside terminal adjacent to the existing airside terminal and adopting the "single roof terminal" concept, the Terminal Modernization Program looks to repurpose unused areas within the existing terminal buildings and ensure there is no longer an operational reliance on the Automated People Mover and Track Transit System, as a result maintenance costs are significantly reduced.

Our approach has ensured that there is clear separation between the old and new infrastructure in order to avoid prohibitive costs associated with system upgrades. Our extensive BIM capabilities have enabled the team to work with the architectural design team to co-ordinate and develop the airport terminal concepts and to develop our Single Analysis Model to evaluate thermal loads and develop the whole building energy model. This approach allowed the design team to evaluate energy conservation measures and their impact on operational costs.

Client: Pittsburgh International Airport

Image: Gensler + HDR in association with luis vidal + architects

15 KING KHALID INTERNATIONAL AIRPORT Riyadh, KSA

With an annual population increase of 9%, Riyadh is one of the fastest growing cities in the world. To keep up with this expansion, Our fume dispersion studies supported the design of the multi-KKIA are integrating terminals 3 and 4 to create a world-class, storey car park (MSCP) at T2. A straightforward code compliance fully IATA compliant mega-terminal that will increase capacity over approach would have required a more costly and energy-intensive 100% from 12 million to 25 million. Translating the architect's vision mechanical ventilation solution. However, using the latest CFD into applied engineering solutions, we are providing energy-efficient techniques, we developed and gained approval for a natural systems that will realise our client's aim to achieve a LEED silver ventilation solution that saves capital and running costs. We have certification. Continuing the signature rooflights of the existing also undertaken wind and rain studies to improve the external terminal means that the building will benefit from large amounts environment in key pedestrian routes around T2. of indirect light. Extending the roof profile is also a simple, cost-Client: Heathrow Airport Limited effective means of reducing the cooling load of the terminals. Image: Buro Happold/LHR Airports Limited

Given the climate, we are also exploring likely sources of renewable energy – such as solar energy and solar thermal hot water – to further reduce the carbon footprint of the new terminal building.





16 HEATHROW AIRPORT

London, UK

Our sustainability and building physics teams have consulted extensively on various projects to drive efficiency and environmental improvements throughout Heathrow.

The team undertook Computational Fluid Dynamics (CFD) analysis to predict the impact of wind and rain on the external concourse area in front of T3, and CFD and dynamic thermal modelling within the terminal. The concourses and entrances previously suffered from significant exposure to wind and driven rain, resulting in a poor passenger experience. We steered the design for the roof canopy upgrade and entrances, resulting in a substantive improvement in passenger comfort, greater levels of energy efficiency and a lower capital cost.

CONNECTIVITY AND PLACEMAKING

Our team has worked on some of the world's most iconic aviation facilities. We collaborate with clients and leading architects to design new terminals and transform outdated buildings into striking new assets with infrastructure that allows the seamless integration of wider multimodal hubs. Delivering something a little bit different, we elevate designs that marry cutting-edge engineering and visionary architecture to create striking international gateways memorable for both their beauty and efficiency.





<u>17</u> JEWEL CHANGI AIRPORT Changi, Singapore

Occupying a site of approximately 1.4 million ft², the Jewel will enhance Changi Airport's facilities and strengthen its position as a global air hub. We have worked alongside the architect to transform a former car park into a contemporary complex housing airport operations, retail units, hotel accommodation, leisure attractions and indoor gardens. Crowning Project Jewel is an enormous glass and steel bubble rising to enclose the five storeys of above-ground amenities.

Our team are providing a range of structural and facade engineering services to realise the iconic structure that, when complete, will be one of the largest gridshells in the world.

Client: Jewel Changi Airport Devt Pte Ltd Architect: Safdie Architects, Image: Jewel Changi Airport Devt

<u>18</u> HEATHROW T3 & T4 London, UK

Working with Foster + Partners and 3DReid, we transformed the departure halls of Terminals 3 and 4 into expansive, open spaces that let in an abundance of natural light. This not only unified the passenger experience throughout the airport, but also offered the potential to increase traffic by up to 35%, which maximises the commercial value of the buildings in keeping with Heathrow's longer-term expansion plans.

Our success in delivering designs that establish brand identity extended even further when we created a new home for Virgin Atlantic's Upper Class check-in service in the south wing of Terminal 3. We provided up-to-date, highly efficient passenger processing facilities and housed them within a breathtaking glazed facade extension – complete with VIP passenger drop-off facility – that added a final, distinguishing feature to complete this on-brand, high-quality environment.

Client: Heathrow Airport Ltd (HAL) Architect: Foster + Partners/3DReid Images: Buro Happold/David Hatfull T4/LHR Airport Ltd

19 HONG KONG INTERNATIONAL

AIRPORT Hong Kong SAR of China

In order to keep pace with rising aviation traffic and meet future passenger demands at the airport, the extension of Terminal 2 will increase capacity at the gateway by 10 million passengers per year.

We applied our extensive experience of long-span design to provide an airport terminal that facilitates a simple, direct and efficient flow of air passengers and baggage. The striking architecture and engineering design is comparable to Terminal 1. This allows for maximum flexibility in terms of space utilisation and future expansion or changes in the functional requirements.

Incorporated into the design is an Automated People Mover Interchange Station, which connects Terminal 2 with Terminal 1 and the SkyPier, to support Hong Kong's growing aviation industry.

Client: Hong Kong International Airport Architect: Aedas, Image: Aedas







20 GIBRALTAR INTERNATIONAL AIRPORT Gibraltar

Welcoming visitors arriving by air, road or on foot, the conceptual design marries the influences of aviation and maritime tradition. The large, sweeping roof spreads its wings across the skyline – mirroring the forms of planes as they arrive and depart – while the expanse of the floor-to-ceiling glass facade offers visitors uninterrupted views of the sea.

Our design team created a world-class facility that responds to a complex operational brief on a sensitive and constrained site. Two entrances to the building separate passengers who are flying into and out of Gibraltar from those using the facility to cross into Spain. Located on different levels, they allow travellers moving through the building to navigate the relevant processes with ease and efficiency. Although security measures dictate the division of air and border passengers, extensive transparency between passenger routes ensures that all users enjoy a unified, positive experience.

Client: Government of Gibraltar Architect: 3DReid/bblur Image: bblur/Hufton + Crow

SECURITY

Our robust but flexible approach ensures compliance with rigorous national and international regulations while preserving the passenger comfort and experience – both critical to the performance of a successful airport. Our harmonious solutions consider mitigation measures to prevent all compromises from internal and external threats and integrate them with our client's vision.





21 HEYDAR ALIYEV INTERNATIONAL AIRPORT Baku, Azerbaijan

Our security design covered all personnel screening at the terminal frontage, central security screening and departure gate screening, the design and full integration of the Terminal Control Centre and all field-devices with their associated infrastructure (such as CCTV, EACS, IDS, HVM, intercom, servers, NVRs, personnel screening, baggage screening, thermal visa system and chemical/biological/radiation detection system).

Collaborating across three different continents and some 26 disciplines, on-site attendance ensured that we were able to both deliver efficiently and brief the client at every step of the design. In conjunction with this, the design and delivery of the ATC was carefully integrated to ensure that this landside development met the appropriate aviation standards and recommended practises.

Client: Azerbaijan Airlines Image: Buro Happold

22 KING KHALID INTERNATIONAL AIRPORT

Riyadh, Saudi Arabia

Our blast vulnerability assessment of the initial design for Terminal 5 included provisions for vehicle-based improvised explosive devices (VBIEDs) at external locations around the terminal as close as 6m, as well as in the service tunnel running through the terminal. We also included an assessment of the response of the facade systems and main structural elements.

Our blast engineers employed a bottom-up approach, evaluating the capability of the proposed scheme design to withstand the prescribed loads. We then suggested enhancements that provided the most cost benefit where needed. This included strengthening roof truss members to provide a balanced design for the roof to prevent a potential catastrophic failure and evaluating structural columns adjacent to the vehicle drop off. We also mitigated debris from the facade systems by providing good practice advice on the choice of system and detailing – subsequently quantitatively calculated – the damage under the prescribed explosive threats.

Client: General Authority of Civil Aviation (GACA) Image: HOK



23 HEATHROW T2 TRANSPORT INTERCHANGE

London, UK

Our specialist aviation security consultants delivered the landside security for the T2 multi-storey car park. This was achieved through the integration of the standards and recommended practices (SARPs) stated within ICAO Annex 17 (Security), ICAO document 8973 (Aviation Security Manual) and the UK DfT Aviation Security in Airport Development (ASIAD) report (specifically chapter six for landside security). This ensured the terminal demise and all the support facilities were designed to a robust level, providing a resilient and operationally functional environment that met the client's needs and requirements for present and future operations. This covered the delivery of the CCTV, EACS, IDS, HVM, intercom, blast mitigation and various security protocols.

Client: Heathrow Airport Ltd (HAL) Image: Buro Happold



24 BRISTOL AIRPORT

Bristol, UK

This project will encompass an increase in the number of aircraft stands, terminal and pier expansion, and various landside infrastructure development with hotels, car parking, vehicle rental, and other commercial entities. Our consultants provided detailed blast analysis and scenario planning to advise the client and design teams of the various risks and vulnerabilities to the structural form.

This has enabled the client to make informed decisions concerning terminal expansion, resulting in cost savings in the material selection and positioning of critical columns and facades.

We delivered an established design capability, supported by the fire design teams, which enabled a responsive and collaborative integration with the client and other design disciplines. This proved best-of-breed by the in-house ICAO and CAA accredited AVSEC Professional Manager.

Client: Bristol Airport Ltd.

MODULAR CONSTRUCTION

Our team has an expert knowledge of the benefits of Design for Manufacture and Assembly (DfMA) for aviation projects. The driver for our off-site solutions centres on limiting the operational impact, quality of product and speed of construction. Sharing our knowledge as a business has provided benefits for clients on transport projects around the world, such as the Haramain High Speed Rail in Saudi Arabia and the Hong Kong Boundary Crossing Facility.





25 LAX MIDFIELD SATELLITE CONCOURSE SOUTH

Los Angeles, USA

The new MSC South concourse will support eight new domestic gates and provide passengers with a significantly improved experience. The site is challenging, as it is constrained on all sides by two active taxiways, an existing hangar, and the MSC North concourse which are to remain operational throughout construction.

The new MSC South concourse will be designed to optimize flexibility as additional expansions are planned near the site. To minimize impact to airport operations our team is proposing a modular approach using offsite construction strategies – a first of its kind at a US airport. This will not only reduce time and the number of workers onsite during construction, but provide higher quality and improved safety as well as helping meet sustainability targets.

Client: Los Angeles World Airports Image: Buro Happold





27 MANCHESTER INTERNATIONAL AIRPORT TERMINAL 2 EXPANSION Manchester, UK

Most recently, our team has used the latest in DfMA techniques at Manchester Airport. The new three-storey 700ft x 80ft pier provides open gate lounges for 11 contact stands with fixed links to node buildings. The multi-storey car park provides short-term spaces for 3,800 vehicles.

The structure benefits from a hybrid precast concrete-steel delta beam arrangement, which significantly reduced on-site crane hook-time to achieve savings in the construction programme. This generated advanced revenue for the client through early parking charges, which contributed to the build cost of other transformation structures.

Client: Manchester Airport Group, Images: Buro Happold

25 HONG KONG BOUNDARY CROSSING FACILITY

Hong Kong SAR of China

Our DfMA approach revolutionised the construction of this complicated building. Supported on a 33m x 42m column grid, the curved roof structure presents a visually striking, flowing profile supported by tapering tree columns.

Constructed without the use of tower cranes due to its proximity to Hong Kong International Airport, the structure has a modular design that enabled the contractor to prefabricate whole sections off-site, including the roofing and soffit cladding. These 60m x 24m modules were delivered to site on barges and crawlers before being moved into position using a unique horizontal launching system. This avoided the need for cranes.

Working closely with the contractor, our team worked to minimise the weight of the manufactured elements, allowed for transportation loads and movements, and designed the structure for the locked-in stresses caused by this unusual sequence.



Client: AECOM/Highways Department Images: Robert Limbrick Architects/Buro Happold

26 HEATHROW AIRPORT

London. UK

Our expertise in DfMA at Heathrow began with the Heathrow Terminal 3 Pier 5 project. The "corridor product" was designed and manufactured remotely - along with the end of pier bridge link and vertical circulation cores - before being transported to site and manoeuvred into position. This greatly enhanced quality, reduced waste and mitigated airside operational impact.

Our teams have since made use of the process on dozens of Heathrow projects, including the Terminal 2B pier building and multi-storey car parks, and link bridges at both Terminal 2 and 3.

The fully precast car park and elevated highways were developed in BIM with every reinforcing bar and nut and bolt. This allowed the building to be constructed in the virtual world before construction, which ensured minimal site issues. The BIM models were shared with the manufacturer, Laing O'Rourke, so that detail could be progressively added and coordinated with all parties.







LONG SPAN STRUCTURES

The Buro Happold team includes some of the world's best structural engineering experts. Our unique approach and innovative designs make us a go-to firm for signature architects. As a collaborative group of creative problem-solvers, we have enabled the vision behind some of the world's greatest passenger experiences.





28 BEIJING DAXING INTERNATIONAL AIRPORT Beijing, China

The radial design of the terminal features a central hub from which six curved spikes extend. This configuration reduces the distance that passengers travel to reach their gate to a maximum of 600 metres, and ensures that this huge building is easy to navigate.

We worked extremely closely with the architect to integrate the engineering design into the architectural form, allowing us to render the spacious areas desired by our client. The result is a terminal that is at once highly functional and aesthetically dazzling.

The strength of the collaboration between our engineers and the architect allowed us to take a highly creative approach to the brief, developing a design for Beijing Daxing Airport that delivers added value to our client and an iconic aviation facility for the city.

29 JEWEL CHANGI AIRPORT

Changi, Singapore

The outer shell of the new mixed-use complex at Jewel Changi Airport poses significant challenges in terms of structural behaviour, geometrical complexity and constructability.

At the apex of Jewel's glass roof is an oculus that showers approximately 130,000 gallons of water down the centre of the building. By using the most advanced analytical and Building Information Modelling (BIM) tools to optimise the design - and working very closely with Safdie Architects - the engineering teams were able to rationalise and develop the design of the envelope to tender drawings.

Key to this was Buro Happold's experience and knowledge of detailing and construction technologies in modular long span applications. This created a design that was not only beautiful but also buildable and affordable.

Client: Jewel Changi Airport Devt Pte Ltd Architect: Safdie Architects Image: Tim Hursley



Client: AECOM/Highways Departments Architect: Rogers Stirk Harbour, Image: Robert Limbrick

31 QUEEN ALIA INTERNATIONAL AIRPORT

Amman, Jordan

Buro Happold was involved in the development of the new Queen Alia International Airport from the outset of the project. We worked in conjunction with Foster + Partners architects to develop a striking, over-arching roof structure under which the new terminal could operate. With engineering and architectural design running in parallel from such an early stage, we were able to devise a structure that combines engineering excellence with stunning beauty of form.

The roof structure comprises a series of shallow concrete domes, reminiscent of giant palm leaves. These are connected to concrete pillars, which support the full weight of the roof. The strength of the stems, which taper out from the supporting pillars, is such that large openings could be set within them to allow bright sunlight to permeate the roof.

Client: AIG Group Architect: Foster + Partners Image: Nigel Young/Foster + Partners



30 HONG KONG BOUNDARY CROSSING FACILITY

Hong Kong SAR of China

Our structural engineers designed the roof and facades structures for the 54,000m² Boundary Crossing Facility. Supported on a 33m x 42m column grid, the roof structure is doubly curved to form an undulating profile supported by elegant columns.

Our team took the lead in defining the complex geometry of the roof structure in order to maximise symmetry, repetition and ensure that each beam section could be defined by a single circular arc.

This resulted in a highly modularised design, not only of the structure itself but also for all subsequent trades fitting the roof and soffit cladding, lighting and services. The repetitive nature of the geometry also enabled a high degree of architectural expression in the exposed steelwork connections through the use of cast steel nodes, made economical by the large numbers of identical nodes.



SEAMLESS INTEGRATION

The needs of new or expanded facilities at airports can have a huge impact on the complex networks that serve them. Whether they transport people, energy, information, water, or waste, these networks need to be planned to ensure that projects can be delivered efficiently. Our engineers are experts at assessing existing infrastructure to develop strategies and solutions for new developments that are efficient, resilient, and respect the day-to-day business operations of the airport.





32 MANCHESTER INTERNATIONAL AIRPORT TERMINAL 2 EXPANSION Manchester, UK

Buro Happold managed to eliminate the need for a significant number of diversions through careful planning and coordination. Working in Civils 3D, our engineers modelled the existing networks and surfaces based on a wide variety of survey and record data, and allocated certainty factors to each element within the model. This allowed us to strip out all redundant services, and question and rationalise proposed new services and diversions.

We identified opportunities to route services that reduced cuts through the half-metre thick apron by around 600m². Coordinating with our bridge design team, we allowed for the continuing operation of a live airport city HV and gas facility during the works. This avoided a 500m diversion of both of these major services.

After learning of the contractor's interest in micro-tunnelling duct banks through hard-to-access areas of the airport, we were able to identify an additional 250m of runs that could easily be bored while the equipment was on site.

We worked alongside a product manufacturer to develop, agree and check a bespoke specification for the below-ground storm water attenuation system. This avoided the need to use expensive oversized pipework as specified. For maximum efficiency, we designed the tanks to be installed during a separate piling operation.



33 HEATHROW AIRPORT T2 TRANSPORT INTERCHANGE London, UK

We successfully oversaw the planning and detailed design of a complex network of below-ground infrastructure.

Crucial to the success of this project was the seamless integration of the new terminal building - and all of its associated networks - into the heart of one of the busiest airports in the world while it remained fully operational. By working closely with the wider project team and extensive airport stakeholder groups, we ensured that all aspirations were translated into the design at every stage.

Our extensive use of Building Information Modelling (BIM) was vital in informing our design solutions throughout the project. Working closely with the contractor, and by sharing this live model, we were able to optimise our construction methodology and sequencing to minimise disruption to airport operations.



Using BIM to peel back the ground surface, and unravel the complex utility networks beneath, allowed us to make informed design decisions at a very early stage. This reduced the potential for error and risk of expensive mistakes. Despite the spatially constrained below-ground environment, we successfully coordinated the new service connections, simplifying designs to ultimately save on the scope of infrastructure to install. We removed the need for a whole pumping station through careful planning and rerouting of a gravity storm water drain.

By identifying and proving a new, more direct service corridor through a constrained part of our site we were able to remove the need for costly microtunnelling operations completely. Our appreciation for the potential utilisation of short-term, temporary boilers also removed a whole phase of the major district heating service diversion, another significant infrastructure saving.

Client: Heathrow Airport Limited Image: Buro Happold

34 NEW LIBREVILLE INTERNATIONAL

Libreville, Gabon

Buro Happold developed the site-wide strategies for the utilities, infrastructure, highway and transportation networks across the new airport, ensuring our building designers were working from a carefully planned, solid foundation.

Collaborating closely with the client, our team acted as the key interface point between all main parties, ensuring our strategies aligned with stakeholder needs and the local environment.

Our detailed and holistic knowledge of the project allowed us to bring the right specialists on board at the earliest opportunity, de-risking potential problems such as overland flows from neighbouring catchment areas.



Client: GSEZ Image: HOK Architects



assessments

AVIATION PROJECT SHOWCASE

Creating sustainable, energy-efficient and environmentally sound aviation facilities.









- 01 Indira Ghandi International Airport, New Delhi, India Architect: HOK, Image: HOK
- Architect: HOK, Image: HOK
 <u>02</u> Heathrow Airport Terminal 3, London, UK
 Architect: Foster + Partners/3DReid, Image: David Hatfield
 <u>03</u> Abu Dhabi International Airport (Midfield Terminal Support Facilities), Abu Dhabi, UAE. Architect: 3DReid/bblur Image: Lifang Vision Technology Co.
 <u>04</u> Turgunga Airport Argonting
- 04 Tucuman Airport, Argentina Architect: Pelli Clarke Pelli
- 05 TAG Farnborough Airport, Farnborough, UK Architect: 3DReid/bblur, Image: 3DReid









- <u>06</u> New Lisbon Airport Masterplan, Portugal Architect: Gensler, Image: Gensler
- Architect: Gensler, Image: Gensler
 <u>07</u> Hamad International Airport, Doha, Qatar Architect: HOK, Image: Associated Press
 <u>08</u> Heathrow Airport Terminal 2, Concourse B North Architect: Grimshaw Architects, Image: Timothy Soar
 <u>09</u> Queen Alia Airport, Jordan Architect: Foster + Partners, Image: Foster + Partners
 <u>10</u> Hachin Esternational Airport Harbin, China
- <u>10</u> Harbin International Airport, Harbin, China Architect: RMJM, Image: RMJM











experience and revenue.

and technology, we work with airport operators, architects and contractors to optimise designs that improve passenger

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