

A photograph of a modern cable-stayed bridge with four tall, white, A-frame pylons. The bridge spans a deep valley filled with a thick layer of white mist or fog. In the background, rolling hills and mountains are visible under a clear, light blue sky. The bridge's design is sleek and modern, with multiple stay cables fanning out from the pylons to the deck.

The Value of Design in Infrastructure Delivery

A report for the
National Infrastructure Commission

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This report was commissioned as part of the evidence base for the National Infrastructure Assessment. It has been produced in collaboration with the Design Task Force of the National Infrastructure Commission. The views expressed and recommendations set out in this report are the authors’ own and do not necessarily reflect the position of the National Infrastructure Commission.

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Foreword

The National Infrastructure Commission set up the Design Task Force to advise on how best to ensure quality design in future major infrastructure. We have reviewed experience of infrastructure design, interrogated infrastructure professionals, and looked at examples from the UK and beyond. Our work has been supported by three important pieces of research, including this portfolio of examples of projects in the UK and abroad which have addressed some of the barriers to integrating design.

The portfolio is compelling. It demonstrates the variety of ways in which major infrastructure projects can deliver great outcomes by embracing design. The themes which emerge around leadership, integration, collaboration, early engagement, sustainability and a user focus can be readily transferred into the planning and delivery of the major investment in the UK's infrastructure over the next decade or more. As infrastructure investment becomes a national priority so the benefits of quality design become ever more important.

Our recommendations for improving the design of major new infrastructure are included in the National Infrastructure Assessment. They include establishing a small, agile, independent National Infrastructure Design Group to act as a design champion and prepare new national infrastructure design principles. We are also asking for all national infrastructure projects to include a design champion in their senior governance and for each to be subject to review and consideration by an independent Design Panel.

May I thank all those who have contributed to this work and the members of the Design Task Force, Lucy Musgrave, Isabel Dedring, Hanif Kara and our advisor Tony Burton.

Professor Sadie Morgan
Commissioner, National Infrastructure Commission





Rotterdam Centraal, Netherlands

1 Introduction

1.1 Background and Objectives

This short research report examines the value of design through a portfolio of examples of infrastructure projects from the UK and beyond.

It has been developed to support the National Infrastructure Commission's Design Task Force work to "put design at the heart of the country's future infrastructure planning" and is published alongside the National Infrastructure Commission's National Infrastructure Assessment.

The National Infrastructure Commission wants to see design at the heart of national infrastructure planning – saving money, reducing risk, adding value and creating a legacy that looks good and works well.

The aim of this portfolio is to understand how some major infrastructure projects have addressed some of the perceived barriers to quality infrastructure design identified through the Design Task Force's early analysis:

- A lack of champions in the way projects are governed
- A lacuna in design knowledge among those running national infrastructure projects
- A failure to embed design in the day to day working practices of those responsible for programme delivery
- A deep-seated perception that good design adds cost and poses risks to delivering projects on time and on budget

It does this by examining both the design process, and the project outcomes. We start to map out emerging themes and practices for how design can be successfully embedded into the planning of infrastructure projects.

1 Introduction

1.2 What We Mean by Design

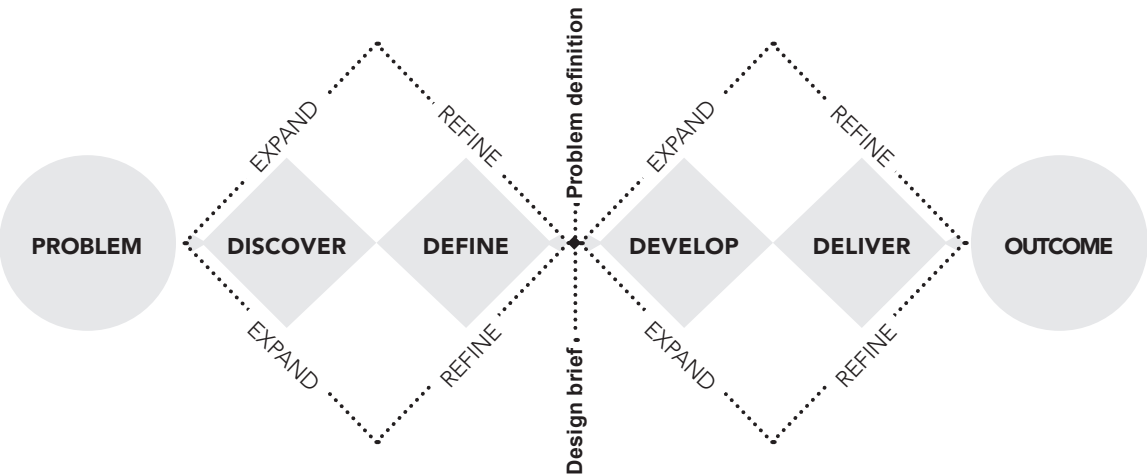
The Design Task Force takes a broad ranging approach to design which extends beyond how it looks to include the processes through which infrastructure is provided and how it works.

Design is about more than aesthetics and architecture; it is about effective problem solving from the outset, making infrastructure human-scale and user-friendly, enhancing the environment and improving quality of life not only for those who benefit directly but also for the communities and places nearby.

Design is an iterative process and occurs at different levels throughout the project delivery process. The Design Council Double Diamond design process illustrates the importance of design from the outset of the project, in defining the problem and developing the project brief.

The selected projects in this report aim to show what we mean by design and how design and design thinking led directly to a wide range of benefits not only for those who commissioned them but also for end users and local communities, including:

- Successfully integrating stakeholders of major transport networks to create a gateway to the city and a civic hub
- Redesign of procurement approach to enable collaborative innovation processes
- Extending the function of utility buildings beyond energy generation to act as an education hub and a new city landmark



1 Introduction

1.3 The Value of Design

The Design Task Force has identified confusion among those delivering national infrastructure projects about the meaning of good design and, despite all the evidence to the contrary, a deep-seated perception that good design adds cost and poses risks to delivering projects on time and on budget.

The exemplar projects in this publication start to unpick how design can help reduce risks, add value, deliver more projects on time and create infrastructure that looks good and works well for everyone.

Each of the selected infrastructure projects demonstrates the value of design on a number of levels, which can be categorized into the following areas:





2 Design Portfolio

2.1 Overview and Methodology

The research is based on National Infrastructure Commission's call for exemplar projects from transport, waste, water, digital and energy sectors which can illustrate the role of design, and design thinking, in unlocking opportunities from a variety of perspectives, overcoming some of the perceived barriers to quality infrastructure design (see 1.1).

The selected projects in this chapter have been chosen from over 80 responses to the call, along with several key infrastructure examples universally recognised as 'best practice'.

Each of the projects presented in this portfolio illustrates a number of facets of what it takes to deliver quality infrastructure, providing a sample of different approaches across the different infrastructure sectors. Given the very short time frame for this publication this is by no means a comprehensive research piece and it only starts to unravel the value that design can bring to delivery of good infrastructure.

For each selected example, we have drawn out the key elements of the project that we believe can contribute to high quality outcomes. The project insights draw on published data and where possible, interviews with clients and design team members.

Collectively they demonstrate the value of design on multiple levels from procurement approach, placemaking and urban design, engineering systems, service design, customer or community experience, environmental sustainability, through to architecture and the delivery process.

We hope this portfolio can serve as inspiration to clients and delivery partners and stimulate further debate on the topic and lead to further evidence based research to share best practice experience.

1. Pudding Mill Sewage Station
2. Oslo Airport, Norway
3. Wessex Water Grid
4. Millau Viaduct, France
5. Blackburn Meadows Biomass
6. One Alliance, UK
7. Knostrop Footbridge and Flood Alleviation
8. Mersey Gateway Bridge
9. Lightrail Station, Den Haag
10. Northala Fields Park, London
11. Victoria Embankment, London
12. Rotterdam Centraal



Knostrop Footbridge and Flood Alleviation

Project Details:

Value: £2.5m

Location: Leeds , UK

Client: Leeds City Council,
Environment Agency

Delivery team:

Knight Architects, Mott
Macdonald, BAM Nuttall,
SH Structures, Arup

INTEGRATING INFRASTRUCTURES TO PROMOTE ACTIVE TRAVEL

The £50million Leeds Flood Alleviation Scheme (FAS) is one of the largest flood defence projects in the country. Led by Leeds City Council, in partnership with the Environment Agency, the scheme will reduce the risk of flooding to over 3,500 city centre properties, areas which were severely impacted following the devastating floods of 2015. One of the key components of the Leeds FAS is the replacement of an existing fixed Victorian weir at Knostrop with an innovative mechanical weir, the first of its kind in the UK.

A further objective of the scheme is the provision of enhanced routes for walkers and cyclists, with the goal of encouraging sustainable behaviours and opening up previously isolated communities and underutilised recreational areas. As part of the wider scheme, a length of island was removed to aid water movement and flood prevention, severing the much-used Trans Pennine Trail.

The natural solution was to combine flood defence function with a new bridge to the city. Leeds City Council recognised the wider value for a design of high quality that will attract users to the bridge and promote active commuting into the city.

LCC appointed a multidisciplinary design team to develop the design solution. The original S- plan scheme was redesigned as straight line, softened with a curving soffit and varying width across its length, creating viewing areas above the piers. The 70m long bridge uses the staggered arrangement of the new weir walls for support, avoiding the need for separate foundations. The bridge sits on slender piers, which cantilever forward from the ends of the tapering weir walls.

Given the accuracy required to realise the bridge designs, it was decided to embrace Building Information Modelling (BIM) from the outset. The bridge Revit model enabled every element to be accurately represented and tested to address buildability constraints. A trial erection of the bridge was undertaken at SH Structures’ facility, allowing many construction challenges to be addressed prior to site installation.

This attention to detail throughout design and construction was critical for a successful installation. The four superstructure spans were ultimately lifted and installed over a two-day period, whilst the piers were accurately installed and surveyed over the preceding week.

The design was refined through a collaborative approach to architecture and structural engineering. The resulting design celebrates the new flood defence with an attractive modern design that is of high quality and immediately identifiable with its place. The flood defence works and new footbridge facilitate Leeds City Council’s ambitions for sustainable growth, in particular linked to the South Bank Leeds Regeneration Framework.

Project outcomes include:

- Relinking of the Trans Pennine way
- Promoting active travel into the city of Leeds
- Environmental enhancement
- Catalyst for development growth of brown field land
- Savings in the cost of additional bridge foundations

KEY MESSAGES

Integrating functions of flood protection and connectivity

Client desire to deliver an integrated and beautiful link bridge

Design a response to the value engineering challenge

Trial erection to mitigate construction risk





Blackburn Meadows Biomass

UTILITY AS A DISTINCT LANDMARK COMBINING RELIABILITY AND EFFICIENCY WITH VALUE FOR MONEY

Project Details:

Value: £120m
Location: Sheffield, UK
Client: E.ON
Delivery team:
 Architect – BDP
 Lighting Consultant – BDP
 Landscape Architect – BDP

“Blackburn Meadows has been described as a ‘beautiful machine’ combining efficiency with value for money.”

Mihalis Walsh
 Architect Associate, BDP

Located in Tinsley, on the site of the former cooling towers, Blackburn Meadows provides a clean and sustainable source of energy whilst creating local employment and a new landmark structure for the area. It generates 30MW of energy by converting locally sourced recycled waste wood into electricity, powering around 40,000 homes and displacing the emissions of around 80,000 tonnes of CO2 per year.

The site selection was based on a number of factors, including fuel availability, electrical connection and transport links which, combined with the site’s history of power generation, contributed to fitness for purpose. E.ON’s £120m investment in Blackburn Meadows includes a community benefits fund worth up to £25,000 a year, set up to support local projects throughout the lifetime of the plant.

Working closely with the Council from the outset has enabled the client and design team to develop a design that meets multiple objectives, from performance in terms of reliability and efficiency, through to providing value for money, whilst creating the character of architecture which was sought by the planning authority.

“The distinct design provides a striking landmark and has helped generate a lot of interest from local organisations and businesses.”

Luke Ellis
 Blackburn Meadows
 Plant Manager, E.ON

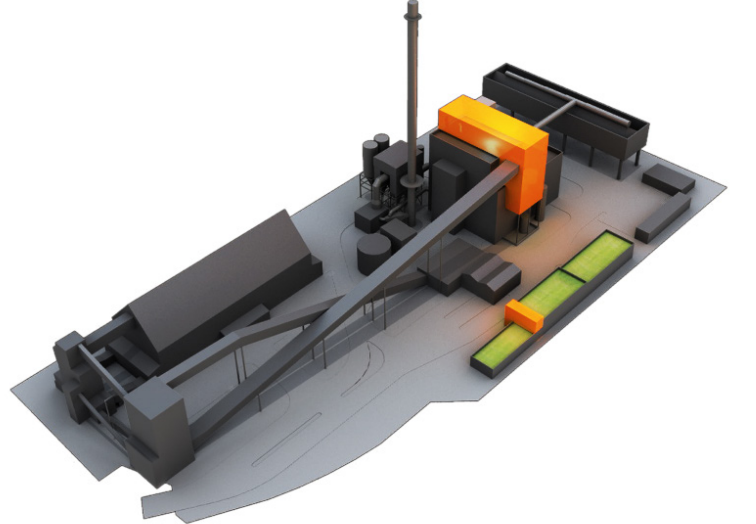
The construction was procured in packages managed directly by the client, providing them with the greatest degree of control in ensuring the project ran on time and budget and achieved high quality outcomes.

Over 3,400 people were involved in the construction process, including local contractors, helping to bring new jobs and investment to the area. Many of the 30 full time jobs created for the operation of the plant have been provided to local people who enjoy working in this attractive environment. The distinct design of the plant became a showcase for prospective E.ON clients, generating new business for the energy operator, with the visitor centre providing an additional educational function.

Working within the constraints of a defined plant configuration, the design extends the industrial aesthetic and expression of function to reveal the heart of the energy making process externally. The boiler house is highlighted as a landmark feature, using orange polycarbonate that is relatively inexpensive and highly contrasting with the rest of the scheme. This glowing volume crowns the power plant, creating a dramatic landmark satisfying both the client’s budgetary constraints and the local planning authority’s aspirations.

Project outcomes include:

- A new landmark for Sheffield
- Educational function and showcase of sustainability
- Local employment - over 3,400 people involved in construction, 30 full time jobs
- Attractive environment where people really enjoy working
- Displacing emissions of around 80,000 tonnes of CO2 per year
- Powering 40,000 homes



KEY MESSAGES

Investment in more than a utility building leading to new business for Client while benefitting wider community

Working closely with local authority to realise a joint vision with multiple objectives

Client managing construction directly through packages enabled tapping into local supply chain, and better cost and quality control



Oslo Airport

SCANDINAVIAN DESIGN SETS NEW STANDARDS FOR SUSTAINABILITY AND PASSENGER WELLBEING

Project Details:

Value: £4.5bn per AMP Cycle
Location: Gardermoen, Norway
Client: Avinor Oslo Lufthavn
Delivery team: Nordic Office of Architecture (assisted by NSW Architects), Cowi, Norconsult, Aas-Jakobsen og Per Rasmussen

“Creating a sense of place is fundamental to the airport branding, particularly in a long haul context. Passengers know they are in Norway.”

Christian Henriksen
 Partner, Nordic Office of Architecture

Oslo Airport needed to increase capacity to accommodate 35 million passengers per year. The project involved expanding the existing terminal building, a new train station at the heart of the airport and a new 300 metre long new pier. Avinor Oslo Lufthavn set a high ambition from the outset to minimise the environmental footprint and enhance passenger wellbeing. They appointed a multidisciplinary team to develop designs for the airport and the result is a highly sustainable airport building extremely well connected to the heart of Norway’s capital city.

The compact layout, with domestic and international gates stacked on top of one another, enables the airport to handle up to 30 million passengers per year whilst keeping maximum walking distances to just 450m, much shorter than most airports. Clear lines of site, use of natural light, great views into the surrounding forests and provision of open spaces, enhances both passenger wellbeing and visual legibility, providing reassurance for travellers and improving passenger flow. This enables passengers to enjoy the services provided by the airport, with direct benefits to airport revenues. This enables passengers to enjoy the services provided by the airport, and staff and goods to move swiftly around the building, with direct benefits to airport revenues.

“The business case for design is clear. We are very proud of our beautiful and functional building.”

Liv Karin Sundsvold
 Avinor Oslo Lufthavn

KEY MESSAGES

Client driver for sustainability and wellbeing of passengers

Design reflects local environment and provides a sense of place

Sense of place and passenger experience important driver of value

Collocated design and client team to enable collaboration

Monitoring of quality through out the contract

Focus on whole life value



Natural materials have been used throughout the building including a curved roof clad in timber sourced from Scandinavian forests, a glulam structure and concrete incorporating volcanic ash. Coupled with the use of recycled steel, this has reduced embodied carbon by 35% against a conventional steel and concrete building. The selection of materials was carefully monitored throughout the project delivery to ensure compliance with quality and sustainability criteria.

The tubular cross section of the pier minimises the amount of façade for the internal floor area provided, reducing both embodied and in use energy. Enhanced insulation, renewable energy and storage of snow for use as a coolant in summer mean that energy consumption in the new expansion has been cut by more than 50% compared to the existing terminal.

The sustainability outcomes for the project not only included value from a whole life cost and passenger experience perspective, they also eased routes for fundraising. Institutional investors were looking for projects which enhance their own brand through investment in sustainable buildings that are designed for the long term.

To deliver the project, the design and delivery team were collocated on site. This facilitated collaboration and quick resolution of issues as they arose. In particular, it enabled the design team to work with airport operations to ensure the functional performance of the building design.

In the face of competition from northern European airports, Oslo provides a distinctive passenger experience. As soon as you arrive, you know you are in Norway and this is a key brand differentiator.

Project outcomes include:

- First BREEAM Excellent airport building
- Enhanced passenger experience
- Compact building, passenger paths only 450m
- 35% reduction in embodied CO2 emissions
- 74% travel by public transport



Pudding Mill Sewage Pump Station

Project Details:

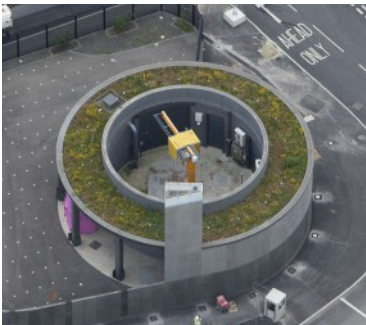
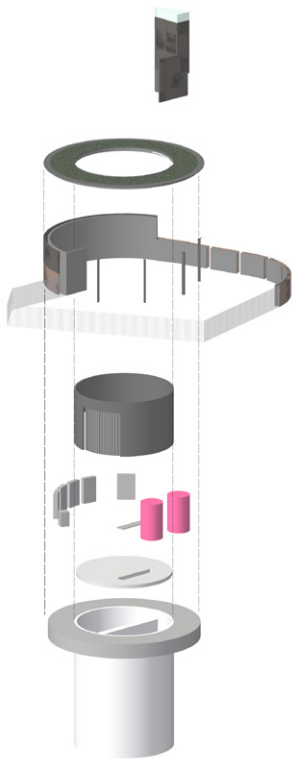
Value: £1m
Location: Queen Elizabeth Park, London
Client: The Olympic Delivery Authority (ODA), Thames Water
 ODA design champion - Kay Hughes
Delivery team:
 Architect - Lyall Bills & Young
 Main contractor and Structural Engineers - Barhale

CELEBRATING ENGINEERING FUNCTION IN THE ARCHITECTURE OF UTILITY BUILDINGS

The ODA was committed to using the 2012 Games to deliver regeneration to east London. Unprecedented standards were set to deliver the greenest Games ever, design excellence in the masterplan and set the foundations for the long-term regeneration of the Lower Lea Valley. New power, water and gas networks were a key component of growing and supporting the development of sustainable communities.

It was important that new utility buildings sat comfortably alongside iconic sporting facilities in a beautiful park and so that future land values were not diminished by unsightly utilitarian appearance. An integrated design approach to architecture, landscape, infrastructure, streetscape and art was required and is reflected in the design of all utility buildings, including the Pudding Mill Pumping Station.

The building is an important new primary foul pumping station, connecting the sewer system built for the Olympic Park to the existing Northern Outfall Sewer. Pumping stations typically comprise a circular shaft for the pumps and storage of wastewater with a grey box above ground to house various



KEY MESSAGES

In house design leadership to oversee the project design and integration

Design standards embedded into the delivery process

Requirement for a high-quality designer

Embedding requirements for a design review approval process in the procurement documentation

controls, surrounded by imposing fences. From the outset, the design for this new sewage pumping station was driven by the desire to make a building that not only reflects its functional use, but also celebrates the achievement of London's sewer networks, old and new.

The first innovation was a result of a challenge to the traditional engineering approach. The architect worked in collaboration to reengineer the above ground building from a square to a circular structure which could sit on the shaft of the pump well, avoiding the need for a separate foundation system. The above ground plant room was then re-planned to sit in a more compact form. In this way, the circular building reflects the functional engineering aspects of the pumping station.

The external façades were created from concrete panels, selected for the need to have a robust finish. The panels were cast with a delicate relief pattern inspired by engineering drawings from nearby Abbey Mills Pumping Station, designed by the great Victorian engineer Joseph Bazalgette. The two distinctive pink tanks, christened 'Pinky and Perky' by the contractors, control odour from the pumping station. The building also incorporates a biodiverse green roof and bird and bat boxes integrated within the inner concrete ring.

The ODA had a strong client side design team who fostered and oversaw the integration of the projects. To support the programme delivery team, the ODA employed design managers, and a network of experts that they could draw on. The ODA design team developed a hands-on collaborative design process where the design was monitored and signed off at all stages by the client. This was not seen as an end in itself, but as an essential tool to meet its design quality aspirations. Architects responsible for utility buildings on the Queen Elizabeth Park have gone on to develop designs for other water and energy infrastructure buildings.

Project outcomes include:

- Avoiding additional foundation costs
- Integrated biodiversity features
- Strong integration with the public realm



Rotterdam Centraal

AN EXEMPLAR OF INTEGRATED TRANSPORT HUB WITH WIDER URBAN RENEWAL

Project Details:

Location: Rotterdam, Netherlands
Client: Municipality Rotterdam, ProRail
Delivery team: Team CS - a cooperation between Benthem Crouwel Architects, MVSA Meyer en Van Schooten Architecten and West 8

A threefold increase in passenger numbers was the impetus for the reconfiguration of Rotterdam’s Central Station, driven in part by the plan to make the city one of 6 stops on a new high speed link.

The historic station arrangements were challenging. The existing building was difficult to navigate and faced away from new city expansions. The main square in front of the station was cut off by the tramlines circulating in front of the building and adjacent neighbourhoods were severed from the city centre by the rail tracks, linked by a single unsafe passageway.

Opened in 2014, the station redesign creates a more integrated multi modal hub enhancing passenger experience and knits the transport infrastructure hub into the neighbouring communities. The station allows passengers to connect between the bus, metro, tram, taxi and cycling and walking infrastructure in addition to the four principal train lines.

The complexity of the project included dealing with the multitude of stakeholders, each with an investment into the

KEY MESSAGES

City investment in station redevelopment ensured wider urban renewal

Concept design team retained through delivery

Building trust amongst stakeholders and developing good working relationships

A memorandum established to agree value drivers from the outset

Proactive client group really involved in the design process

project. These included the city, state government, the rail operating companies, and the rail infrastructure owner, all looking to realise the value of their investment. The city played an important role in ensuring that the development brief was more than just a new station, making Rotterdam Centraal part of a much larger urban renewal project.

Early on in the process, stakeholders developed and signed a memorandum of understanding that identified the shared goals for the station. This facilitated a mutual understanding of how decisions about one project influenced the other projects at the station. A key strength of the design, and the design process, is the way that different stakeholder requirements were balanced, and conflicts were managed. This approach is also reflected in the way the building is constructed, a series of structures responding to individual needs but seamlessly integrated so that they appear as one building.

Another design challenge was the reconfiguration of the station without changing the footprint of the track or platforms. The rail service schedule had to be redesigned to accommodate more trains and new high-speed services with the same platform and track footprint. To enable the station to be developed whilst maintaining an operational service required the construction of a temporary station, complete with pop up shops, temporary bike racks and a cinema.

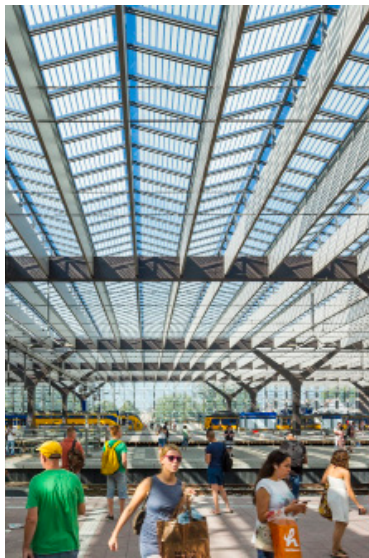
The resulting station is widely cited as an exemplar in integrated urban design around a transport infrastructure hub. Tramlines were relocated to create better links to the rail network, creating a new area of public realm in front of the station. Natural light cascades into the building with clear lines of sight to the platforms enabling navigation around the station. Retail spaces are integrated in a delicate and unobtrusive way. The tall glass and timber structure clearly marks the way in to the new building. It is a grand entrance without being overdone.

Project outcomes include:

- A grand entrance within project budget
- Integration with the urban realm
- Easy transfer between different transport modes
- A destination station and square

“Good design can bring a project to reality.”

Jan Bentham
 BCA





Mersey Gateway

Project Details:

Value: £600m
Location: Widnes-Runcorn, UK
Client: Mersey Gateway Crossings Board for Halton Borough Council
Delivery team: CH2M, DLA Piper, Knight Architects, KPMG, Ramboll Merseylink JV (FCC Construcción, Kier Infrastructure & Overseas Limited (England), Samsung C&T Corporation)

STRATEGIC INFRASTRUCTURE LINK DELIVERED BY 5TH SMALLEST UNITARY AUTHORITY

A second road crossing over the Mersey was a long-held aspiration of Halton Borough Council and its neighbouring local authorities, to relieve congestion on the ageing Silver Jubilee Bridge. Opened in October 2017, the new link between Widnes and Runcorn was an important investment to improve regional connectivity and ensure prominent local employers remain in the area. The distinctive design comprises three singular pylons which vary in height, the configuration a result of height restrictions prescribed by the nearby John Lennon Airport and limited locations where supports could be placed in the sensitive tidal estuary environment.

The 5th smallest unitary authority in the UK, Halton Borough Council wanted to ensure that the bridge design would deliver economic development while protecting and enhancing the environment. They recognised the importance of good design quality in supporting this aspiration from an early stage in the project.

The sudden cooling of the economic climate in 2008 threatened the viability of the project. As a result, Mersey Gateway followed an adaptive model of design delivery. Having achieved

“Success came from the quality of specialist expertise that shared HBC’s key aspirations for the project.”

Mike Bennett
 Managing Director, Mersey Gateway Crossings Board Ltd

permission through the Transport & Works Act process, the project returned to planning with the detailed design removed and replaced with a quality guide in the form of a Design & Access Statement. The market was provided increased freedom to submit tender designs which suited their preferred method of construction, thereby encouraging genuine innovation and improving viability, without falling below a quality standard set by the first planning consent which had, in effect, been ‘promised’ to the public.

Tender designs were progressed through a period of Competitive Dialogue to ensure they met project requirements before award was made to the most attractive economic offer. Design quality was secured by embedding adherence to the planning conditions into construction contract.

Mersey Gateway is a rare example of empowering the planning process to demand and secure high quality design, through a contractual obligation to satisfy planning conditions. Even though the bridge is only in its first year of operation, the benefits to the travelling public and businesses of drastically decreased journey times and increased reliability are already obvious.

Project outcomes include:

- Complex project delivered within agreed budget
- Improved regional connectivity
- Sensitive integration within the Mersey Estuary

KEY MESSAGES

Design quality championed by the client

Design quality part of planning consent and a requirement of the contract

Concept design team retained as client side design advisor

Adaptive model of design delivery to assure best economic price for given quality

Importance of collective specialist expertise

Cross boundary collaboration to deliver infrastructure at scale





Northala Fields Park

Project Details:

Value: £6m
Location: London, UK
Client: London Borough of Ealing
Delivery team:
Concept and Lead Designer - Peter Fink (Studio Fink), Igor Marko (Marko&Placemakers), Design Team - Peter Neal, LDA Design, Aecom (EDAW UK)
Contractor - C J Pryor

“Coming up with the idea how to fund the park delivery persuaded the client to proceed with this bold design vision.”

Igor Marko
Director, Marko&Placemakers

LANDMARK PARK FINANCED THROUGH USE OF RECYCLED WASTE FROM LOCAL INFRASTRUCTURE PROJECTS

Northala Fields is an exemplary new park made from recycled construction waste, proving that creative design can be economic while delivering a range of social and environmental benefits far beyond its immediate site boundary. Since its completion in 2008, it has become a case study in how to use land fill to create new landscape typologies worldwide.

The most significant feature of the Northala Fields design is construction of a new monumental land form utilizing imported construction rubble from a pool of local development projects. The controlled deposition of 600,000 cubic meters of clean construction spoil, which was recycled and sorted on site, has generated £6 million of income, effectively delivering the park at no cost to the tax payer. The project was commissioned by London Borough of Ealing through an open competition for a wasteland site seeking art-led landscape proposals that would open a discussion about possible future scenarios and use of this underutilised land adjacent to the A40.

The winning design team came up with a land-art concept which would become a new gateway for West London and reduce visual and noise pollution from the adjacent road. The initial concept

“The council was prepared to try something innovative, the design team engaged with the community openly, and the contractor truly embraced the concept of a partnership contract.”

Rob Cairns
Client Agent for Northala Fields,
Ealing Council

included the idea for how the park could be funded through recycling waste material from near-by infrastructure projects.

The importation of fill was managed by the contractor and a recycling plant was set up on site to process waste materials. Developers of near-by sites including Heathrow Terminal 5, White City and Wembley Stadium paid for each lorryload of rubble deposited at Northala Fields, while saving considerable costs of transporting their waste to remote landfill sites. This meant the 65,000 lorry loads of waste material used to create Northala Fields also made a dramatic contribution to shrinking the ecological footprint of west London construction projects.

An innovative target price construction contract was used, with 50/50 contractor/client share of any income generated over or under target and 50/50 share of cost over or under target, which meant that all parties had incentives to work collaboratively to achieve best possible outcomes.

Creating the park involved a very engaged public consultation process, through which local residents became the park's biggest supporters. Since its opening to the public, locals are actively engaged in organising activities and programmes in the park, which has become a vital resource for the whole area.

KEY MESSAGES

Interdisciplinary design approach

Open competition to obtain most innovative design ideas

Reuse of existing materials in large scale to fund the project

Lateral design thinking beyond site boundary leading to innovative solutions

Use of innovative contract to share risk between client and contractor leading to better cost control and quality outcome

Project outcomes include:

- £6 million income generated through use of inert waste
- New landmark park and a vital community asset
- Reduced noise and visual pollution from adjacent road
- Reduced carbon emissions associated with 65,000 lorry journeys to local site instead of remote landfill sites
- Enhanced biodiversity





Lightrail Station, The Hague

Project Details:

Value: €45m

Location: The Hague, Netherlands

Client: Municipality The Hague, ProRail

Delivery team:

Architect – ZJA Zwarts & Jansma Architects

Structural engineers – BAM

Infraconsult, Knippers Helbig

Advanced Engineering, Royal

HaskoningDHV, Ney & Partners,

Movares

Contractor - BAM Infra NL

“We translated the municipality’s ambition into an architectural vision and design.”

Ralph Kieft
Architect Associate, ZJA

DESIGN HELPS OVERCOME PRACTICAL CHALLENGES ON A NARROW URBAN SITE CREATING A GATEWAY TO THE CITY

The new lightrail station has transformed the formerly gloomy rear of The Hague Central Station into a striking and recognizable entrance that welcomes travellers to the city. Connecting the cities of The Hague, Nootdorp, Pijnacker and Rotterdam, a sculptural fully transparent roof canopy shelters the column-free light rail station, bringing daylight onto the station platforms while improving the surrounding public realm.

The process started with the local municipality’s ambition to deliver a new station that will not only increase capacity and create more space for train traffic, but act as a signifying gateway to The Hague and increase its competitiveness amongst neighbouring cities with high quality infrastructure.

The design team developed a computational model to optimise the form of the roof geometry. This enabled simplification of the roof panels to a single-curvature and reduced the number of panel types. The prefabricated diamond shaped glass panels are based on 3 curves, reducing material waste while contributing to cost-efficiency of the structure. Prefabrication further helped with construction on this narrow urban site.

“Investing in detailed design and mock-ups helped contractor build it first time around on a very challenging site.”

Edward Ruiter
Project Manager, ProRail

The tracks arrive at the station via a long viaduct that carries the Light Rail Vehicles to the station at more than twelve meters above ground level. The slender design of the viaduct worked within the parameters of the challenging site, minimizing the impact of the track on its surroundings. The 35m clear span structure has been designed to be as lightweight as possible, generating significant cost savings on materials while reducing visual impact and improving wayfinding. Investment into a durable high-quality coating applied to the steel structure prevents corrosion, reducing maintenance costs over the life of the project. Since its opening in 2016, the passenger numbers have increased by 15% encouraging more people to use public transport by creating a pleasant passenger experience.

KEY MESSAGES

Investing in design up front reduces risk and provides more cost certainty

Integrated and collaborative working between client, design team and contractor

Client’s ambition translated into a design vision, driving delivery

Using prefabrication to unlock challenging urban site

Computational design to reduce waste and cost, optimizing buildability

Collaborative working between client, contractor and design team with investment into design up front led to reduced risk and more cost certainty. Control on aesthetic quality during execution design and realization was achieved by novating the architects under a Design and Build contract, with the architect directly responsible for detailed design. Mock-ups were built to test and de-risk the design prior to construction, enabling the construction to run smoothly and to budget, while achieving high quality standards. The architects were also intensively involved in scenario analysis with emergency services and customer and stakeholder management.

Project outcomes include:

- Recognizable gateway to the city
- Great user experience
- 15% increase in passenger numbers
- Minimal maintenance costs
- High quality design within set budget and programme





Millau Viaduct

Project Details:

Value: €350m
Location: Millau, Aveyron, France
Client: French Ministry of Public Works (Highways)
Delivery team:
Design Team - Foster + Partners (Architect) with Michel Virlogeux (Engineer)
Construction - Compagnie Eiffage de Millau

FULL STATE COMMITMENT TO INFRASTRUCTURE DESIGN QUALITY FROM CONCEPT TO CONSTRUCTION

The Millau Viaduct was built to allow the A75 highway from Paris to Beziers (and onwards to Barcelona) to cross the Tarn Gorge close to the town of Millau in South West France. Being located within an area designated as a National Park, the site for the proposed new bridge meant that the design of the new bridge had to be very sensitive to its setting. In order to address the new bridge’s design sensitivity, the French state held a design competition for the new bridge with each team being comprised as a collaboration between an architect and an engineer. The design that was produced by the winning design team was used as the clear basis for the bridge’s construction contract.

Given its setting in an area of natural beauty, the proposal to build a major bridge across the Tarn Gorge close to the town of Millau was highly contentious with a significant proportion of the local population being opposed to the project. The French state’s commitment to ensuring that the new bridge should have the highest quality design was crucial to the project’s success. Importantly, the company that was awarded the contract to build the new bridge was contractually required to

“We can design elegant bridges with reasonable costs.”

Michel Virlogeux
Engineer

“You have to make a bridge that is fitted to the need and the site of the landscape.”

Michel Virlogeux
Engineer

respect a fully defined 3D geometric form. This external design form had been jointly developed by the architect/engineer team to remove any major uncertainty with regard to its feasibility having already been overcome. A retained design guardian role on behalf of the French state was important for ensuring that the detailed construction design of the bridge respected the design intent.

A key design intervention as a result of the collaboration between engineer and architects was the refinement of the piers. An elegant gap was created by removing elements of structure that were not working efficiently, and hence also reduced the amount of material used.

Following its completion, the Millau Viaduct has been widely cited as an exemplar in infrastructure design. Its successful integration into the landscape has also led to the Viaduct becoming a major tourist attraction in its own right with the town of Millau experiencing a significant economic boost. The small premium on design, cited as a few percent, has been more than offset through greater returns from the concession agreement and wider economic benefits.

Project outcomes include:

- Local boost to the economy of Millau
- Tourist attraction in its own right with 1 million visitors each year
- Concession returns above predicted levels

KEY MESSAGES

Client commitment to design quality

Trust collaboration between engineer and architect

Clear definition of design quality through developed reference design

Design standards embedded into the delivery process

Pre-proving the technical feasibility of the design intent by suitable engineering studies.

Inclusion of landscape design insertion as an integral part of the project.

Role of concept guardian through the delivery process





One Alliance Collaboration Model

Project Details:

Value: £4.5bn per AMP Cycle

Location: City, Country

Client: Client Organisation

Delivery team:

@one Alliance*

*Balfour Beatty, Barhale, MMB (Mott MacDonald Bentley), Grontmij (Sweco), MWH and Skanska – and the wider supply chain through framework agreements.

“Infrastructure clients get hung up on the cost of design rather than the value.”

Dale Evans
Director, @one Alliance

FROM PROJECT TO PRODUCT PROCUREMENT THROUGH COLLABORATIVE WORKING

Anglian Water provides water services to an area stretching from the Thames Estuary to the Humber, providing 1.2 billion litres of water a day, to six million customers. Like all UK water companies, Anglian Water maintains its assets through five year Asset Management Periods (AMPs), typically investing £4.5 bn in each cycle.

Historically, and in line with infrastructure generally, projects were delivered in a largely transactional tendering process, selecting the most economically advantageous proposal. AMP 3, whilst successfully having delivered the required outputs through a partnering approach, was felt to be less effective than it could have been. Anglian Water decided to shift to a different delivery model. A review of best practice across different sectors led to Anglian adopting a strategy based on a more integrated and collaborative working approach, @One Alliance. Members of the alliance are not rewarded on the basis of delivering a project, but a programme of work under the AMP cycle, and incentivised through a performance share. Performance is clearly defined against the delivery of efficiency and an improved customer service.

“In series procurement is out of date. Innovation comes from the connections you create.”

Dale Evans
Director, @one Alliance



Solar-powered booth
@one Alliance

KEY MESSAGES

Shift from project to product based design

Collaborative working with the supply chain

Traditional engineering specifications create lock in and prohibit innovation

Create a continuous improvement organization, much more closely resembling a manufacturing company.

Investments in upfront design have delivered whole life savings

A shift towards a product based focus and a reframing of the brief at the programme level has led to several design innovations targeted at components which are used in large quantities across the network. A typical example of this product based approach is the sampling kiosks used for checking the water quality at reservoirs. Traditionally each kiosk was developed as part of a unique solution on individual projects, leading to a wide variety of different layouts and materials installed with large on-site concrete bases, all requiring long lead times. Faced with a demand for up to 50 kiosks across the AMP programme, the Alliance developed a space-optimized solar-powered kiosk manufactured off-site. Demand for the sampling kiosks is aggregated enabling optimal manufacturing efficiencies and then stored at Anglian Water sites. The units can be called off and installed at short notice on integral metal bases without the need for any on-site trades. The sampling kiosks are today produced and installed at a cost of just 70% of the 2005 cost, embodied carbon has been reduced by over 30% and operational carbon is now zero, thanks to the use of solar power.

Another innovation that has come out of this approach is the development of a digital platform to provide a catalogue of standard products. This product catalogue allows information-rich products to be dragged and dropped into proposed solutions. The products include all of the data and information required to manage the product across its lifecycle. This has become a best practice example of digital product lifecycle management.

This product based approach has been enabled by delivery through a much more collaborative and integrated delivery vehicle - the @one alliance. It has also required a shift from technical engineering specifications, historically perceived to provide greater certainty, to performance requirements and asset standards. More broadly, the organisation has fostered a cultural change to embrace a new mindset of products based delivery, production amazement and continuous improvement.

Project outcomes include:

- Increased supply to customers by 20ML/day
- Annual savings of 2 to 3% while increasing quality of service delivery to its customers
- Accident frequency rate decreased from one every 300,000 to a million hours worked
- Carbon emissions associated with construction reduced by 54% from 2010–2015,
- Operational carbon reduced by 41%, against a 20% target



Wessex Water Supply Grid

Project Details:

Value: £250m
Location: Dorset, Wiltshire and Somerset
Client: Wessex Water
Delivery team: Wessex Engineering and Construction Services

“We work really hard to develop designs in-house to reduce risks in operational performance and construction delivery.”

Julian Welbank
Wessex Water

SMART GRID INNOVATION TO DELIVER MULTIPLE OUTCOMES

Wessex Water operates in a heavily regulated sector, supplying drinking water to some 1.3 million customers in the southwest of the UK. They plan the maintenance and investment of assets within the 5 year Asset Management Plan cycle, which can make long term investment decisions more challenging.

A traditional approach could be described as responding to immediate problems with single solutions. Faced with a number of pressing challenges, Wessex Water saw the value of taking a more integrated long-term approach. They especially needed to address:

- reducing the level of water abstraction from the River Avon to improve flows and protect ecology
- deteriorating quality of some groundwater sources
- resilience of supply to catastrophic failure - a number of towns had only a single connection to the network; and
- the balance of supply and demand for water for the area over the next 25 years.

The solution was to create a smart water network, connecting up existing water mains with new pipelines, providing additional storage and pumping stations.



Wessex Water Control Room

Wessex Water had to justify the business case for a programme of investment that would take them beyond the 5 year AMP, without the guarantee of further investment over the 8 years required to deliver the infrastructure improvements. To do this they developed a business case. This included asking their customers how much they would value greater resilience and the broader environmental benefits of investment. They also developed concept designs of the best of the alternative solutions to enable cost comparison with the Water Grid option. The alternative was to develop new water resources and provide lots of individual reinforcements which would not have provided the long-term flexibility and adaptability and would be more complex and costly to deliver.

Wessex Water’s philosophy is to develop concept design solutions in house and manage the risk of project delivery themselves. These two aspects go hand in hand. By taking ownership of the design, they were able to provide a greater level of certainty in the delivery process both from a cost and whole life performance perspective.

KEY MESSAGES

Design concept driven by in-house design team, partnering with the supply chain

Risk managed by the client organisation

Developed design to de-risk the project prior to construction

Strategic options developed to demonstrate business case

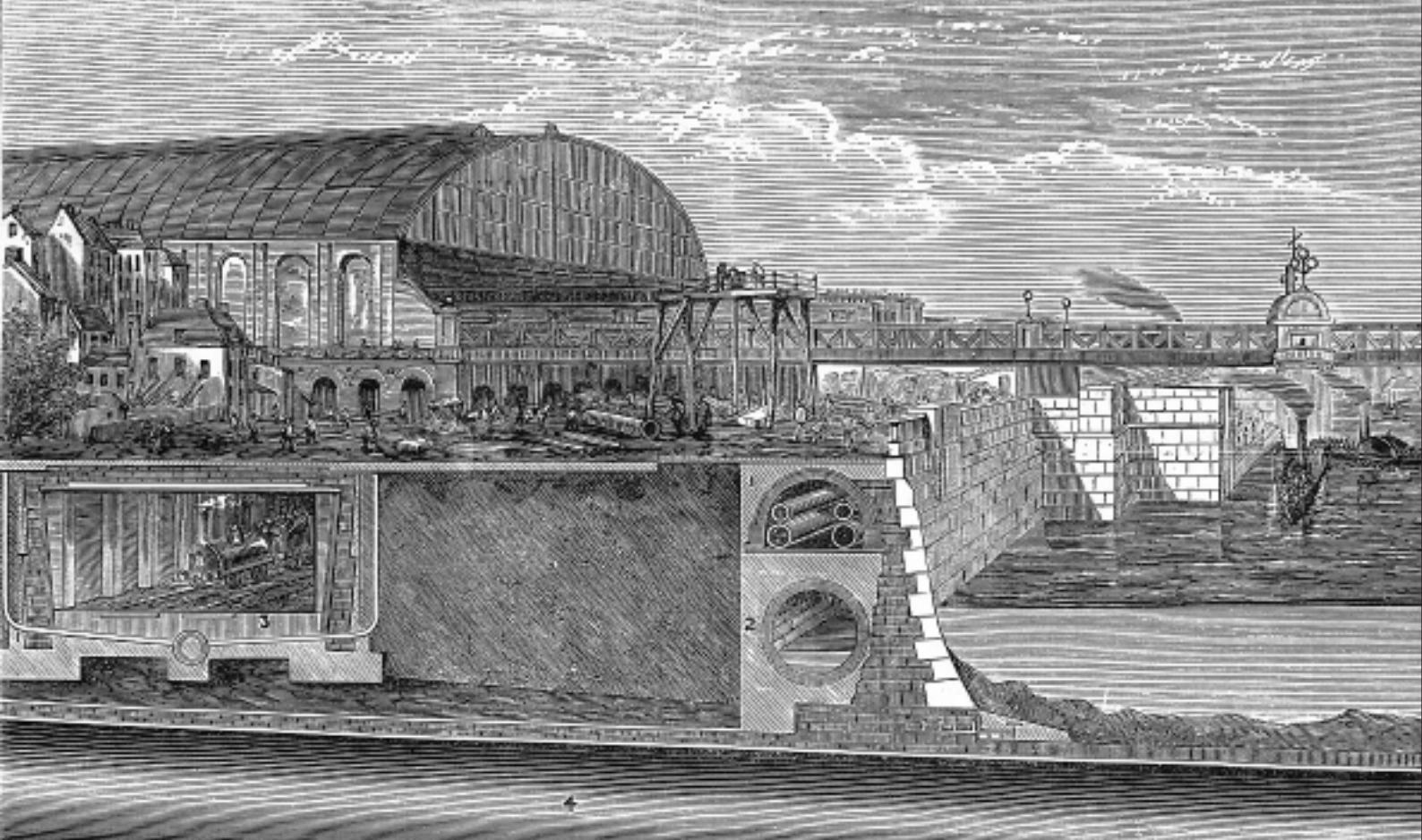
Shift from single problem solutions to design concepts that achieve multiple objectives

That’s not to say Wessex Water don’t engage with delivery partners to help them to create solutions. One of the key innovations on the Water Grid is the overall flow control system which came out of collaboration with the supply chain. Wessex Water worked in partnership with Servelec to develop the functional design specification for the ‘optimiser’ which is one of the UK’s first real time closed loop optimisation systems. It controls and monitors bulk transfers around the grid in the most efficient way. Links have been designed to be bidirectional, enabling greater flexibility, and energy recovery turbines have also been installed.

To mitigate the risk of adopting new technology, the novel control system was first installed on an existing infrastructure system. Wessex Water were also able to drive down construction costs from £330m to £250m (2017/18 prices) through a number of additional design interventions.

Project outcomes include:

- Security of supply to customers
- Reduction in construction costs by £80m
- Reduction in abstraction leading to ecological improvements
- Impact on charges to customers minimised



Victoria Embankment

Project Details:

Value: £4m
Location: Central London, UK
Client: Metropolitan Board of Works
Delivery team:
 Design - Sir Joseph Bazalgette, Chief Engineer
 Construction - Thomas Brassey Contractor

INTEGRATED MULTI-PURPOSE URBAN INFRASTRUCTURE

Constructed between 1865 and 1870, the Victoria Embankment project was a visionary and transformational infrastructure project that combined several types of infrastructure into one integrated project to address multiple needs at the heart of a fast growing metropolis. Whilst the main impetus for the embankment was to provide a modern sewerage system, heightened by the big stink of 1858, the opportunity was also taken to develop an approach which would help to relieve congestion around the Strand and Fleet Street and prevent flooding. Hence the project incorporates multiple infrastructure components including:

- Interceptor Sewer
- River Wall flood defence
- Underground railway
- Public Utilities
- Public Highway
- Public Green Space

The multi-purpose aspects of the project developed by a single client body serves as an example of what can be achieved if separate infrastructure sectors are brought together into one project. The integrated nature of the design means that both the total physical space taken, and construction costs, are less



KEY MESSAGES

Multi-purpose infrastructure assets integrated into one project

A single client body to overlook the planning, design and construction of the project

Design attention paid to the visual parts of the project

than they would be had the separate infrastructure components developed as individual projects. The forward thinking nature of the design means that the Victoria Embankment represents a vital piece of urban infrastructure within modern London.

The construction of the Victoria Embankment had to overcome difficulties encountered due to the sheer scale of the project at the heart of a busy metropolis. The project had to contend with pressure from the UK parliament to complete construction within a limited period of three years.

This ambitious target proved not to be achievable partly due to the shortage of suitable labour. The project also had difficulties in acquiring the land assets needed to construct the project. There were the technical challenges in having to maintain access to river piers at Westminster and overcoming teething problems with new types of construction technologies such as cofferdams. Ultimately the single client body meant that a co-ordinated and determined approach to realizing the project lead to its ultimate successful delivery.

The new Thames Tideway tunnel is currently under construction and will increase the capacity of the Victorian sewers by intercepting overflows and thereby improving water quality. The approach to public realm integration seeks to build on Bazalgette's original vision. At Victorian Embankment a new pumping station will be deep below an event space reaching out into the River Thames.

Project outcomes include:

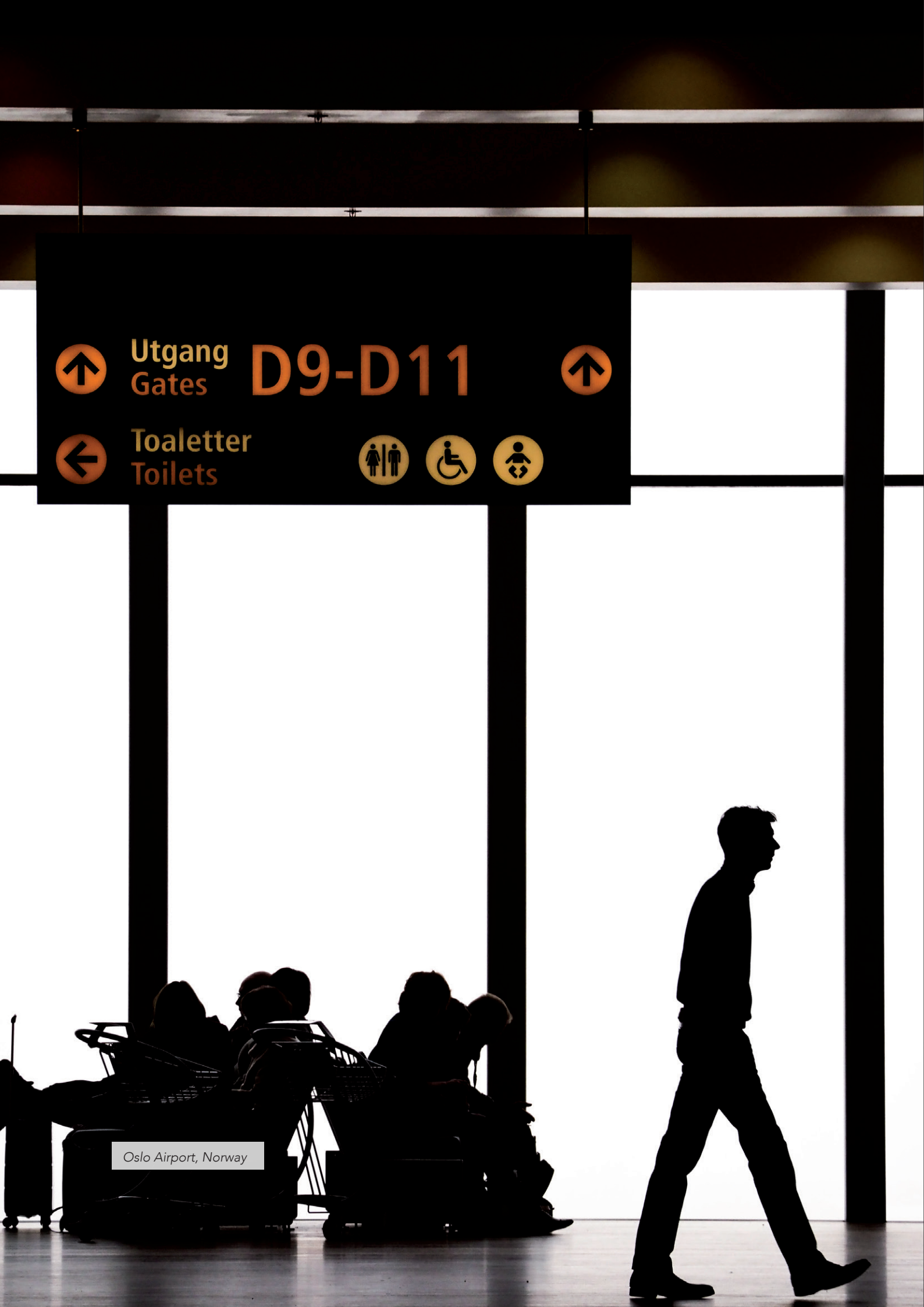
- Enhanced public realm
- Designing infrastructure to last for future generations
- Space saving nature of integrated design

Above
Victoria Embankment Today

Top left:
Section of the Thames
Embankment, 1867

Right:
Proposed public realm
on Thames Tideway





Oslo Airport, Norway

3 Emerging Themes

The projects included in this portfolio illustrate how good design and design thinking can deliver the values illustrated in section 1.3.

Through our research and in discussions with those involved in the selected examples, we have encountered many advocates for the important role that design plays in delivering key infrastructure projects, as well as a spirit of true collaboration between the client, design teams and contractors, who worked together towards achieving best possible outcomes from initial project briefs through to implementation.

The following common themes that have facilitated good design outcomes emerge from this brief research showcase, which are further described in the next pages of this chapter:

- Client design leadership
- Invest in design upfront
- Integrated approach delivers multiple benefits
- Collaboration results in innovation
- People focus
- Simple sustainable outcomes

3 Emerging Themes



Client design leadership

Setting a clear expectation for design quality from the outset was cited as key for setting the ambition of the project. It is important that requirements such as the brief and design parameters are embedded into the design, procurement and delivery process.

Client’s leadership in the design team selection process was also fundamental to procurement of good design outcomes. To make a real difference, clients also combined authority in design leadership with a hands-on approach, their role going beyond that of traditional project managers.

The appointment of a client-side design advisor has been a key feature of many of the examples. An informed client involved in the project details facilitates the decision making. This was coupled with client ownership and management of project risks, both to ensure design quality but also reduce costs.

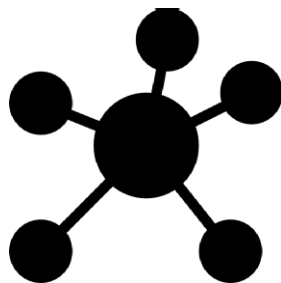


Invest in design upfront

The projects included in this portfolio show that upfront investment in concept development and design information minimises risk, providing both quality and cost certainty by reducing information asymmetry in the procurement process.

This includes developing a reference design, 3D/digital visualisation, use of prototypes and trial installations.

The design process includes ensuring that the problem is well defined and considers how multiple issues might be tackled.

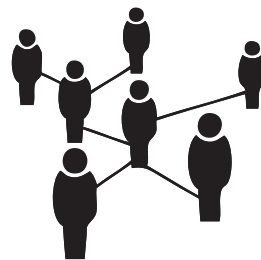


Integrated approach delivers multiple benefits

Really successful outcomes have been achieved by reframing the brief to think more broadly about how infrastructure could deliver social, economic and environmental benefits, as opposed to a single fix solution.

Several projects demonstrated the integration of different infrastructures for example the Knopstrop Footbridge and of course Bazalgette’s Victoria Embankment. Value was also added when the brief was widened to consider surrounding interfaces, for example Rotterdam Centraal, which was reconsidered as an urban realm project and Blackburn Meadows which has added an educational component.

3 Emerging Themes



Collaboration results in innovation

All those interviewed advocated that the best results come from effective collaboration and interdisciplinary working. That collaboration includes client organisations, all design disciplines, contractors and partnerships that stretch well into the supply chain.

Early stakeholder engagement helps to develop a joint vision and ensure values are aligned. Operational teams and end user involvement in design process was cited as especially important in ensuring functionality of design proposals.

Rethinking models of collaboration has led to the adoption of alternative processes from collocation, collaborative dialogue tender processes and risk share contracts to innovative collaborative shareholder model at @onealliance.



People focus

Common to all the projects included is a clear desire from the teams to make designs work for people, both from how they will be operated and the user or customer experience. A number of the selected projects, such as Northala Fields Park and Knostrop Footbridge, also addressed the needs of the communities with new infrastructure development in their neighbourhood.

Good design ensures functionality, supports wellbeing, enables navigation and connects to wider public realm and the place. The outcome is ease of travel, resilient water supply, increased footfall and knock on economic and social benefits.

Good designs can become destinations in themselves – Millau and Rotterdam Centraal both receive 4.5 stars on Tripadvisor.



Simple sustainable outcomes

The examples in the portfolio illustrate that good design does not need to be heroic or iconic, and can be delivered within project budget.

Examples such as Knopstrop Footbridge show how elegant and refined design can promote wider economic value. Rotterdam Centraal demonstrates how design can be used to deal with high levels of complexity to deliver seamless solutions.

Sustainability has been used as a driver in many projects from the promotion of active travel, use of natural materials and goals to reduced carbon footprint. These are successful as they have been approached as part of a fully integrated design process, not as technological gimmick. The whole life value that this creates is clear, and in some cases capital cost has also been reduced.



Pudding Mill Sewage Station, Olympic Park, London

References

Blackburn Meadows Biomass	
People interviewed:	Luke Ellis, Blackburn Meadows Plant Manager, E.ON Mihalis Walsh, Architect Associate, BDP
References:	RICS Awards 2016 Yorkshire & Humber Award Entry by BDP
Knostrop Bridge	
People interviewed:	Martin Knight, Director, Knight Architects Martin Farrington Leeds CC, Director of City Development
References:	Mott Macdonald Project Reference Sheets Knight Architects Project Reference Sheets RICS Yorkshire & Humber Awards 2018 Design through Innovation Award Entry
Lightrail Station, The Hague	
People interviewed:	Ralph Kieft, Architect Associate, ZJA Zwarts & Jansma Architecten Edward Ruiter, Project Manager, ProRail
References:	ZJA Zwarts & Jansma Architecten Project Reference Sheets ZJA Zwarts & Jansma Architecten Dezeen Awards Entry
Mersey Gateway	
People interviewed:	Mike Bennett, Managing Director, Mersey Gateway Crossings Board Ltd Martin Knight, Director, Knight Architects
References:	Knight Architects project sheet AJ, Knight Architects’ Mersey Gateway Bridge opens, 16 October 2017 http://www.merseygateway.co.uk
Millau Viaduct	
References:	Foster and Partners Project Sheet ‘Engineering elegance in bridge design’ - Bridge designer Michel Virlogeux interviewed by Mary Searle http://www.worldhighways.com/categories/road-highway-structures/features/engineering-elegance-in-bridge-design/ ‘The Millau Viaduct’ https://www.designingbuildings.co.uk/wiki/The_Millau_Viaduct ‘A world-class bridge, a unique blend of architectural and structural design’ https://www.arcadis.com/en/united-kingdom/what-we-do/our-projects/europe/france/millau-viaduct/
Northala Fields Park	
People interviewed:	Rob Cairns, Project Manager Northolt and Greenford Countryside Park and Client Agent for Northala Fields, Ealing Council Igor Marko, Director, Marko&Placemakers
References:	Landscape Institute Awards publication 2008 Bullivant, L., Ermacora, T., Recoded City: Co-creating Urban Futures, Routledge London, 2015.

References

One Alliance	
People interviewed:	Dale Evans Director @one Alliance and Andy Flowerday, Barhale
References:	WEF Case Study 2017
<hr/>	
Oslo Airport	
People interviewed:	Christian Henriksen, Nordic Office of Architecture and Liv Karin Sundsvold, Avinor
References:	Nordic Office of Architecture Project Sheet 'Nordic doubles the size of Oslo Airport with curved extension' https://www.dezeen.com/2017/04/27/nordic-office-architecture-double-oslo-airport-major-curved-extension-norway/
<hr/>	
Pudding Mill Pump Station	
People interviewed:	John Lyall, Lyall Bills & Young
References:	Lessons from masterplanning and designing London 2012 – Learning Legacy Paper, Lucy Carmichael Micro report – Learning Legacy Paper, Kay Hughes – Principal Design Advisor 'Complementary engineering and architecture of the Primary Foul Water Pumping Station' Lessons learned from the London 2012 Games construction project, Learning Legacy Project Information Sheet – Lyall Bills & Young Architects
<hr/>	
Rotterdam Centraal	
People interviewed:	Jan Bentham, Bentham Crouwell Architects
References:	Bentham Crouwell Architects Project Information Sheet Rotterdam Central Station https://mvsa-architects.com/project/projects-rotterdam-central-station-transportation-logistics/ 'Lessons for Diridon: Rebuilding Rotterdam Centraal Station' https://www.spur.org/news/2016-09-22/lessons-diridon-rebuilding-rotterdam-centraal-station
<hr/>	
Victoria Embankment	
References:	'Stories of London, An additional set of postcards of old London' http://stories-of-london.org/embankment/ 'Seven man made wonders, London Sewers' http://www.bbc.co.uk/england/sevenwonders/london/sewers_mm/index.shtml Information on Tideway – Clare Donnelly and Lucy Webster.
<hr/>	
Wessex Water Grid	
People interviewed:	Julian Welbank, Head of Asset Strategy, Wessex Water
References:	Wessex Water – Our water supply grid project.
<hr/>	

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Cover page	Millau viaduct, Foster and Partners Eiffage Daniel Jamme
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1 Introduction	Rotterdam Centraal photo by Jannes Linders
<hr/>	
2 Case studies	
Blackburn Meadows Biomass	Paul Karalius, BDP Architects
Knostrop Bridge	Paul White, Martin Selby
Lightrail Station, The Hague	Bart van Hoek, Jeroen Musch
Mersey Gateway	Paul White, James Newton Photography
Millau Viaduct	Foster+Partners, Eiffage, Daniel Jamme
Northala Fields Park	Marko&Placemakers, Francis Moss
One Alliance	Dalton Piercy, @one Alliance
Oslo airport	Ivan Brodey
Pudding Mill Pump Station	Edmund Sumner, Jason Hawkes
Rotterdam Centraal	Jannes Linders, Benthem Crouwel Architects
Wessex Water Grid	Photo courtesy of Wessex Water
Victoria Embankment	Expedition, Thames Tideway
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3 Emerging Themes	Oslo Airport photo by Dag Spant
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References	Pudding Mill Sewage Pump Station, photo courtesy of Olympic Delivery Authority
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