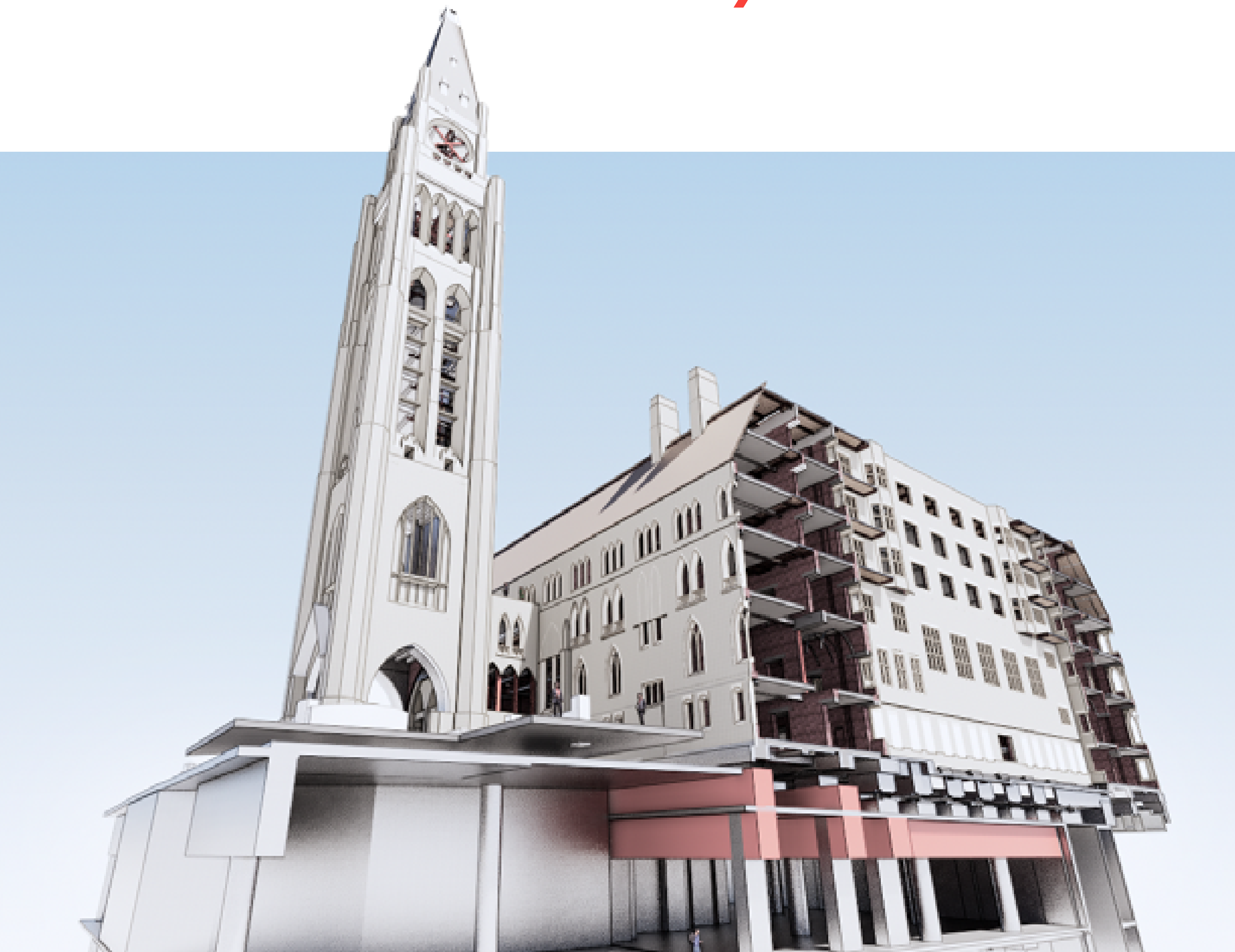
Pursuing Sustainability and Productivity Gains *with Digital Project Delivery*



Contents

Foreword

The way in which we deliver projects is steadily evolving, from hand-drawn to increasingly digital forms of delivery. This applies to all functions of design and construction, from scheduling to note taking and field documentation. Digital technology is overtaking traditional techniques and, as technology continues to accelerate, we are on the verge of a new digital frontier.

People may debate whether Moore's Law, which states that the processing power of computer chips doubles every two years while halving the cost, still holds true, but recent technological advancements in processing power, scanning, and the Internet of Things (IoT) has opened new opportunities in Digital Project Delivery (DPD).

From scans used to survey to construction monitoring, everything can now be integrated into common platforms and environments – known as the Common Data Environment (CDE). This allows for the creation of digital twins of the current state as well as full virtual development of projects. These advances contribute to risk reduction, productivity increase and greater automation.

This, combined with the acceleration of digital platforms and workflows with the COVID pandemic, paves the way to transform the construction industry.

According to studies by McKinsey, "global labour-productivity growth in construction has averaged only 1 percent a year over the past two decades, compared with growth of 2.8 percent for the total world economy". DPD promises to deliver the greatest gains in the construction industry in a generation.

Furthermore, CDEs also propel collaboration to a new level between all stakeholders, while opening opportunities to reduce carbon emissions throughout the project lifecycle.

WSP, as a world-leading design and consulting firm, is committed to working with contractors and builders to transform our industry and provide leadership in DPD to enable projects to be built faster and with less risk. This paper explores the current state of the practice, as well as the exciting future of our industry.

We look forward to discussing your future project outcomes and how best to apply DPD to achieve them.

Eric Peissel
Global Director, Transport & Infrastructure

Global *Digital Project Delivery* Overview

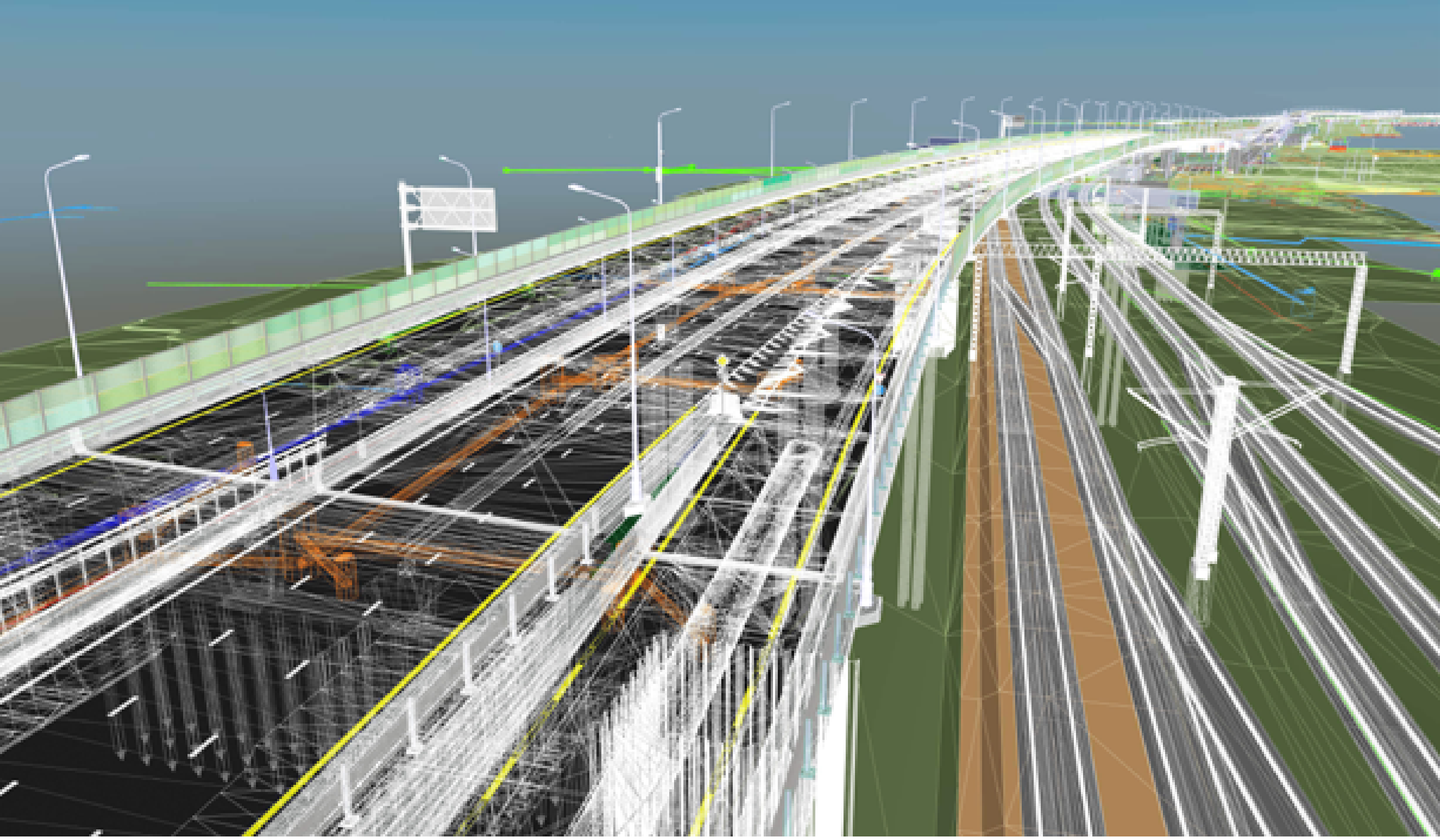
What Does Digital Project Delivery (Digital/BIM) Mean Across Regions?

Digital Project Delivery (DPD), also commonly referred to as BIM, may have different meanings across the globe. However, they remain anchored in one common notion, namely the pivotal role played by "data" in the DPD process. Data is at the forefront of project delivery using digital project delivery methods. In its simplest form, this can be a 3D design with improved coordination, clash detection and collaboration. More complex scenarios include structured metadata, automation, 4D/5D integration, cross-discipline interoperability, and formal approval processes governed by ISO standards. DPD allows fully integrated flow of digital data and information in a common digital twin. The use of the digital data set can extend through the entire lifecycle to a live digital twin of the infrastructure asset. Hosting the data and digital twin in a cloud-based environment means that the data can be harvested, analyzed, and updated by any client or organization.

DPD can be considered as a solution to dead data (drawings). In a digital project environment, each element of the digital twin is linked (associated) with valuable information.

Valuable Information in a Nutshell

- ✓ Design data
- ✓ Design development constraints
- ✓ Material properties
- ✓ Procurement information
- ✓ Cost
- ✓ Project controls
- ✓ Quality
- ✓ Construction / manufacturing requirements
- ✓ Commissioning information
- ✓ Maintenance requirements
- ✓ In-service condition survey
- ✓ Asset management



What Is the Level of Maturity of DPD Across Regions?

The level of DPD maturity varies across the globe. Regions such as Australia, New Zealand, the UK, and the Nordic countries are leading the way in DPD adoption. In these regions, high profile, high value projects with major clients tend to have a more mature approach. North America is not as mature but is quickly catching up. In the US, most departments of transportation define digital project delivery as submitting base CAD files and/or models and information databases along with or instead of construction documents. These digital deliverables require new workflows for production, verification, delivery, and maintenance. Digital project delivery is starting to mature in the US to also cover the process of achieving data and geometry as deliverables instead of printed documentation. Consistently, worldwide, DPD is more advanced on vertical infrastructure and process management projects than on linear infrastructure projects commonly tied to the transportation industry. With its roots in Building Information Management (BIM), a holistic process covering the lifecycle of a built asset, vertical infrastructure projects lead the way in DPD. However, in recent years, we have seen linear infrastructure projects following suit. Thanks to international standards, such as ISO 19650, which define this process more precisely, it now covers the entire industry.

When looking at the maturity of DPD in regions across the globe, it is important to ask who or what is driving the adoption of DPD. In the Nordic countries, many countries mandate DPD on government-funded projects. The requirement for DPD and how data is used is embedded in the Request for Proposal (RFP) terms. Companies wishing to bid on these projects must commit to delivering according to the DPD requirements specified in the RFP documents. In Canada, some government-funded projects have also adopted this approach in recent years. However, the main driver is the private sector with contractors adopting digital models and mandating the digital models to the consulting industry. They have adopted this approach to minimize risk and achieve better project control. In other regions, such as the Middle East, clients are driving the adoption of DPD on large scale projects where there is a critical mass for this type of investment by the private sector.

In terms of who is responsible to drive the adoption of DPD, many countries have indicated that it is a shared responsibility between owner, contractors, and consultants.

What Are the Biggest Barriers to DPD Across Regions?

Initial investment, lack of clear client requirements, and improvement of DPD standards, including consolidation of tools, were cited as barriers to adoption of DPD. A common set of tools and platform, training, and lower initial efficiency also play a role in slow adoption. When the initial decision and investment have been made, the lack of proper change management impacts both the acceptance, engagement, and the results of DPD. There appears to be a general lack of understanding at senior levels of the risks and opportunities created by DPD. Better communication of DPD at all levels of the organization may be what is required to provide the spark for significant gains to be made across regions.

In the US, there has not been a common federally driven platform for digital delivery and each state is moving at a different pace with development or implementation of digital delivery policies. There is an increasing momentum across states to develop and implement digital delivery policies. As a result, the industry is similarly both responding and, in some cases, leading the way towards its adoption.

DPD also requires industry and supply chains to be aligned in their level of maturity, commitment, and implementation. Lack of collaboration among industry partners, fragmentation along the value chain, and maturity of contractual arrangements hinder the scaling of DPD. Finally, the accelerated acceptance and uptake of DPD has created a shortage of capabilities and resources. To effectively harness capacity, the industry will need to be proactive and aggressive in training the next generation of experts. Clients can facilitate this effort by engaging the industry and requiring DPD to be at the forefront of service offerings.

What Are the Biggest Opportunities to DPD Across Regions?

Establishing frameworks, standards, and tools to shift from a project based DPD to a national DPD represents a big opportunity. The release of an international standard ISO 19650 has seen both local councils, institutions and private clients develop their Digital Framework and aspirations including Organization Information Requirements (OIRs), Exchange Information Requirements (EIRs), Asset Information Requirements (AIRs) through to their own BIM Execution Plan (BEP) templates. These are the means for a client to set out a BIM process as well as developing their own Common Data Environments.

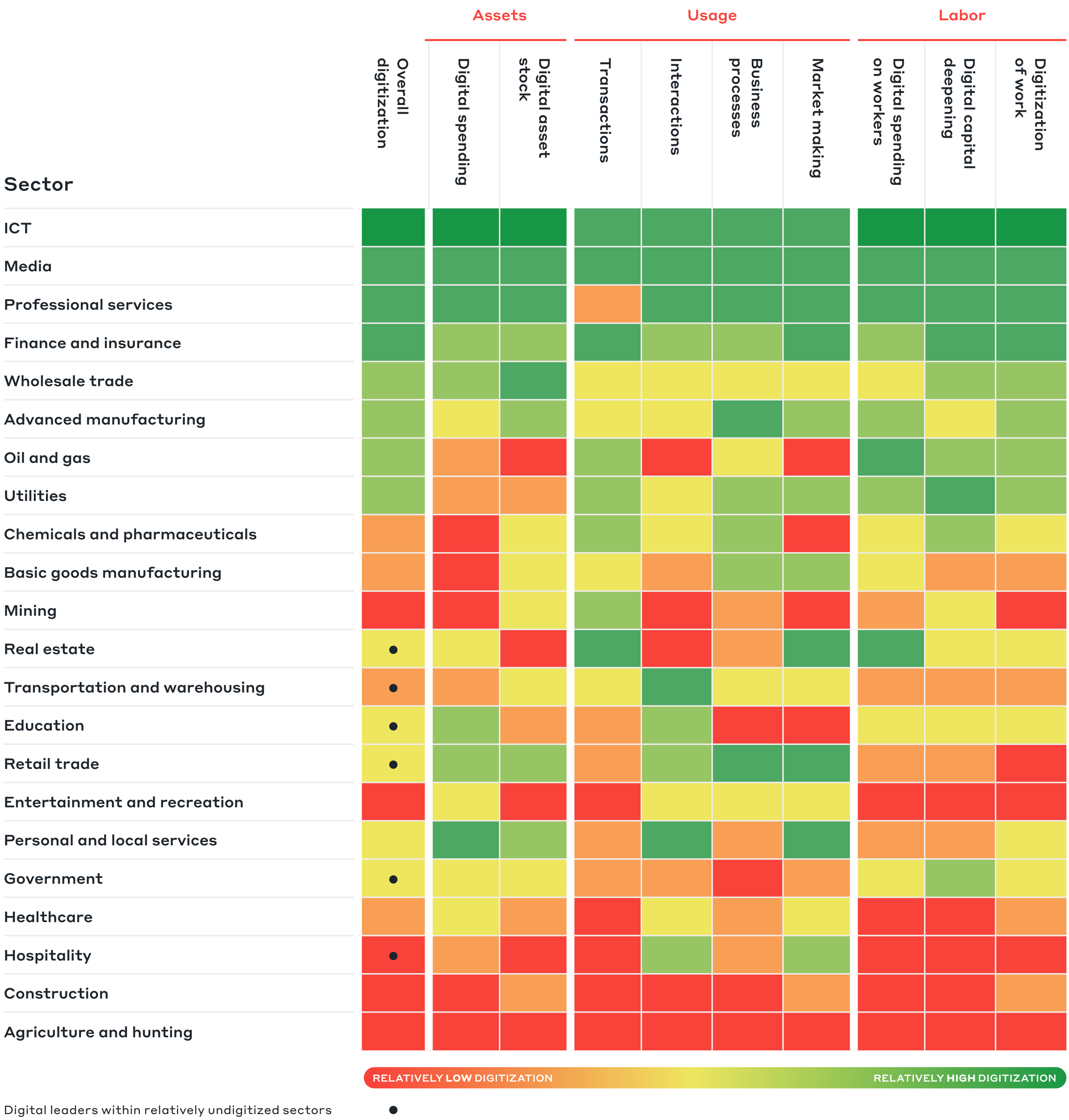
Some regions/owners define DPD end-result requirements (performance-based) at project level, leaving many tools and libraries to be defined by industry. There is an opportunity to have DPD tools and libraries developed at the national level for common use on projects. In this case, the project DPD requirements can remain end-results (performance-based) at the project level based on common tools and libraries. This produces a consistent DPD outcome for all parties on the project, promotes a positive outcome, and encourages wider adoption of DPD. Successes with a common DPD approach at the national level has been observed in some Nordic countries.

Reducing project risks is also a great opportunity for DPD. Eliminating risk from a project can mean a dramatic reduction in clashes and conflicts and a reduction in cost escalation. With the addition of virtual reality (VR), risk reduction can also mean a reduced design development risk for the owner. For contractors, risk reduction can mean fewer incidents or harm with time losses. Holding virtual health and safety walk-through is an opportunity to analyze, mitigate and/or eliminate safety risks. It is also an opportunity for staff health and safety training in an immersive environment.

DPD also enables us to address key challenges such as modern construction methods, off-site construction and modulization, which will help to close the productivity gap between manufacturing and construction. Construction sub-trades working directly in a digital model can more accurately manufacture components offsite in a controlled environment with just-in-time delivery to the construction site. DPD can reduce the time it takes to commoditise certain elements and automate routine tasks to focus more on high-touch, high-value items, including client and public engagement.

The Construction Industry Is Among The Least Digitized

McKinsey Global Institute industry digitization index: 2015 or latest available data



Source: McKinsey & Company, "Imagining construction's digital future" by Rajata Agarwal, Shankar Chandrasekaran, and Mukund Sridhar, June 24, 2016

In the US, in the short-term, there is an opportunity to engage with owners and contractors to help them define their requirements and standards for digital delivery. Many of the advantages from digital delivery can only be achieved if there are programmatic standards that inform and require digital deliverables from designers and contractors. Longer-term opportunities include the ability to act as an information integrator and information provider of choice. The consultant firms that can create coherent sales offerings are able to provide an increasingly new set of digital deliverables.

Digital is being requested and driven where it provides value. The value from digital is different for each stakeholder in the process, so different aspects are being driven ultimately by client needs that are applied by designers and contractors to provide efficiency during the delivery process.

All the benefits to the designer and contractor apply to the owner. Model-based deliverables can include asset classifications, asset data attribution, and metadata enabling lifecycle benefits as well as contribute to data improvement during construction and operations. The model deliverables can be used in a digital twin solution to enable the owner to better deliver future planning, design, construction, and operations activities.

For contractors, existing conditions models with appropriate data allocations (e.g., SUE Quality Levels) can reduce conflicts, risks, errors, and omissions during construction. Digital delivery increase stakeholder awareness as well as reduces rework and late changes. Tools such as BIM360, Revizto, iTwin and BIMTrack can reduce the amount of quality control issues, avoid rework, reduce RFI, and streamline the submittal review process. For the designer, digital delivery reduces the amount of time spent producing plans, allowing engineers to focus on delivering the proposed design rather than documents representing the design.

The model's deliverables improve the construction planning and phasing process, reducing construction time and decreasing errors and omissions in site logistics. They enable automated machine guidance and robotic construction techniques. Digital models also improve quantity estimation and reduce the time required to produce quantity takeoffs initially and during changes, while enabling offsite manufacturing and assembly.

While digital delivery has been successful in the traditional design process, there is a need to further integrate with specialist disciplines (Acoustics, Sustainability, Fire Engineering) that typically work in independent systems without two-way data connections to design tools.

Successes Seen with DPD

Design development has improved in terms of speed, quality, and risk mitigation. DPD has led to better coordination on multi-discipline projects, fewer errors, and earlier detection of errors in the design model (prior to construction). It has also led to lower environmental impacts by facilitating the analysis of multiple design solutions during design development. DPD in a VR environment has also been successfully implemented in public consultations to garner better input from the public. The ability for end users to be immersed in the digital model results in an increased client-centric solution with lower environmental impacts and increase public acceptance.

These successes have been seen by early adopters of DPD on railway projects (light rail transit and high-speed rail) and large-scale motorway projects.

The integration of DPD in the delivery of projects has also facilitated collaboration across teams and regions across the world. Collaboration under the common digital model can be an answer to workforce capacity issues seen in the industry.

We seem to have the most success when we can influence across all parts of an organization. Examples include the Interstate Bridge Replacement Program in the US where WSP is delivering a very forward-thinking digital program that incorporates programming, planning, design, and public outreach during the early phases and at the Illinois Tollway Authority where we can influence programming, delivery, and construction standards for a client that operates a very large asset.

Case Study

Interstate Bridge Replacement (IBR) Program

Location
Portland OR, Vancouver WA, USA

Client
Washington Department of Transportation (WSDOT) and Oregon (ODOT) Department of Transportation

Start Date
September 2020

End Date
Ongoing through construction start in 2025

Procurement Model:
Joint Venture General Engineering Consultant (GEC)

Description

The Interstate Bridge is a critical connection between Oregon and Washington, located on Interstate 5 where it crosses the Columbia River. Replacing the aging Interstate Bridge across the Columbia River with a modern, seismically resilient, multimodal structure that provides improved mobility for people, goods and services is a high priority for Oregon and Washington.

WSP is the General Engineering Consultant (GEC) on this project. Its role involves providing the digital products and services related to capital project delivery. The GEC provides the Interstate Bridge Replacement (IBR) Program with the resources needed to advance the program through NEPA completion (Record of Decision) and pre-construction using digital project delivery and digital operations advisory.

The work requires coordination and engagement with many different groups. This includes, program partners, stakeholders, cities, counties, governmental entities, utility companies, neighborhood groups, businesses, Federal Highway Administration (FHWA), Federal Transit Administration (FTA), local/state/federal permitting agencies, other State and local projects/programs, preliminary design consultants, on-call consultants, and contractors. In addition, the GEC is assisting the Owners with evolving approaches to equity and inclusion in all aspects of the program, by providing access to best-in-class approaches and implementing processes to achieve desired outcomes.

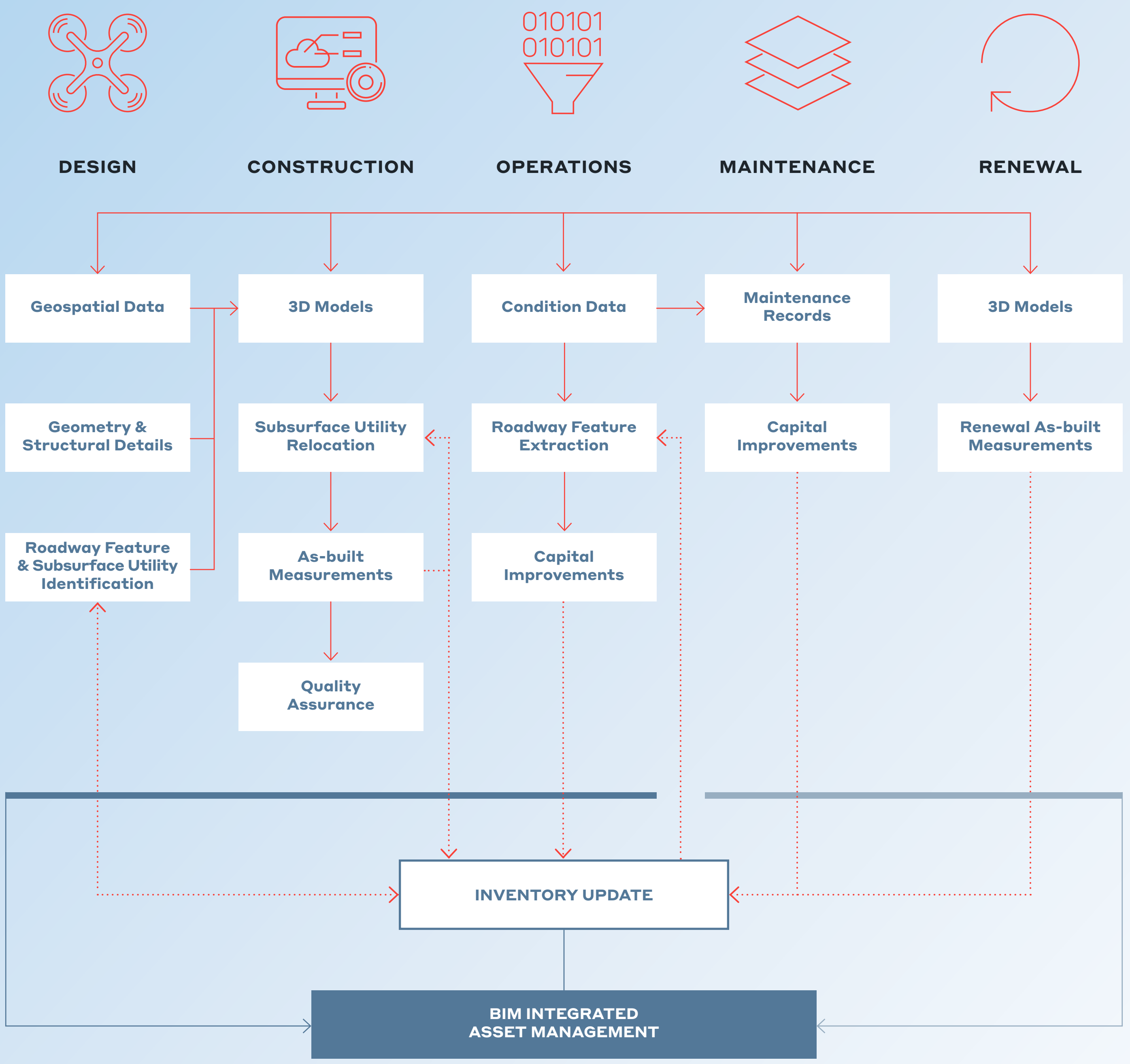
Digital Project Delivery and Digital Operations Advisory

WSP is working with our most innovative transportation clients to develop “digital twins” of our programs’ utilizing digital project delivery and digital operations advisory.

Digital Project Delivery — involves providing the digital products and services related to capital project delivery. These are products and services associated with designing, constructing, and delivering an infrastructure asset as part of the capital project delivery phase of the asset lifecycle.

Digital Operations Advisory — involves providing the digital products and services associated with infrastructure asset operations and maintenance activities that are carried out during the life of the built infrastructure facility.

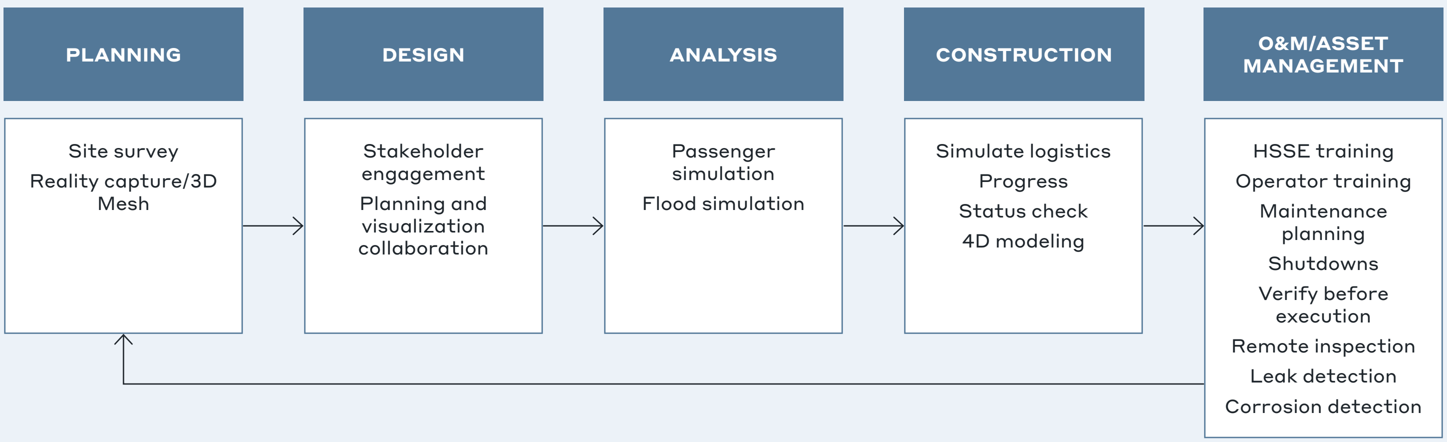
For example, on the multi-billion-dollar IBR Program, WSDOT and ODOT are supporting the use of a digital twin model throughout the full program cycle, from public outreach with conceptual design, through detailed design, into construction, and eventually for operations and as an asset management tool. This is an emerging method in transportation engineering, and WSP is glad to be on the forefront of the practice. BIM Integrated Asset Management acts as the foundation of the IBR Digital Twin lifecycle from design, construction, operations, maintenance, and renewal.



Contributions to Decarbonization, Resiliency, Sustainability and/or Social Values

The IBR Digital Twin will define the entire lifecycle of the program from concept to design, into construction and then handing over an operational BIM Integrated Asset Management model to the client. This will be accomplished while allowing interventions for corrective actions and enabling better decision making for more effective outcomes, including those related to environmental review, cost estimating decarbonization, resiliency, sustainability, and social values.

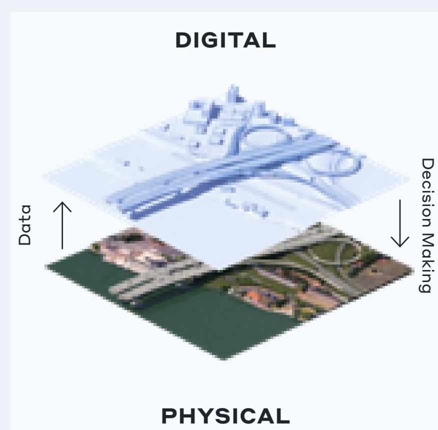
IBR Digital Twins Lifecycle Implementation



Equity in Infrastructure Plan

The IBR Program is committed to centering equity in our processes and our outcomes throughout the project lifecyle. Equitable infrastructure considers the short- and long-term impacts on human health and well-being, and takes shape based on input from all members of a community. Equitable infrastructure is, at its core, defined by the principle that everyone deserves a fair opportunity to thrive. Any effort that doesn't prioritize the human impact at all levels can arguably be dismissed as discriminatory. And any infrastructure policy that doesn't place equity at its center will fail to meet our society's future needs.

We are engaging the community by elevating the voices of underserved communities throughout our processes and ensuring these communities receive the program's economic and transportation benefits. We also commit to not furthering harm to these communities and leveraging digital delivery and digital operations advisory to achieve this.



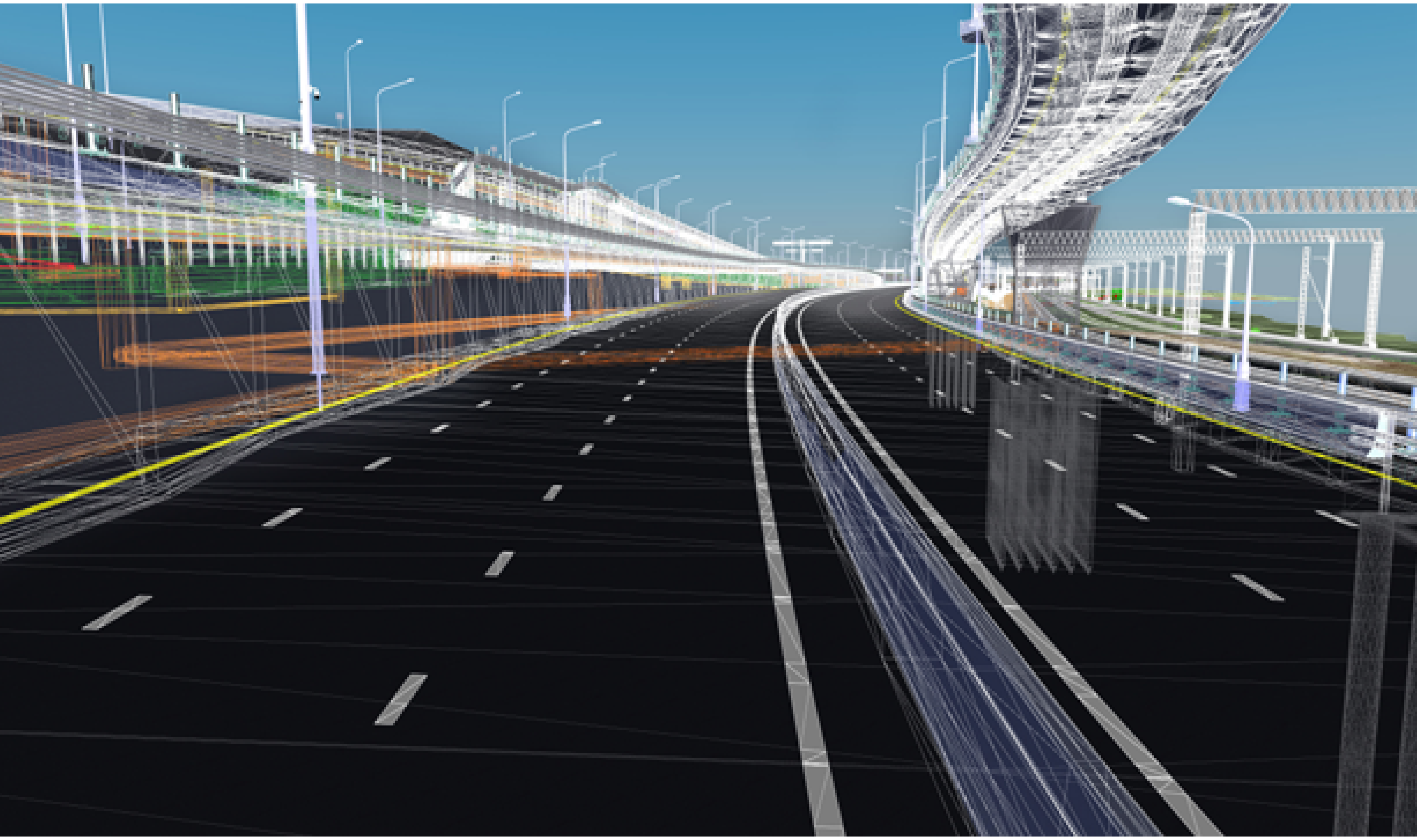
Competitive Landscape

It is extremely competitive in the DPD space. However, the advancement of the technology is often fragmented with firms working independently to advance DPD at the project level. There is a need to focus on building common frameworks, standards, and tools to truly advance and leverage DPD on a project lifecycle scale. We have seen greater adoption of DPD in some regions such as the UK, Australia, New Zealand, and the Nordic countries. Projects in Australia and New Zealand are now looking at leveraging DPD in asset management, human behavioural analysis, sustainability and decarbonization. To compete in the DPD space, we also need to invest. As an industry, we need to better define a career path for our digital delivery experts, invest in training and development opportunities. Investing in IT infrastructure to support DPD is also important. The IT infrastructure of the company or project should not become a bottleneck for DPD adoption.

Leveraging DPD to Achieve Net Zero / Sustainability Goals

Digital models are being used to quantify embodied carbon in projects, including materials used and associated losses, plant usage, transportation, and operations. This allows selection of materials, construction and manufacturing methods, systems selection, and sourcing decisions to target carbon reduction during design and construction planning. The earlier these elements are considered in the project lifecycle, the greater the chance of achieving reductions against meaningful baselines.

There are a range of sustainability rating tools that have been developed that provide a rating framework into which DPD digital models are being used to input into key rating areas. These include the Infrastructure Sustainability Council, Green Building Council, and Greenroads.



Delivery Efficiency to Meet Market Demands

The Role of DPD in Getting Designs to Market More Efficiently

DPD plays a key role in bringing designs to market more efficiently. It is not uncommon for the pre-delivery phases of major projects to take two or three times longer than the delivery and construction of a project. These earlier phases typically include business cases, approvals, and permissions, as well as preliminary or detailed design. The role of DPD is linked to the challenges of these phases and associated definition of objectives, scope, solution details, risks, cost and schedules. These challenges exist irrespective of the contract delivery method, e.g., build only, design and build, collaborative Alliances or P3's, and include:

Delivery Challenge	Opportunities for DPD
Starting with the Real Problem Rather than a Solution	Developing a clear definition of the problem and desired outcomes sets projects on a path to success. Digital tools and data mining can efficiently analyze a variety of data to help define and visualize problems and relationships to assist with the definition of outcomes being sought for a range of users, asset owners and operators. Such a consistent digital-led business base approach can also reduce potential to rework in later phases.
Getting Alignment and Agreement	Getting alignment on options and solutions requires engagement of stakeholders, users, and owners. DPD tools can be used for visualization of projects including VR, comparison of options, analysis of feedback, and assessment of benefits and environmental effects. This assists with obtaining agreement of key decision makers and obtaining social licence and community buy-in.
Impact of Multiple Phases	Multiple pre-delivery phases often involve a range of personnel, advisors, and suppliers, each with a need for information transfer and familiarization. DPD provides a platform for such transfers that speeds up familiarization and reduces potential for data loss. It allows successive addition of data and design development with documented change control.
Getting Reliable Data Early	Early project phases will typically use macro and less detailed existing data sources. GIS platforms provide an accessible platform for managing and analyzing such data. As projects progress and more detailed investigation data and option designs are developed, a transition to a DPD platform or model provides more reliable data that still allows access to earlier data from a GIS platform. Laser or digital survey data of existing buildings / sites are easily integrated into a DPD model.
Data Overload at the Market Phase	When projects are market ready, there will typically be an abundance of data from previous phases, including preliminary or developed designs in a project data room/library. A DPD platform will allow multiple users to locate, access and visualize existing data. Such efficiency is particularly valuable during constrained tender periods.
Design Optimization	Designers and advisors use a wide range of digital design software and tools, particularly diverse for horizontal or linear infrastructure. A common DPD platform allows this information to be integrated into a common digital model. This can be used to optimize designs, accelerate decarbonization, enhance client experience and improve operational excellence. It also allows integration of constructability feedback, construction sequencing and linkage to programming.

The Role of DPD to Deliver a Healthy Project Pipeline

It is important for infrastructure investors, their users, builders and suppliers to have a healthy project pipeline in order to achieve service levels for users, return on investment, and continuity for businesses and employees. DPD can assist with this through efficient delivery of design and earlier phases. DPD also enables enhanced forward planning for suppliers for resourcing, materials, and multi-program management. By developing a portfolio of projects that are ready to go to market or in the process of going to market, a healthy pipeline is created, which allows for risks and slippage.

Leveraging DPD Across the Whole Supply Chain

The supply chain of any major construction project is a complex network of interconnected relationships. The fragmentation of builders, material, equipment suppliers, and engineers can make it more difficult to control the inputs and outputs of a complex infrastructure program. This problem is not new to the construction industry but has hampered the sector for decades. According to a 2017 McKinsey study, labour productivity growth in the construction industry has trailed manufacturing by 62% over the past three decades[1].

Although there is no single cause for this delay, the fragmented adoption of digitization across the supply chain has contributed to it. To date, the construction industry has not adopted a single platform, or vision, for an integrated DPD platform. By aligning all stakeholders along a value chain, we can maximize the benefits and efficiency of DPD. For example, if contractors, engineers, and suppliers worked from the same digital model, the entire workflow process could incorporate design changes, optimizations, and value engineering. Furthermore, by capturing these inputs in a "digital twin", real-time data can be shared across parties to contribute to more sophisticated logistics management, just-in-time delivery, and waste reduction.

The construction market will gradually evolve as new technologies are developed and DPD solutions offer real benefits for their users. However, the range of stakeholder sophistication and the varying complexities of construction projects will continue to hinder aggressive adoption. Ultimately, it is the infrastructure owners who will see the most benefit from DPD implementation, and, as such, can play a key role in moving the sector forward.

1. Source: McKinsey & Company, "Improving construction productivity", by Filipe Barbosa, Jan Mischke, and Matthew Parsons, July 18, 2017

Responsibilities in Defining Platform and Supply Chain Adoption

It can be argued that owners, contractors, consultants, and suppliers all share the responsibility of defining a platform and its adoption by the supply chain. All concerned parties must work together to define the standards/platform and drive adoption in the supply chain. Working with the industry, owners can lead the development of a common platform and make DPD mandatory for large infrastructure projects. Owners can include clear DPD requirements in their RFP documents to minimize the need for the industry to develop bespoke tools to deliver individual projects. Owners can also work with suppliers to develop common tools and object libraries to be implemented across a region. A consolidation of tools and platform is required for large-scale success in the industry. Contractors, consultants, and suppliers can drive the supply chain adoption by adopting DPD from the onset of the design; the contractor tenders using digital models and suppliers leverage the digital models to deliver the product to the site. Modular construction is a growing trend and digital models are having a big impact in that segment. The digital delivery does not create the opportunities in modular construction as it already exists, but rather makes it much more efficient. Elements are built in a factory from a digital model with higher precision, better tolerances, and then shipped to site in parts.

DPD Initial Investment and ROI

A cultural change is required for this digital transformation to take place. The change requires owners, contractors, and consultants to have the courage to invest time in training and developing libraries that result in lower initial productivity. When done correctly, a mature DPD can provide a significant reduction in time on commoditized engineering elements. In the long term, this will decrease project costs and the owners will benefit from these savings. This will have a definite impact on projects and our communities.

Case Study

Partnering for Success (P4S) Program

Location
Sydney, Australia

Client
Sydney Water

Project Start & End Date
2020-2030

Procurement Model
Alliance contracting including WSP, John Holland, Comdain & Lendlease

Description

Sydney Water is the largest water authority in Australia, serving approximately five million customers over a large geographical area. Maintaining the health of Sydney's waterways including beaches, rivers and tributaries is becoming more challenging as the thriving city's population continues to grow.

To deliver world-class services within a market environment of continued population growth, evolving customer expectations, competition parameters, and the challenges of climate change including drought and coastal erosion, Sydney Water (SW) developed its Partnering for Success (P4S) program – a new model for procurement and capital works delivery using the New Engineering Contract (NEC) collaborative contract developed by the UK Institution of Engineering. The NEC contract had not been used previously on such a large scale in Australia.

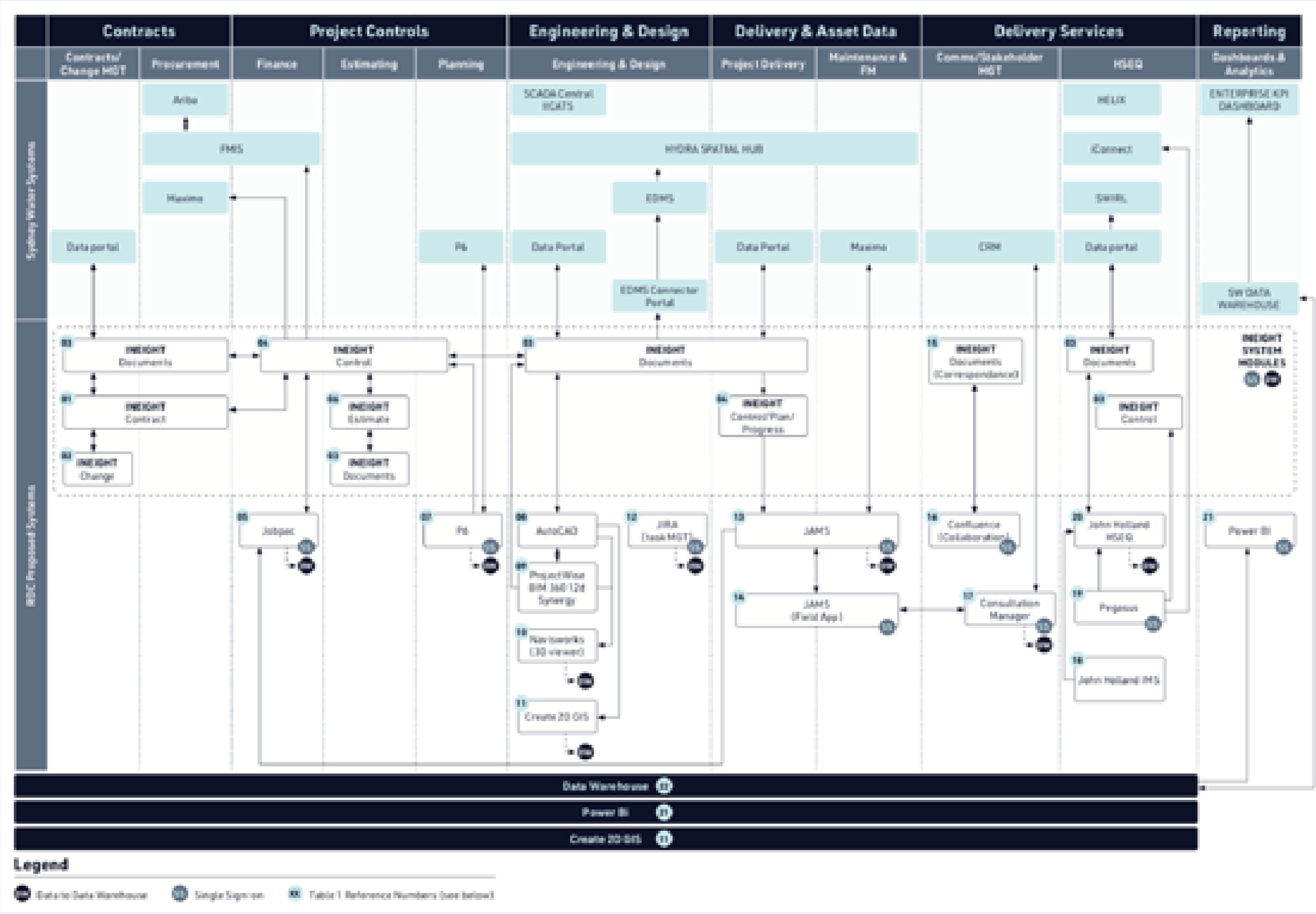
In 2020, Delivering for Customers (D4C) – a joint venture between WSP, John Holland, Lendlease Services and Comdain – was appointed by Sydney Water as a regional delivery contractor for the South region, under its P4S program. Responsible for the delivery of design, construction, maintenance and facility management across Sydney Water's assets for the next 10 years, D4C will contribute to the program's aims of meeting the future needs of Sydney's growing population.

Setup & Benefits of Digital Project Delivery

To bring together the 300-member team (expected to expand to 600 over the 10-year period) to solve project challenges and evolve into the future, WSP brought our Future Ready 'project in a box' approach to the joint venture, blending the importance of digital engineering with new ways of project control and delivery. This model, developed for managing data in a large joint venture operation utilises a modular architecture, complex integrations and single-sign-on as the foundations of a future proofed system.

Key benefits include:

- Ubiquitous connectivity – to enable easy, inexpensive and reliable data connectivity and access, practically all applications are housed in the Cloud. Every application complies to a standard for single-sign-on. This means that access and permissions to all applications is controlled and accessed through only one unique login and password for each authorised user.
- Data & transparency – the entire system is ISO:27001 compliant, the global standard for data security and management. Four key aspects were considered: integration of disparate data from 23 software applications in total including project control software, occupational health and safety software, financial and time sheeting systems; automating the data to be fit-for-purpose, so you get information where you want it, when you want it; equipping people to enable them to do their jobs efficiently; and the network and hosting infrastructure.
- Digital expectations – with P4S derived from the customer centric journey, D4C became the chosen name for the joint venture. Delivering world class service is when the customer is seamlessly delivered water – be it in the form of public health; clean waterways; or clean, running water in their homes. Sharing of information across all aspects of Sydney Water's operation for the benefit of their customers enables this seamless delivery.
- Automation – the reduction or elimination of manual handling of data was a key objective from the outset. We set out to free our team up to work on high value tasks and activities. The 'project in a box' approach created a technology model for large joint venture or alliance projects enabling premium and cost-effective future-proof efficiency.



Project controls and expertise in technology were evident as the critical success factors for the project. To overcome the challenges of many teams working together as one in the joint venture, WSP engaged early on with our partners and Sydney Water, to develop an approach and solution that meets stakeholder needs now and into the future.

WSP recognised that the required technology needed to be an evolving, changing system. We designed the system to be modular so components can be replaced as technology changes and improves over time. This recognises that the rate of change and advancements in technology is inevitable and therefore needs to be designed into the architecture.

The project was awarded in December 2019, mobilisation began in January 2020 and the system went live on 1 July in the same year despite the restrictions of the Coronavirus pandemic. It was in this regard very much like a start-up company. WSP essentially built an enterprise system in less than six months, including an IT infrastructure and applications architecture that would more usually be implemented over a far longer period.

Contributions to Resiliency, Sustainability and Social Values

The P4S model provides a platform to ensure the projects delivered increase the resilience of Sydney's water and wastewater networks, while aligning with Sydney Water's net zero targets and prioritising customer at the heart of everything we do.

Sydney Water is aiming to achieve "net zero" with respect to carbon emissions from operations and investment programs by 2030. This will extend to the supply chain by 2040. The 2030 target aligns with the end of the P4S 10-year program providing a perfect platform for WSP to progressively introduce future ready and net zero design principles, taking a Totex view of value for Sydney Water's customers.

Under the P4S program, design, construction and maintenance are delivered under the one team, integrated with Sydney Water. This approach is yielding benefits in the ability of Sydney Water's networks and facilities to be made more resilient. Examples include:

Pipelines

- D4C is using integrated GIS (Create) and design software (Civil 3D) to take environmental factors and heritage items in consideration in early phases of the design development of pipeline alignments for growth projects. Pipeline alignments are also published in Create allowing the design team and stakeholders to evaluate different options and adjust on site using portable devices.
- Civil 3D modelling was to model the impact of building a pump station within floodplain area. The ability to visualise the required earthworks allowed the team to demonstrate that the suggested site location would have a significant impact on the adjacent riparian corridor, which is an environmentally significant area, and further analyse other more suitable areas.
- Using 3d modelling for critical watermain renewals has allowed the team to make easier optimised route alignments to save significant trees.
- Improved stakeholder engagement, enabled by the P4S model, has resulted in changes to previous Concept Design alignments to avoid installing a new pipeline in newly constructed roads and handing over part of the project to developers to align with construction timing and not disrupt new roads in the future. These changes provide a significant improvement in customer experience.

Pumping Stations

- The use of 3D modelling in pumping station in design of pumping station upgrades has allowed the design team to get a better grasp on small building (superstructure) constraints. With this modelling, D4C have been able to confidently place electrical boards within the small building rather than outside. This reduces maintenance and increases the design life.

- 3D modelling is used to make several design optimisations aimed at improving ease of maintenance in brownfield pumping stations with space constraints. One example was the ability to gain a clear picture of clearances which helped to confirm the positioning of large non-return valves whilst providing operators with the confidence that they could access the area for maintenance.

Treatment Plants

- Use of 3D modelling for the design of four new screw presses as part of an inlet works upgrade allowed quick stakeholder agreement on optimisation of the design while considering ease of maintenance, process optimisation and cost.

- Ability to confidently locate new wash presses inside the building while assuring the operators that ease of maintenance would be achieved, avoiding having to locate the presses outside the building where they would be visible to the nearby golf course.

- Using lessons learned from other projects deviations from SW technical standards are sought where a benefit can be demonstrated. The use of stainless-steel pipework for an above ground installation at a recent brownfield upgrade provided a reduction in maintenance as well as improved ease of installation compared with the SW standard of ABS or Copper.

- On a Cogen project, the design team have used 3D modelling to help operators / maintainers understand how the infrastructure will operate and then made changes to improve it. These include:

  - Increasing the spacing between the cogeneration units to improve access for equipment removal by forklift.
  - Minimising the number of ground mounted pipe supports to limit the interference for maintenance access.
  - Moving the position of the switch room to improve access for maintenance of the transformers
  - Using the 3D model to discuss and agree piping, valve and instrument arrangements.

Case Study

Centre Block Rehabilitation – Digital Project Delivery of a 100-year-old Heritage Parliament Building

Location
Ottawa, Canada

Client
Public Services and Procurement Canada (PSPC)

Start Date
2017 – ongoing

Integrated Project Team
WSP Canada is leading the joint venture, CENTRUS, with HOK, as well as providing principal engineering and project management services to complete the design of the expansion, conservation, and rehabilitation of Centre Block.

Description

Centre Block with its Peace Tower is one of Canada's most iconic buildings. Built nearly a century ago after the original Parliament building was destroyed by fire, Centre Block houses the Senate of Canada, House of Commons, and Library of Parliament. It also includes the Memorial Chamber that commemorates Canadian citizens who gave their lives in military service. It's one of the country's most important heritage sites, the seat of Canada's democracy and a leading tourist destination.

The Centre Block Rehabilitation (CBR) project is the largest and most complex heritage project of its kind in Canada and includes both the restoration and modernization of the historic Centre Block and the design and construction of a new Parliament Welcome Centre. The design vision involves a holistic approach to balance heritage conservation with the functional program mandate that includes security and life-safety enhancements, a full seismic upgrade utilising base isolation, renewal of all base building systems, universal accessibility, and a sustainable, carbon neutral design.

Integrated Digital Project Delivery

Digital project delivery on this highly complex project enables CENTRUS to create an integrated network of tools, design models and intelligent data that can be used throughout the lifecycle of the project, from pre- to post-construction:

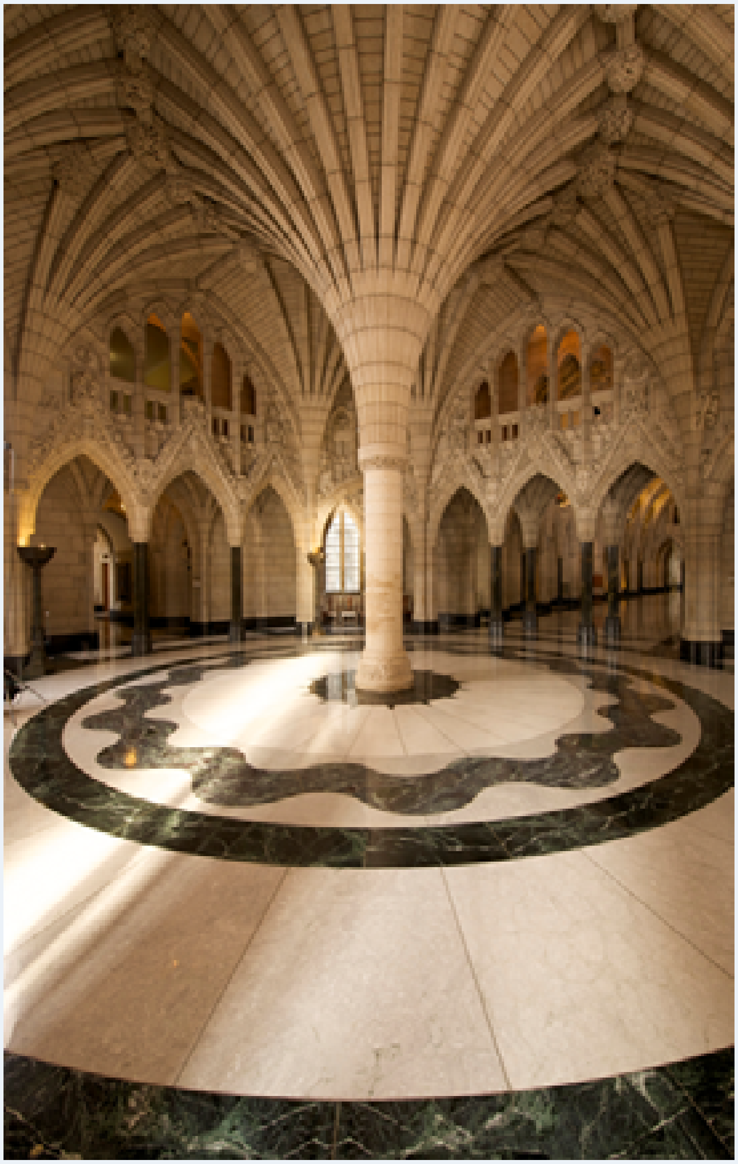
- During the planning phase we combined reality capture and real-world data to generate 3D models of the existing built and natural environment.
- Through the design phase, BIM helps us in conceptual design, analysis, detailing and documentation.
- During build phase, fabrication uses BIM specifications, and project construction logistics can be shared with trades and contractors to ensure optimum timing and efficiency.
- BIM data will also carry over to the operations and maintenance of the finished assets – BIM data can be used in the future to support efficient operations and cost-effective renovation.

The Network of Digital Tools

The CBR BIM ecosystem involves a network of tools including point cloud scanning and visualization software, Engineering analysis, 3D modelling, and construction documentation, all working together to turn our models into a powerful design aid tool to facilitate the progression of the project from concept to finished product. The digital project delivery tools are all chosen to suit a specific need, with a focus on interoperability to ensure data is never duplicated or restricted from being transferred. Key examples include:

- ***Streamlining Existing Information*** – Extensive use of laser scanning reduced the time and effort to capture existing conditions while greatly increasing the level of detail and accuracy.
  - Creation of an "As-Found" digital model incorporated a vast amount of available information verified by a comprehensive field investigation program.
  - The digital scanning / point cloud data in the model allows design team members to conduct detail analysis of existing building conditions without the need to go to site.
  - The As-Found model is used as the basis for developing the design and contract documents, and streamlining existing information increases the ability to produce design packages that more accurately reflect real-world conditions and further unlock the potential to fast track the project.
- ***Integrating Engineering and Design*** – Leveraging the geometry and data contained in the BIM for real-time collaboration, project teams are making use of internally developed tools and workflows to connect Engineering and Design data to the BIM environment to save time and improve quality.
  - Linking together the Architectural BIM, Structural BIM and Structural Engineering models for the new roofscape meant that an architectural or client driven change to the geometry can be updated and studied on the fly without the need to separately update the BIM and Engineering models in a disconnected manner.
- ***Integrating Heritage Asset Management*** – The heritage asset management strategy is fully implemented within BIM by linking between point clouds using bounding boxes and connecting this to the asset database, design models, and the construction manager's (CM) asset tracking tools.
- ***Advanced Analytical Modeling*** – Due to the depth of reality capture and point cloud solutions used in the project to develop the sophisticated and accurate As-Found BIM model, we are able to perform detailed analysis on unique aspects of the building.
  - The BIM can be used by disciplines/consultants to perform computational fluid dynamic (CFD) studies, such as for wind, snow, blast, and internal temperature/airflow effects.
- ***Sustainability, Decarbonization, and Resiliency*** – Digital project delivery is key to supporting the CBR project goals to reduce the environmental footprint, optimize energy use, enhance occupant health and well-being, and produce a Future Ready carbon neutral design.
  - BIM2BEM (Building Information Model to Building Energy Model) – CENTRUS is developing processes and tools to improve the energy modeling process by using digital data in the BIM for the building energy model, to connect the design and analysis tools, to allow seamless exchange of data between the BIM and BEM, and to eliminate duplication of effort in reconstructing geometry and inputting relevant data points. BIM2BEM is an enabler and gateway to greater levels of analysis (daylight, thermal comfort, CFD, hygrothermal, thermal bridging, parametric analysis, etc.) as the process can be adapted to feed into other analysis tools.
  - Daylight analysis – Building on the BIM2BEM process, we extract geometry from the design models to daylight analysis software to analyze daylight conditions (glare conditions, quality of daylight, daylight hours, solar heat gains, etc.) to better inform the design.
  - Improved performance of the building design – Energy models obtained from the BIM2BEM and used for energy analysis are also used to:
    - improve envelope thermal performance,
    - perform energy and load calculations to support the mechanical system design,
    - study unique or complex spaces to provide more detailed information to better inform the design,
    - analyze and optimise electrical demand management, and
    - conduct renewable energy analysis to inform photovoltaic (PV) recommendations and design.

- Carbon neutral options analysis – CENTRUS leveraged digital tools and processes in conducting the CBR carbon options analysis which led to the recommended carbon neutral vision for the CBR, including:
  - Extensive computer modelling (energy, daylight, demand management, hygrothermal, thermal bridging),
  - Parametric analysis to explore a broader number of options in a shorter timeframe and to optimize multi-factor design options,
  - Life-cycle cost analysis tool,
  - Sustainability Matrix (database) to report and track all sustainability measures,
  - Use of BIM model for material take offs to enable embodied carbon calculations, and
  - BIM model and python scripting to analyze the reuse of existing structural steel members in lieu of new steel.
- Resilience – Detailed analysis of historical and forecasted future weather parameters to identify notable changes in future weather due to climate change, to:
  - Create a detailed energy, load and system sizing analysis outlook to 2030, 2050 & 2080, and
  - Identify potential recommended changes to the building design and systems to provide greater resilience to future climate conditions.



Summary

The CENTRUS integrated digital project delivery approach enables greater visibility, better informed decision-making, holistic sustainable options, and increased cost-savings for the CBR project. BIM is used to enhance the design and construction process of this complex heritage restoration project and to provide a Future Ready approach for the next generations. The information captured, the design proposed, and the completed building will live on in a digital twin, to enable building operators, architects, and engineers of the future to benefit from and build on the extensive information integrated into our digital models today.

Leveraging Digital Project Delivery in All Phases of a Project

Bid/Design Phase – Design Optimization and Optioneering

A significant challenge facing our industry is the time commitment required to develop optimized competitive designs. This applies equally to reduced multipliers during a bid phase or for a fixed fee during the design phase. There is a tremendous amount of pressure on consultants to present multiple alternative technical solutions, debate their merits and then optimize the solutions. When working at their own cost, or at breakeven revenues, a multiple optioneering process is not possible without a significant investment that may not see a return if unsuccessful in the pursuit.

Digital Project Delivery (DPD) and the 3D design model create a terrific opportunity for consultants to offer more design optimization during both the bid and design phases at a lower cost. The digital design model allows the consultant, owner and/or contractor to review the optimized design options directly in the model in real time and to make critical informed decisions on the spot. For the consultant, this provides an opportunity to offer more options to the client while keeping costs down. For example, in a design-build environment, the contractor and consultant can work directly in the model to review the impacts of various horizontal and vertical alignments on the mass haul. The contractor can then make efficient alignment decisions to achieve the desired quantity balance, and the consultant can offer multiple iterations at a lower cost. In a bid/pursuit environment, this can result in a more competitive bid and increase the chances of success. The digital model can also be leveraged to quickly evaluate various bridge span options, girder types and materials. It can even be used to optimize the actual route selection for a highway, optimize the locations of water crossings and minimize environmental impacts. In essence, depending on the level of detail in the model, multiple design options can be reviewed against a set of predetermined criteria.

"Less errors, better information to make decisions, speed & efficiency, recruitment & retention of younger staff, integration with machine control, better as-built-in."

Fulton Hogan

© Washington State Department of Transportation

"The use of a digital model has enabled us to automate processes in tender, detailed design, construction, commissioning and handover. This creates efficiencies which give us a cost advantage."

CPB Contractors

The same design optimization opportunities available during the bid phase are carried into the design phase. Following award of the project, an owner and/or contractor may wish to further optimize the design based on new or more accurate field information. A digital model allows the consultant to do it more efficiently and for a lower cost, thus reducing the pressure on the consultant's fixed fee. DPD can also lead to less rework that can come from design optimization. In a 3D digital environment, an owner and/or contractor can more clearly see and evaluate impacts and make an informed decision on the preferred design option.

Finally, parametric design allows us to vary key inputs in a design. For example, we can look at different geometries to make it easier to fabricate glazed roofs. Generative design is increasingly employed to look at how to reduce embodied carbon by using additive manufacturing to make moulds for concrete forms or to make repetitive steel structures lighter. However, as industry shifts away from construction to manufacturing, our recent DPD efforts and emphasis have been focused on using the tools of the manufacturer, such as Autodesk products, to provide more detailed subassembly information with additional emphasis on better management of broad and disparate datasets for specifications, carbon reduction, cost management and more.

A successful Digital delivery starts with establishing dedicated Digital/BIM/Information Management processes as part of the project to develop the civil BIM Execution Plan and ensure the project's approach to information management starts with the end in mind. The digital approach will begin by identifying key outcomes the program wishes to achieve. These outcomes can range from ensuring an integrated clash free delivery to using virtual and augmented reality to engage stakeholders for early sign-off. Having an information management plan will enable the team to deliver fit-for-purpose design and achieve meaningful results without waste or confusion.

Role of DPD in Operations/ Maintenance During Design

Digital delivery is a collaborative way of working, using digital processes to enable more productive methods of planning, designing, constructing, operating and maintaining assets. Digital delivery is the natural result from a set of changing internal and external priorities. Internally, we utilize digital delivery to improve the quality and efficiency in our client deliverables. Our clients can request digital delivery to enable them to achieve outcomes such as design for offsite fabrication and design for asset and operations management. Ultimately, our deliveries can enable intelligent virtual twins of the built environment. The underlying change to what we deliver and how we deliver it boils down to the fact that we must incorporate data into the digital representations of our designs and deliverables, which can be utilized throughout the entire lifecycle of the asset. Data and information are critical to enabling these new outcomes for ourselves and for our clients. This means we need to stop thinking about digital delivery as being about 3D models and start focusing on providing the right information in the right format to achieve better outcomes.

Owners and operators of large public infrastructure such as a government highway department or airport will be focused on achieving operational efficiency and reducing the costs and risks associated with their infrastructure failing. They may also be concerned about investing their money to achieve the best outcomes for the public and will rely on us to reduce the risks associated with construction and promote early stakeholder buy-in.

The contractor community will be focused on eliminating issues arising during construction that impact cost and schedule. They may also want to reduce the labour required to plan and estimate construction activities during pre-construction. Both clients—the owner and the contractor—have challenges and desired outcomes that digital delivery can address, but it is important for us to assess the delivery goals and uses that these clients have and deliver information models that achieve those outcomes. This is discussed in more detail in the following sections.

Quantity Management

Our industry has been using drawings and documents on construction projects for more than 500 years, and the challenges associated with the cultural shift of moving away from these forms of deliverables are immense. The opportunities are endless. For example, we can use design automation tools to make scheduling and the production of information faster and more accurate. To transform the costing process, we are now delivering new information formats such as Bills of Materials (BOMs) and subassembly drawings directly to manufacturers. The goal is to put data at the fingertips of consultants, contractors and manufacturers to allow better informed decisions to be made in real time. All this can lead to more efficient designs and can manage quantity growth throughout the lifecycle of a project.

WSP is deploying a digital delivery strategy throughout transportation by building a standard procedure for projects based on international standards in digital delivery (ISO 19650). This standard allows us to adopt a model-centric delivery approach to projects that focuses on improving our internal efficiencies and the quality of our deliverables. WSP also leads in industry engagement where we author industry standards that our clients can use to inform their own BIM and digital delivery requirements. For example, WSP has co-authored a National Strategic Roadmap (NSR) for BIM pertaining to Infrastructure assets for the Federal Highway Administration. The NSR proposes the development of BIM data and a standards-compliant Common Data Environment (CDE) for storage and management of the various enterprise data models, including the digital twins.

> ***"A digital model creates opportunities in the planning process. From simplified construction planning using reliable existing conditions data to reliable cost planning using parametrically linked quantity calculations."***
>
> **CPB Contractors**

©Washington State Department Of Transportation

Digitization for Owner & Stakeholder Consultation

Another challenge facing consultants is the presentation of 2D design plans (plans, profiles, bridge general arrangement drawings, etc.) when reviewing design progress with owners. Design review meetings with owners where consultants are seeking design input on a proposed solution have led to rework due to a lack of understanding of the design solution in three dimensions. Working directly in a 3D model gives the consultant the opportunity to review a full three-dimensional version of the design model during progress meetings. This can give the owner a more informed understanding of the proposed design solution and accelerate buy-in, reducing the possibility of rework for the consultant.

For both owner and stakeholder consultations, presenting various design options in 3D can be a costly process. Creating a 3D rendering from a 2D design is an additional step that adds time and costs to the process. Following owner and stakeholder consultations, the consultant will typically create revised design options based on the feedback received. Recreating new renderings from revised 2D information is once again a step that adds cost to the process.

Presenting information to owners and stakeholders from a 3D model eliminates these additional steps and provides tremendous value. When combined with Virtual Reality (VR), it can make for a more immersive experience and ensure feedback on the final product is more valuable and accurate. For example, consultants can present multiple digital options from various viewpoints or angles that accurately reflect the as-built condition and obtain owner/stakeholder feedback. Armed with that feedback, the consultant can then adjust the design directly in the model and more accurately capture the intent of the consultation process. This can lead to quicker approval of the project by owners and stakeholders as well as better buy-in from the community.

The Potential of DPD as a Contributor to Decarbonization, Resilience, Sustainability and Social Value Targets

The early phases of projects present the greatest ability to influence sustainable outcomes, including decarbonization, resiliency and promotion of broader social value. However, a key challenge in these early stages is that they typically have less scope definition and detail upon which to create benchmarks or base cases for embodied and operational energy/carbon. A further challenge lies with targeting construction energy/carbon in these early phases ahead of constructability assessments both for transport of materials and use of energy on site. Other challenges include adopting sustainability initiatives that are location dependent, for example, power grid switching may be more beneficial in areas with low levels of renewal generation but not in areas with a high level of renewables. Understanding the carbon footprint of differing materials (including differing sources) is both a challenge and an opportunity. The earlier business case and planning phase of a project ideally needs an asset owner/investor to provide a framework or targets for delivering a project sustainably. The tender/design phase is the first step in starting to realize those sustainable outcomes.

The use of DPD tools can be adapted to assess, measure and compare sustainable outcomes as part of design decision-making. Designs are typically undertaken using a range of different source design software. This can present a challenge in terms of coordination unless we can integrate it all into a federated digital model. This integrated model provides an ideal base for measuring and assessing sustainable aspects of the design, including:

— Measurement of principal quantities such as concrete, reinforcing steel, structural steel, cladding, architectural finishes, building services, earthworks and pavement

— The range and type of materials being specified including codification of carbon content

— The range and categorization of various equipment and plants being specified together with operational energy and embodied carbon

— The range of componentry and extent of standardization

— The range of design lives being specified and provided together with replacement and maintenance cycles

— The ability to bring a design to "life" through visualization and virtual reality, making it more accessible for diverse inputs and demonstration of social value uplift and opportunity

These digital tools can then be used to input and influence design decisions to promote decarbonization and enhance resilience and sustainability, while creating the opportunity for social value enhancement. These decisions include:

Design Decisions and Influences	DPD Quantities	DPD Materials Specified	DPD Equipment/ Plant Specified	DPD Standardization	DPD Design Lives	DPD Visualization	Other Modelling Tools
Assess whole-life carbon	✓	✓	✓		✓		✓
Minimize embodied carbon	✓	✓	✓				✓
Minimize materials used	✓			✓			
Design out waste	✓			✓		✓	✓
Option assessment considering broad sustainability	✓	✓	✓	✓	✓	✓	✓
Specification of low carbon materials		✓	✓				
Design for use of recycled materials		✓		✓	✓		
Renovate rather than replace		✓			✓		
Design to repurpose infrastructure			✓	✓	✓		
Design for resiliency		✓			✓		✓
Design for energy efficiency			✓				✓
Design for operational carbon			✓		✓		✓
Design with social inclusion						✓	✓

> ***"The biggest impact of DPD on our construction projects is the immediate visibility of the totality of the project in the design model and on site through the importation of the model data. The implementation of Virtual Superintendent gives us the ability to simulate load and haul providing great insight into materials logistics."***

CPB Contractors

The digital tools are typically used with and input into other models such as carbon calculators, energy models and whole-life cost models to make decisions on options, materials and equipment selection as part of the design process. Where there has been insufficient detail or scope definition in earlier phases to create a benchmark, then the digital model or tools can be used to "backcast" to create a baseline. This is particularly useful with construction and operational energy assessments. By using this approach, holistic decisions are made that promote sustainable and best whole-life outcomes. Digital models can also be used to promote these sustainable outcomes during the construction phase, which is covered in more detail below.

Construction Phase – Increased Reliance on Modular Construction

Modular construction is increasingly becoming an important and critical method for infrastructure development. On some of our largest infrastructure programs, designers and builders are looking to optimize the design process, increase quality and reduce cost through the use of modularized components. The success of most modular construction projects is contingent on how well information is shared between the various parties—the designer, manufacturer and builder. DPD is crucial in the transfer from construction to manufacturing. The biggest driver for change is the shift towards larger, configurable subassemblies. These might be digitally enabled for manufacturing in local micro-factories empowering social value propositions or assembled in "flying" factories on site. Such subassemblies include unitized façade panels and toilet pods. In the future, these subassemblies will be available from manufacturers' catalogues with configuration and pricing options allowing early carbon and cost decisions. Our economists are helping us define how to leverage economies of scale to prime this new design environment. Our own catalogues contain agnostic manufacture-ready content that can be pushed into construction management environments where blockchain or other tools allow dynamic pricing processes to mature.

Digital design also enables flexibility in design to counterbalance the constraints inherent to manufacturing. For example, digital twins offer the advantage of detailing components to the individual material and component, as well as the means, methods and behaviours of the system during construction. This can help address how manufacturing tolerances can complicate high-volume production or how materials may react to real-world environments.

Layout and GPS Grade-Controlled Equipment

In a non-digital project environment, layout and grade information is typically extracted from the design model by the consultant and transferred to a drawing or in tabular format. This information is then provided to contractors for construction in the field. The multiple steps and manual keyboard entries can lead to human errors, resulting in rework for the consultant. Since the layout or earthwork grade errors will surface during construction, this can mean standby time for the contractor's equipment while the consultant corrects the error. This exposes the project to delays and puts both the contractor and consultants at risk of claims. For the contractor, traditional (non-GPS grade-controlled) construction equipment relies on the experience and quality of the operators to achieve the desired gradeline. The speed and quality of the construction process is highly operator-dependent.

Working on a project with a 3D model, combined with GPS grade-controlled equipment, significantly reduces construction risks and increases quality for both the consultant and contractor. On such projects, the 3D digital model layout and grade information are directly transferred into the GPS grade-controlled equipment with no additional keyboard steps. If there is an error in the layout or grade information in the consultant's digital model, it will turn up when the model is imported into the contractor's equipment prior to the equipment actually being mobilized. Therefore, the model errors can be corrected before the construction equipment is mobilized on the site, mitigating the equipment standby risk. This greatly reduces schedule slip risks/costs for both the contractor and the consultant.

For the contractor, digital layout/grade information directly transferred to GPS grade-controlled equipment also improves the quality of construction. For example, slope grading and culvert grade excavation no longer rely solely on operator experience, but also rely on the digital model within the equipment itself guiding the operator. A real-time view of the gradeline compared to finished model grade is displayed in the operator's cab. In essence, a 2:1 slope will be built consistently at 2:1 using GPS grade-controlled equipment. This improves the aesthetics and quality of construction and can lead to fewer Non-Conformance Reports (NCRs) during construction.

"The adoption of digital project delivery has led to better decision-making, less errors and facilitated the integration with machine control construction. It has also helped with recruitment and retention of younger staff"

Fulton Hogan

Construction Quality Control and Assurance

Site observation and quality control testing records can be incorporated into the digital models. A range of bespoke and third-party software systems have been developed to interface such data with the digital models, including onsite recording using tablets and smart phones. This requires consistent element/asset referencing to align with the digital model attributes. While the model can be used in real time, updating the overall master digital model may lag to allow on-site recordings when out of data coverage or for the data to be checked before processing into the master digital WSP Research have developed a range for remote monitoring equipment such as measuring bridge and structural live load and dynamic behaviours, ground water levels and tilt metres for structures. These transmit data that are then integrated into digital models for monitoring during construction and in-service operational phases of asset lifecycles.

On Design-Build projects, Non-Conformance Reports (NCRs) are tracked in documents outside of the design model. Tracking the status and closure of NCRs can be a laborious process during the project, especially for final certification at completion. Project documentation on NCR status and proposed solutions must be clearly documented for final certification. DPD provides the opportunity to track the NCR status and proposed solution as an attribute directly in the digital model. Tying NCRs and statuses directly into the digital model as attributes allows for a single source of truth, more accuracy and greater speed when it comes to final certification. It also means there is a common environment shared between the owner, contractor and consultant for active management of NCRs, reducing the steps required compared to non-digital NCR documentation.

Accelerogram sensors are now built into intelligent compaction equipment to measure rebound like a Clegg hammer. While these cannot be calibrated as standalone tests, they can be calibrated on material layers that have undergone conventional compaction testing. This allows comparative continuous testing to be undertaken to demonstrate consistency of compaction and identify any soft spots for rectification. The continuous digital data can then be uploaded as part of quality control data into digital models for use during the asset lifespan. This level of sophistication has proved particularly useful in pavement construction but less so with general earthworks. These intelligent compactors also vary the level of vibration based on sensor data and preset targets.

Payment Process & Impact on Claims

In a non-DPD environment, payment processing, earned-value tracking and milestone payments are accomplished separately outside the digital model. This requires progress to be coordinated and extracted from multiple sources and then added to an earned-value tracking system or payment mechanism. The additional external steps increase processing and approval times and can lead to human error. In a DPD environment, pre-established payment milestones, rules of credit or earned-value calculations can be directly added as attributes to the digital model. This greatly increases the accuracy and speed of payment processing, potentially reducing input times and payment approval timelines for both the consultant and contractor.

As outlined earlier in this chapter, constructability and design optimizations input directly into the 3D digital model create a better understanding of the project scope and outcomes by all parties, which can create more accountability and can reduce the potential for claims. When a claim does arise, traceability in a digital model that includes attributes such as key design decision sign-off can make the process more efficient, reducing stress on everyone involved. The adoption of a full 3D digital model on multidisciplinary projects also greatly facilitates interdisciplinary reviews/coordination, which in turn reduces clashes, limits standby time in construction and can result in fewer claims.

> ***"Digital Project Delivery has given us better control when executing our projects, better understanding of risk and allowed us to notify and warn of issues earlier than traditionally identified."***
>
> **Canadian Contractor**

HSE and Safety Training

DPD can have immeasurable impacts on health and safety performance. There are many digital tools that can support health and safety awareness and performance throughout the lifecycle of a project. Most construction hazards are caused by poor decision-making during the design phase related to safety implication during execution. Traditional staging, logistics and health and safety plans leverage the experience of project personnel and are based on 2D drawings. This practice is unreliable and often does not fully consider all onsite safety hazards. DPD can help identify hazard sources and contribute to construction safety management in five ways:

1. Visualizing
2. Coordinating
3. Simulating
4. Rendering
5. Optimizing

For example, 4D digital modelling will detail construction sequencing, allowing project personnel to identify related hazards and proactively avoid, distance or design away the risk. Furthermore, new technologies including virtual reality can support training to educate and familiarize site representatives with hazard exposure, emergency response procedures and safety mitigation protocols.

DPD can also support safe work practices during construction. A fully developed model can facilitate quality control and quality assurance over the course of a project. The integration of a design model with construction sensors and technology (GPS, Unmanned Arial Vehicles, Advanced Tracking, etc.) can improve worker safety by reducing exposure to heavy equipment, providing alerts on hazards in real time and removing the needs for personnel to be on site.

The Potential of DPD as a Contributor to Decarbonization, Resilience, Sustainability and Social Value Targets

The construction phase provides the opportunity to realize sustainable outcomes targeted using the permanent design solution, such as embodied carbon, and to reduce carbon emissions and wastage from temporary and construction activities. It also provides the opportunity to enhance social value during construction through the supply chain and employment/training market.

This federated model also provides an ideal base for measuring and assessing sustainable aspects of construction. Aspects in addition to those from the design phase include:

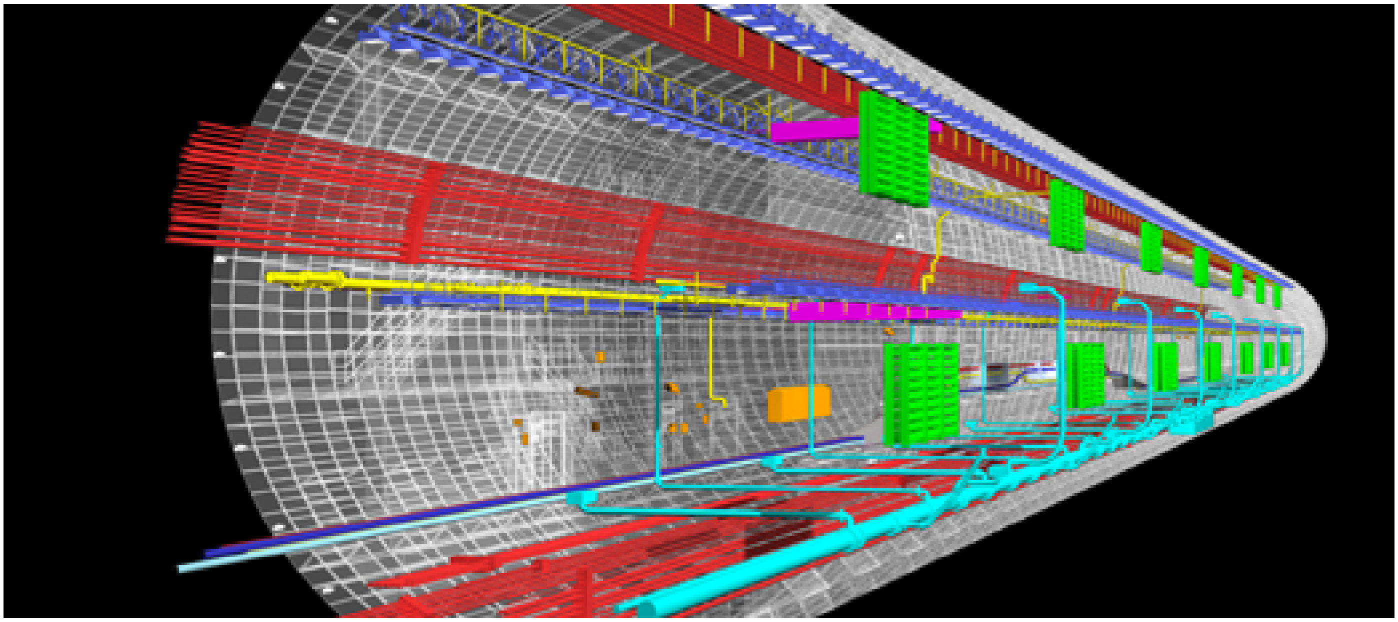
— Supply chain and sourcing options

— Construction sequencing to minimize handling and durations

— Temporary modelling of works, including falsework and temporary access

— Construction fuel consumption modelling, including mass haul analysis from digital models

— Visualization tools to illustrate sequencing, social impacts and improve Health and Safety training and planning



These digital tools can then be used to input and influence construction decisions to promote decarbonization and enhance resilience and sustainability, while creating the opportunity for social value enhancement. These decisions include:

Construction Decisions and Influences	DPD Quantities	DPD Materials/ Supply Chain	DPD Equipment/ Plant Specified	DPD Standardization	DPD Construction Sequencing	DPD Temporary Works Modelling	DPD Construction Fuel Consumption	DPD Visualization	Other Modelling Tools
Minimize embodied carbon	✓	✓	✓				✓		✓
Minimize materials used	✓			✓	✓	✓			
Supply chain/materials transportation		✓				✓			
Minimize construction waste	✓	✓		✓	✓		✓		✓
Reuse of construction materials		✓			✓	✓			✓
Construction scheduling	✓	✓		✓	✓	✓		✓	✓
Construction sequencing		✓	✓			✓	✓	✓	✓
Temporary works design	✓	✓		✓	✓	✓		✓	
Vendor/subcontractor design		✓	✓	✓	✓			✓	
Minimize construction carbon emissions			✓		✓	✓			✓
Construction with social inclusion		✓	✓					✓	✓

Digital models are also used during construction as a benchmark to measure achievement and realization of sustainable outcomes during construction. These are typically used as inputs for Sustainability Rating tools and are covered in a later section (see page 35).

> *"Digital Project Delivery provides us the opportunity to track and manage embodied carbon through integrated PAS2080 with the quantity extraction process, through enabling a 5D+ environment (Quantity + embodied carbon against material take-off)."*
>
> Canadian Contractor

Operations/Maintenance Phase – Role of DPD in the Whole Asset Lifecycle, Including Asset Management

The development of digital models through design, construction and project completion phases not only documents the as-built 3D configuration, but it can also incorporate a wide range of elemental attributes. These attributes can record a range of asset information such as material type and grade, design life, coating or protection data, life to first maintenance, routine maintenance and renewal information. To this, asset condition data can be added throughout the asset lifecycle. These attributes can be used to allow:

- Access to the digital model and asset information on site
- Visual and onsite assessments/inspections to be added directly to the digital model in real time
- Remote monitoring of asset information to be added to the digital model in real time
- Laser-generated 3D spatial surveys of in-service state to be compared with the original as-built model or the previous survey to assess and monitor changes
- Use of Virtual Reality technology to access asset information and also to merge it with onsite viewing
- Immediate access to asset information and the previous condition when responding to emergency and disaster situations

These can significantly improve asset management processes and promote extended service lives of assets.

The Potential of DPD as a Contributor to Decarbonization, Resilience, Sustainability and Social Value Targets During the Operations/Maintenance Phase

The Operational/Maintenance phase provides the opportunity to maintain sustainable outcomes targeted with the completed project, including optimizing operational performance and minimizing carbon emissions through effective asset management. It also provides the opportunity to enhance social value during operations through maintenance operations and the employment/training market.

This federated model with embedded asset management data provides an ideal base for delivering sustainable outcomes during the operational life of the asset. Aspects in addition to those from the design and construction phases include:

- Measurement and assessment of asset condition
- Optimization of performance and service levels
- Maintenance and renewals to minimize emissions and improve energy efficiency
- Parts and consumables supply chain and sourcing option

> *"The challenge with DPD in the asset management phase is ensuring a fully functional digital twin is handed over at commissioning."*
>
> CPB Contractors

These digital tools can then be used to input and influence operational and maintenance decisions and processes to promote decarbonization and enhance resilience and sustainability, while creating the opportunity for social value enhancement. These decisions and processes include:

Operations/Maintenance Decisions and Influences	DPD Asset Information and Condition	DPD Consumables/ Parts Supply Chain	DPD Equipment/ Plant Maintenance	DPD Standardization for Replacement	DPD Operational Fuel/Energy Consumption	DPD Visualization	Other Modelling Tools
Minimize embodied carbon	✓	✓	✓		✓		✓
Minimize materials used	✓	✓		✓			
Replacement parts/repair material availability		✓					
Planned maintenance	✓	✓	✓	✓	✓	✓	✓
Repainting/Refurbishment Schedule	✓	✓		✓	✓	✓	
Achieve design lives/avoid premature failure	✓	✓	✓	✓	✓		✓
Renewal/Upgrade to extend service life	✓	✓	✓	✓	✓		✓
Preserve service levels	✓		✓		✓	✓	✓
Minimize operational carbon emissions	✓		✓		✓		✓
Operations with social inclusion		✓	✓			✓	✓

This completes the use of the Digital Model in the project/asset lifecycle.

Multi-Phase Elements – Use of the Digital Twin to Track Sustainability Ratings During All Phases of Projects

A range of sustainability rating tools have been developed to assess and benchmark suitability targets and achievements. This allows an asset owner/investor to specify a target level of sustainability for a given project or program of investment. Some examples of these include:

— Green Building Councils (in multiple jurisdictions)

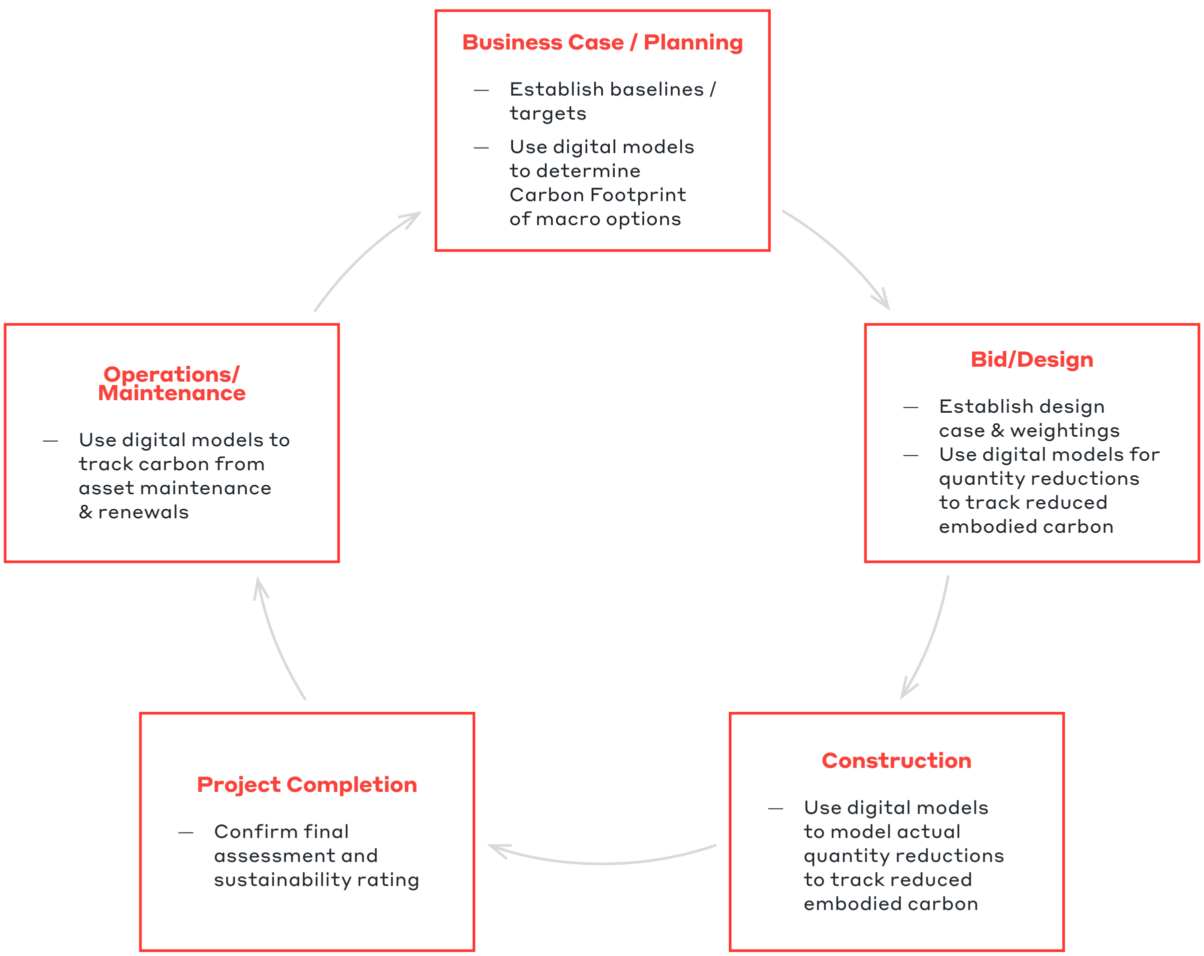
— Infrastructure Sustainability Council (Australasia)

— Greenroads (USA)

These typically are based on a series of steps including:

1. Selecting sustainability assessment areas and weightings
2. Establishing a baseline case assessment
3. Assessing sustainability achievement from the design case against the targets
4. Measuring assessment areas during Construction to assess the As-Built case achievements against the target

The earlier this process starts, the greater the influence on sustainable outcomes and achievement of Sustainability Targets. Applying this during all phases of a project and use of the digital model are important tools as inputs for tracking and achieving those targets. This is illustrated in the diagram below showing quantity reduction tracking to target embodied carbon reduction.



Case Study

City Rail Link

Location
Auckland, New Zealand

Client
City Rail Link Limited (Jointly funded by NZ Govt & Auckland Council)

Project Start & End Date
2019 – 2024/2025

Procurement Model
Alliance Contracting

Description

City Rail Link (CRL) is the largest, most complicated infrastructure project ever attempted in New Zealand.

The overall project is New Zealand's first underground railway and includes a 3.45km twin tunnel underground rail link and four train stations.

The main section of the project is delivered using an alliance contract model. The Link Alliance (LKA) is a consortium of six companies (WSP, Aecom, Tonkin & Taylor, Vinci, Solentanche Bachy and Downer) together with City Rail Link Limited (CRLL) concurrently delivering design and construction of stations and tunnels, connection with the existing North Auckland Line, and operational rail systems.

Setup & Benefits of Digital Project Delivery

CRL's common data environment (CDE) enabled the project's globally distributed workforce— 430 designers, 30 countries, 16 disciplines—to share live one-to-one digital twin models of the entire project. The result enabled unprecedented collaboration on live files regardless of location or time zone. As it turned out, the CDE was also the perfect environment to provide resilience to the project when the pandemic hit. When the pandemic forced lockdowns across the world, the Link Alliance project team was ready to continue working from home, equipped with laptops, workstations and an internet connection—no reliance on accessing local project servers from within a shared physical office. While on site construction was halted for a period, the design and forward construction planning continued remotely enabled by the CDE.

The project's digital twin hosted in an online CDE is an absolute game-changer for the industry.

The team is able to fill the needs of projects remotely with the best minds available globally relying less on people journeying to a site office and resulting in best outcomes not only for a project but for individuals and wider society impact.

Contributions to Decarbonization, Resiliency, Sustainability and/or Social Values

The CRL project identified carbon-emissions reduction as a key aspect of its sustainable design, including whole of life emissions from energy use and embodied-carbon emissions from construction phase materials.

Selection of materials, design concepts and construction methodologies all contribute to reducing embodied carbon emissions. There are many ways to influence sustainability throughout all phases of a project, including water use, waste to landfill, efficient delivery of materials to site, to name a few.

The Link Alliance Team has set out to achieve this 15-percent reduction target through a hybrid system that includes cutting-edge cloud-based technology, data being applied to digital models via automation, instantaneous reporting and a dedicated sustainability team. This system provides feedback and embodied-carbon-emissions metrics to both design and construction teams at all stages of the project.

These digital engineering tools and initiatives are enabling us to integrate data across all aspects of the project. Embedding aligned metadata into the digital twin models has been a game-changer for all parties involved, allowing us to interrogate for both quantities of materials used. This enables design optimisation and coordination between disciplines including clash detection.

Whole of life (WOL) cycle aspects are a core consideration in design development and decision making. A structured WOL Management Plan included staged assessment tools covering system level to asset components. These are included in the design packages information for construction which are being delivered at Level of Detail (LoD) 350. At project completion and hand over, the asset information will be delivered at LoD500 including the as-built status and WOL information such as operational and maintenance information. The design twin is planned to be used throughout the asset life cycle. With multiple asset owners, operators, maintainers and facility manager, this common digital asset information will also allow stakeholders to manage assets efficiently and ultimately deliver a high level of service to transport users and customers.

Case Study

Old Oak Common Station

Location
London, UK

Client
HS2

Project Start & End Date
Contractors Lead Designer – Ongoing

Procurement Model
Design and Build

Description

Old Oak Common will be a key hub connecting London to the rest of the UK. The six sub-surface HS2 platforms are connected to the eight surface level platforms of the Great Western Mainline and new Elizabeth line, creating a major interchange hub.

Almost 1 km long and 20 metres deep, it will be the UK's largest subsurface station.

WSP led the multidisciplinary design development for HS2 and is now Contractors Lead Designer. Co-located with HS2 and Balfour Beatty VINCI SYSTRA, our team is designing a world class, people-centred station that will support local regeneration, paving the way for 25,000 new homes and creating 65,000 new jobs.

Setup & Benefits of Digital Project Delivery

Digital Twin: enabling closer collaboration and reducing time, cost and risk

A Digital Twin of WSP's station design was created by WSP, providing a safe and easy-to-use platform for learning, and enhancing the planning and design of this new station.

Only authorised users can access the online, single user interface where they can interrogate the design, review design data, instantly raise issues e.g. clash detection, and review hypothetical situations e.g. wayfinding during evacuation. The subsequent design data is tracked in real time and applied to a version controlled work-in-progress model of the Digital Twin, until all changes have been accepted, when a shared (approved) version of the model is made available.

Set within a common data environment, the data does not need to be converted from its native format before these changes can be made available to the project team. A further benefit is that this ongoing, transparent, and collaborative review process reduces the need for time-consuming multidisciplinary design reviews.

The iTwin is an open, scalable cloud platform for creating, visualizing, and analyzing digital twins of infrastructure asset. It also enables augmented reality where digital data about the station's physical assets can be overlaid onto a virtual environment and visualized on site prior to construction in a safe environment.

As well as clearly demonstrating the impact of any design intervention, the Digital Twin can record the overall carbon content of the project, which can significantly reduce the cost of the project. We believe it can do likewise on comparable projects.

Virtual Reality (VR) with Eyetracking Integration into Wayfinding Design

Complementing our innovative use of Digital Twin technology, WSP worked with Mima (formerly CCD), a specialist in human behaviour and design, and HS2 to drive inclusivity into our design.

Combining VR, eye-tracking and emotion-sensing technology, we sought to improve wayfinding and the customer experience.

As one of the objectives was to ensure the wayfinding solution is designed with inclusion and accessibility at its heart, trial participants included those with a range of physical, sensory and cognitive impairments.

Wearing VR headsets fitted with eye-tracking and emotion-sensing technology, members of the travelling public entered the virtual station. They were asked to navigate to meeting points, platforms and to change between HS2 and Crossrail services using the signage included in the design. The three-week process immersed them in the environment to get a real-life understanding of the station, including how they interacted with the shop fronts and advertising competing for their attention.

Eye-tracking technology fitted to VR headsets monitored in detail how the eye was drawn around the station's interior and any distractions which could hamper easy and stress-free movement. This was then paired with emotion-sensing software (electromyography) that observed the wearer's facial expressions and monitored heart rate changes. It detected levels of stress/anxiety that were imperceptible to the participants themselves.

Evidence-based recommendations from the trial have been suggested to improve the zoning, iconography, concourse level signage, and platform level signage of the station.

What's Next?

Our joint successes in Digital Twin and VR-enhanced wayfinding, prove the potential to deliver HS2's ambition for a stress-free and inclusive passenger experience across all of its stations.

In December 2022, WSP established a direct link from the Digital Twin to Unreal Engine, state-of-the-art gaming software that will enable a real-time VR model.

The team continues to use this exciting technology to capture the imagination of students in its STEM outreach.

© Wilkinson Eyre Architects

Case Study

Versova Bandra Sea Link Project

Location
Mumbai, India

Client
Maharashtra State Road Development Corporation (MSRDC)

Project Start & End Date
2017-2026

Procurement Model
Engineering, procurement and construction (EPC)

Description

The Versova-Bandra Sea Link is a bridge construction project in the city of Mumbai 17 km in length. The new bridge will connect Versova, a neighbourhood in the suburb of Andheri to the Bandra–Worli sea link in Bandra, as part of the coastal road. The 8-lane sea link will reduce congestion on the Western Express Highway and the Western Line of the Mumbai Suburban Railway, expecting to cut down commute time for Mumbaikars from over 90 minutes to 10 minutes.

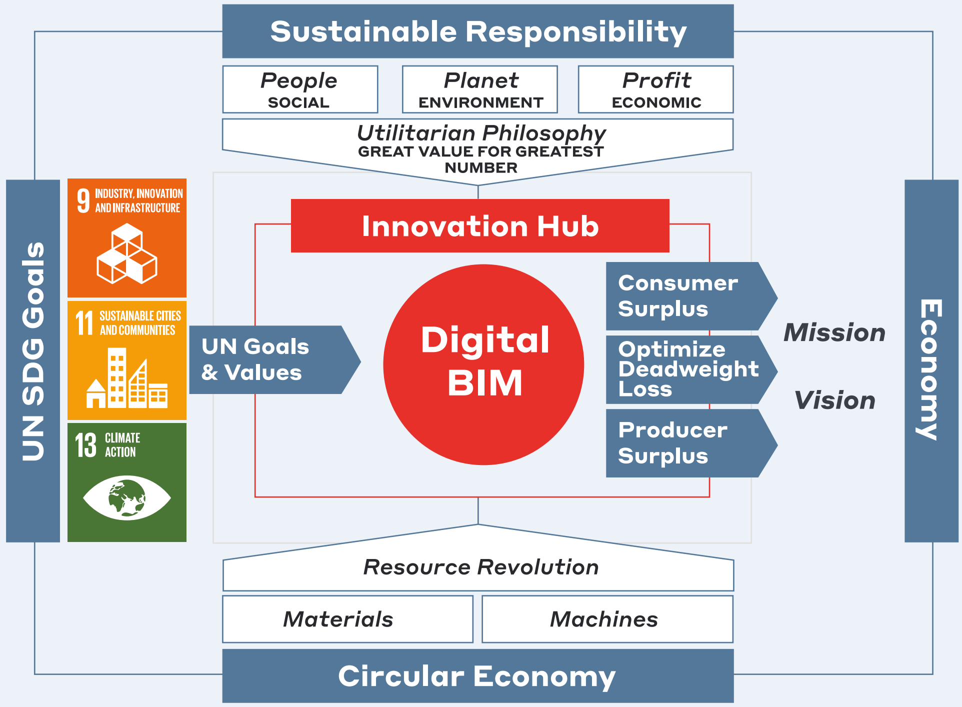
The key elements of the bridge structure include one main viaduct, a 300-m long cable-stayed bridge, three balance cantilever bridges and four connectors.

Setup & Benefits of Digital Project Delivery

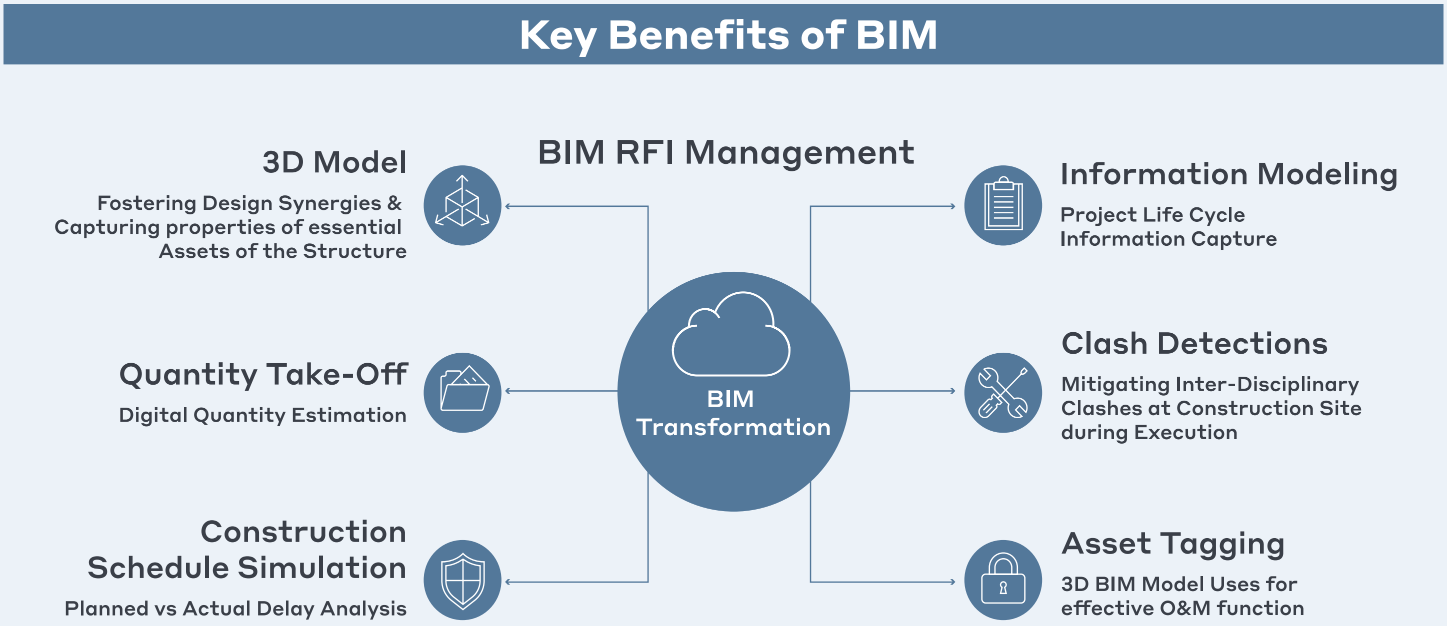
For this project, the team has committed to deliver Sustainability Responsibility Goals by adopting the Utilitarian Philosophy that essentially translates to "Great Value for Greatest Number", the Greatest Number stands for the Society by and large. The Digital BIM ecosystem is an integral part of the Sustainability Framework in line with fulfilling the project's goals of Social, Economic & Environmental Responsibility.

The BIM system includes:

- 3D Models – LOD 300 BIM models are developed for the Sea link project along with the cable-stayed structure.
- 4D BIM Simulations – Construction simulations produced leveraging 3D Models with the objective to drive insights for delay analysis – planned vs actual.
- 5D BIM Simulations – Construction simulations to be produced leveraging 3D models by integrating construction schedules & cost with the objective of driving insights on project progress.
- Common Data Environment set up to drive collaboration among all the key stakeholders and cross functional experts and discipline owners.



The benefits derived from the BIM implementation cover multiple facets:



In addition, as the BIM ecosystem captures all the project life cycle information, it will yield for higher accountability, transparency, information symmetry among all the key stakeholders.

Contributions to Decarbonization, Resiliency, Sustainability and/or Social Values

The team has adopted the Life Cycle Assessment (LCA) Value Chain for the quantification of Embodied Carbon and Green House Gas Analysis to meet one of their Sustainability Goals throughout the project:

CARBON LIFE CYCLE															
Production & Supply Chain			Construction		Operations & Maintenance							Demolition			
Raw Material Supply	Transport	Manufacturing	Transport	Construction / Installation	Use	Maintenance	Repair	Replacement	Refurbishment	Operational Energy Use	Operational Water Use	De-Construction / Demolition	Transport	Waste Processing	Disposal
A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4

As part of our Sustainability responsibility, we will continue to map the quantification of CO_2 Equivalent. with the reference to the datasets and information captured in the Digital BIM Ecosystem to calculate the Actual CO_2 emissions during the execution of construction operations & activities till the completion of the project.

Conclusion

The level of sophistication in DPD is increasing rapidly across regions around the world. The industry is on the cusp of using DPD to its full potential and extracting the full value from the process. DPD is a powerful tool on complex multi-disciplinary projects as it accelerates the collaborative environment for all parties participating in the project and results in a tight coordination of all parties and disciplines. This can lead to time and cost savings, but also produces highly compliant results. Digital delivery is a core pillar of WSP's 2022-2024 strategic plan ensuring that we are leading the consulting industry in the digital delivery space.

“Today’s major capital projects are increasingly complex and under significant scrutiny. Scale, duration, and complexity are growing, as are expectations around predictability and control. No one likes surprises; the unexpected is unacceptable. This is why a right first-time approach to project delivery is important and digital delivery can help us in this journey.”

Canadian Contractor

What’s Next?

Digital Project Delivery is a tool that brings tremendous value to owners, contractors and consultants throughout the project lifecycle, from the Business Case to the Operations & Maintenance phase. Getting the full value from DPD in all project phases requires establishing dedicated BIM Management and a dedicated BIM team at the outset of the project. The Digital Model then evolves with each phase of the project, resulting in a full digital twin being available for the Operations & Maintenance phase. This tool also facilitates tremendous opportunities for efficiencies when delivering projects in today’s realities. A few examples include:

- Getting project pipelines to market more efficiently
- Attracting more skilled talent to your project
- De-risking of project elements, such as stakeholder acceptance, commercial risks and HSE risks
- Using modern construction methods, such as offsite construction, modularization and quantity management
- Greatly accelerating/facilitating the achievement of decarbonization, resiliency and social targets

For the industry to succeed and really get the full value from DPD, we must also look at establishing national DPD frameworks, standards and tools to shift away from bespoke project-based requirements. This requires owners to go to market with projects procured around a DPD framework and not a bolt-on. This requires contractors and consultants to embrace the shift and leverage the process to its full potential.

As we nudge away from optimizing traditional ways of doing things towards game-changing solutions, we will see infrastructure and buildings designed and constructed faster with data-led intuition. This will also allow the next generation of designers and engineers to focus on the challenges of the future, including delivering a net zero society. On larger infrastructure projects, where it is difficult to avoid substantial interfaces with the earth, simulation software and new digital workflows will allow more informed and rapid decision-making while allowing a project’s context to be better considered. This is an exciting time to be in the industry.

Key
Contacts

Dominique Quesnel
Canada
dominique.quesnel@wsp.com

Mike D'Alton
United Kingdom
mike.dalton@wsp.com

Ettore Morelli
United States
ettore.morelli@wsp.com

Tim Gosbell
Australia
tim.gosbell@wsp.com

Keryn Kliskey
New Zealand
keryn.kliskey@wsp.com

WSP is one of the world's leading professional services consulting firms. We are dedicated to our local communities and propelled by international brainpower. We are technical experts and strategic advisors including engineers, technicians, scientists, architects, planners, surveyors and environmental specialists, as well as other design, program and construction management professionals. We design lasting solutions in the Transportation & Infrastructure, Property & Buildings, Environment, Power & Energy, Resources and Industry sectors, as well as offering strategic advisory services. Our talented people around the globe engineer projects that will help societies grow for lifetimes to come.

WSP Global Inc.
1600 René-Lévesque Blvd. West
11th floor, Montreal, Quebec
H3H 1P9

wsp.com