# Embracing Connected Sites in Construction

## An integrated digital approach to develop the built environment

# Contents



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We would be delighted to share more of our insights with you; please do get in touch with our team via globalt&i@wsp.com or contact the team members noted at the end of the whitepaper.

# Foreword

In an era defined by rapid technological advancements and interconnectedness, the construction industry stands at the precipice of a transformative journey. Construction, the biggest industry in the world economy, has seen remarkable advancements over the centuries but few productivity gains in recent decades. On top of that, the challenges construction faces today are uniquely complex. Increasingly complicated projects, stringent timelines, more regulations and requirements, a growing need for infrastructure, and the intensifying demand for environmentally responsible practices require comprehensive actions to effect impactful change. Compounding this issue, construction remains one of the least digitalized industries in an increasingly digital age.

The vision of a connected site presents an opportunity to revolutionize the construction process—toward enhancing productivity, project predictability, efficiency, and safety and supporting environmental sustainability. The core idea behind a connected site is to integrate cutting-edge digital solutions with intelligent infrastructure, creating a cohesive ecosystem where data-driven decisions and real-time collaboration are the norm. The connected site is an evolution of the growing use of digital twins, which capture continuously updated models of construction sites and assets across their lifecycle. The connected site builds upon this foundation of data and harnesses the power of autonomy, connectivity, advanced analytics, and augmented reality. Achieving the connected site vision will bring other benefits, including the elimination of silos, streamlined workflows, and optimized resource allocation. This vision reinforces the need for interoperability to link all aspects of the connected site, to implement a construction ecosystem that operates with unmatched precision, responsiveness, and foresight while supporting safety and delivering productivity and efficiency improvements.

Our whitepaper delves into the fundamental principles that underpin the connected site. It discusses the challenges faced by the owners and operators of infrastructure and those who are delivering on the construction of new assets around the world, across roads, railways, bridges, aviation, maritime, energy and other sectors. The analysis explores how different innovations can contribute toward realizing the connected site vision. Recognizing the wide-ranging technological advancements in recent years, the multifaceted nature of each construction project, the need to engage multiple stakeholders, and the differing requirements across sectors, WSP is committed to taking this journey together—as a trusted collaborative partner, with those who share the ambition to achieve a smarter, more interconnected and sustainable future.

If you are interested in learning more about developing a connected site in your region, we can offer valuable insights for different markets around the world. We would be delighted to speak with you—please do get in touch with our team.

**Eric Peissel**
Global Director, Transport and Infrastructure

# Construction Today

**The construction industry plays a vital role in shaping global infrastructure, bringing visions to life and laying the foundation for economic growth and development.**

Throughout history, construction has been a cornerstone of human civilization. As societies evolve, so too does the construction industry, adopting new techniques, materials, and technologies to meet the growing demands for innovative and sustainable structures. However, compared to other industries such as manufacturing and mining, construction has been slow in fully embracing the potential of technology.

This whitepaper introduces the concept of the connected site as a global opportunity to transform onsite assembly by leveraging technology to shape the future of construction. It sets out the role of integration across the industry to achieve successful transformation and outlines a framework for realizing change.

## The scale of the challenge

The construction industry grapples with formidable challenges that span productivity, skilled labour shortages, affordability, safety, and environmental considerations, all of which have far-reaching repercussions. These issues underscore the pressing need for forward-thinking, innovative solutions to steer the industry toward sustainable growth.

**Productivity:** As reported by McKinsey & Company in 2020, global construction productivity increased by just 1 percent annually over the last two decades, lagging behind the 2.8 percent average growth rate for the global economy.[1] This sluggish growth is attributed to a number of factors; key ones are fragmented processes, labour-intensive practices, and the slow adoption of technology and modern construction methods.[2]

**Skilled Labour Shortages:** The World Economic Forum indicates that the skills gap in construction is pervasive and represents a significant challenge.[3] As older workers retire, there is an alarming shortage of skilled labour entering the construction industry. The demand for appropriately skilled construction workers far exceeds the supply in many countries, affecting construction projects across the globe.[4] This challenge is made more complex by the widely varying needs of construction industries around the world, preventing the implementation of a universal solution.

**Affordability:** The decreasing availability of appropriately skilled labour is compounded by the increase in the cost of materials leading to a growing affordability challenge. A publication from the UK Construction Products Association found that globally 80 percent of large infrastructure products experience cost or programme overruns.[5]

**Safety:** Construction workers face a higher risk of accidents compared to workers in other industries,[6] making it a pressing concern for the wellbeing of workers and project success. Looking at Great Britain, where health and safety is already a strong focus for construction, fatal injuries were double that of other industries in 2022/23 (Figure 1).

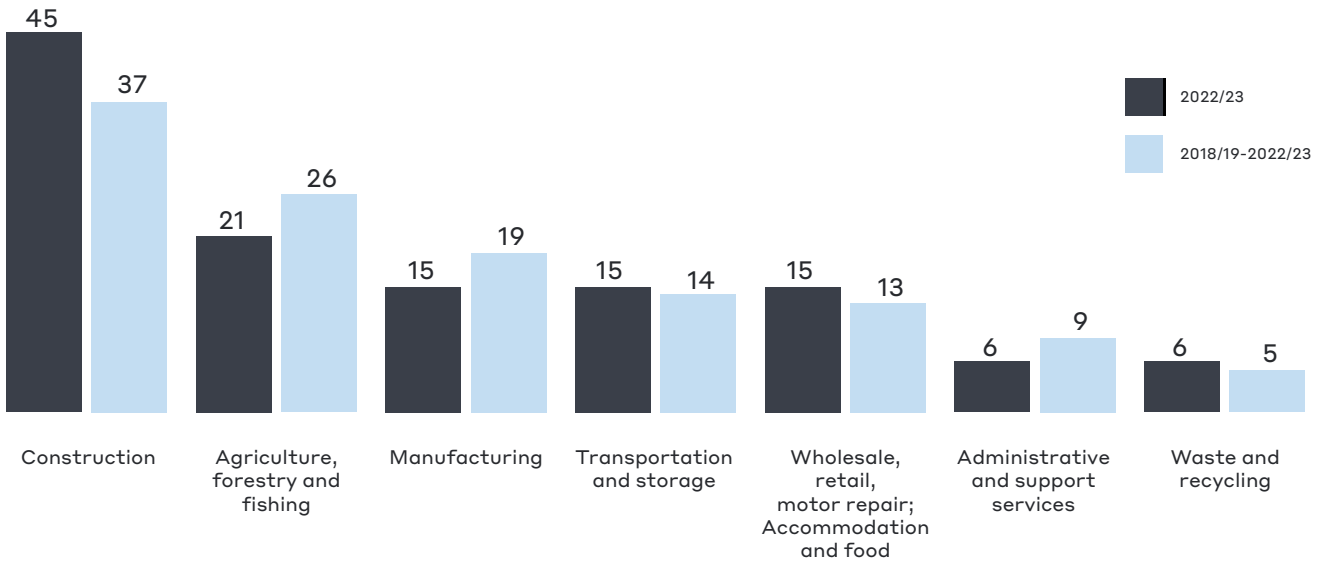



Figure 1 – Number of fatal injuries in Great Britain, by industry. 2022/23 shows exact figure, 2018/19-2022/23 shows annual averages. Adapted from: Work-related fatal injuries in Great Britain, 2023, *UK Health and Safety Executive*, 6 July 2023. Licensed under the Open Government Licence v3.0.

1 "The next normal in construction: How disruption is reshaping the world's largest ecosystem," McKinsey & Company, June 2020.

2 Christoper J Turner et al., "Utilizing Industry 4.0 on the Construction Site: Challenges and Opportunities." *IEEE Transactions on Industrial Informatics*, February 2021.

3 "An Action Plan to solve the Industry's Talent Gap," World Economic Forum, February 2018.

4 Belinda Brucker Juricic et al., "Review of the Construction Labour Demand and Shortages in the EU," Buildings, 2 January, 2021.

5 Amandeep Bahra, "What causes delays and cost overruns on major infrastructure projects?," Construction Products Association, 24 May, 2019.

6 "Construction: a hazardous work," International Labour Organization, 23 March, 2015.

**Environmental Concerns:** With global greenhouse gas emissions having reached a new peak in 2022,[7] it is critical for all industries to make considerable progress toward reaching net zero. The construction industry is a significant contributor to greenhouse gas emissions, energy consumption, and waste generation. The United Nations Environment Programme noted in 2020 that the construction industry is responsible for 7 Gt $CO_2e$ of global energy-related emissions (Figure 2). As environmental regulations become stricter worldwide, the construction industry faces mounting pressure to adopt sustainable practices and reduce its ecological footprint.

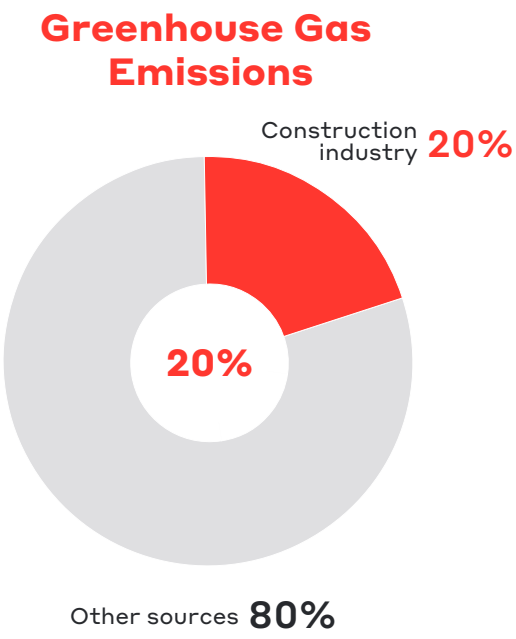



Figure 2 – Buildings and construction's share of global final energy and energy-related CO2 emissions 2020. Source: "Net Zero Carbon Construction Future Ready Research," WSP, 15 March, 2021.

In addition to the challenges outlined above, the construction industry has been subject to considerable constraints that have limited its transformation compared to other industries. These stem from the use of pervasive traditional working practices, fragmentation, risk aversion, complex regulations, a lack of standardization, and a slower industry-wide adoption of technology.

However, there is a growing awareness within the construction industry that technological integration is essential to its future success. Innovative technologies, such as connected and autonomous machinery, extended reality,[8] cloud computing, and the platform approach to modular construction, are gradually making their way into construction processes, promising enhanced efficiency, cost reduction, safety improvements, and greater environmental sustainability.

7 "Emissions Gap Report 2023: Broken Record – Temperatures hit new highs, yet world fails to cut emissions (again)," United Nations Environment Programme, 20 November, 2023.

8 Extended reality refers to any combination of augmented, virtual and mixed reality solutions to combine both digital and real space environments.

# Remodelling Construction

## Rethinking construction through a systems-based approach

To initiate the transformation of construction, industry stakeholders should first frame the discussion in an ecosystem context, which will recognize construction as a complex and intricate system—a dynamic process that brings together a multitude of elements to create the built environment. The system at its core involves the interaction of people, technology, and logistics, alongside processes, data, and place (Figure 3). This multifaceted system is characterized by its interconnected nature, where each component influences and depends on the others.

Understanding construction as a system is pivotal in the context of making progress: to devise strategies for the improvement of the industry's efficiency and safety, minimize the impact on the environment, and bring the best outcomes for society. Adopting this approach will aid in overcoming the traditionally siloed nature of construction, where each phase of work is apportioned to stakeholders and carried out consecutively. To fully consider the system of construction, all parties interacting with the system must be engaged and represented to enable the transformation to be successful.


Figure 3 – Construction as a system.

## Revolutionizing construction through a paradigm shift

Industry 4.0 represents a paradigm shift in production. It is the latest phase in the ongoing evolution of industry, driven by the integration of cutting-edge technologies and digital advancements. Also known as the Fourth Industrial Revolution, Industry 4.0 leverages the power of the Internet of Things (IoT), artificial intelligence (AI), big data analytics, and automation to create smarter, more efficient, and interconnected systems.[9] This capability is characterized by the seamless connectivity of machines, processes, and people, enabling real-time data exchange and intelligent decision-making. Industry 4.0 promises to enhance productivity, reduce operational costs, and open new opportunities across various sectors, paving the way for a more agile, sustainable, and competitive industrial landscape.

## Embracing a framework for transformation

Within the built environment, Modern Methods of Construction (MMC) is revolutionizing the way buildings and infrastructure are designed and constructed. By marrying the efficiency of offsite modular construction and the power of digital technologies, it aims to enhance the efficiency, sustainability, and quality of construction projects.

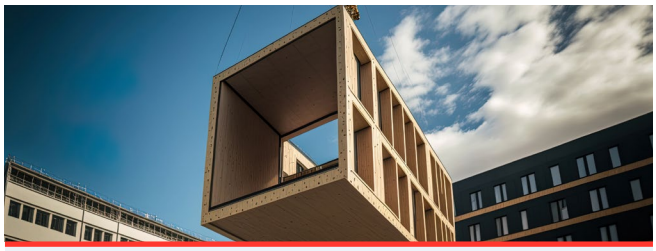
At the core of MMC is the use of Building Information Modelling to accurately develop the designs, plan the construction process, and capture the as-built information. 3D modelling enables the adoption of a platform approach to construction, where repeated components are identified and selected for offsite prefabrication. These modules can be made in a factory setting, using greener materials and sustainable building practices, minimizing waste and avoiding hazards. The production of modular components in a factory setting lends itself to the introduction of robotics and automation, delivering further productivity and efficiency improvements. An added benefit is the potential to reuse modules across multiple assets where the design needs are similar. Following the manufacture of the modules, the modules are then transported to site for assembly, where the final as-built information is captured and fed back into the 3D model.

9 Klaus Schwab, "The Fourth Industrial Revolution: What It Means and How to Respond," World Economic Forum, 14 January, 2016.

MMC is reducing waste, accelerating project timelines, and promoting environmentally responsible practices. By emphasizing offsite manufacturing and digital advancements, MMC is driving a more cost-effective, sustainable, and efficient construction industry, ultimately improving the environmental footprint and the overall quality of built environments.

Although MMC features offsite construction when possible, the final onsite assembly remains a fundamental component that presents significant challenges around productivity, safety, and environmental impact.[10] This onsite stage, marked by manual-intensive labour and fragmented processes, has been a longstanding impediment to improving productivity. Moreover, it poses safety concerns in the inherently hazardous construction environment, contributing to a higher rate of accidents. Environmental aspects also come into play as onsite assembly generates harmful emissions, waste and consumes extensive resources.

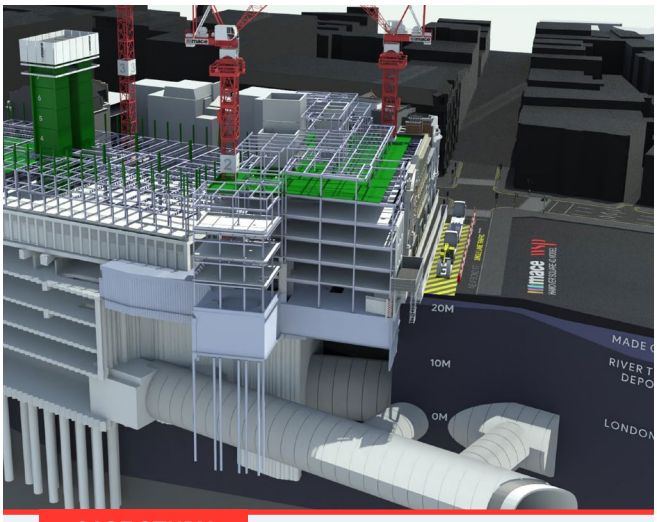
To fully harness the potential of MMC, the industry should apply innovative practices for onsite assembly, such as Design for Manufacturing and Assembly, automation, leaner processes, and sustainable practices. Together they will streamline operations, improve safety, and reduce the environmental footprint of construction projects. These practices will be crucial to realize the full benefits of MMC.



## Modern Methods of Construction | WSP

Using a combination of digital technologies, technical innovation, and a continuous improvement ethos, WSP's MMC expertise improves the efficiency, productivity and whole-life carbon impact throughout the project lifecycle, with particular value for the planning, construction, and operations and maintenance phases.

**More** *here*




**CASE STUDY**

## Using MMC to leave a digital legacy while constructing Hanover, London, United Kingdom

Situated in the prestigious district of Mayfair, London, Hanover is a prime mixed-use development elegantly situated above the new Bond Street Elizabeth Line station. Developer Great Portland Estates promoted cutting-edge digital construction techniques to de-risk the highly complex project and develop a digital asset that would be used post-construction in operations. WSP developed a detailed process for managing the creation of an accurate-to-life spatial model. This process allowed us to coordinate trends, report potential issues, de-risk the project, and provide a collaborative environment for the design team to work within. The models were then linked to the construction programme in a 4D Installation and Logistics model to bring a level of surety to the design and construction programme and align the oversite development with the station below. Finally, an asset information model was developed, capturing all the asset data required from the sub-contractor teams and linking the model to the cloud-based operations and maintenance system to leave a digital legacy post-construction.

10 Mungo Stacy "Transforming delivery of major infrastructure projects using Modern Methods of Construction," WSP, August 14, 2023.

# The Future of Construction Sites

Taking the opportunity to remodel construction will provide the basis for transformation. The concept of the connected site emerges as a solution to address the challenges the industry faces within the framework of MMC.

A departure from traditional practices, the connected site envisions a transformative shift toward an integrated digital approach in constructing the built environment. By harnessing the power of data, technology, and connectivity, it holds the promise of revolutionizing the construction industry. The connected site not only addresses the productivity bottlenecks of onsite assembly, it also—by enabling real-time data exchange, smart monitoring, and the automation of critical tasks (enabled by 5G communication networks)—offers considerable potential to enhance construction site safety[11] and boost productivity.[12] The connected site will also improve the environmental impact of the industry, tackling unsustainable consumption of fuel and materials,[13] pollution levels (air and noise), and vibration exposure during construction work.[14]

The holistic vision for a connected site is shown in Figure 4.

11 J. Beale and J. J. Smallwood, "The potential of Industry 4.0 to enhance construction health and safety (H&S) performance," *14th International Postgraduate Research Conference 2019: Contemporary and Future Directions in the Built Environment*, 16-17 December, 2019.

12 Christoper J. Turner et al., "Utilizing Industry 4.0 on the Construction Site: Challenges and Opportunities," *IEEE Transactions on Industrial Informatics*, February 2021.

13 Judit Oláh et al., "Impact of Industry 4.0 on Environmental Sustainability," *Sustainability*, 8 June, 2023.

14 Sreejith Balasubramanian et al., "Construction Industry 4.0 and Sustainability: An Enabling Framework," *IEEE Transactions on Engineering Management*, 11 October, 2021.

# Connected Site Vision

## Connected machinery

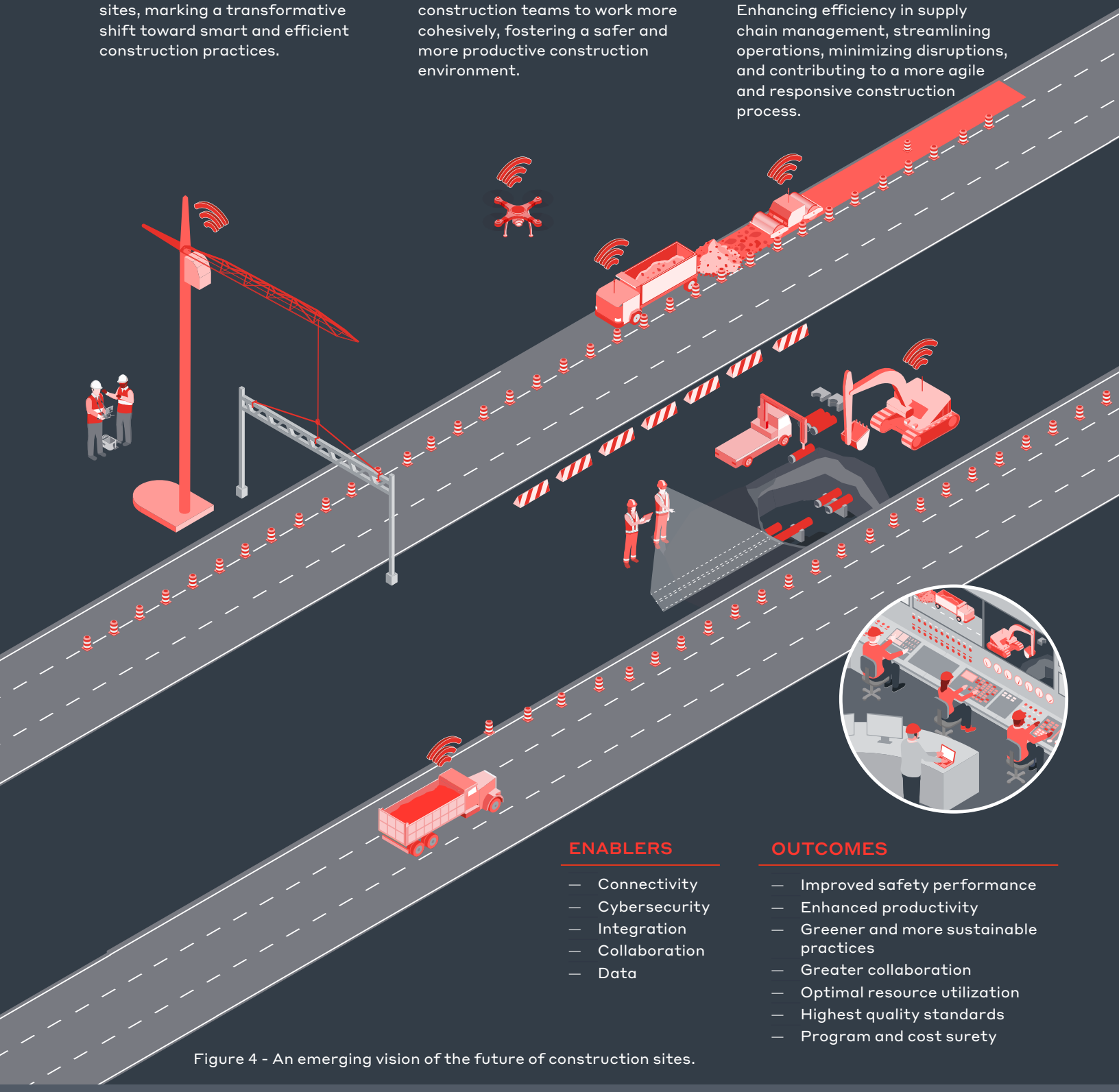
Integrating technology to optimize tasks, enhance efficiency, and improve safety on construction sites, marking a transformative shift toward smart and efficient construction practices.

## Connected workers

Utilizing technology to coordinate tasks, receive updates, and access critical information—empowering construction teams to work more cohesively, fostering a safer and more productive construction environment.

## Connected logistics

Optimizing the movement of materials, equipment, and resources on construction sites. Enhancing efficiency in supply chain management, streamlining operations, minimizing disruptions, and contributing to a more agile and responsive construction process.



### ENABLERS

- Connectivity
- Cybersecurity
- Integration
- Collaboration
- Data

### OUTCOMES

- Improved safety performance
- Enhanced productivity
- Greener and more sustainable practices
- Greater collaboration
- Optimal resource utilization
- Highest quality standards
- Program and cost surety

Figure 4 - An emerging vision of the future of construction sites.

## A toolbox for tailored transformation

Through the adoption of MMC and modular construction, the design and components that comprise both structures and linear infrastructure are being standardized, which supports efficiency, waste reduction, and safety. However, these offsite components still require a complex assembly process onsite.

To address this, the connected site proposes the digital transformation of the entire construction system. Recognizing that innovations often fail when too much is changed too quickly, the connected site is defined by many technological, behavioural and process interventions that target specific areas of the system. These interventions form a toolbox of solutions that can be applied to address issues on a given construction site.

Technological innovations involve the introduction of new hardware and software solutions that make use of automation, AI, and enhanced digital capability to focus on specific issues within onsite assembly. Behavioural transformation is more complex, requiring changes to the way people think about and interact with the whole system of construction—adopting a more digital mindset to delivery and evolving work practices past the traditional approaches. Interventions around process are a key part of evolving work practices, with the adoption of digital platforms, continuous provision of data, and the use of automated systems to streamline how this data is used. Components of the connected site toolbox are shown in Figure 5.

The use of a centralized **command and control centre** gives site supervisors, programme managers, and delivery leads a single source of the truth, providing continuous progress reporting.

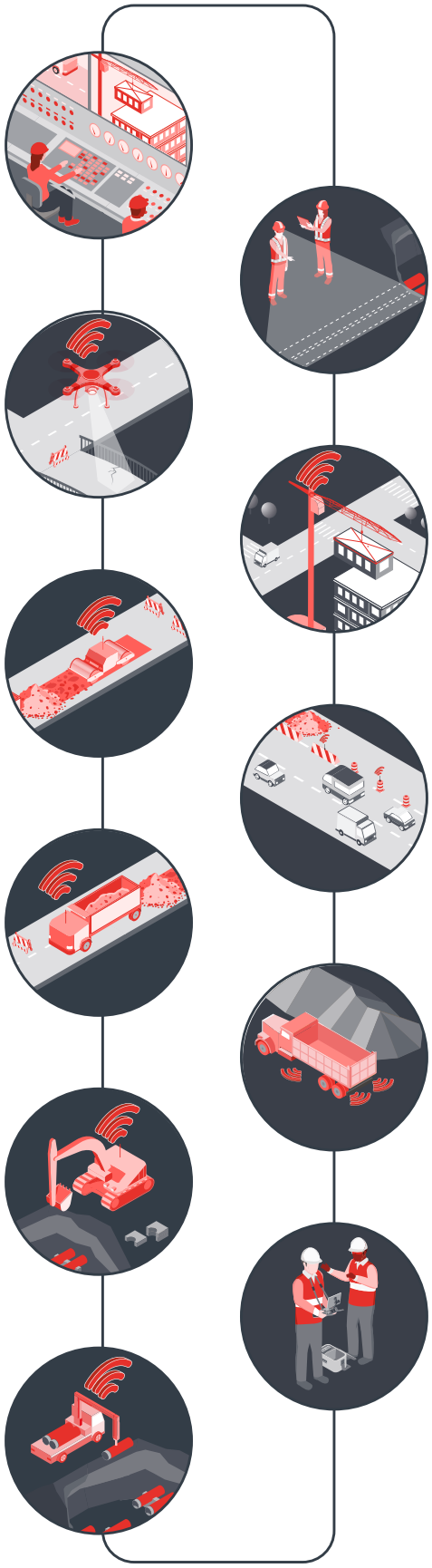
**Drone surveys** generate precise 3D models for initial designs, clash detection, and quality assurance, forming the basis for a comprehensive digital twin for operations and maintenance.

**Intelligent compaction** enhances consistent compaction quality, improving the performance of surface assets, extending their life and reducing the need for costly repairs.

Establishing a **shared digital platform** for tracking material logistics streamlines accurate bookkeeping, prevents the loss of Goods Received Notes, and expedites the invoicing process within a scheme.

**Excavators equipped with semi-autonomous and autonomous technologies** deliver faster, more accurate excavation, cutting, and grading by reducing the burden on operators and preventing costly reworks.

Workers using **robotic load handlers** can swiftly and efficiently perform manual handling tasks, reducing the risk to personal health and alleviating societal impact related to common musculoskeletal issues among construction workers.



**Augmented reality** headsets connect on-and-offsite workers, helping onsite workers understand how designs interacts with real construction locations. Guided workflows further enhance delivery speed and minimize errors.

**Cranes equipped with remote controls**, 360° cameras, and local positioning systems eliminate the need for people to work at height and allows for the operation of cranes in more confined spaces.

**Intelligent traffic management** systems provide a continuous assessment of the quality of deployed traffic management to the command centre, eliminating drive-by surveys, while also warning onsite operatives of incursions or hazards.

**Geofence and collision avoidance** systems on construction machinery mitigate the risk of personnel operating too closely to heavy machinery by controlling equipment motion and issuing warnings to operators.

**Remote control of heavy machinery** allows skilled operators to remotely train junior colleagues and handle complex tasks with heavy machinery, especially in environments unsuitable for onsite personnel.

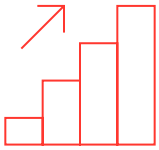
Figure 5 – Addressing challenges through a tailored toolbox approach.

## Driving value through adoption

The connected site introduces a myriad of advantages for the construction industry, redefining traditional practices and propelling the industry toward a more technologically advanced future.[15] Key benefits encompass:

### Safety Enhancement

Through the integration of wearable devices and IoT sensors, workers receive timely alerts about potential hazards, and the control of the people-machinery interface is optimized, significantly improving overall site safety. National Highways within the United Kingdom estimates that the introduction of automation to construction machinery would improve safety by 30 percent.[16]

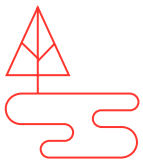


### Productivity Boost

Automation of construction equipment and the adoption of digital solutions leads to more precise delivery, increasing the number of tasks completed correctly on the first attempt. This not only enhances productivity but also reduces the administrative workload associated with construction projects. Research from McKinsey & Company indicates that digitization in construction can increase productivity by 14 to 15 percent.[17]

### Operational Efficiency

Improved connectivity, collaboration, and communication between designers and onsite teams facilitate the swift identification and resolution of delivery obstacles. Remote access minimizes travel time, providing greater flexibility and adaptability.

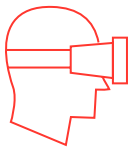


### Environmental Impact Reduction

The connected site allows for the optimization of resource use, waste reduction, decreased fossil fuel consumption, and the promotion of sustainable construction practices, thereby lessening the environmental impact of construction projects. The World Green Building Council estimates that green construction practices can reduce carbon emissions, across the buildings sector, by up to 84 gigatons by 2050.[18]

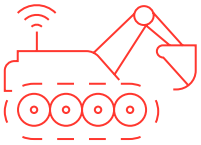
### Social Value Creation

Automating hazardous construction activities improves site safety and lessens the knock-on burden to healthcare systems. The effect on communities is also improved through better data to lessen the impacts from: machinery noise, air quality, impact on adjacent local roads and traffic impacts.



### Future-Proofing Workforce

Addressing skilled labour shortages through the integration of attractive technological roles ensures the construction industry remains resilient and adaptable in the face of evolving challenges. The U.S. Bureau of Labor Statistics predicts a 2.5 percent growth in construction-related jobs over the next decade.[19]



### Ongoing Operations Support

By leaving a comprehensive digital legacy through detailed as-built records, the connected site supports the ongoing operations and maintenance of constructed assets, streamlining post-construction activities. This delivers further health and safety benefits by eliminating the need to send workers to site to carry out surveys and mitigating against unknown underground assets.

### Regulatory Compliance Facilitation

The connected site simplifies the process of providing detailed records and monitoring tools, aiding compliance with construction industry regulations and standards.

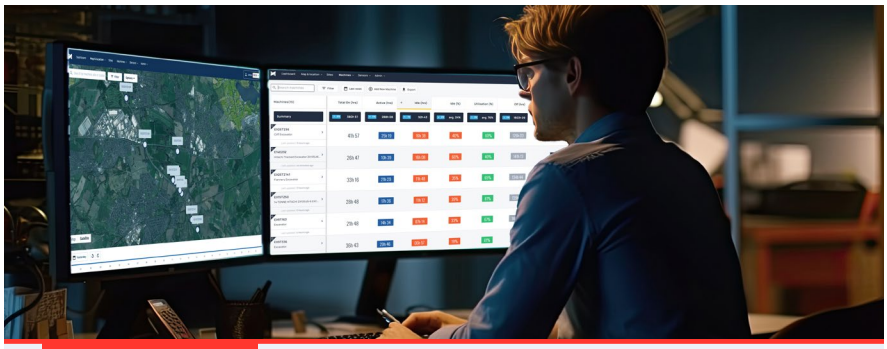
15 Adetayo Olugbenga Onososen and Innocent Musonda, "Perceived Benefits of Automation and Artificial Intelligence in the AEC Sector: An Interpretive Structural Modelling Approach," Frontiers in Built Environment, 20 April, 2022.

16 "Connected and Autonomous Plant Roadmap to 2035," National Highways, accessed November 2023.

17 Jan Koeleman et al., "Decoding digital transformation in construction," McKinsey & Company, August 20, 2019.

18 "WorldGBC launches groundbreaking programme to ensure all buildings are "net zero" by 2050," World Green Building Council, accessed November 2023.

19 "Employment projections — 2022–2032," US Bureau of Labor Statistics, September 6, 2023.



CASE STUDY

## Demonstrating efficiency through enhanced construction machinery telematics, United Kingdom

WSP collaborated with multiple delivery partners on a significant highway upgrade project in the UK and put the connected site strategy into action by implementing state-of-the-art monitoring tools to gather vital data on construction machinery, including location, operation, and performance. This information was transmitted to a centralized platform, providing comprehensive overviews, actionable insights and detailed analyses of machine and operator performance. The utilization of key metrics, such as idle time, emissions, and fuel use, resulted in substantial financial and environmental benefits for the project.

### Project benefits

During the period from October 2022 to July 2023:

Approximately 20 machines were equipped with sensors

Significant reduction in idle time from **56% to 19%**

Saved over **6,000 liters** of fuel

Prevented the release of **over 16,000 kilograms of $CO_2$** into the atmosphere

The success of the project has been achieved through extensive collaboration across the supply chain, not simply through the introduction of a new technology. Behavioural change training played a pivotal role, engaging operators in the concerted effort to reduce idle time and thereby making significant contributions to emission reductions. This not only enhanced air quality for site workers but also had positive implications for the wellbeing of nearby residents. The project demonstrated the power of innovative technology coupled with strategic collaboration, showcasing the potential for positive environmental and operational outcomes in large-scale infrastructure projects.

CASE STUDY

## Using digital technologies to advance safety in rectifying landslips, New Zealand

A vital transport link within the Maungataniwha Range in New Zealand was severed by numerous landslips, requiring extensive remedial works. Due to the nature of the environment, workers could have been at significant risk due to the potential for further slips. A network of sensors developed by WSP for client Waka Kotahi NZ Transport Agency is playing a crucial role overcoming this and delivering site safety—tirelessly detecting ground movement and determining the real-time risk. Eighty-four locations have been equipped with ground movement sensors. Sixteen locations monitor soil moisture. Rain gauges measure volume and intensity of rainfall. Every day, this extensive network of sensors registers seven million data points, which feed into a Trigger Action Response Plan (TARP) that calculates the real-time risk of ground movement.

## Aiding the transition to net zero construction

The construction industry is making significant strides toward decarbonizing construction materials,[20] but progress toward transforming construction activity, a vital component of reaching net zero targets, is less advanced. A significant amount of the carbon emissions associated with construction occur during the onsite assembly phase when moving large numbers of people and materials to site, facilitated by fossil-fuel-powered off-road mobile machinery (ORMM).[21] While efforts are ongoing to transition ORMM to net zero operation using alternative power sources, such as electricity, hydrogen, and biofuels, the machinery is limited in their application to certain construction activities due to their energy density and the power requirements for the activity.

The connected site introduces opportunities to maximize value of both existing and upcoming net zero ORMM assets, for example by extending the machinery's operational periods, reducing fuel/power usage, optimizing the number of ORMM assets required, and delivering consistent, predictable operations that create consistent loads on motors and batteries. Furthermore, with new ORMM assets making use of electrical control and actuator systems, the connected site can also introduce elements of automation reducing people's exposure to dangerous activities onsite and also mitigate the factors limiting industry growth, namely skilled labour shortages, low productivity and innovation.[22]

20 "Net Zero Carbon Construction Future Ready Research," WSP, 15 March, 2021.

21 "How to reduce carbon emissions in construction operations," Atlas Copco, accessed November 2023.

22 Juan Manuel Davila Delgado et al., "Robotics and automated systems in construction: Understanding industry-specific challenges for adoption," *Journal of Building Engineering*, November 2019.

## A systems approach to net zero through technology integration

All industries must work toward consistent decarbonization to achieve net zero targets and prevent further ecological harm. There are diverse ways that each industry can contribute to net zero. By adopting a holistic perspective, it is possible to assess how individual steps can maximize an industry's contribution to net zero.

WSP used this holistic perspective to consider how people, processes, places, infrastructure, vehicles, technology, and data all contribute to achieving net zero ambitions in the transportation industry. By considering influences across the system lifecycle, the whitepaper identifies net zero investment opportunities that provide social, economic and environmental benefits to society. Common to these opportunities is the requirement for strong collaboration and innovation among stakeholders—this same approach and whole-system thinking will also enable the net zero benefits of the technologies that support the connected site.

Read more about the whole-system approach to decarbonization in WSP's whitepaper *here*.

# An Integrated Digital Approach

By embracing an integrated digital approach, all stakeholders can benefit from the connected site and the technologies and mindset that come with it. However, such an approach is only possible if digital transformation is embraced throughout the project lifecycle and the construction system as a whole (Figure 6).

## Integration across the project lifecycle

The potential of digital transformation should be considered early in the pre-design stages during the initial concept and business case development. The capability offered will impact the viability of different approaches and may facilitate the delivery of an asset that would otherwise not be possible or allow for innovative designs to be offered by using a new technology. By having a clear idea of the benefits of digital transformation from the outset of the scheme, it is more likely that these benefits will be realized throughout delivery. A key activity in unlocking these benefits is introducing the concept of designing for connected sites—that is, making the designs suitable and interoperable with the technology that will be deployed onsite without requiring complicated processing. The Design for Machines approach is an example of how this is being implemented in practice today, where designs are made readable and actionable by construction machinery directly through integrated 3D models rather than the traditional drawings-on-a-page approach.

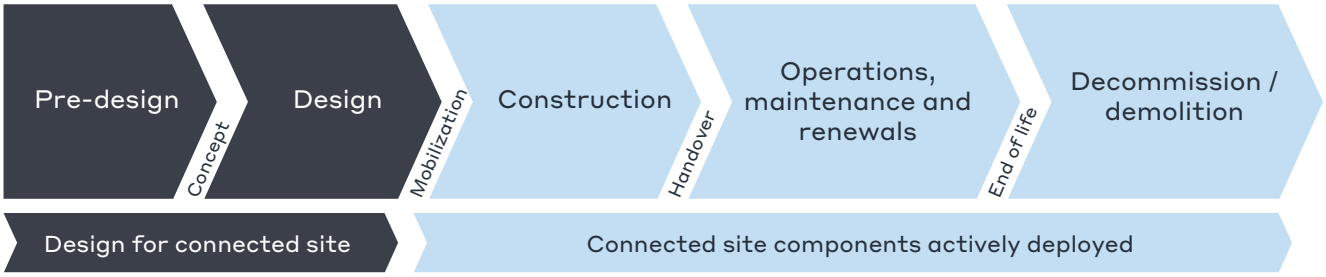



Figure 6 – The connected site and the project lifecycle, showing how connected site is linked to each phase of the project lifecycle.

Digitized designs and survey data play a crucial role in the operation of a connected site. They not only facilitate day-to-day site activities but also generate valuable data that serves multiple purposes. For example, the data and data framework created during the concept and design phases are utilized and augmented during the construction phase. Together, they act as the foundational element for creating a digital twin of the asset and aid in capturing as-built information vital for smooth handover and ongoing operations and maintenance. This wealth of information is also a valuable resource for optimizing the construction process, where it provides insights into specific challenges that might require a disproportionate allocation of resources. This data can then be deployed at the appropriate level, be it at the local level to address issues related to site layout or resource bottlenecks, or at the broader macro-level to refine construction processes and methodologies.

As the connected site is a transformation of a traditional construction site, its influence is most direct during phases involving construction activities, such as onsite assembly—during the operations and maintenance, and decommission/demolition phases. However, the connected site is also embedded throughout the project lifecycle through a "golden thread of data," beginning from the pre-design concept definition, creation of digitized designs, evolving through the construction process with real-time, as-built information, and progressing through operations and maintenance as the asset is used and maintained (Figure 7). This golden thread acts as a bridge ensuring knowledge and insights accumulated during each phase are not lost but transparently carried forward to inform subsequent steps. This transition to a centralized data environment (CDE) of shared information will eliminate siloed working and prevent information being lost as the asset progresses through its lifecycle.

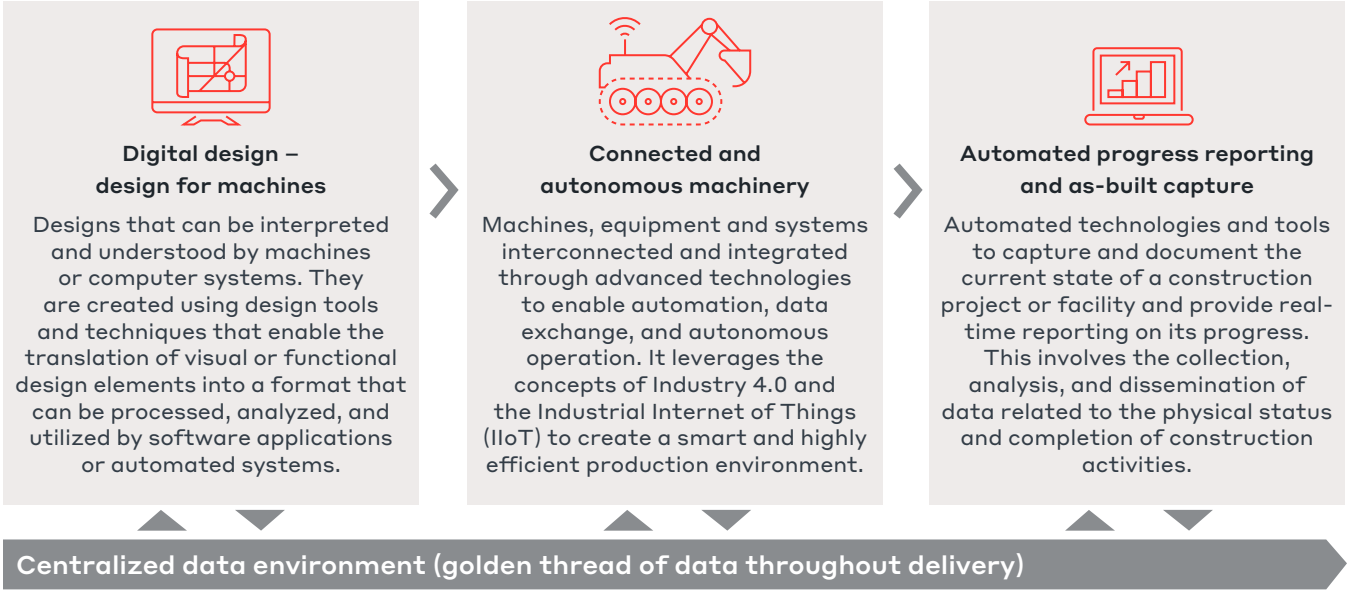



Figure 7 – Integrating toolbox components enables sites to unlock greater value.

The integration of digitalized designs, real-time survey data, project management systems, and communication tools, leads to a more streamlined process, improving collaboration and enhancing data-driven decision-making. It not only increases efficiency on the construction site itself but also facilitates better project management, cost control, and resource allocation.

## Digital Project Delivery | WSP

Through the use of digital platforms and workflows, supported by the use of digital twins, WSP's digital project delivery accelerates the delivery of projects while reducing the risk and enabling seamless collaboration across project teams.

**More** *here*

CASE STUDY

## Revolutionizing construction management – digital transformation of site management through a centralized data environment, South Africa

In the recent construction of a 100 megaliter reservoir, WSP employed CDE to revolutionize site management through digital transformation. This unified platform was instrumental in providing real-time, comprehensive oversight for our client, encompassing drawing issuance, file sharing, submittal management, and responding to requests for information. Notably, the integration of tablets enabled onsite application of the CDE, enhancing quality management processes. The tablets' LiDAR scanning capabilities, coupled with the CDE's 3D functionalities, were pivotal in offering real-time data and facilitating swift alternative design solutions. This technological synergy not only met but exceeded client expectations, demonstrating the efficacy of digital tools in optimizing construction project management.

## The integrator at the heart of a connected system

The construction industry consists of a multifaceted stakeholder landscape, each group bringing its unique set of perspectives and objectives. As explored in the section Remodelling Construction, the intricate dynamics and interdependencies among these stakeholders can hinder innovation if not understood and engaged from a systems perspective. Moreover, recognizing that each stakeholder group is inherently influenced by their specific roles and objectives within the construction delivery process, effective coordination, facilitated by a dedicated integrator, becomes paramount (Figure 8). The integrator offers an impartial and comprehensive viewpoint, crucial in navigating complexities and aligning the diverse interests toward an effective strategy and delivery plan.

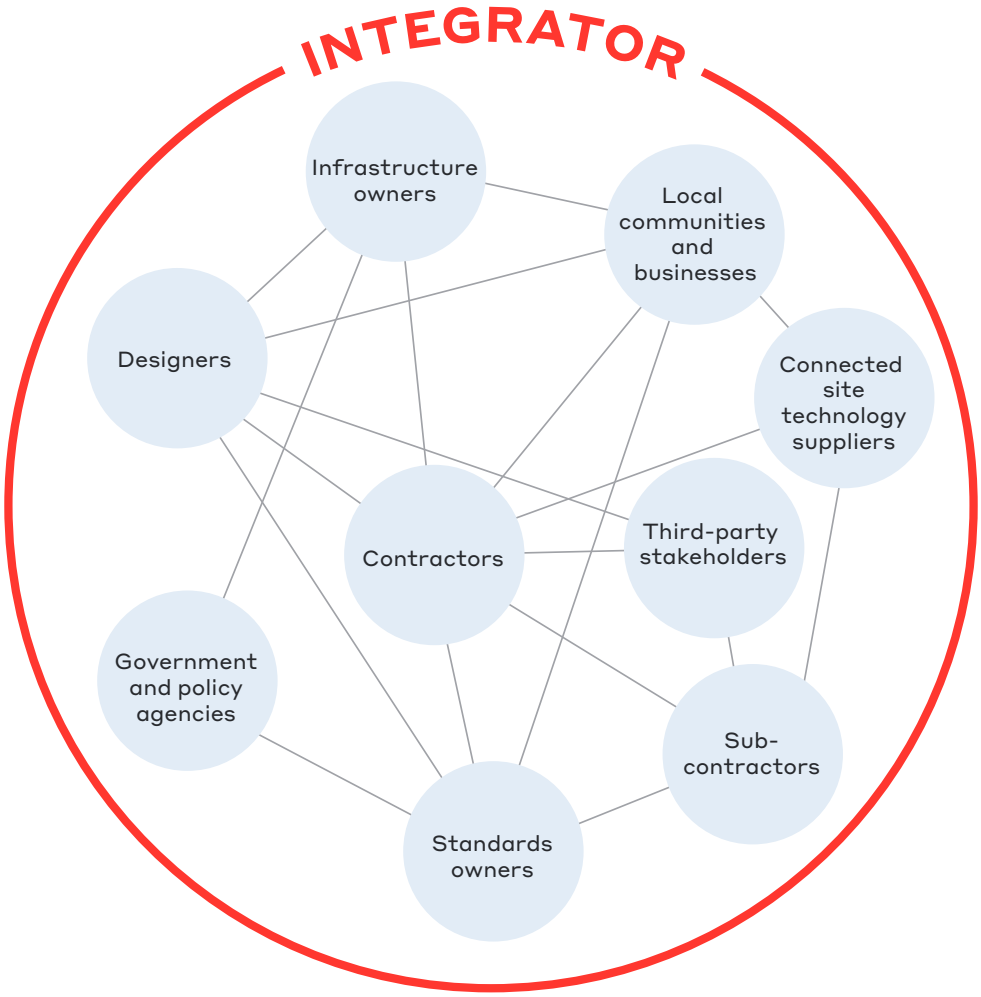



Figure 8 – Relationships between stakeholders in the construction industry, operating with an integrator to bring stakeholders together.

Traditionally, the construction industry has operated within a linear and hierarchical framework, as evidenced by the term *supply chain*, which is commonly used to describe its operation. However, as Figure 8 demonstrates, the reality is far more dynamic. Achieving transformation necessitates a shift toward a more collaborative structure, where relationships are viewed as an active network. The change from a rigid model to a collaborative and interconnected approach is essential to foster the adaptability necessary for innovation in the sector. The integrator can help to make this transition.

CASE STUDY

## Integrating delivery of the Woolgoolga to Ballina Pacific Highway Upgrade, Australia

WSP and partners have managed the delivery of 129 km of the upgrade to the Woolgoolga to Ballina Pacific Highway Upgrade in New South Wales, covering all aspects of planning, programming, design management, procurement, and construction management services. The upgrade involved the installation of dual-carriageway median-separated motorways bypassing towns, provision of new service areas, and grade-separated interchanges across diverse and challenging environments, such as threatened species habitats, sensitive heritage areas, and major river catchments.

Delivering such a comprehensive upgrade involved a significant and complex network, with many individual stakeholders. To ensure consistency of delivery and improve efficiency, innovative digital engineering systems were developed, such as a web-enabled Geographic Information System. This provided instant access to real-time data and information on one accessible system for all users, wherever they were, acting as a single source of the truth. The teams could quickly access data onsite to identify and resolve any design, construction, community or environmental compliance issue, saving time and money.

CASE STUDY

## Using technology to connect stakeholders on the Gordie Howe International Bridge, United States

The Gordie Howe International Bridge between Detroit, United States, and Windsor, Canada will be one of the longest cable-stayed bridges in North America once complete, with CAN$5.7 billion of investment. An international bridge of this size must draw on the expertise of a wide range of experts and involves communication across numerous stakeholders within each country. In such a case, WSP frequently needs to involve multiple decision-making bodies to assess and correct the issue at hand.

Employing a virtual collaboration platform through the use of augmented reality headsets onsite has improved project efficiency by avoiding costly and time-consuming international travel to bring all stakeholders to site, with numerous instances of half-day site visits being reduced to 30-minute calls. This reduction in effort to communicate across the project has led to the adoption of frequent dissemination interviews to communicate lessons learned and best practice across the project as each segment is constructed.

# Delivering the Connected Site

## A framework to deliver innovation

Construction today faces a multitude of challenges limiting its capacity to innovate. To address this issue a new approach is needed. Through remodelling construction, transformation across the whole system can be achieved by facilitating a positive environment for change. The connected site provides an opportunity to embrace and deliver this transformation. A scalable delivery approach is required to achieve the connected site, adaptable to both small-scale technological advancements and more comprehensive processes.

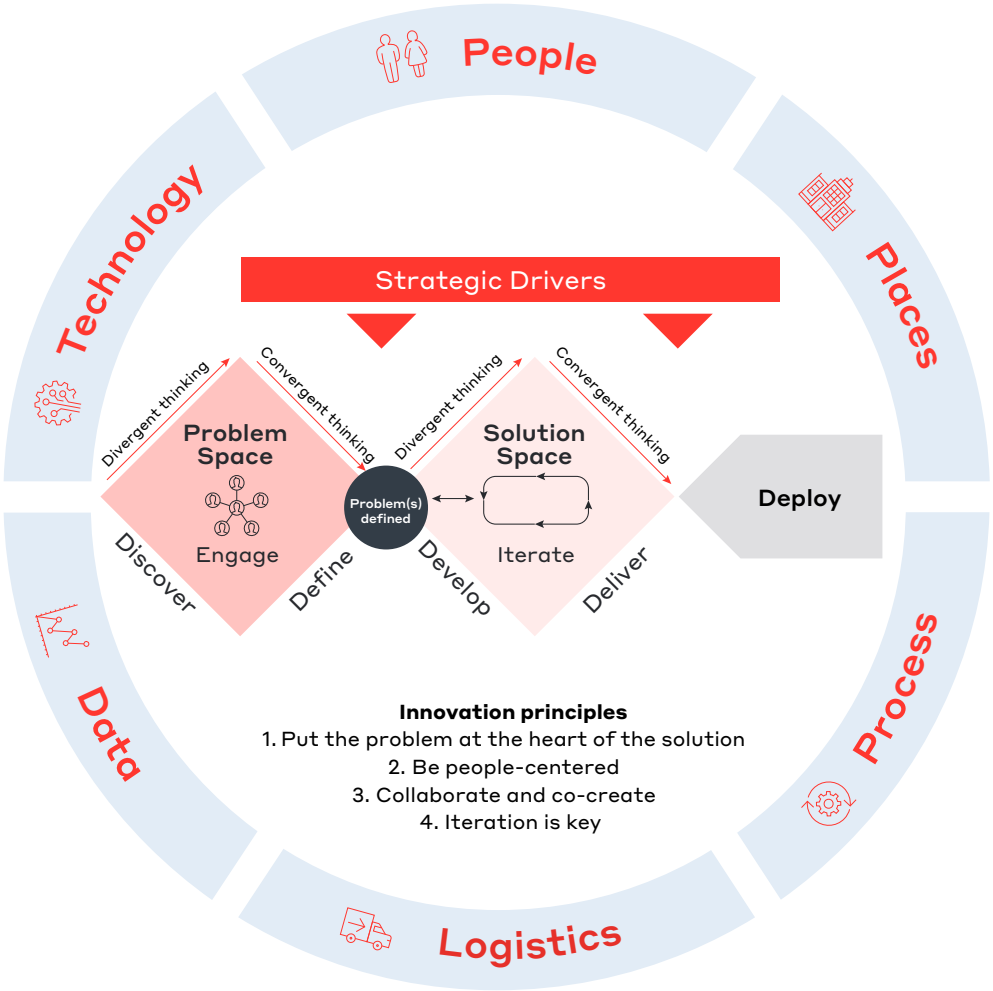



Figure 9 – Adapted from The Design Council "Framework for Innovation." Licensed under the Creative Commons Attribution 4.0 International Public License.

At its core, the Double Diamond[23] approach places paramount importance on being **problem-centric**, emphasizing the need to invest time and effort in understanding the challenges at hand, including their intricacies and underlying root causes. This directed approach enables the identification of targeted and effective solutions.

The approach promotes the adoption of **convergent and divergent thinking** at the right times to promote the exploration of a range of problems and solutions. It also encourages the generation of diverse sets of possibilities (divergent thinking) before channelling efforts toward the most promising opportunities (convergent thinking). This balance fuels creativity and ensures that the final solutions are thoroughly refined to the specific needs identified during the problem-definition phase.

Throughout the Double Diamond approach, the **whole system** is ever-present and is considered, enabling a comprehensive evaluation of all elements of the construction site. Such an approach not only facilitates alignment through integration with other processes but also serves to mitigate unforeseen consequences, future-proofing solutions.

**Strategic drivers** provide a "pull" to stimulate and incentivize the adoption of connected site technologies. They serve to align with broader organizational goals and objectives. These strategic imperatives not only catalyze the adoption of technologies but also ensure integration that strives toward enhanced efficiency and achievement of overarching aims.

While the Double Diamond provides a guiding framework to deliver innovation, success is ultimately determined by people, behaviours, and culture. Initiating **engagement** across diverse stakeholder groups from the outset proves instrumental, particularly in the problem space, to identify specific onsite challenges. This proactive engagement ensures that the most salient problems are not only identified but deeply understood. By involving stakeholders in the co-creation of solutions, a collaborative ethos is established, helping to realize maximum value from implementation.

Within the solution space, particular emphasis is placed on acknowledging the **iterative** nature of solution development. This deliberate recognition enables the ongoing refinement of the solution, pinpointing and rectifying errors along the way. It also empowers the stakeholders to continuously realign with the problem statement.

The delivery framework can be broken down into the stages of: Discover, Define, Develop, Deliver, Deploy, collectively known as the **5Ds**. This offers a phased approach to delivery spanning the entire spectrum from problem identification to solution deployment. The 5Ds also facilitate the granular definition and organization of discrete tasks within each stage. This systematic breakdown enhances the clarity and manageability of the delivery process, ensuring a more effective and organized progression from conception to implementation.

23 "Framework for Innovation," The Design Council, accessed October 2023.


CASE STUDY

## Applying the Double Diamond to transform delivery for the Smart Motorways Programme Alliance, United Kingdom

WSP, alongside SMP Alliance partners, was tasked with crafting a plan for delivery of a connected site to drive transformation over the 10-year duration of the programme. Guided by the client's strategic drivers to enhance safety, productivity, and environmental outcomes, the team embraced the Double Diamond framework. Employing a people-centric strategy, extensive engagement was undertaken to comprehend the diverse challenges confronting the programme. A detailed assessment identified root causes addressable by the connected site, tailored to programme-specific needs—considering site constraints, scheme duration, and contractual mechanisms for technology adoption. Thorough market scrutiny then narrowed down optimal solutions.

After assessing the list of technologies based on programme needs, the long list of connected site technologies was whittled down to a short list of connected site solutions to implement. The resultant delivery plan outlined a staged approach through the development, trial, pilot, and deployment phases. This included plans and processes for managing safety risks, business case development, user training, and operation / maintenance guidance. This was concluded by producing a deployment plan template to enable solutions to progress towards business as usual activities where appropriate. This holistic approach provided the programme with a detailed plan for how to deliver the connected site.

## Delivery in action

Expanding on the delivery framework, an example is shown in Figure 10 demonstrating the 5D stages in action, bringing to life the typical steps involved in realizing value from the connected site.

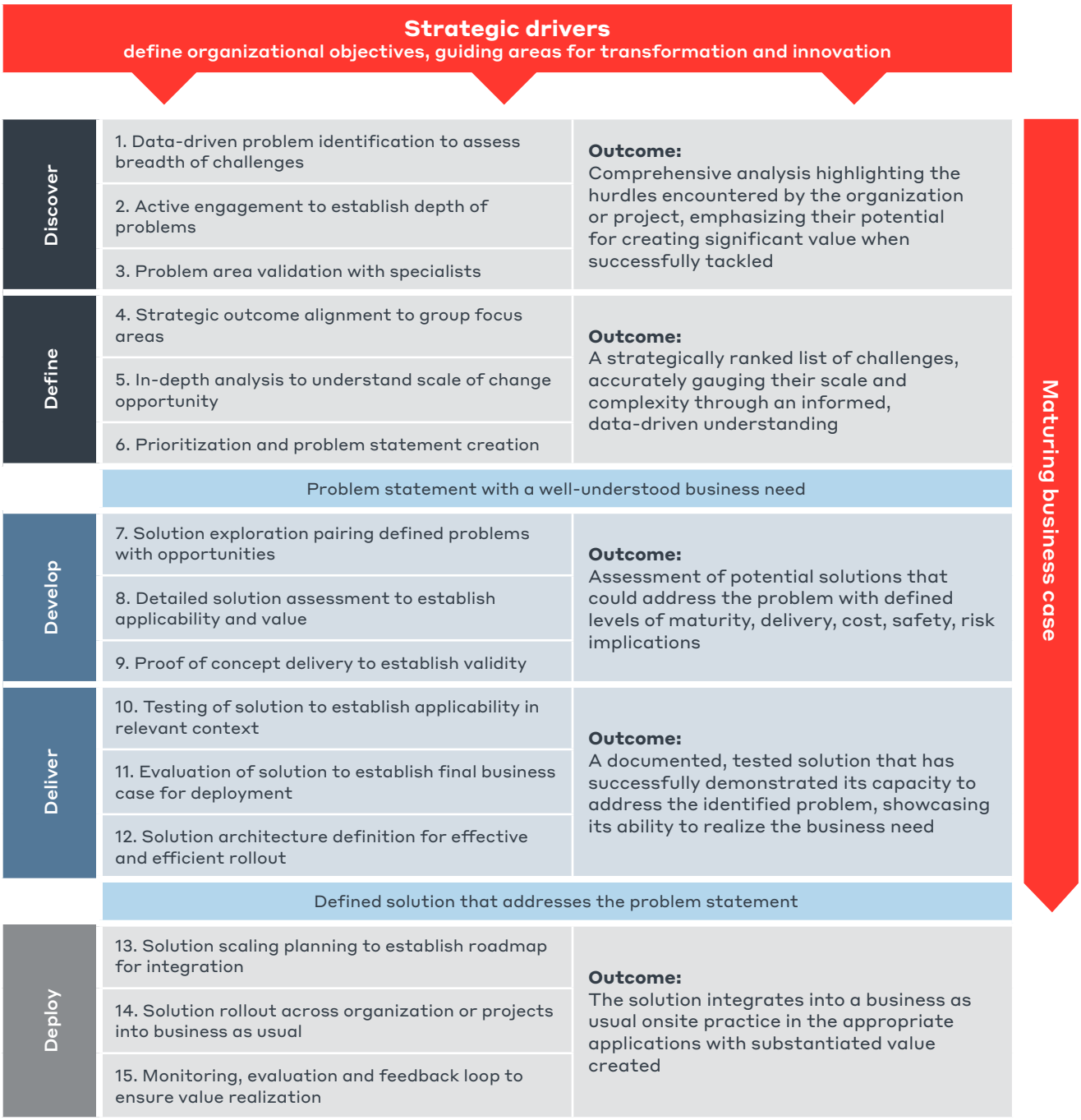



Figure 10 – Example delivery plan, using the principles of the Double Diamond, with tasks grouped under each of the 5D stages.

CASE STUDY

# Enhancing construction efficiency through augmented reality on M6 J21a to J26 highways upgrade, United Kingdom

WSP, in collaboration with delivery partners, tackled challenges in the construction of the M6 J21a to J26 highways upgrade scheme, which involved substantial civil works and the implementation of roadside technology. One key issue was the frequent ad hoc site visits during construction and commissioning, leading to increased risk exposure and project delays.

**Discover:** To address this challenge, WSP conducted a detailed analysis in collaboration with onsite installation managers and engineers. The team identified the need for a digital solution that could streamline communication, address construction queries, and assure the quality of completed activities.

**Define:** Market research was conducted to explore potential digital solutions, considering factors such as problem-solving ability, technology maturity, compatibility, and cost. After scoring and prioritizing, an augmented reality headset emerged as the optimal solution. The augmented reality headset facilitated direct communication between onsite workers and remote experts, eliminating the need for frequent onsite visits.

**Develop:** A proof of concept was developed by trialing the augmented reality headset in a controlled off-road facility, focusing on core use cases. The trial successfully demonstrated the potential value of the headset but required adjustments for a construction site setting, such as compatibility with personal protective equipment and enhanced connectivity for offsite video calls.

**Deliver:** With the feasibility established, a pilot was conducted in an active construction site to showcase real-world benefits. Prior to the pilot, users were identified and upskilled, and a system was put in place to capture the benefits realized during the trial. Iterations were made to the design solution, incorporating lessons learned about practical considerations onsite, including hardware management, charging logistics, and training requirements.

**Deploy:** The pilot conclusively demonstrated the value of the augmented reality headset in the highways environment, leading to a deployment phase and a wider rollout of the solution. The technology enabled direct communication, swift resolution of construction queries, and seamless execution of quality assurance tasks, ultimately improving efficiency, and reducing project risks.

WSP's strategic implementation of augmented reality technology not only addressed the challenges of frequent onsite visits but also showcased the potential for innovative solutions in the construction industry. As a result of the technology: programme delays were reduced, quality checks were achieved quicker and more accurately, and travel / accommodation costs were reduced from avoided visits to site. The success of the project highlights the importance of collaborative problem-solving, market research, and iterative testing in implementing cutting-edge technologies in construction projects.

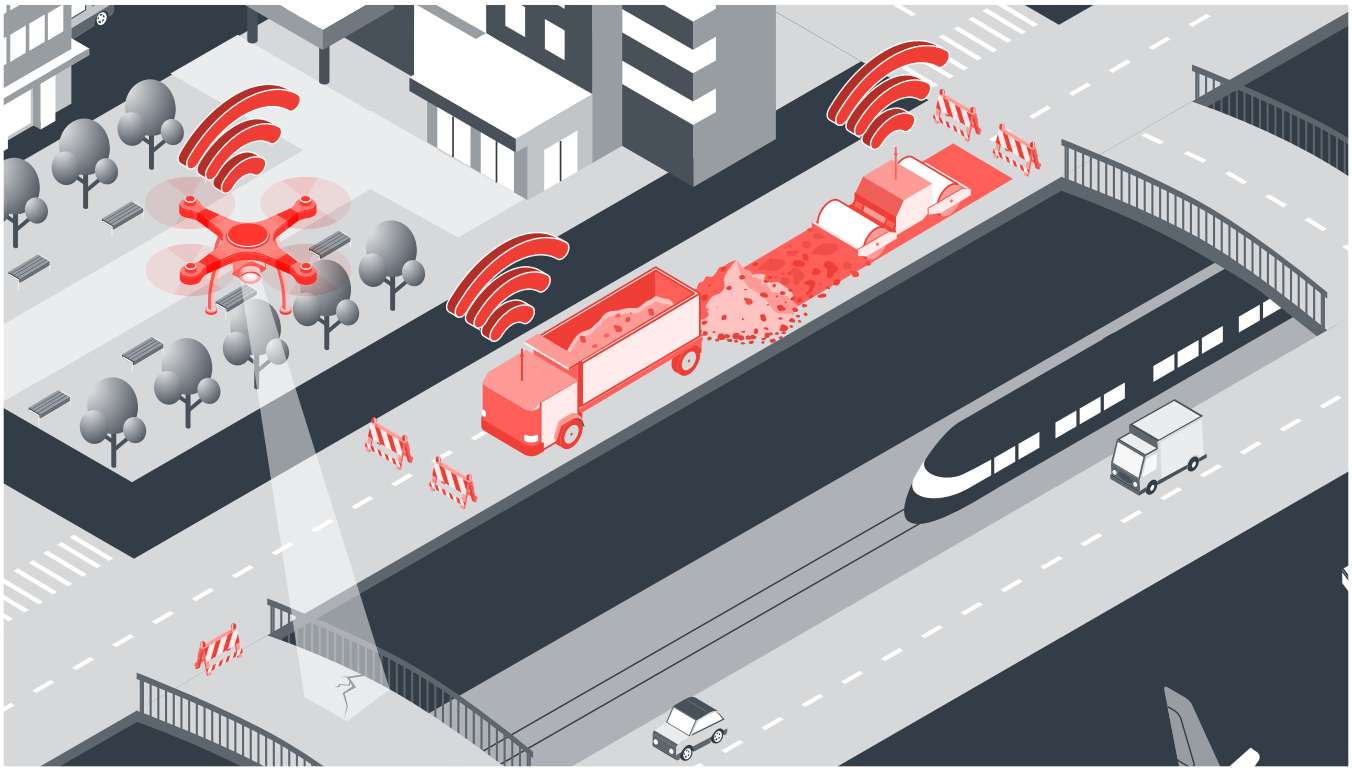
# Moving Toward Connected Sites

The vision of a connected site emerges as an opportunity to transform onsite assembly within the construction industry. The intricate interplay of onsite processes, supported by seamless information flow, promises real-time decision-making and optimal resource utilization. The incorporation of connected and autonomous solutions not only enhances project delivery but also facilitates the achievement of wider benefits, including safety, productivity, project predictability, efficiency, and environmental sustainability.

While technology serves as the crucial enabler for a connected construction site, it is important to recognize that the realization of this vision is not solely driven by technological advancements. The transformative potential of a connected site lies not only in the sophistication of the technology itself but in the strategic and collaborative utilization of these tools. By establishing a collaborative ecosystem, the connected site enables effortless communication and data sharing among designers, engineers, contractors, and other stakeholders. This collaborative environment not only expedites construction timelines but also ensures projects are executed with precision, upholding the highest quality standards.

Successful implementation of the connected site relies on the alignment of technological capabilities with industry needs, coupled with comprehensive workforce training to ensure proficient practice. While acknowledging the potential challenges associated with transitioning to a fully connected site, it is crucial to recognize that the enduring advantages far surpass the initial investment. Embracing this forward-looking vision for onsite assembly not only redefines construction practices but also positions the industry at the forefront of digital transformation. With technology as the catalyst, an enabling regulatory environment, future-focused industry standards, and a collaborative ecosystem will enable the potential benefits of connected construction sites to be fully realized.

The connected site emerges as the evolutionary step the construction industry needs to meet the demands of an ever-changing world. As we stand on the cusp of this transformative era, embracing the connected site is not merely an option but a strategic imperative for a progressive and resilient construction industry.



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