Best Practise Sustainable Infrastructure Construction

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Contents

Executive Summary

This Churchill Fellowship facilitated a comprehensive exploration of sustainable infrastructure practices across Singapore, England, France, and Australia. The research aimed to collect insights from global leaders in sustainability, examining major infrastructure projects and engaging with industry experts to identify best practices applicable to New Zealand's construction sector. This report summarises the key findings from these engagements, offering a roadmap for integrating sustainable principles into projects across Aotearoa.

Observations from 50 sustainability professionals and visits to various projects underscored common factors contributing to successful sustainability programs. These centred around governance, environmental and social aspects, as well as other pertinent considerations.

Good governance structures were paramount, with bold targets and senior leadership buy-in shaping project trajectories. Notably, ambitious targets were seen to foster innovation and meaningful change, while sustainable procurement processes wielded significant influence in driving sustainability outcomes. Investments in training, industry-wide knowledge sharing, and client-driven innovation underscored the importance of collaboration and continuous learning.

Overseas projects showcased innovative approaches to decarbonizing construction and prioritizing sustainable transport and material reuse. Overseas advancements in low-carbon concrete technology and nature-based solutions present opportunities for New Zealand to leverage global expertise and drive positive environmental impacts.

However, there are some global challenges, including sustainability data management and a shortage of skilled professionals. Addressing these requires a fundamental shift in business as usual.

As the construction sector navigates complex sustainability challenges, embracing bold targets, fostering collaboration, and leveraging global insights will be essential for driving meaningful progress towards a more sustainable future. This report will serve as a catalyst for action, inspiring industry to embrace best practise sustainable practices and champion transformative change within New Zealand's construction industry. My role will be to advocate for and engage with industry on these enablers for success, as well as demonstrate practical implementation at the project or organisational level to drive improvements across the industry.

1. Introduction

In October 2023, the Churchill Fellowship enabled me to travel to Singapore, England, France, and Australia to connect and engage with sustainability leaders on high-performing major infrastructure projects, as well as industry and other leading organisations to understand factors that contribute to best practice sustainable infrastructure construction. The research objective was simple, observe and learn from some of the best, and then bring those ideas back to Aotearoa.

The countries visited were primarily selected for their depth of experience in delivering sustainability ratings on major infrastructure projects and therefore maturity of process around integrating sustainability effectively into a project (e.g., UK and Australia), something which is still in its infancy in New Zealand; their leadership in specific technical sustainability fields (e.g., Vinci/Exergy - France); or to provide a comparison to another industry sector (e.g., Singapore). In total I met with 50 sustainability professionals, all leaders in their field. Where possible, interviews were conducted in conjunction with a site visit to observe best practices in action. The projects visited were broad and included Ecopark South, High Speed Two (HS2) Victoria Road Crossover Box, HS2 Atlas Road, HS2 Euston and Tideway East - Chambers Wharf, in London, Balfour Beatty VINCI JV (BBVJV) Sublot 4 and 5 in Birmingham, Paris Olympics Athletes Village, Sydney Metro Central Station, and North Western Program Alliance - Preston Station and Bell Station in Melbourne.

The purpose of this report is to describe common factors which contribute to successful sustainability programmes which could be applied and leveraged by the New Zealand construction industry, with a focus on what mature sustainability organisations and leaders do to set their projects up for success.

The opportunity to explore and compare different approaches has given me insights into how to do things better, and to see that some challenges are universal. It has also allowed me to see more clearly that there are pockets of excellence everywhere, including here in New Zealand.

A collection of my key findings and observations are presented in this report. Implementation becomes the next critical step. It is imperative that we leverage these learnings to drive meaningful change within the New Zealand construction industry, improving the success of sustainability programmes and the quality of the outcomes on projects across Aotearoa. In my view this will require a multifaceted approach, involving advocacy for and engagement around the enablers for success with the industry, as well as demonstrating practical application of a range of these best practise principles at the project and/or organisational level here in New Zealand.

2. Key Learnings

Overall, I met a lot of very passionate, inspiring sustainability leaders across the organisations and projects that I visited, all working on very similar sustainability challenges.

There are several great examples of best practice sustainable infrastructure construction which I observed while on this fellowship which could be applied and leveraged by the New Zealand construction industry. I have grouped the key learnings by broad themes in this Section. Projects visited included Ecopark South, HS2 Victoria Road Crossover Box, HS2 Atlas Road, HS2 Euston and Tideway East - Chambers Wharf, in London, BBVJV HS2 Sublot 4 and 5 in Birmingham, Paris Olympics Athletes Village, Sydney Metro Central Station, and North Western Program Alliance - Preston Station and Bell Station in Melbourne. A complete list of all projects visited, and people interviewed are provided in Appendix A. Further detail on each individual site visit and supplementary photos are provided in Appendix B.

2.1. Governance

2.1.1. Client Leadership and Bold Targets

On many of the projects I visited, the client had set a very clear mandate around sustainability, reflected in bold targets which evolved as the project progressed. As an example, HS2 Limited set two core targets based on a materiality assessment which was completed early in the planning stage; to cut carbon emissions and boost nature recovery. If we focus on the carbon emissions target, at the start of the project the target was a 50% reduction in Scope 1 and 2 across the whole of life. This target is double that set for the City Rail Link Project in New Zealand, considered a leading project for sustainable outcomes across the industry. This target on HS2 has since evolved to include more detailed targets around carbon reduction as the project progressed including:

- All HS2 sites to be diesel-free by 2029.
- Achieve a 50% reduction in carbon emissions from steel (tCO2e/t) compared with 2021 by 2030.
- Achieve a 50% reduction in carbon emissions from concrete (tCO2e/t) compared with 2021 by 2030.
- Achieve an 11% reduction in HGV gCO2e/km compared with 2020 by 2027.

These bold targets were observed to foster innovation, encouraging contractors to explore innovative solutions and technologies that can help achieve these goals, and collaboration between the client and contractor as they work together on common sustainability objectives.

One innovative and collaborative solution I came across was on the Skanska Costain STRABAG Joint Venture (SCS Railways) the contractor set a target to be ‘diesel free by 2023’. Geri Badura, Environment & Sustainability Director for SCS Railways, shared some insights with me into their journey to be diesel free on all of their sites. I have included this as a case study below as it is really a fascinating example of how to create a movement, and

meaningful change in a relatively short period of time. HS2 Limited has since adopted this approach, and rolled it out on all of its other sites across the Project.

It is an interesting contrast to New Zealand where so often targets are set at the lower end, to provide a realistic starting point that allows organizations to build momentum, gain confidence, and demonstrate progress over time. It is worth considering whether in certain circumstances (e.g., where there is strong client leadership and funding driving sustainability innovation) there is merit in setting bolder targets to drive innovation and meaningful change, accepting that we may not get there, but will be further ahead for having tried as has been demonstrated overseas.

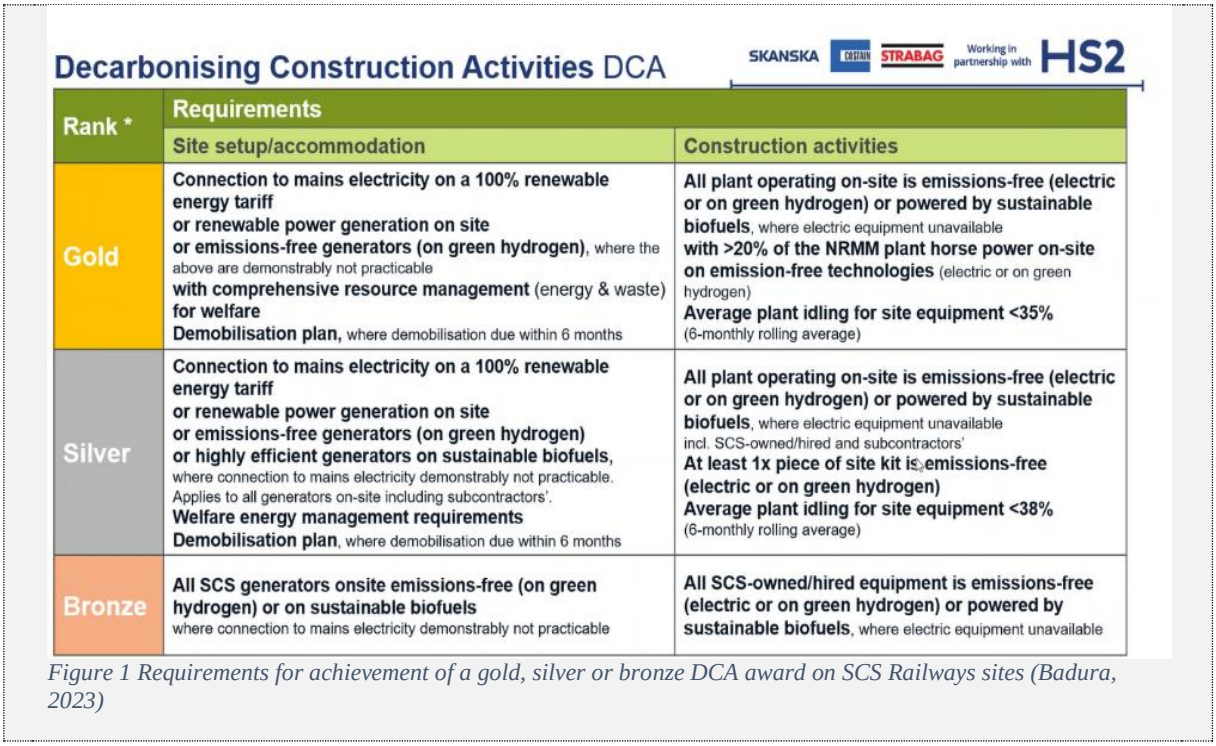
Spotlight: SCS Railways – 'Diesel Free by 2023' Journey

SCS Railways had trialled Hydrotreated Vegetable Oil (HVO) on one of their sites, and it was working well. In 2021 the project received some complaints in Euston about diesel generators running at night. Geri went to the next SSG meeting with a proposition "I want to be diesel free by 2023". She explained they had some good trials with HVO, and there was potential to roll this out further, but it's not just about HVO she wanted them to start thinking electric, getting electrical connections, but HVO could be a good stepping stone to get there.

She asked if anyone could give her a good reason why they can't do this. Everyone on the SSG agreed it was ambitious, and quite far-fetched since it had no precedent. However, there was consensus that if they try it, they will be in a better position than they are now regardless. No one had a clue how to achieve it. But it had traction and buy in at leadership level. By June 2021, they achieved 80% replacement of diesel across the project. Towards the end of the year, they built a framework on how to assess each site regarding their overall decarbonisation efforts (e.g., uptake of HVO and getting electric connections during site setup, hybrid generators, hybrid/electric plant etc.). It was called the Decarbonising Construction Activities (DCA) framework and was rolled out over 2022 (refer Figure 1). The Sustainability Lead and Assurance Lead worked together to audit each site against this framework, awarding them bronze, silver or gold; only awarding gold to sites that don't use any diesel at all.

This case study is a fascinating example of how a bold idea that challenges the status quo, together with leadership buy-in and a willingness to innovate, can create a movement. Some people in the sustainability team hated the concept of diesel free, it was considered to be sending the wrong message as it's not just about diesel. However, there was a bigger picture, and understanding that sometimes you need to sacrifice messaging a little bit to get to where you want to go. 'It's now the DCA framework. But now everybody gets it, so now its ok, now we can take the step forward and say actually it's not about diesel, it's about decarbonising construction and added other elements to it' Badura, 2023.

The DCA framework has since evolved even further with behavioural elements like idling reduction now captured in framework; this leads to nice competition between the sites. By the end of 2022 the project was 98% diesel free, with the last 2% in tunnels where for safety reasons that can't change over. At the time of my visit in October 2023, all SCS sites were silver, and one site is going for gold.



Decarbonising Construction Activities DCA

SKANSKA | COSTAIN | STRABAG | Working in partnership with HS2

Rank *	Requirements	
	Site setup/accommodation	Construction activities
Gold	**Connection to mains electricity on a 100% renewable energy tariff** **or renewable power generation on site** **or emissions-free generators (on green hydrogen)**, where the above are demonstrably not practicable **with comprehensive resource management** (energy & waste) **for welfare** **Demobilisation plan**, where demobilisation due within 6 months	**All plant operating on-site is emissions-free (electric or on green hydrogen) or powered by sustainable biofuels**, where electric equipment unavailable **with >20% of the NRMM plant horse power on-site on emission-free technologies** (electric or on green hydrogen) **Average plant idling for site equipment <35%** (6-monthly rolling average)
Silver	**Connection to mains electricity on a 100% renewable energy tariff** **or renewable power generation on site** **or emissions-free generators (on green hydrogen)** **or highly efficient generators on sustainable biofuels**, where connection to mains electricity demonstrably not practicable. Applies to all generators on-site including subcontractors'. **Welfare energy management requirements** **Demobilisation plan**, where demobilisation due within 6 months	**All plant operating on-site is emissions-free (electric or on green hydrogen) or powered by sustainable biofuels**, where electric equipment unavailable incl. SCS-owned/hired and subcontractors' **At least 1x piece of site kit is emissions-free (electric or on green hydrogen)** **Average plant idling for site equipment <38%** (6-monthly rolling average)
Bronze	**All SCS generators onsite emissions-free (on green hydrogen) or on sustainable biofuels** where connection to mains electricity demonstrably not practicable	**All SCS-owned/hired equipment is emissions-free (electric or on green hydrogen) or powered by sustainable biofuels**, where electric equipment unavailable

Figure 1 Requirements for achievement of a gold, silver or bronze DCA award on SCS Railways sites (Badura, 2023)

2.1.2. Senior Leadership Buy-In

Senior leadership buy-in to sustainability outcomes is critical for success. I came across some great examples of how senior leadership buy-in was achieved on the contractor team, for example, on SCS Railways, a Sustainability Steering Group (SSG) was set up by the Environment & Sustainability Director, made up of senior leaders (e.g., Project director, client director, commercial director, design director). Initially the focus was on carbon, to meet the intent of Publicly Available Specification (PAS) 2080 around leadership, however in the delivery phase the meetings broke out by area, where they could look at more detail and specific opportunities in their areas. The SCS Railways Environment & Sustainability Director described this as her biggest success, and the single most important meeting of the month. This is where the project makes decisions on the big things they want to do across the project, and was pivotal in developing leadership buy-in. She described her role in the SSG as involving 'Microdose upskilling – upskilling leaders with little bits of information that they don't realise they are being taught something through values moments'.

One of the learnings that she talked about in relation to the SSG was how to approach this group. Her advice was while you are the Subject Matter Expert (SME), you need to acknowledge that they are SMEs in their fields, and stressed the importance of putting problem statements on the table that allows senior leaders to provide solutions, so it's not a one-way conversation. Six years in she is still finding improvements, one of these is to formalise a preparation session with the Operations Director as the sponsor, prior to each SSG.

Interestingly, every single member of the SSG has completed a full days' worth of carbon literacy training; showing commitment around things like this really echo's across the project.

2.1.3. Economic Structures

2.1.3.1. Green finance

Green finance refers to the integration of environmental considerations into financial decision-making processes, with the goal of promoting sustainable and environmentally responsible investments. It encompasses a wide range of financial products, services, and mechanisms that aim to support projects, businesses, and initiatives with positive environmental impacts. Tideway, the company financing, and building the Thames Tideway Tunnel (a major infrastructure project aimed at constructing a 25km tunnel to prevent untreated sewage from overflowing into the River Thames) was the only project I visited which had green finance in place. Of interest they implemented:

- A sustainable finance framework aligned with the Sustainability Linked Loan Principles. For this, the 54 legacy commitments (covering five main areas: environment and sustainability, health, safety and wellbeing, economy and employment, community engagement and skills and education) form the basis of the sustainability performance targets used for the sustainability linked loan and, specifically, the Key Performance Indicators (KPIs) used to demonstrate the projects commitment to improving their sustainability profile over the term of the loan. Tideway currently has one sustainability linked loan which includes the agreed sustainability KPI which is meeting at least 85 % of the live legacy commitments. The credit margin on the facility is reduced if the performance target is met.
- 18 green bonds totalling £1.8bn GBP with a £160m GBP sustainability linked Revolving Credit Facility (RCF). Savings from the RCF are reinvested into environmental community projects in the areas the project is working in.

In New Zealand I have seen examples of green finance applied at the organisational level (e.g., Downer's sustainability linked loan) but Tideway was the first example I have seen of green finance applied to a major project.

2.1.3.2. Other

There were some examples (e.g., BBVJV HS2 project) of environmental and sustainability aspects in executive's performance scorecards, linked to their annual bonus entitlement. While this was not common practice across all the projects I visited, it is a clear opportunity, as most executives have safety aspects in their performance scorecards, so why not also environmental and sustainability.

This seems like a potential opportunity for New Zealand projects where we so often struggle with buy-in around sustainability. By including sustainability metrics in executive performance scorecards, it sends a strong signal of commitment at the Project level, it also motivates executives to take ownership of sustainability initiatives, drive progress towards sustainability goals and prioritise sustainability in decision making.

2.1.4. Procurement

The procurement process is a great tool to leverage sustainability outcomes. It sends a clear signal to the market to invest and innovate. On the City Rail Link project in New Zealand, we developed a sustainable procurement framework, which included an upfront risk assessment, enabling focus on the highest impact procurements. High impact procurements then incorporated specific questions around sustainability, responses were considered in the tender evaluation process, and specific targets set in contracts. I saw several similar approaches on the projects that I visited overseas, with high impact procurements typically including a 10-15% weighting on environment/sustainability. It was reassuring that the procurement process that we established for City Rail Link was on par with some of the most mature major projects overseas.

The workload associated with implementing a sustainable procurement framework was highlighted by several people I spoke to as a key challenge. SCS Railways recognised this and had a sustainability supply chain manager embedded in the procurement team, who was a direct conduit between the sustainability team and the procurement team. I can see that such a role is critical to success, especially at the beginning of a project when the procurement workload is at peak.

Supply chain engagement events were regularly delivered across most projects, enabling collaboration, sharing of lessons learnt, and challenges. This is something that projects would benefit from doing more, especially given the limited understanding and maturity around sustainability in the supply chain in New Zealand.

SCS Railways had some good examples of how they have upskilled their supply chain through the development of information packs (e.g., Carbon information pack, which introduce HS2s Net Zero Carbon Plan to HS2 supply chain and provides a brief outline of the projects key ambitions and journey to achieving destination net zero, the importance of the supply chain in delivering the projects net zero ambitions, links to resources available to support the supply chain partners in achieving their net zero ambitions) and through supply chain training (this is covered in detail in Section 2.1.4.1).

SCS Railways also had a performance assessment framework which they implemented with their top 20 suppliers (from an environment/sustainability impact perspective). Suppliers are audited annually and awarded bronze, silver or gold; bronze for meeting all of the contractual requirements, and silver/gold for exceeding these requirements and implementing best practices/innovations etc.

2.1.5. Training

2.1.5.1. Project teams

Overall, I observed a much greater focus and investment in training than in New Zealand. Little value was placed in training through site inductions. Instead, many projects/businesses were offering dedicated environmental and sustainability awareness training as well as carbon awareness training and carbon literacy training. Often incorporating minimum employee training hours/year or compulsory modules. Some examples included:

- On SCS Railways (HS2) two targeted trainings were provided for senior leaders. The first focussed on environmental litigation and risk, it made senior leaders aware of what happens if things go wrong and why it's important to manage environment risk. This was delivered by an external lawyer adding to its impact. The second was a carbon literacy training programme developed in partnership with the Carbon Literacy Project, to raise awareness about carbon reduction and encourage staff to take carbon reduction action. This involves a full days training (4 hours online modules and 3-hour workshop). A fundamental output of the carbon literacy project is commitment to action, i.e., now you fully understand the impact we are having, what are you going to do in your zone of influence. This was about getting people in a room that have influence, and bringing people to the point where they get in on a personal level. The majority of the Board and Executive have been certified carbon literate, and the training has now been rolled out organisation-wide with more than 300 staff accredited. Tideway also ran a programme of three mandatory carbon training workshops for Tideway executives.

Spotlight: Carbon Literacy Project

The Carbon Literacy Project defines carbon literacy as "an awareness of the carbon costs and impacts of everyday activities and the ability and motivation to reduce emissions on an individual, community and organisational basis."

The Carbon Literacy Project works with organisations, communities, and individuals providing a training framework for the development of materials. It also accredits individuals, groups, and organisations as Carbon Literate. They have some great resources – off the shelf courses for certain sectors, which can be used as is or tailored, customised and reaccredited. They also have 'The Carbon Literacy Course Kit' with preapproved materials and resource documents, and a carbon literacy knowledge e-learning that can be used in conjunction with, or independent of an accredited carbon literacy course.

As part of the accreditation process, the Carbon Literacy Project reviews all pledges to assure they are significant.

- Beyond senior leadership training, SCS Railways developed two 45-minute online e-learns for all staff (~1,000+ people); this included an Environmental Foundations module and a carbon awareness module. They also have specific training targets, for 2023 these include: carbon literacy training to 50 more people; carbon awareness training to 70% of staff; environmental foundations to 90% of staff, Site Environmental Awareness Training Scheme (SEATS)[1] to 90% of target roles and waste duty of care to 60 people. When asked where to next, the response was to role targeted training (e.g., procurement manager, site supervisors etc.).
- Even on smaller projects such as Ecopark South environmental training modules are mandated through the Chartered Institution of Highways & Transportation (CIHT),

[1] Site Environmental Awareness Training Scheme (SEATS)[1] is a one-day interactive course has been developed for site supervisors/managers with the aim of providing candidates with an introduction to environmental issues on construction sites.

including an introduction to transport decarbonisation, and carbon literacy accounting (1 hour e-learns). SEATS is also mandated for certain roles.

- Spark North East Link Design & Construct Joint Venture (Spark) are taking a slightly different direction delivering a Sustainability Culture Changemakers Programme, a cutting-edge programme to improve the sustainability culture of the project team. Refer to the case study below.

Figure 2 Tunnel Vision: Knowledge Share session where Viv Heslop (Spark DC) presented on the Sustainability Culture Changemakers Programme, and I presented on the interim findings of my fellowship. Image shows participants at the session, held at Spark North East Link Office, Melbourne on 19 October 2024.

Spotlight: Spark - Sustainability Culture Changemakers Programme

This was signalled from the tender phase, where a target was put forward to increase awareness of sustainability across the project by 10%. The programme seeks to clarify three aspects; what actions can we take to embed a culture of sustainability, how do we measure and track sustainability culture and how do we communicate our approach. The programme drew on existing resource, such as the Embedding Project (www.embeddingproject.org) to frame up their approach.

The programme is made up of four quadrants, recognises that first priority has to be the 'deliver' phase, then the 'advance' phase, these included:

1. *Clarifying expectations*
   - *Everyone on the project is aware of what they need to do.*

- *Sustainability Director on the SLT*

2. *Fostering commitment*
   - *Build and reinforce importance of sustainability.*
3. *Instilling capacity for change*
   - *Structures and supports that enable change.*
4. *Building momentum for change*
   - *Support a culture of sustainable innovation by fostering new ideas which align to the organisations sustainability goals.*

*Some key '**deliver**' wins included: upskilling sustainability team to become powerful influencers - designed and delivered 'make your spark' training; conducted discipline briefings; integrated sustainability into the design process and induction process; developed a sustainability dashboard; developed information sheets on key sustainability topics incl. low carbon concrete; delivered 'snack n learns'; developed sustainability page on website; identified training for leaders/engineers; individual coaching sessions with the team; developing playbooks - simple way of capturing how to do something including for example capturing economic benefits, low carbon construction sites, and integrating sustainability into design.*

*Key '**advance**' wins include developing an approach for quantifying non-financial benefits; delivery of a sustainability leadership programme, launching SparkLab, an innovation lab to harvest ideas across the project and encourage knowledge sharing and continuous improvement, and committing to survey Spark staff annually to measure the sustainability culture.*

2.1.5.1. Supply chain

Many projects are also delivering training programmes for their supply chain to ensure they have the capacity, capability, and competency to deliver the Project's ambitious targets and leave a legacy of green skills for future infrastructure projects.

For example, the SCSJV Supply Chain Enterprise Academy is a free learning and development program designed to upskill the industry and stimulate supply chain development. It's an industry leading initiative which aims to promote a legacy of learning and skills development in the infrastructure sector and to develop resilience and growth within their supply chain. They support skills development by providing a structured programme of learning delivered by experts from both within their business and from their strategic partners. The programme aims to increase supplier performance by briefing them on the project's values and the key requirements that will help them win future work. Topics include the 'Lean' approach to improvement; commercial awareness; creating social value; carbon management and developing & financing an effective innovation strategy.

In addition, SCS Railways require all of their suppliers to achieve bronze status with the Supply Chain Sustainability School. They use a range of engagement opportunities such as meetings, workshops, and forums to engage with the supply chain on key topics.

2.1.6. Knowledge Sharing

There is an industry wide understanding of the importance of sharing lessons learned and the challenges faced across major infrastructure projects. This is how the industry moves forward at pace.

I encountered several examples of knowledge sharing practices both on a project level, at organisational level, and globally across the industry. More often, knowledge sharing is incentivised through competition, encouraging people to participate, and be rewarded where exemplary outcomes are achieved. I have provided three examples below:

- HS2 administer a Learning Legacy website to highlight best practices, lessons learned and innovations from the HS2 Programme aimed at raising the bar in industry. The goal is to celebrate the ways their teams are delivering environmental excellence on the ground, with over 170 resources published to date. There is an annual Learning Legacy challenge, open to anyone working on HS2, to submit an abstract. This is read by the Challenge Panel, and if selected a full learning legacy submission is prepared. The best submissions are recognised at the Learning Legacy Awards each year.

  On Tideway East, best practise case study requirements are also handed down from home organisations, with a minimum requirement to prepare one best practise example per year.

- Vinci developed an Environment Prize within its organisation to identify and share best practices and accelerate deployment of solutions across the business. The inaugural Environment Prize run in 2021 received more than 2,500 best practice initiatives, with the top initiatives receiving awards. Following this, a catalogue of the initiatives was produced for all Vinci employees to draw from.

- I also came across the Environmental Best Practise - The Green Book (www.thegreenorganisation.info). The Green Book is the world's only annual international work of reference on environmental best practice.

Major projects in New Zealand and around the world generally produce so much best practise, but having the mechanisms to make the information available to the wider industry in a format that is consistent and useful is challenging. These three examples provide some guidance on how this could be achieved. Examples I came across suggest that incentivising knowledge sharing through an industry-wide competition may be a successful route, provided all entries were shared.

2.1.7. Innovation

Many clients play a crucial role in investing in and driving innovation. With most client organisations on major projects administering innovation funds to enable uptake of new and innovative approaches. This approach helps overcome the hurdle where a new initiative might cost more upfront to explore.

For example, on the Transpennine Route Upgrade Project (TRU) a dedicated carbon innovation fund of £30 million has been created, governed by a Carbon Council. This aims to bridge the gap for low carbon initiatives that may incur more costs than a traditional

approach. Similarly, on Tideway, an innovation programme awards funding for innovative initiatives, with teams bidding for funding in a dragon den style panel (Figure 3). And on HS2, an Investment Committee is fundamental in providing the funding required to support some of the innovative trials onsite e.g., low carbon concrete, hydrogen generators etc.

Tideway also runs a RightWay Award ceremony which includes a Carbon Initiative Award for initiatives that demonstrate solutions to reducing carbon on site, through design or construction. And HS2 delivers the HS2 Accelerator Programme, open to any individual or firm with bright ideas to specific innovation challenges at the time. The Accelerator Programme then provides the winning firms with commercial and technical support and rent-free working space to develop their proposal. After approximately 6 months of development within the programme, the companies' innovations are pitched to industry investors and the wider HS2 supply chain.

At an organisational level, some companies are also investing in innovation, e.g., Vinci Group developed Leonard in 2017 to connect their business units and drive innovation. Leonard is made up of four programmes – entrepreneurship, artificial intelligence, seed incubation, and catalyst collaboration (mature startups). It recognises the role innovators, and entrepreneurs play.

Figure 3 Dragon den style panel on Tideway where teams can bid for funding for bright ideas or innovation.

2.2. Environmental and Social Aspects

2.2.1. Carbon and Energy

2.2.1.1. Overview

Carbon and energy were key focus areas on all projects that I visited, unsurprisingly, as the construction industry grapples with the pathway to net zero. It was also an area that was clearly more advanced than New Zealand, both in terms of the level of commitments being made and in terms of outcomes. There appeared to be much to learn from and leverage off in this space. Key initiatives centre around the use of low/zero emission plant and equipment (be it electric, solar, hybrid or hydrogen technology), replacing diesel, and the specification of low carbon concrete. The following sections provide some key insights into these three areas.

2.2.1.2. Low/zero emission plant and equipment

There was a strong commitment to trial and use low/zero emission plant and equipment on all of the projects I visited in the UK. In London, the Low Emission Zone for Non-Road Mobile Machinery (NRMM)[2] set emission standards depending on location. These standards will get tighter with time, e.g., From 2025 the standards will be stage IV throughout London, from 2030 the standards will be stage V throughout London, and by January 2040 only zero emission machinery will be allowed. This is driving the uptake of electric/other low or zero emission plant and equipment. On HS2 they have set their own strict emission requirements for heavy goods vehicles by zone, e.g., initial target was 100% EURO VI, from 2020 targeting percentage cleaner than EURO VI (50% cleaner in London low emission zone, 25% cleaner in clean air zones, and 10% cleaner on the rest of the route).

In terms of initiatives, it was relatively common practice to have solar powered tower lights or eco tower lights (hybrid lights using HVO) for access and temporary works lighting and solar powered security systems with examples of these common place on all sites I visited in the UK.

There were interesting examples of projects trialling fully electric heavy construction plant, for example:

- In 2023, SCS Railways trialled a plug-in electric high-capacity drilling rig, and hydrogen dual-fuel piling rig. It was a learning experience for the team, with the fully electric piling rig caused some issues in the grid, drawing too much power.
- HS2 trialled a fully electric battery powered crawler crane in Birmingham in 2021, and by 2022 had procured three more cranes to work across the project sites in London.
- BBVJV trialled an all-electric, high-capacity drilling rig on a construction site in Warwickshire, which saved 1,200 CO_2/day and reduces noise by 50%.

[2] Includes mobile machines and transportable industrial equipment or vehicles that are fitted with an internal combustion engine and not meant for transporting goods or passengers on roads.

And examples of projects trialling hybrid and/or hydrogen generators, including:

- Two GeoPura 250kVA hydrogen power units were trialled over the last year at HS2's Victoria Road Crossover Box, as a direct replacement for diesel generators to power machinery on the site. With power capabilities ranging from 20kW through to 2MW data from the trial showed that running the units for 400 hours eliminated around 51 tonnes of carbon compared to using standard diesel generators.
- BBVJV undertook a demonstration project on Sublot 2A and converted 8 generators to hybrid, with battery storage units. This demonstrated payback of 25 tonnes of carbon per week/£1,400 per week. They also trialled a hydrogen battery unit and have plans to blend this with lightweight solar PV on cabins however, it comes at a significant cost and will need funding from the HS2 investment committee to enable its trial.

Overall, there appear to be greater drivers in the UK pushing projects to trial fully electric, hybrid and hydrogen plant and equipment. This is delivering not only carbon savings, but other benefits such as improved air quality, and reduced noise. It's still expensive, and not considered like for like. But these trials are important as they pave the way to construction site decarbonisation by proving the potential for fuelling other types of heavy plant with hydrogen dual-fuel or all-electric. It is worth noting that in many of the examples provided client held innovation funds have been used to enable these trials.

2.2.1.3. Fuel switching

Most projects in the UK used HVO as a diesel replacement (Figure 4). It is generally acknowledged to be a transitional fuel, with the ambition to move to hydrogen or electrification as soon as technology allows. There are some concerns about the source of HVO with the wider impacts on crops used to create the fuels and transportation impacts where sourced globally, may undermine low carbon credentials. Therefore, it is important that it is sustainably sourced (can be confirmed through a certificate of origin).

There were some initial barriers discussed to the uptake of HVO, with many manufacturers saying it would void the warranty if they used it in their plant, however, the general experience has been that once one site/project uses it and demonstrates viability, it's a catalyst for uptake across the industry. However, in certain areas (e.g., tunnelling works) it is still banned due to the potential fire risk.

Some projects that I visited were using HVO to power all site plant and equipment, e.g., SCS Railways sites, and Tideway Chambers Wharf site, i.e., they were diesel free.

Given that HVO is not available in New Zealand this has limited applicability at this stage, however, could be of interest if HVO could be sourced at a reasonable cost, from a sustainable source in the future. Some other concepts presented, such as the DCA framework described in Section 2.1.2 has potential to be adapted for use in New Zealand now provided the requirements were tailored to the available options to decarbonise.

Figure 4 Green D+ HVO fuel tank on Victoria Crossover Box Site.

2.2.1.4. Low carbon concrete

There are many ways in which to reduce the carbon associated with concrete, from minimising the amount of concrete to be poured, properly defining early strength criteria, and maximising cement replacement. It is the latter opportunity which the following section focusses on. Low carbon concrete is achieved through partial or complete cement replacement with a Supplementary Cementitious Material (SCM). Typical SCMs being used are either by products of industry (e.g., fly ash, ground-granulated blast furnace slag (GGBS) and silica fume) or occur naturally (e.g., limestone filler, pozzolana, metakaolin, or calcined clay) (Table 1).

In the UK and Australia, it was common practice to replace cement with GGBS. The percentage replacements being achieved are significantly higher than in New Zealand, as up until recently GGBS was not imported or available in NZ. In some countries there are standards which limit the replacement percentage, and in other countries a performance-based approach is taken.

There appears to be greater scope for trailing innovative concrete mixes (e.g., zero cement concrete) in temporary works structures such as piling platforms; avoiding the need for extensive testing and client approval needed to enable this product to be used in permanent works. This is seen as a pathway to start building a case for the revision of standards.

Table 1 Types of SCMs and the percentage replacements which can be and are typically achieved Boumaaza (2023).

SCM	*Source*	*% Portland Cement Replacement*	
		Max	*Typical*
Limestone	*Natural resource*	*Up to 35%*	*20%*
Fly ash	*By product of coal fired power plant*	*Up to 50%*	*25%*
Slag – GGBS	*Smelting iron ore as part of steel manufacturing process*	*Up to 95%*	*60%*
Silica Fume	*By product of producing silicon metal*	*Up to 10%*	
Pozzolans	*Natural resource*	*Up to 55%*	*20%*
Metakaolin	*Calcination of pure refined kaolinitic clay*	*Up to 20%*	
Calcined clay	*Calcination of clay and addition of limestone filler*	*Up to 35%*	

SCS Railways, Tideway, Ecopark South and the Athletes Village in Paris had examples of successful trials of zero cement concrete. For example, a 96% GGBS and 4% alkali activated binder (0% Portland cement) cement replacement was used on Ecopark South. A total of 350 m^3 was poured to create a 50mm thick concrete ground floor slab in a temporary facility. This pour also achieved placement via a pump, considered a world first, and critical in terms of overcoming barriers of largescale pours. Some challenges / lessons learnt from zero cement concrete trials include:

- Cost – zero cement concrete comes at a premium. In these trials the client funded the additional cost, and it is hoped that these uplifts will reduce with economies of scale.
- Temperature – it could not go below 15 degrees in order to properly cure. This proved challenging as works were over winter, hot water had to be added to the mix, frost blankets to contain heat, and temperature sensors placed inside the pour to monitor the internal temperature.
- In the absence of similar projects to learn from, extensive scenario planning had to be carried out to facilitate informed decisions.
- It is agreed that while zero cement concrete with GGBS is useful to demonstrate capability, it is not considered a smart option due to the limited availability of GGBS.

There are also examples of high cement replacement being achieved in permanent works. E.g., SCS Railways (HS2) developed a 79% cement replacement mix for use in permanent piling works. Approved for use, and introduced to the project in January 2023, the new mix has the potential to deliver carbon savings of 45% CO_2e. By the end of the project, they expect to deliver a saving of 4,600 tonnes CO_2e on the estimated 40,000m^3 of concrete required from January 2023 onwards.

In the UK, limited supply of GGBS is providing momentum to investigate other solutions. For example, on Tideway they are working with MIT to use recycled plastics as a cement replacement material (at 3% replacement). On HS2, a current feasibility is being to assess the potential to transform excavated London clay spoil into calcined clay for use as an SCM in concrete. To date they have tested it and proven it in concept in concrete mixes and are now at the point of scaling up. The HS2 innovation fund provided the funding for the initial

testing, and the SCS Leadership team agreed to fund the second part, with the client covering peoples time. The next step is through government/industry funding.

Many projects that I visited had targets around cement reduction and/or percentage replacement by SCMs. However, it was clear that the wrong target can drive perverse outcomes, i.e., specifying minimum quantities of GGBS drives no change to the total cementitious content.

Spotlight: Exergy – Low Carbon Concrete Journey

I had the opportunity to meet with a concrete technologist from Vinci, a company pioneering low carbon concrete (LCC) trials, to discuss their LCC journey. Vinci Construction launched Exegy's LCC range in September 2020, and has a target to generalise the use of LCC with 90% of their concrete to be low carbon by 2030 (in 2022, 45% achieved).

There is currently no standard definition of a carbon reduction threshold above which a concrete mix can be classified as LCC, therefore Exergy created its own standard. It defines LCC as a concrete with a significant reduction in carbon footprint compared to concrete made with Portland cement and equivalent or higher technical performance. Four types of concrete are defined based on the carbon footprint and compressive strength (Figure 5) – conventional, LCC, very low carbon concrete (VLCC) and ultra-low carbon concrete (ULCC).

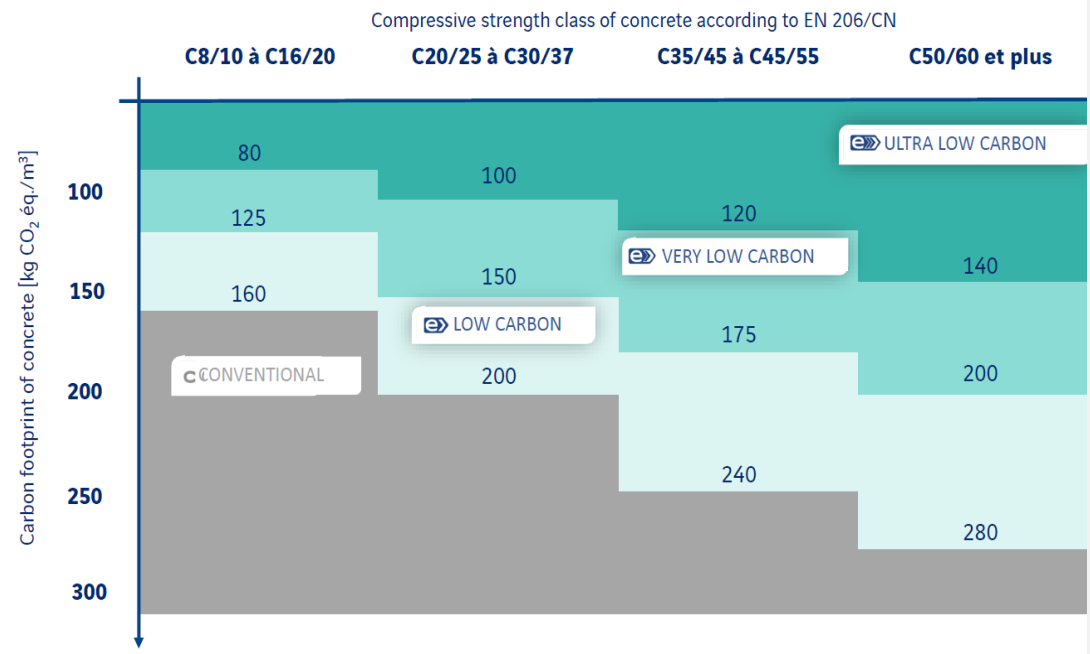


Figure 5 Exergy standard for low carbon concrete Boumaaza (2023).

Many factors must be considered when assessing feasibility of LCC – project performance requirements (durability, strength, and workability), the projects schedule (methods, formwork duration) and budget. Trials have demonstrated LCC is typically good year-round for vertical and horizontal elements (Figure 6). VLCC is problematic in winter for vertical elements, and ULCC is only applicable for foundation/horizontal elements.

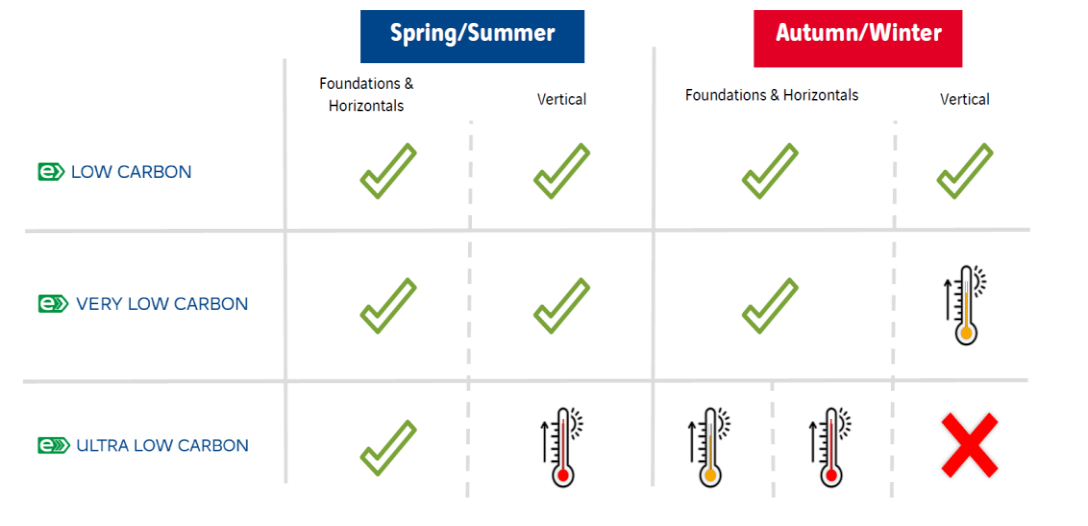


Figure 6 Suitability of LC, VLC and ULC concrete depending on structure and season Boumaaza (2023).

Exergy is working on a variety of trial mixes (Figure 7). Research is heavily focused around limestone filler (as this is universally available) and other additives such as metakaolin's, calcined clay and silica fume.

Clearly Exergy/other parts of the world are successfully delivering low carbon concrete, at much higher cement replacement percentages than New Zealand. Leveraging Exergy's experience, there appear to be a couple of good considerations for New Zealand:

- *Firstly, to consider whether there are any readily available industry waste products in New Zealand which could be used as SCM, e.g., in Canada, Exergy undertook this exercise and found that glass powder is readily available and designed a mix using this waste.*
- *Secondly, it was recommended that if NZ was to import any SCMs consideration should be made of silica fume, as it's used in very small quantities, and has been shown to boost durability performance. This can be used in conjunction with limestone filler (which is widely available), to compensate for the degradation of performance seen with this material.*

Overall, consideration of alternative SCMs are going to be important in the coming years. Particularly in New Zealand where the supply of byproducts of industry like fly ash, and GGBS are very limited, and/or imported. Easily and locally available SCMs appear to be the way forwards, e.g., limestone filler, and calcinated clay, in order to meet the growing demand for LCC.

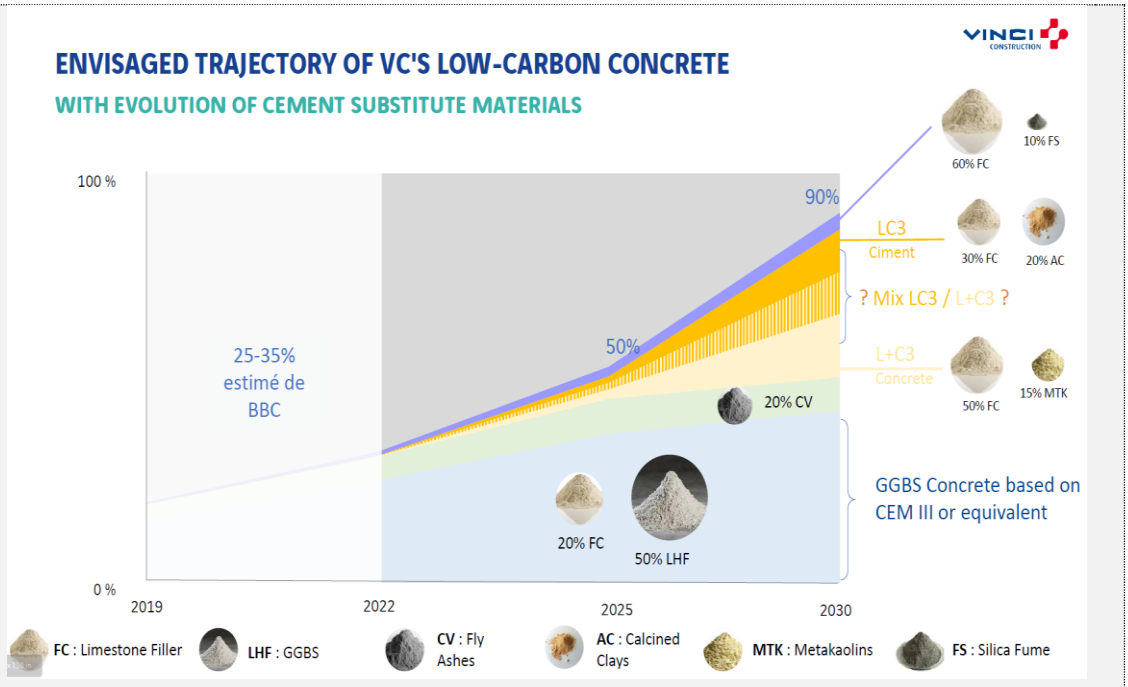


Figure 7 Envisaged trajectory of low carbon concrete at Vinci with the evolution of SCMs Boumaaza (2023).

2.2.1.5. Sustainable transport

The planning and logistics that had gone into a low carbon solution for the transportation and disposal of excavated materials on both HS2 and Tideway sites in London was really impressive. On HS2 two of the main contractors collaborated to construct a huge (3km long) conveyor (Figure 8) which takes spoil from three sites to a logistics hub at Willesden Euro Terminal where it is loaded onto trains and transported to one of three disposal sites for beneficial reuse (Figures 9-10). The sheer scale of this conveyor network is extraordinary. It moves on average 3,000-5,000 tonnes of spoil per day, removing 70 truck movements from the road per day. It's a great example of how rail freight can work in collaboration with large construction projects and delivers multiple benefits including reduced emissions, efficiencies in the movement of materials, and reduced impact on the local community.

For Tideway, the sustainable transport of materials was part of their 'More by River Strategy' which set a target of at least 90% of specified materials to be transported by river. This included the use of river barges to transport materials to site (e.g., TBM segments, reinforcing) and excavated material from site (Figure 11). This lowered transport emissions, reduced congestion, improved air quality on the road network and increased safety for other road users by limiting HGV movements. By the end of 2023, 4.8 million tonnes of materials had been transported by river, including 100% of excavated material. This removed 672,000 HGV journeys, avoiding 24,000 tonnes of CO_2.

I was interested to understand what mechanisms and specific resources there were in the project teams to enable such a large initiative to be realised. My personal experience on the City Rail Link project was that while sustainable transport of excavated materials was discussed early on in the project in principle (the site was also ideally located to enable this

with all spoil being removed to Mt Eden, in close proximity to the rail network) there was little buy in or even understanding of how to progress such an idea.

It was apparent that to enable this outcome the following were important:

- Client directive – Tideway had clearly specified a transport strategy by river. On HS2 no sustainable transport target existed, however, ambitious targets around carbon reduction drove innovative solutions like this.
- Dedicated resource – On both Tideway and SCS Railways (HS2) sites there was a dedicated person/team employed to drive this initiative; on Tideway this was the River Transport Strategy Manager, and on SCS Railways a logistics team within which there was a waste manager looking at beneficial reuse options. Resourcing of these types of roles are not well thought through in New Zealand. It is interesting to think if we had a logistics manager/team whether we could have transported our spoil by rail instead of road.

It was noted that building a case for rail transport requires rail experts who are well versed in things such as how to book train movements on the network. In most cases, this is something that needs to happen up to a year in advance. This is clearly not an environment/sustainability team function. On HS2 the environment team provided support to assess the cost/benefit of the conveyor, but that was the extent of their involvement.

Some challenges were discussed, on HS2 depending on the geology there were issues around the consistency of the material to travel that distance on the conveyor, on Tideway they had to make some modifications to the wharfs to enable the barges to access the site. However, these were both overcome.

Figure 8 Atlas Road site, High Speed 2 Project, showing the spoil conveyor system.

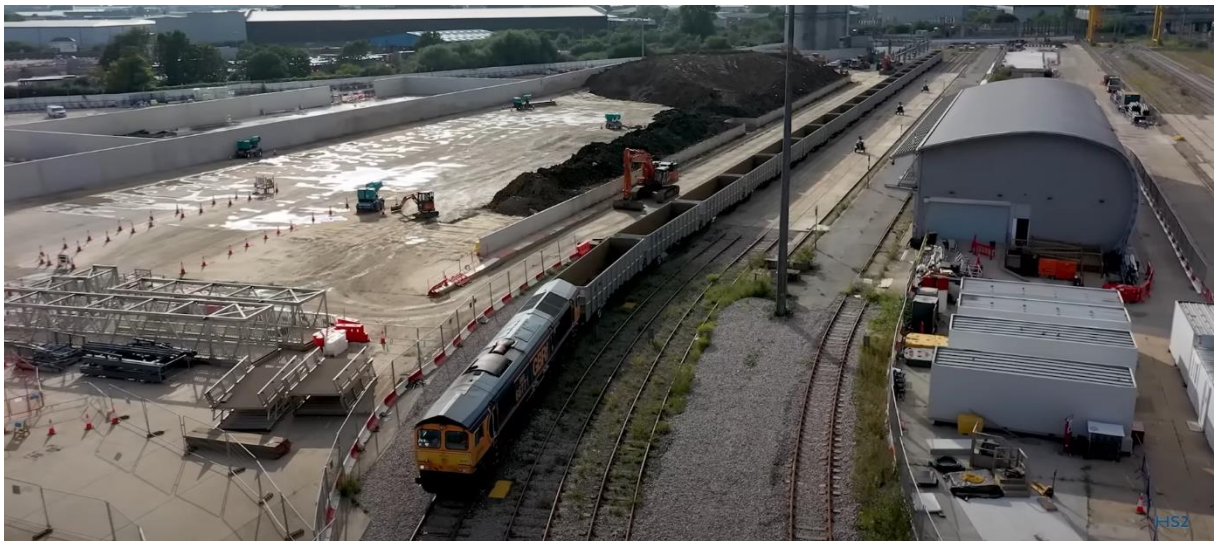


Figure 9 Willesden Euro Terminal where excavated material is received from the conveyor system and stored prior to being loaded onto trains.

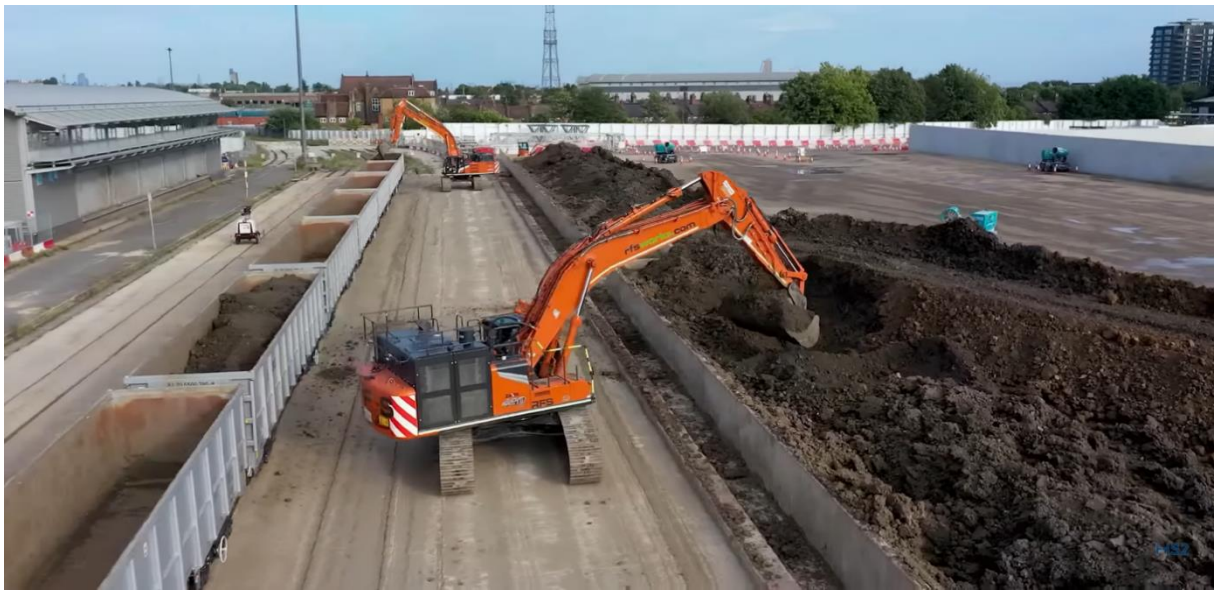


Figure 10 Willesden Euro Terminal showing the excavated material being loaded onto the train and transported by rail to one of three disposal sites for beneficial reuse.

Figure 11 Chambers Wharf site boundary, showing the river barges which are used to bring materials to site, and remove spoil from site as part of the "More by River "strategy.

2.2.2. Waste

In general, across all the projects I visited, there were very high waste reuse/diversion targets specified, and high rates being achieved. The targets were also similar to that specified on the City Rail Link project in New Zealand. There were some points of difference around excavated materials though where beneficial reuse was the norm and around some of the specific initiatives being implemented onsite to achieve the diversion and reuse targets. I have provided some comment on both in the Sections below.

2.2.2.1. Excavated material

It was common practice on most of the projects visited that all clean spoil excavated during the project had to be beneficially reused, not just diverted from landfill. This is a point of difference to business as usual practices in New Zealand. On some projects I saw they had developed a 'spoil hierarchy' to inform reuse options (Figure 12).

On other projects, such as HS2 and Tideway, beneficial reuse options were identified early and tied into the biodiversity legacy outcomes for the project. For example, on Tideway all excavated material was taken by barge to a riverside site (site of special interest for bird life) and used to create 1 km^2 of new wetlands to attract wildlife to the Thames estuary. Chalk material is being used to create the topography for the wetland habitat, and clay material is

being used to create an impermeable layer to retain water in new lakes. On HS2 London sites, material is being transport by rail to one of three locations for beneficial reuse - Barrington in Cambridgeshire, Cliffe in Kent, and Rugby in Warwickshire.

Figure 12 Western Sydney Airport spoil management hierarchy (Sydney Metro: Western Sydney Airport Sustainability Plan, January 2022).

2.2.2.2. General construction waste

There were many initiatives implemented on the projects I visited to reuse and recycle construction waste; a couple of the more interesting ones were:

- BBVJV developed an app called Community Resource Information Sharing Platform (CRISP). Any over ordered items or left over materials can be listed on CRISP, and other sites along the route can access it. This is forecast to have good carbon savings, and financial savings.
- Sydney Metro and TfNSW collaborated on the development of information guides intended to support the optimised usage of recycled and reused materials in rail and road infrastructure projects with a 'Recycled and Reused Material Opportunities in Rail Projects Visual Guide' (Figure 13). This demystifies recycled materials and reuse visually demonstrating BAU minimum, approved alternatives to be used where practical, as well as innovations that must be considered.

Figure 13 Excerpt from the Recycled and Reused Material Opportunities in Rail Projects Visual Guide – to rail sleeper showing BAU minimum, through to innovations to be considered.

2.2.3. Nature-Based Solutions

There are many examples of planting KPIs on projects, which is similar to the approach in New Zealand where projects are typically required to put back what they remove at a minimum. However, in the UK there were many examples of nature-based solutions (beyond planting alone), aimed primarily at boosting biodiversity, being implemented at the project level.

Some good examples included:

- On the Tideway Project they recognised the way they build their new structures in and around the river can provide a legacy of new habitats for aquatic and other wildlife. For example, their intertidal river wall panels were designed to provide a textured surface, horizontal ledges, and deeply recessed niches to improve the habitat for marine life in the Thames (Figure 14).
- Also, on Tideway they have integrating nature-based solutions into other structures, providing softened edges to several structures that will encourage wildlife into the urban estuary seeking to enhance biodiversity through the design of their infrastructure. For example, they installed biodiverse roofs/green roofs/native wildflower roofs on their above ground structures aiming for a total of 753 m^2 of new habitat on the roofs of these structures. Their vent structures are wrapped in gabions filled with different types of materials, arranged in a way which promotes biodiversity and support plant growth as well as providing habitat for insects, small invertebrates, and small mammals (bug hotels) refer Figure 15.

- Ecopark South, which was a project on a much smaller scale to Thames Tideway, included a range of solutions including bird boxes, bat boxes, insect hotels and habitat enhancement for reptiles and amphibians.

In addition, BBVJV use the Department for Environment, Food and Rural Affairs (Defra) biodiversity metric to measure progress against their biodiversity targets (of no net loss, and 10-15% net gain more recently). This mechanism scores habitats, showing them how many 'units' of biodiversity there are before the railway is built (units depend on the type of habitat, and maturity) and how many need to be in place after construction to meet the target of no net loss/net gain, with losses balanced by gains. While this is not dissimilar to the ecological value calculator provided by the Infrastructure Sustainability Council (ISC) in New Zealand, the method of application is quite different, with biodiversity net loss/gains being recalculated every six months. While I am not an ecologist, and therefore could not be considered a subject matter expert in this field, I have not encountered a project approaching biodiversity accounting in this way with this level of oversight/forecasting.

Overall, nature-based solutions appeared to be an integral part of many major projects in the UK especially. This seems to be a largely missed opportunity in New Zealand. There is potential for NZ projects to give more consideration to our built structures, so they are serving a more dual purpose, looking for opportunities to enhance biodiversity by providing nature-based solutions alongside hard civil engineering solutions.

Figure 14 Intertidal River wall using a geometric design to provide 'shelving' to retain moisture and promote colonisation (Tideway London, 2023)

Figure 15 Examples of nature-based solutions on the Thames Tideway Project (Tideway, 2023).

2.2.4. Social Legacy

Leaving a lasting legacy and the desire to deliver wider sustainability benefits seems to be a common mandate for large infrastructure projects across the world and in New Zealand, where the scale of the project presents a historic legacy opportunity. However, valuing the social impact being created by delivery of these legacy programmes isn't commonplace. Two examples of this were encountered, on TRU with their social value tool, and Tideway with their social impact assessment.

Tideway's social impact assessment was finished in 2023 and included a third-party evaluation of the social value created by Tideway's legacy programme (only valuing those initiatives which were above and beyond the core environmental benefits the tunnel will deliver). This demonstrated that £1 invested by Tideway produced £1.72 of social value.

Tideway likens social value to a "ripple effect", where every decision has the potential to create positive 'ripples' and make a difference to society and the environment locally and beyond. The premise is they may not get every decision right but if they understand and measure the impact of what they did every step of the way they can share those lessons. And other can do even better. They call this the ripple effect.

2.3. Other Matters

2.3.1. Measuring Sustainability Performance

2.3.1.1. Sustainability rating frameworks

All projects that I visited were contractually obligated to deliver a sustainability rating, through the BREAAM rating scheme in the UK, or ISC rating scheme in Australia. Given that the ISC rating scheme is already in use in New Zealand I did not focus on the detail of these schemes as part of my fellowship.

However, there are some differences in how rating schemes are being mandated on certain projects which I think is useful to highlight. For example, on HS2 an Act of Parliament was passed to permit construction. Interestingly the BREAAM rating target of 'excellent' is a legal minimum that must be achieved as part of the Act, similarly New South Wales mandate minimum ISC rating requirements as part of the planning approvals. This contrasts with New Zealand, where a sustainability rating target may be specified by a client, depending on their maturity in this space. This is most commonly a contractual requirement between client and contractor, which may or may not have a penalty if not achieved. The approach taken on HS2 makes the rating requirement a lot stronger and enforceable. This also drives a lot more investment by the client to set up their contractors for success, e.g., HS2 Limited invested significant time and effort into a strategy stage assessment, developing specific technical standards which then helped drive the contractor to deliver the rating.

2.3.1.1. Other tools

I came across several examples of organisational level tools which have been developed to internally drive and reward sustainable outcomes; two examples are highlighted, one at a company level and the other at a government agency level.

The Environment Label ('Attitude Environnement Label') was a tool developed by Vinci Construction for assessing the implementation of Vinci's environmental ambition on its construction projects and to recognise projects going above and beyond. Started in 2012, and revised in 2021, it comprises of 43 requirements based around regulatory requirements, ISO requirements, and best practices. The requirements include topics such as removing nuisances, taking action for biodiversity, reducing waste, controlling the risk of pollution, reducing consumption, and disseminating an environment culture. There are four levels which can be achieved (bronze, silver, and gold), which are verified by an internal/independent environmental practitioner within Vinci. Silver and gold labels reward projects that perform well and meet all applicable environmental requirements, and have at least four, and seven environmental innovations respectively.

A similar example was seen on Sydney Metro, where the Principal Contractor was responsible for achieving a minimum 'Gold' rating under the Transport for New South Wales's Sustainable Design Guidelines. The guidelines cover a broad range of themes; compulsory requirements have five performance levels, and an associated list of supporting initiatives.

While this is not something I have seen in New Zealand, I would consider there is real merit in the development of internal tools to help companies and organisations to realise sustainable outcomes either complementary to or independent of a rating framework such as those described in Section 2.4.1.1.

2.3.2. Sustainability Data Management

Everyone I met understood the importance of sustainability data in guiding decision making, assessing performance, and driving continuous improvement. However, there was a consensus that as an industry we are not where we need to be in regard to sustainability data collection and reporting.

There are many challenges, mostly notably gathering the data requires significant resource and effort, particularly for large projects with complex supply chains, with data coming from many different sources. For many projects, data collection was the responsibility of the environmental/sustainability team. For some projects, e.g., SCS Railways, there was a standalone data analyst employed to manage the data. Many people queried whether this function would be a better fit in the commercial team, either that or an environmental/commercial partnership. All projects managed their data in a large excel spreadsheet.

Some promising avenues included:

- Maximising automation and getting data directly system to system. For example, SCS Railways use waste electronic ticketing, where the data is sent electronically and bypasses paperwork. Spark D&C are using cost breakdown structure (CBS) codes to link forecast to actuals, then a bot identifies what the line items are.
- Artificial Intelligence (AI) was used to extract key information from scanned documents, and automatically populate a data spreadsheet.

Some challenges which were shared included:

- Often the commercial system cannot provide the information that is needed, e.g., able to access information on cost, but not quantity.
- The time it takes to build good systems around data management. Project lifecycles don't lend themselves to bespoke systems, and instead home organisations are better placed to advance this.
- Maximising automation requires agreement with subcontractors and suppliers on how they specify products in invoices.

Overall, sustainability data management was highlighted as a global challenge. There was agreement that there needs to be a fundamental shift in how sustainability data is collected and managed. Data management platforms that integrate with both internal and external systems, enabling data to be captured at source and leveraging automation and AI as much as possible provide some promising solutions.

2.3.3. Contractor Team Structures

While not one of the core questions of my fellowship, it was interesting to see how contractor teams were organised on major projects overseas. In some projects I visited, the structure was very similar to projects in New Zealand, with an overarching Environment and/or Sustainability Manager, and advisors supporting the site teams covering a broad range of environment and sustainability risks. On all projects, it was considered crucial to align the delivery team to the delivery structure, so you have people available to integrate into that process.

Both HS2 teams I met with presented a different model. On SCS Railways, there are Environmental and Sustainability leads for each area responsible for delivery of both aspects onsite. Additionally, there is a sustainability and carbon lead (including a data analyst) in the core team. This structure was considered crucial to 'balance the day-to-day environmental site management, and the big picture sustainability stuff'. In addition, there was a large specialist team (of SMEs) in house, with a pool of additional consultants that can be drawn on when demand is high. Geri Badura of SCS Railways described this as '*their own mini consultancy supporting the team'* and considered this one of their biggest successes, presenting a significant cost saving to the project, and as all the technical leads are full time, embedded in the project team, there is much more ownership of technical issues. In the BBVJV team, there was a Head of Environment and every sublot was supported by a site-based team which included an Environmental Manager, Advisors, Coordinators and Technicians. Like SCS Railways, SMEs were employed by and embedded into the construction team for the duration of the project. In the core team, there were several technical leads reflecting the key client requirements, e.g., Carbon Lead and Carbon Coordinator, Energy and Efficiency Specialist, Waste and Resources Lead etc.

I can see some real advantages to segregating the site-based environmental and sustainability roles from core team roles and having technical leads in the core team aligned with each of the most material sustainability issues/client requirements/desired outcomes. In New Zealand, this would only be practical however on large scale major projects where there was sufficient scope and budget to enable this level of resourcing.

2.3.4. Resourcing

A common theme across all my visits was the chronic skills shortage in construction, including environmental and sustainability professionals. This is no different in New Zealand and appears to be an is in industry wide challenge.

On SCS Railways I had an interesting insight into a Safety Health and Environmental (SHE) apprenticeship programme which was developed in collaboration with tertiary providers, and construction companies in UK to enable pathways into construction and attract and retain talent. This apprenticeship programme is for school leavers, it runs for 5 years and involves one day tertiary study a week, and four days practical work onsite. This programme allows apprentices to learn while they earn and gain real work experiences in parallel to academic studies, and employers gain by expanding the environmental capability of their business as well as being able to reclaim their apprenticeship levy contributions. I can see application for

this type of programme in the New Zealand context, given the difficulty there is with resourcing sustainability roles across the industry.

3. Conclusions and Recommendations

It was evident that there were a broad range of common factors which contributed to successful sustainability programmes on the projects that I visited and there were also some universal challenges. Broken down by main theme I have summarised the top 12 most common factors which I observed that contribute to successful sustainability programmes on infrastructure construction projects, these included:

Governance

Client leadership/Bold Targets

- Client leadership is pivotal in shaping project outcomes. Clients who establish bold sustainability targets and mandates integrated into project requirements, provide a framework that guides the entire project lifecycle, empowering contractors to steer results at the project level. Bold targets also foster innovation, encouraging contractors to explore innovative solutions and technologies that can help achieve these goals, and collaboration between the client and contractor as they work together on common sustainability objectives.
- Contractors are setting some bold targets to speed up the pace of change across the industry, e.g., Diesel-free by 2023. There is a sense that an aggressive target will still significantly accelerate improvements, even if it is not achieved. So often in New Zealand targets are set at the lower end, to provide a realistic starting point that allows organizations to build momentum, gain confidence, and demonstrate progress over time. Experience overseas shows that under the right circumstances there is merit in aiming high to drive innovation and meaningful change across the industry, accepting that we may not get there, but will be further ahead for having tried.

Senior Leadership Buy in

- Senior leadership buy-in is critical. Having a regular forum to engage with senior leaders on the big-ticket sustainability decisions, such as the Sustainability Steering Group on SCS Railways, is pivotal for success.
- Including sustainability metrics in executive performance scorecards sends a strong signal of commitment at the Project level, and motivates executives to take ownership of sustainability initiatives, drive progress towards sustainability goals and prioritise sustainability in decision making.

Procurement Process Used to Leverage Sustainability Outcomes

- Recognising that there is considerable workload associated with ensuring sustainability is considered in the procurement process, dedicated resource (e.g., sustainability supply chain manager) embedded in the procurement team appears key to success, even if it's just for a period at the start of a project when the bulk of the tenders go out.

- Supply chain engagement events were regularly delivered across most projects, enabling collaboration, sharing of lessons learnt, and challenges. This is something that New Zealand projects would benefit from doing more, especially given the limited understanding and maturity around sustainability in the supply chain.
- Any mechanisms that upskill the supply chain around a projects sustainability targets and their role in supporting this is useful, information packs used on HS2 were a great example.

Focus and Investment in Training

- There is a much greater focus and investment in environmental and sustainability training overseas on projects and within organisations. This is a missed opportunity currently in New Zealand, and more focus need to be placed on this to raise awareness and encourage staff to act within their zone of influence.
- There are good examples of effective training programmes overseas which could be leveraged here including general environmental awareness training and carbon awareness and/or carbon literacy training for staff. Senior leaders and Executives are being provided targeted training in carbon literacy and there are existing mechanisms for them to become certified carbon literate. Again, this could be replicated in New Zealand.
- Projects commonly had targets around training.
- Training of our supply chain is just as important to ensure they have the capacity, capability, and competency to deliver a project's targets and to leave a legacy of green skills for future infrastructure projects.

Industry Wide Knowledge Sharing of Best Practises

- There were formal knowledge sharing schemes on most of the major projects I visited, incentivised through competition, encouraging people to participate, and be rewarded where exemplary outcomes are achieved. Addition examples were seen at the organisational and industry level.
- Major projects in New Zealand produce so much best practise, but having the mechanisms to make the information available to the wider industry in a format that is consistent and useful is challenging. Often successes are written up as part of award submissions but unless you are the overall winner, these best practice examples are not shared wider. As an industry, we need to explore options to share and leverage all the best practise happening in New Zealand. Examples I came across suggest that incentivising knowledge sharing through an industry-wide competition may be a successful route, provided all entries were shared.

Clients Investing in and Driving Innovation

- Many clients play a crucial role in investing in and driving innovation, with most client organisations on major projects administering innovation funds to enable uptake of new and innovative approaches. This approach helps overcome the hurdle where a new initiative might cost more upfront to explore.

Environmental/Social Aspects

Action to decarbonise construction is a key focus area - through fuel switching, low/zero emission plant and equipment and low carbon concrete

- HVO is being used with great success in the UK as a transitional fuel to replace diesel with several projects operating close to diesel free. Key to success has been access to cheap HVO. Given that this fuel is not available in New Zealand it has limited applicability at this stage, however, could be of interest if it could be sourced at a reasonable cost, from a sustainable source in the future.
- A framework to assess each sites commitment to decarbonising construction activities, such as the DCA framework rolled out on SCS Railways sites, is a great initiative which could be adapted for use in New Zealand now provided the requirements were tailored to the available options to decarbonise.
- There are greater drivers for the uptake of low/zero emission electric/hybrid or hydrogen plant and machinery in the UK due to emissions targets and low emission zones in cities like London. It's interesting to consider this as what's potentially to come for New Zealand.
- There are several examples of projects trialling fully electric heavy construction plant proving the potential for fuelling other types of heavy plant with hydrogen dual-fuel or all-electric. This is useful evidence to support further uptake in New Zealand.
- The fact remains that in the absence of any emissions standards, it hard to drive the update of low/zero emission plant and machinery currently due to cost. However, other benefits such as improved air quality, and reduced noise need to be taken into consideration when evaluating the cost benefit of different options.
- Client held innovation funds enabled many of the trials of low/zero emission plant overseas, and this is currently lacking in New Zealand and would support uptake.

Low Carbon Concrete Technology Far Advanced Overseas

- There is a strong focus on innovative low and zero carbon concrete overseas with high emissions reduction targets forcing innovative exploration throughout the industry. There is an opportunity for New Zealand to leverage the experience and learnings in this space.
- Trials of innovative concrete mixes are best done in temporary works structures to avoid extensive testing and client approval needed to enable this product to be used in permanent works.
- While zero-cement concrete has been demonstrated it is not considered a smart option due to the limited availability of some SCMs.
- Consideration of alternative SCMs are going to be important in the coming years. Particularly in New Zealand where the supply of byproducts of industry like fly ash, and GGBS are very limited, and mostly imported. Easily and locally available SCMs appear to be the way forwards, e.g., limestone filler, and calcinated clay, to meet the growing demand for LCC. If we were to import any SCMs consideration should be

made of silica fume, as it's used in very small quantities, and has been shown to boost durability performance.

Sustainable transport and beneficial reuse of excavated material is a priority

- Sustainable transport of materials delivers multiple benefits including reduced emissions, efficiencies in the movement of materials, reduced congestion on the road, improved air quality and increased safety for other road users by limiting truck movements.
- Building a case for sustainable transport of materials (e.g., by rail or river) requires experts in that field to lead it; it is not an environmental/sustainability team function.
- Clients play a role in requiring sustainable transport through establishing sustainability criteria for transportation in their procurement contracts and project specifications.
- Beneficial reuse options need to be identified early, and dedicated resource to be employed to drive the solution. The best solutions enable material to be taken directly to locations to be reused, without the need for long term/large scale storage. For added impact, solutions should be linked to biodiversity legacy outcomes for the project.

Other environmental dimensions are valued

- Nature-based solutions, aimed at boosting biodiversity, appeared to be an integral part of many major projects in the UK especially. This seems to be a largely missed opportunity in New Zealand. There is potential for New Zealand projects to give more consideration to our built structures, so they are serving a more dual purpose, looking for opportunities to enhance biodiversity by providing nature-based solutions alongside hard civil engineering solutions.
- Leaving a lasting legacy and the desire to deliver wider sustainability benefits is a common mandate for large infrastructure projects across the world and in New Zealand, where the scale of the project presents a historic legacy opportunity. However, there is an opportunity to quantify the social value generated by a legacy programme, demonstrating impact through social return on investment.

<u>Other Matters</u>

Resourcing critical roles to deliver key outcomes

- It is crucial to align the sustainability team to the delivery structure, so you have people available to integrate into that process.
- The blend of site based/area based Environmental & Sustainability Advisors, with technical lead roles aligned with each of the most material sustainability issues has some real merit in terms of outcome delivery. In New Zealand, this would only be practical on large scale major projects where there was sufficient scope and budget to enable this level of resourcing. Additionally, SMEs employed on the contractor team presents an opportunity for significant cost savings, and greater ownership of technical issues.
- Sustainable transport and reuse of excavated materials is a high impact area for many major projects. To deliver best practice outcomes dedicated roles with specific skill

sets are needed to drive this. Resourcing of these types of roles is not well thought through in New Zealand.

The emergence and importance of internal tools to drive outcomes

Several examples of organisational level tools which have been developed to internally drive and reward sustainable outcomes were highlighted.

While this is not something I have encountered in New Zealand, the development of internal tools to help companies and organisations to realise sustainable outcomes either complementary to or independent of a formal rating framework could be beneficial.

Some universal challenges

Sustainability data management and the sustainability skills shortage are global problems, which are mirrored here in New Zealand. Some common themes included:

- There needs to be a fundamental shift in how sustainability data is collected and managed. With support for data management platforms that integrate with both internal and external systems, enabling data to be captured at source and leveraging automation and AI as much as possible.
- Alternative solutions to enable pathways into construction need to be actively explored; this could include industry collaboration with tertiary providers to explore the opportunity for an apprenticeship programme to attract and retain talent in the construction industry.

Next steps

Implementation becomes the next critical step. It is imperative that we leverage these learnings to drive meaningful change within the New Zealand construction industry, improving the success of sustainability programmes and the quality of the outcomes on projects across Aotearoa. In my view this will require a multifaceted approach, involving advocacy for and engagement around the enablers for success with the industry, as well as demonstrating practical application of a range of these best practise principles at the project and/or organisational level here in New Zealand.

I will continue to share my learnings widely with the New Zealand industry. This will include a presentation at the annual Infrastructure Sustainability Conference in Auckland on the 20 June 2024, as well as many other engagement opportunities. In relation to demonstrating practical application of these learnings, I am currently reviewing implementation options within my organisation, with the end goal to obtain wide-spread adoption of these approaches in future projects in New Zealand.

Appendices

Appendix A: Fellowship Itinerary

Table 2 List of sites and persons visited and interviewed for this research Fellowship in September-October 2023.

Date	Person		Role	Organisation/Project
29-Sep-23	Gerald Ng	Meeting	Vice President Sustainability	Changi Airport Group
29-Sep-23	Rachel Hill	Online Meeting	Senior Waste Management Consultant RSK / Environmental consultant for SV3	Old Oak Common Station High Speed 2 Project
2-Oct-23	Amirul Islam	Site Visit	Sustainability Manager, Vinci Construction UK	Ecopark South, Waste to Energy Plant
	Sihaam Ahmed		Environmental Advisor Taylor Woodrow	
3-Oct-23	Lauren Arnott	Site Visit	Environmental Advisor	Skanska Costain STRABAG Joint Venture (SCS Railways) Victoria Road Crossover Box Site, Area Central
3-Oct-23	Joseph de la Fuente	Site Visit	Senior Environmental Advisor	Skanska Costain STRABAG Joint Venture (SCS Railways) Atlas Road Site, Area Central
3-Oct-23	Samantha Freelove	Meeting	Legacy & Sustainability Manager	Thames Tideway Tunnel
3-Oct-23	Grace McCormack	Meeting	Sustainability Consultant, Jacobs	Transpennine Route Upgrade Project (TRU Project)
3-Oct-23	Pallab Chatterjee	Meeting	Principal Consultant (Sustainable Design and Construction Management, Jacobs	High Speed 2 Project
	James Langstraat		Senior Associate Director, Sustainable Infrastructure, Jacobs	
4-Oct-23	Geri Badura	Meeting	Environment & Sustainability Director	Skanska Costain STRABAG Joint Venture (SCS Railways)
4-Oct-23	Anna Fish	Site Visit	Senior Environmental Advisor	Skanska Costain STRABAG Joint Venture (SCS Railways), Euston

5-Oct-23	Matthew Gardiner	Site Visit	Environmental Manager	Tideway East, Chambers Wharf
6-Oct-23	Papa-Samba Drame & team	Meeting	Head of Environment & Sustainability Design	Balfour Beatty VINCI (BBVJV) HS2 Project
6-Oct-23	Papa-Samba Drame	Site Visit	Head of Environment & Sustainability Design	Balfour Beatty VINCI (BBVJV) HS2 Project Sublot 4 & 5
9-Oct-23	Cédric Ruelland,	Meeting	QSE Manager	Vinci Construction
10-Oct-23	Laurene Pietri	Meeting	Environmental Engineer	Vinci Construction Grand Projets
10-Oct-23	Ariyada Souvanlasy	Meeting	Environmental Project Manager	Vinci Construction
11-Oct-23	Ariyada Souvanlasy	Site Visit	Environmental Project Manager, Vinci Construction	Paris Olympics Village
	Karen Bernard		Environmental Manager, Vinci Construction	
12-Oct-23	Mouna Boumaaza	Meeting	Concrete technologist	Vinci Construction Grands Projets
12-Oct-23	Cyriane Fournier	Meeting	Research, Development & Innovation Manager	Vinci Construction Grands Projets
	Bruno Daunay		AI Lead at Leonard	
12-Oct-23	Ian Nicholson	Online Meeting	Senior Sustainability Leader Stantec & Value Delivery Lead for Construction Innovation Hub	Construction Innovation Hub
16-Oct-23	Meg Wrixon	Meeting	CPB Contractors	Western Sydney Airport
	Albert Ng			Warringah freeway upgrade project
17-Oct-23	James Stevens	Site Visit	Senior Associate Sustainability Consultant	Sydney Metro, Central Station
	Alyssa Slaney		Project Sustainability Manager, Laing O'Rourke	
17-Oct-23	James Stevens	Online Meeting	Senior Associate Sustainability Consultant	Sydney Metro/CRL knowledge share session
	Jo Haggerty		Associate Director Sustainability	

19-Oct-23	Viv Heslop	Meeting	Manager, Sustainability Culture + Strategy, Spark NEL D&C	Knowledge share session between CRL, NELP, and Suburban Rail Loop
	Rachael Lee		Sustainability Director, North East Link Tunnels Package: Spark D&C	
	Ross Brookshaw		Sustainability Manager, Acciona	
	Sarah Reid		Principal Advisor – Sustainability, Suburban Rail Loop Authority	
	Rob D Harper		Senior Sustainability Advisor, North East Link Program	
	Steph Rich		Climate Change and Strategic Sustainability Specialist, John Holland Group	
	Julia Rodgerson		Sustainability Advisor at SPARK Consortium - North East Link	
	Lucy Whalen		Senior Sustainability Advisor, Webuild	
	Jessamine Welsh		Senior Sustainability Advisor, Spark North East Link Tunnels D&C	
	Jo McArdle		Spark-DC Health, Safety & Wellbeing Director at Webuild	
20-10-23	Fiona Bowie		Director Transformation and Sustainability, John Holland Group	LXRP North Western Program Alliance, Preston Station/Bell Station

Appendix B: Site Visit Observations and Photos

The fellowship enabled me to visit a range of major infrastructure construction projects in the UK, France, and Australia, all at varying stages of delivery. While this report is not intended to be a journal cataloguing each individual site visit, this appendix documents the main projects visited, and any insights or observations made that are additional the key learnings presented in Section 2.0.

1. Changi Airport Group, Singapore

On 29 September 2023 I met with Gerald Ng, Vice President Sustainability at Changi Airport Group and two of his colleagues (Figure 16).

Figure 16 Visit to Changi Airport Group Offices, Singapore.

2. Ecopark South Resource Recovery Facility, London

On 2 October 2023 I visited the Ecopark South Resource Recovery Facility in London with Sihaam Ahmed (Environmental Advisor, Taylor Woodrow) and Amirul Islam (Sustainability Manager, Vinci Construction UK). This is a North London Waste Authority scheme to create a sustainable waste management hub at Edmonton Ecopark and includes a new resource recovery facility, and an education and visitors centre (Figures 17 and 18).

Insights & Observations

- Carbon/energy and biodiversity were the key sustainability focus areas and are discussed in detail Section 2.0.
- Examples of other initiatives shared:
    - Warm mix asphalt was used on the road (380 tonnes), mixed at temperatures 20-40 degrees lower than tradition asphalt, providing up to a 48% carbon saving per tonne.
    - Trenchmix®, a deep soil mixing process, was used to construct the cut off wall in place of sheet piled wall, 30% reduction in embodied carbon, and produced little/no spoil.
- Amirul shared an interactive pollution management spill response board which was developed within Vinci (Figure 19). It is an A3 magnetic board that comes with a variety of magnetic spill response material etc. It is often challenging to find ways to engage with site crews around spill response in a practical/hands on way. This was noted as an interesting opportunity for hands on learning with site teams.

Figure 17 London Energy's Waste to Energy Facility at Edmonton EcoPark.

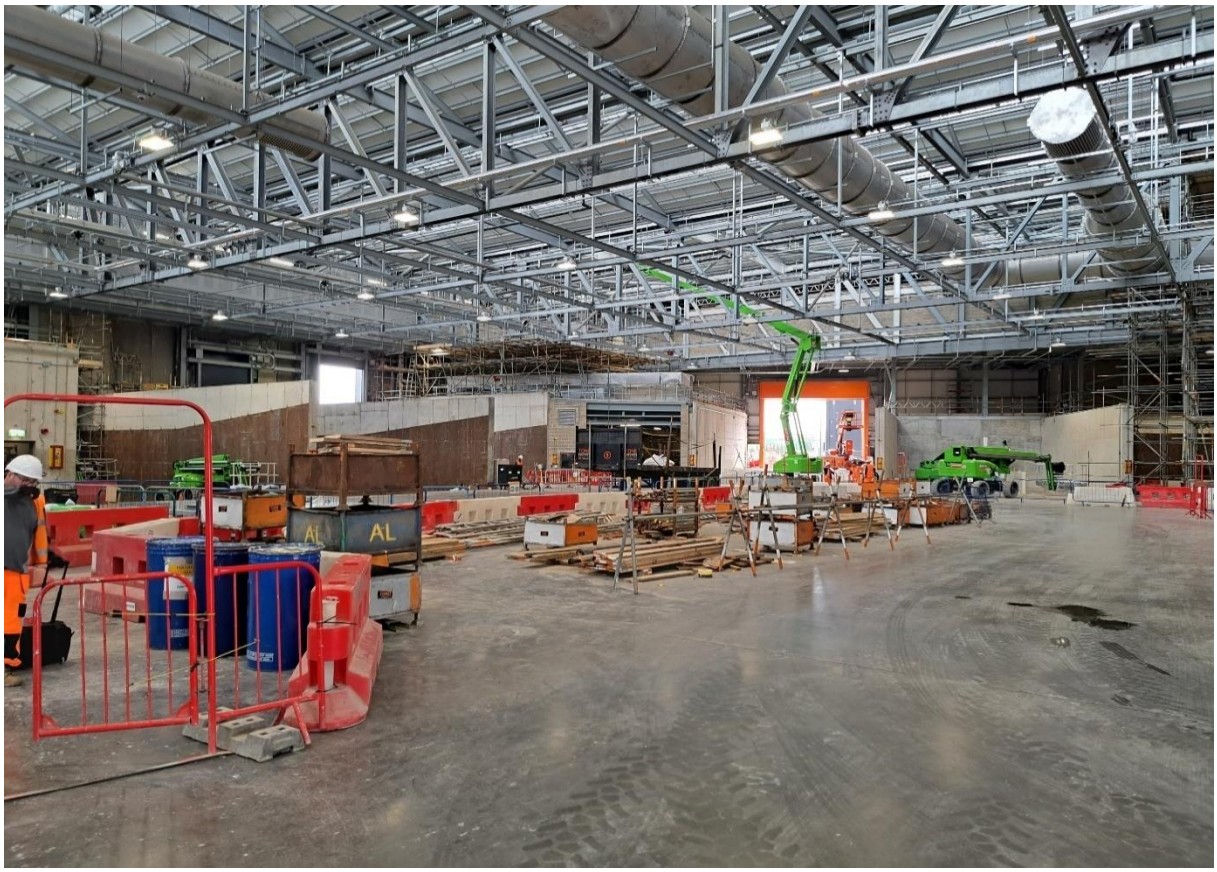


Figure 18 Inside the new Resource Recovery Facility.

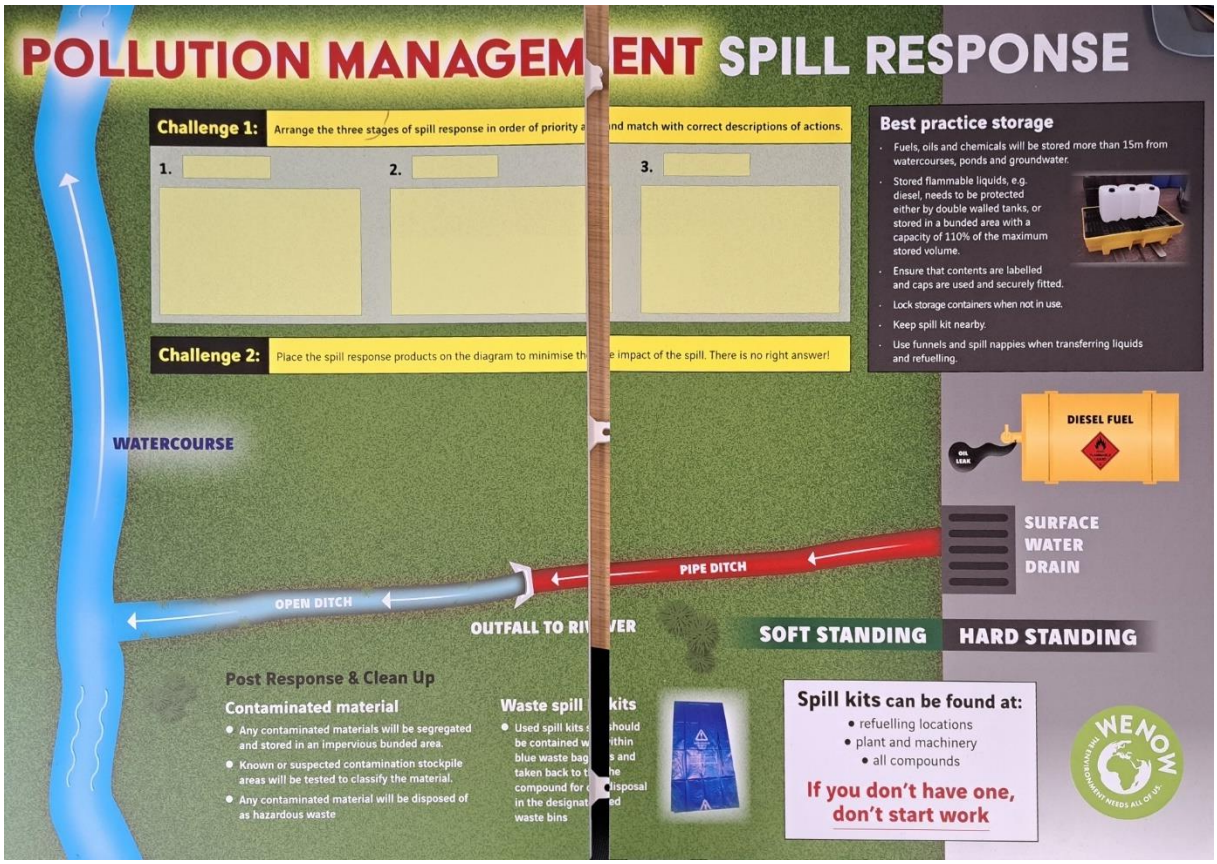


Figure 19 Interactive pollution spill response board.

3. High Speed Two, Area Central, London

On 3 October 2023 I visited High Speed Two, Area Central in London with Lauren Arnott (Environmental Advisor, SCS Railways) and Joseph de la Fuente (Senior Environmental Advisor, SCS Railways). The visit included two sites, the Victoria Road Crossover Box, and Atlas Road site in Area Central.

The Victoria Road Crossover Box is 128m long, 25m deep, with 1.5m thick diaphragm walls and constructed of 5 interconnecting bubbles (Figures 20 and 21). The base slab of the crossover box is supported by 77 piles which have been installed 20m into the ground below the slab level. Viewed from above, the design resembles the shape of a caterpillar with a bunch of "bubbles" and is the first caterpillar shaft to be excavated in the UK.

The Crossover Box was prepared to launch two tunnel boring machines (TBMs), which will construct the eastern section of the Northolt Tunnel. These two TBMs are planned to be launched in 2024. Following construction, it will house a crossover track mechanism that will allow HS2 trains to switch between tracks, on the approach and descent from Old Oak Common station.

Figure 20 Victoria Road Crossover Box site, Area Central, London.

Figure 21 Close up of the Victoria Road Crossover Box

4. High Speed Two, Area East, London

On 4 October 2023 I visited the High Speed Two, Area East (Euston Site) in London with Anna Fish (Senior Environmental Advisor, SCS Railways). The site, which stretches for almost a kilometre, will house the lines coming into Euston Station and involves the installation of almost 2,000 piles (Figures 22-24).

Insights & Observations

- An innovative zero trim pile technique was developed on this site – traditionally in piling concrete is overpoured, then workers have to break out the excess concrete. Zero trim piling involves sucking out excess concrete whilst still wet using a vacuum excavator technique. Extracted concrete is retained and being reused in construction elsewhere. This delivers benefits in terms of efficiency, carbon reduction, noise reduction, and health and safety.
- Digital vibration exclusion zones have been used on this site, like the virtual safety exclusion zones which I have come across in New Zealand. This shows the potential opportunity to use the same technology used for safety and apply it to manage the effects of construction vibration.
- A behaviour change initiative on idling was rolled out at this site, with flashing lights installed in vehicles to signal to operators when they have been idling for too long.

- Hoarding artwork installation was very impressive both in terms of height (~ 5m high) and the art installation itself which reflects the brick wall and trees that were in this location prior to construction (Figure 25).
- The projects environment and sustainability dashboard was shared (Figure 26), this was an interesting insight to the type of metrics being tracked on the Project.
- Two examples were seen of the use of QR code posters around the site allowing site crew to easily submit values awards, and ideas (Figure 27).

Figure 22 High Speed Two – Euston, Area East view 1 of 3.

Figure 23 High Speed Two – Euston, Area East view 2 of 3.

Figure 24 High Speed Two – Euston, Area East view 3 of 3.

Figure 25 High Speed Two – Euston, Area East hoarding artwork installation.

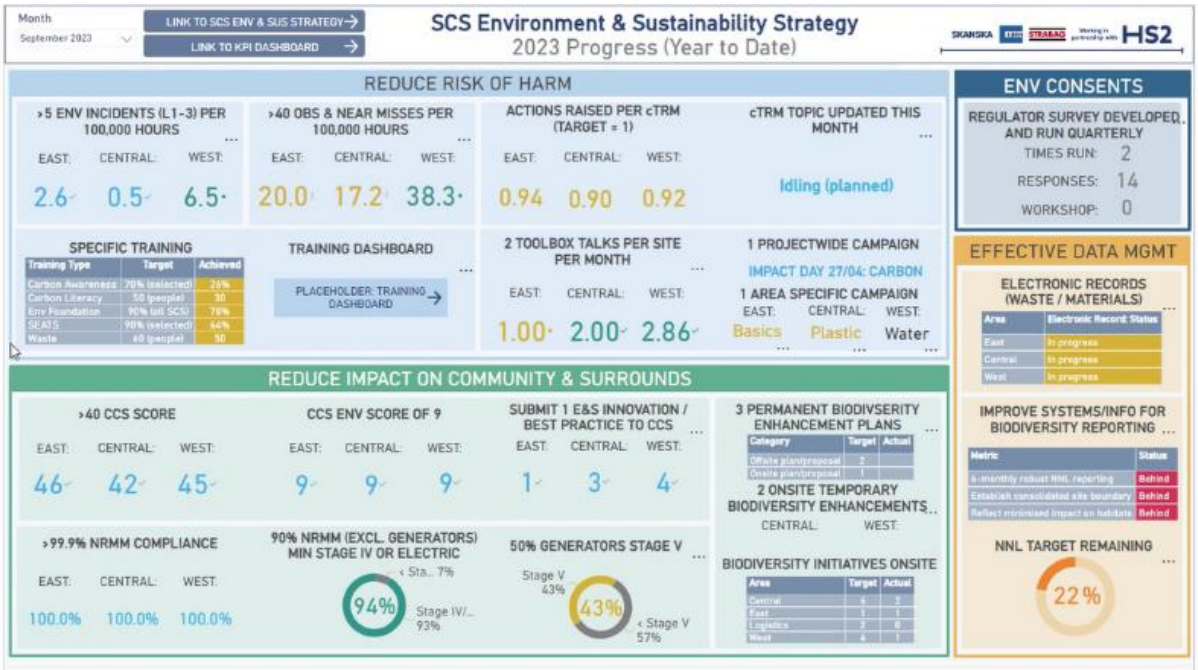


Figure 26 Environment & Sustainability dashboard for SCS Railways on HS2 Project.

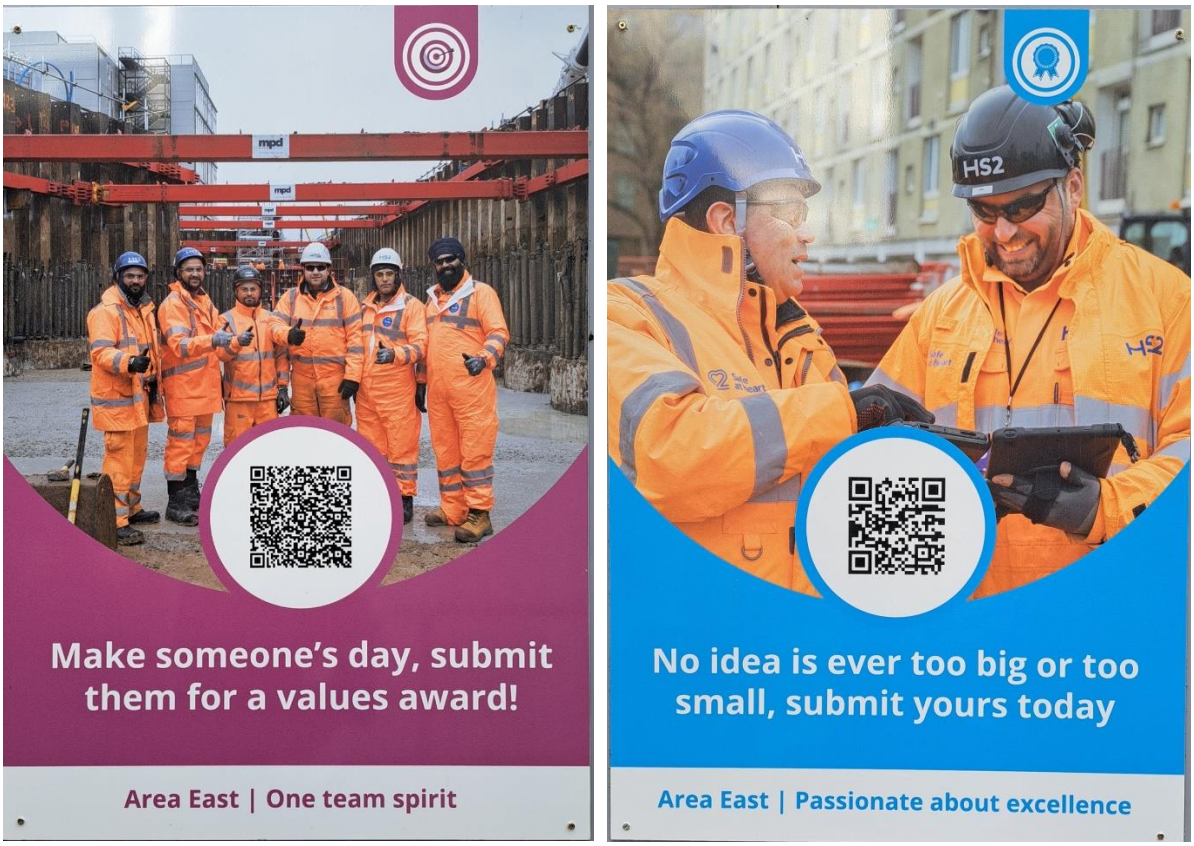


Figure 27 High Speed Two – Euston, Area East simple QR code posters around the site allowing site crew easily to submit values awards, and ideas.

5. Thames Tideway Tunnel, Tideway East (Chambers Wharf)

On 5 October 2023 I visited the Tideway East, Chambers Wharf site in London with Matthew Gardiner (Environment Manager, Costain Vinci Bachy Joint Venture (CVBJV)).

Insights & Observations

- Design initiatives were limited, but included redesigning the geometry of the shafts, and making the base slab concave rather than a thick slab, reducing overall quantity of concrete/rebar (Figure 29). Also reduced the thickness of the secondary lining, which avoided 11,800 tonnes carbon.
- TBM water system was closed loop, with all water treated onsite, and recycled through the system. Other initiatives, such as water harvesting from all sheds/roofs onsite, were observed; this is a standard set up for all sites.
- Tunnelling methodology required the shafts to be flooded to create pressure within them for the TBM to operate. Large volumes of water were taken off mains water supply (~23,000 m^3), however, for the Abby Mills Shaft the project managed to obtain consent to abstract 23,000 m^3 from the River Lee and discharge it afterwards.
- Due to some very stringent noise limits at Chambers Wharf, the project had to electrify the hydrofraise machine and connect to a local substation. Came at a significant cost, however, huge benefits in terms of carbon, air quality, and noise.

- Behavioural idling initiative implemented on this site. Broad range of benefits delivered including noise, air quality and carbon. However, ongoing engagement required to continue to deliver benefits.
- The project worked with a community wood recycling company who collect used wood and use it to train people on how to work with wood, and any waste goes to be made into sawdust for animal beds.

Figure 28 View into the huge shaft at Tideway East, Chambers Wharf site – 28m wide, and 60m deep.

6. High Speed Two, Birmingham (BBVJV)

On 6 October 2023 I visited Sublot 4 and 5 of the HS2 Project in Birmingham with Papa-Samba Drame (Head of Environment & Sustainability Design, BBVJV) and Jamie Clancy (Environmental Coordinator, BBVJV).

The BBVJV Area North is made up of several sublots, overall, the route is 95km long, and includes over 200 major structures (bridges, viaducts). Construction started in 2021 and is due to be completed in 2025 (Figures 29, 31-32).

Insights & Observations

- Achieved 42.4% reduction in whole of life carbon emissions to date (against a target of 50%). The majority of savings have been design-related, for example, removed a retaining wall, made changes to steepness of slopes/required earthworks, and reduced

the quantity of lime content required for soil stabilisation (3% standard, 2.25-2.5% demonstrated to work just as well through trials).

- Engaged with a company that takes chrysotile roof sheets and denatures the asbestos fibres to create a dry and inert product, called Calmag, which can be used as a cement replacement. BBVJV plan to trial Calmag in their temporary works.
- Some innovation around dust suppression, using Aqua Eco sprayer boom resulting in savings of water consumption by 40%, and 80 m^3 per day/per boom.
- Several examples of solar powered equipment onsite, e.g., solar powered security system (Figure 30).

Figure 29 Washwood Heath (Sublot 4) BBVJV pictured from left Jamie Clancy (Environmental Coordinator, BBVJV), Papa-Samba Dramé (Head of Environment & Sustainability Design BBVJV) and Sarah Sutherland.

Figure 30 Washwood Heath (Sublot 4) solar powered security system.

Figure 31 Sublot 5 BBVJV.

Figure 32 Sublot 5 BBVJV showing extent of earthworks in this section of the network.

7. Paris Olympics Village, Saint Denis, Paris

On 11 October 2023 I visited the Paris Olympics Village with Ariyada Souvanlasy (Environmental Project Manager, Vinci Construction) and Karen Bernard (Environmental Manager, Vinci Construction) (Figure 33-35).

This project chose to transform 6.4 hectares of former brownfield land (industrial wasteland) into the Athletes Village, the underlying concept was to use what already existed, and add to this, to reduce the carbon footprint of construction (95% of the sites that will be used in Paris are existing venues or temporary structures). By 2025, all buildings and facilities will be converted into housing, offices, and shops where approximately 12,000 people will live, aiming to revitalise the Saint Denis district.

Insights & Observations

It was evident during the visit that there was a strong focus on low carbon building, adapting to climate change and enabling reversibility in design to support the post games legacy of delivering a sustainable community for the area. With the overall ambition to achieve a carbon footprint 40% lower than that of a conventional building.

Low carbon building/climate change adaptation initiatives included:

- Preference for wood and low carbon concrete in the buildings, e.g., ultra-low carbon concrete used for floor slabs; timber used in structural support for buildings as well as for facades and floors.
- Recycled concrete was used as ballast on the site and mixed with compost to form a base layer for the gardens.
- The Seine River was used to transport excavated material.
- A water recycling system was set up to collect and reuse rainwater and wastewater that can be used on the gardens.
- High-performance insulation and sunshades were used, as well as reversible underfloor plumbing linked to a local geothermal power plant that draws cool water from beneath the surface during the summer and heat in the winter in place of air-conditioning units in every room.

In addition, I saw recycled materials in use for the fit out of the accommodation facilities, including things like bed bases made from reinforced cardboard and mattresses made from recycled fishing nets and the reuse of old carpet (10-year-old) in rooms. Modular partitions are planned to be removed and reused following the games, and salvage/reuse of all other furniture and fittings has been preplanned. The only barrier that they shared was around the reuse of the bathrooms, as they are one block unit, and have found little interest in reuse of this design.

Figure 33 One of the accommodation buildings for the athletes – showing recycled concrete used in the façade of building and the gardens, recycled wood in walkways, and the overall water sensitive design of garden areas, providing green spaces and habitat for wildlife (e.g., bat boxes).

Figure 34 Close up of the recycled concrete used in the building's façade.

Figure 35 View of garden area which is under construction, including the extensive irrigation system to support watering with treated wastewater year-round.

8. Western Sydney Airport

On 16 October 2023 I met with Meg Wrixon, Sustainability Consultant (Wrixon Consulting Ltd), to discuss the Western Sydney Airport Project.

Bulk earthworks construction of Western Sydney Airport involved moving around 25 million cubic metres of earth over the 1,780-hectare site to support the construction of the airport including the runway and terminal. While I didn't visit the site, a few insights to the project best practises included:

Insights & Innovations

- A compaction control system was retrofitted to the compactor to allow real time machine tracking, paired with customised grade control system to achieve design grade when spreading material (one pass only, compared to an average of 3 passes). The adaptation of this technology made the compactor the first in the world to diverge from standard industry compactor use. In this non-BAU scenario, the compactor grades material to within +/- 20mm of design grade, avoiding the need for a grader to follow. This delivered social (safety through plant minimisation), environmental (fuel reduction), economic (cost reduction) and quality (greater precision in material level) benefits.
- Achieved 99.5% replacement of potable water with non-potable. This involved utilising temporary and permanent drainage structures to capture rainfall which could

then be used for dust suppression and other construction processes. Key basins were selected based on location and accessibility to have standpipes with smart meter attachments installed to provide a trackable fill point for water carts.

9. Sydney Metro, Central Station, Laing O'Rourke

On 17 October 2023 I visited Sydney Metro, Central Station with James Stevens (Sustainability Consultant, Jacobs) and Alyssa Slaney (Project Sustainability Manager, Laing O'Rourke).

The Sydney Metro, Central Station is an underground station, located within the existing Central Station precinct. It is a critical interchange, connecting the station with suburban, intercity, and regional rail services, buses, coaches, and light rail. The project includes new underground platforms, escalators to suburban platforms, and an upgraded northern concourse with transformed pedestrian throughfares. Construction started in 2018 but was largely completed at the time of my visit.

Insights & Observations

- The finishes in the Station concourses and platforms were very impressive. This appeared to be due to the height of the ceiling (17m above the platforms due to some clever engineering), and the design, with the beautifully lit Glass Reinforced Concrete (GRC) walls designed to echo the sandstone used in the original station above, built in 1906 (Figures 36-37).
- An interesting heritage installation was viewed inside Central Station which tells the story of the Devonshire Street Cemetery which was on this site from 1820 to 1901. An aerial map of the area has been printed onto the wall (Figure 38), and objects which have been found in the soil of the cemetery from the late 1800s are embedded in the map (Figures 39-40).
- Public art is a key part of Sydney Metros placemaking approach. The racetrack art installation in Central Stations North-South Concourse (Figure 36) is one of the largest art installations pieces to be installed inside an Australian railway station. Its reflective of an athletics track and evokes the constant flow and circularity of daily life (supporting intuitive navigation through the station environment). The red colour and materiality of the artwork is also intended to reflect upon Central Station's built heritage acknowledging the former ticketing office and brickwork of the northern concourse facades.
- This was the first construction project in Australia to specify GECA certification for their waste collection services, an independent third-party lifecycle ecolabelling scheme.

Figure 36 Central Stations 140m long North-South concourse featuring a 'racetrack' art piece by artist Rose Nolan called "All Alongside of Each Other".

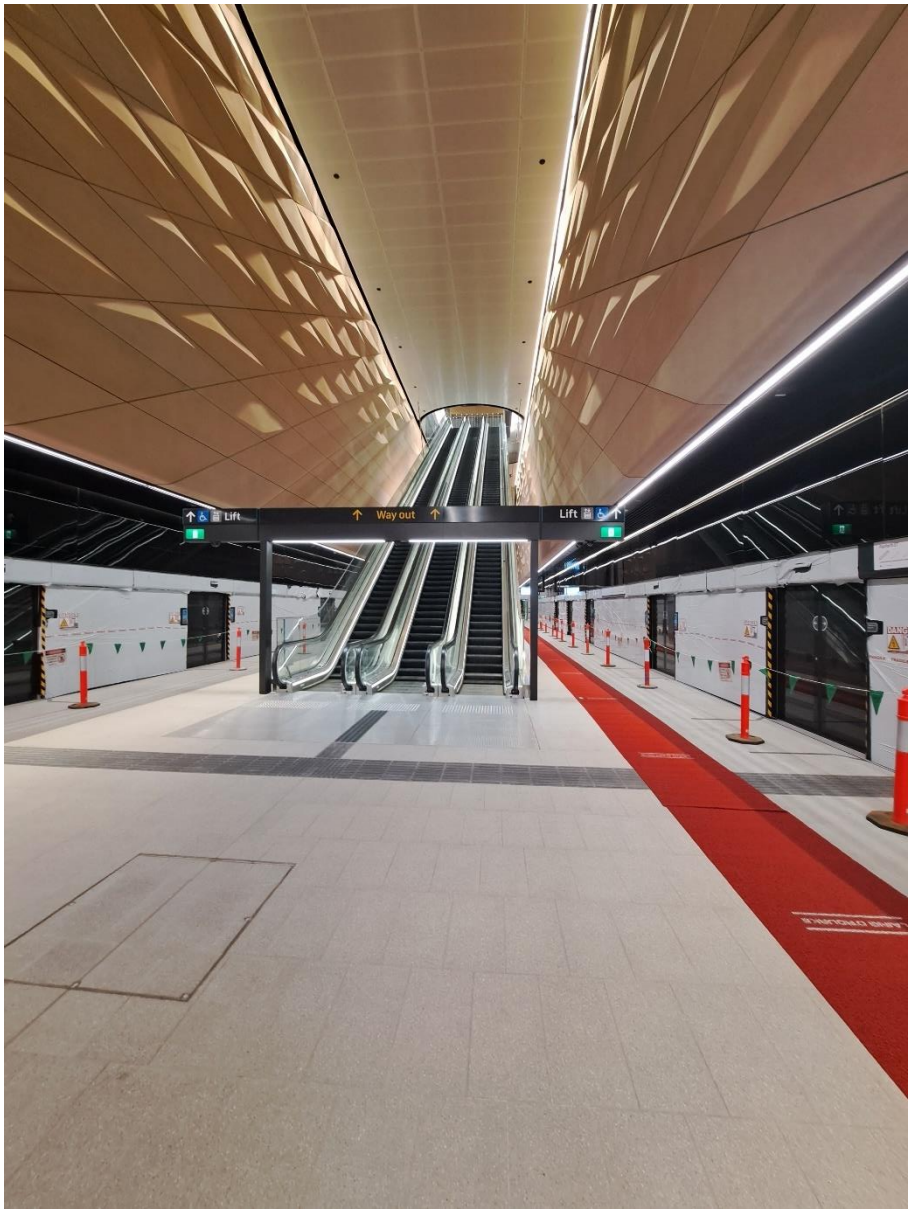


Figure 37 Platform level at Central Station showing GRC sandstone finishes and use of light.

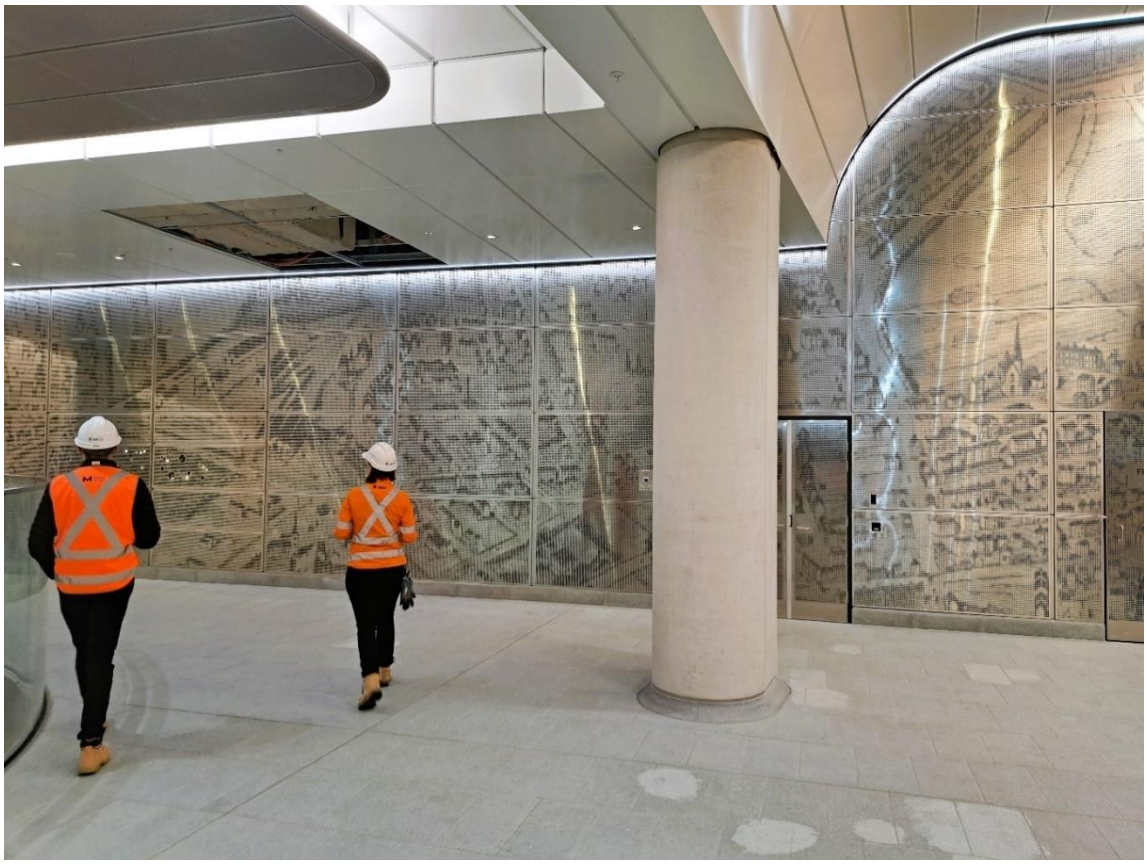


Figure 38 Aerial view of the site from 1879 showing the Devonshire Street Cemetery.

Figure 39 Inset into the aerial map are viewing windows displaying objects found during excavations for the new Metro Station.

Figure 40 Examples of the objects from the late 1800s embedded into the map wall.

10. North Western Programme Alliance, Preston/Bell Station

On 20 October 2023 I visited Preston and Bell Stations, which are part of the North West Programme Alliance (NWPA) with Fiona Bowie (Director Transformation and Sustainability, John Holland Group).

NWPA is one of the four ongoing program Alliances established by Victoria's Major Transport Infrastructure Authority (MTIA) (previously, Level Crossing Removal Authority) to deliver the Level Crossing Removal Program. Construction commenced in 2017 and involves a programme of incremental contract award. I visited the fully operational Preston and Bell Stations.

Insights & Observations

- The raised station at Preston and Bell Station had created new green open space and connections through shared pathways (Figure 41).
- The bright facade at Preston Station features a barcode that is meant to reflect the vivid colours of the produce found in Preston Market (Figure 42). At Bell Station, the façade incorporates pastel-coloured acrylic panels which reflect inside the station (Figure 43-44).

- Integrated into each station are solar panels (providing around half of the stations energy requirements at Preston Station), rainwater reuse, and smart lights (lights with motion detectors) which dim during low activity.
- The Project was required to optimise the use of recycled and reused materials as part of the Victorian Government's Recycled First Policy. Many great examples of this, e.g., the use of e-mesh (recycled plastic) in concrete in footpaths and cycle routes (in place of steel mesh reinforcement or virgin polypropylene fibres); use of PolyPave in the Preston car park which incorporates up to 50% reclaimed asphalt, pavement, recycled glass sand and recycled plastics.

Figure 41 View of Preston Station showing the elevated station enabling space for shared pathways, and green spaces

Figure 42 View of Preston Stations bright façade, with barcode design

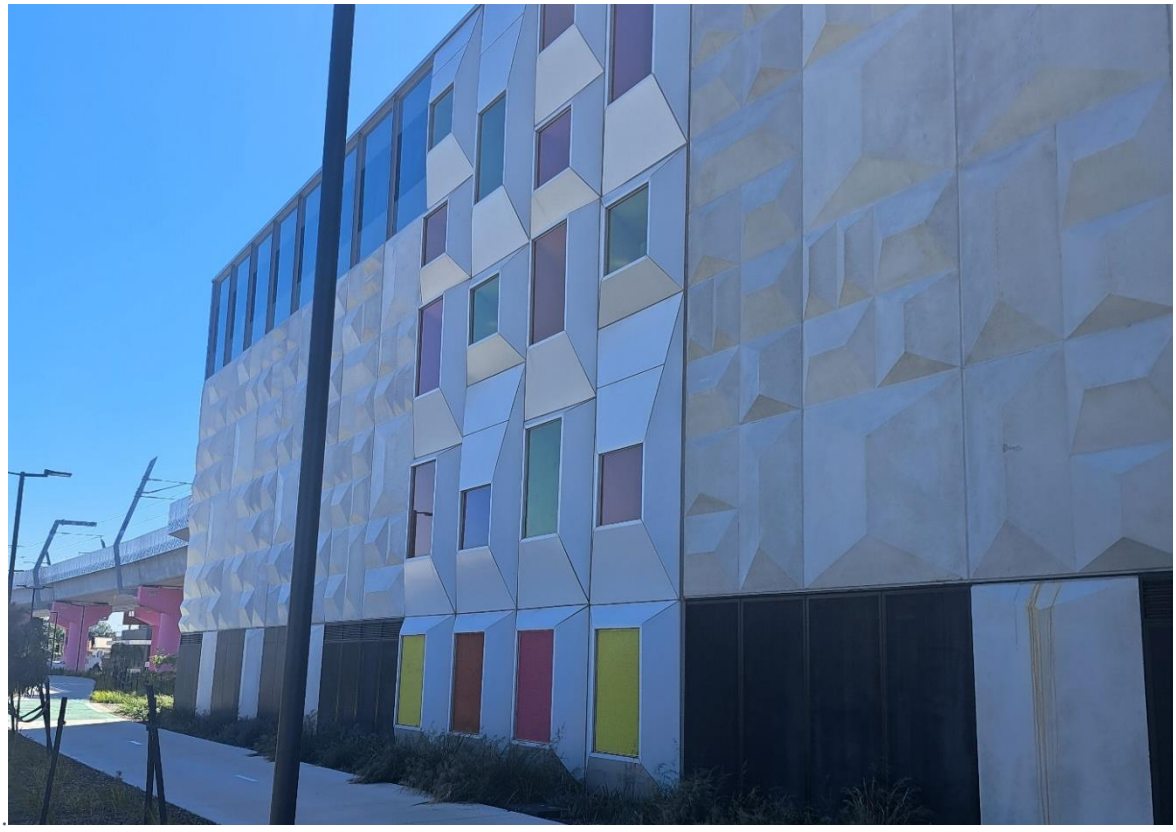


Figure 43 View of Bell Stations façade showing the pastel-coloured acrylic panels which reflect inside the station (as shown in Figure 43 below).

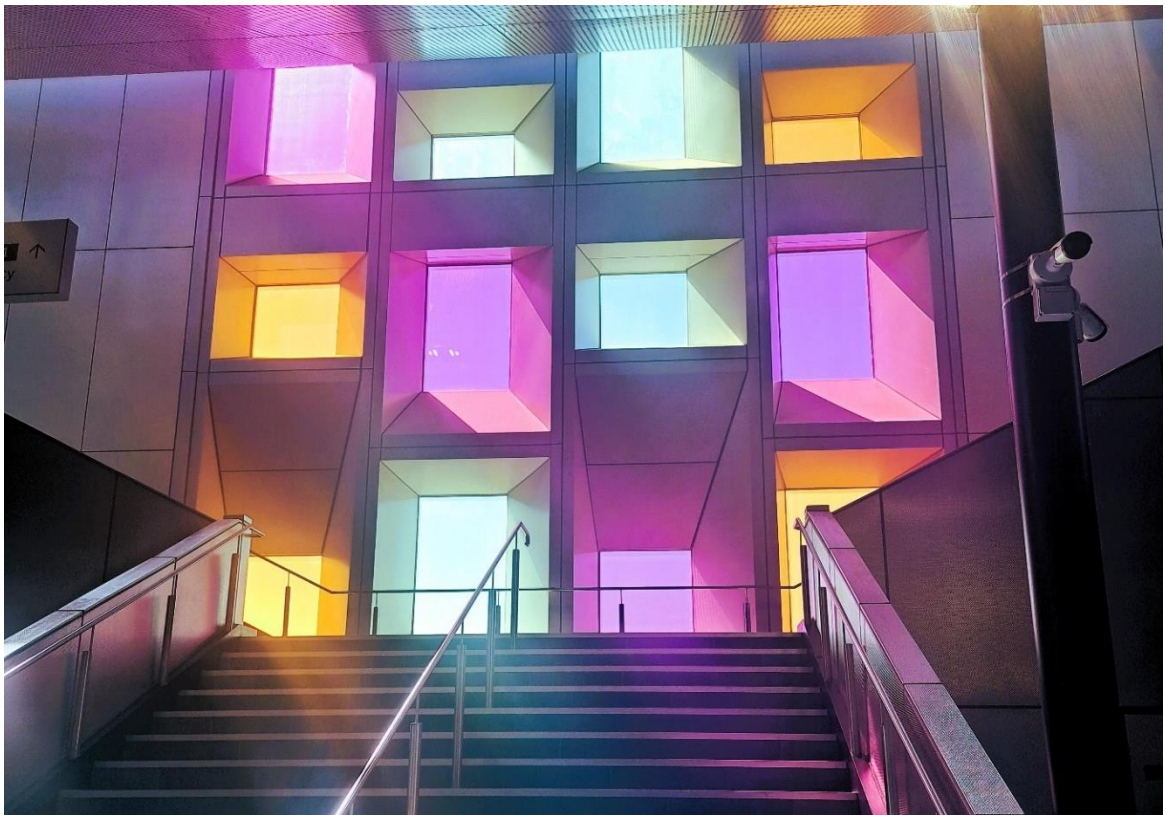


Figure 44 Inside Bell Station.

Figure 45 Aboriginal design elements in the public spaces between Preston and Bell Station – yarning circle pictured to the right.

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