DecarboN8

Place-based decarbonisation for transport

Integrating embodied carbon into transport infrastructure scenarios

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April 2022

Reference as:

Giesekam et al. (2022) Integrating embodied carbon into transport infrastructure scenarios. Leeds: DecarboN8. DOI: https://doi.org/10.48785/100/132

www.decarbon8.org.uk

UKRI Engineering and Physical Sciences Research Council

This project was supported by DecarboN8. DecarboN8 is funded by the EPSRC Energy Programme, grant agreement EP/S032002/1.

Executive summary

This report summarizes the aims, objectives and results of a DecarboN8 Seedcorn funded project completed in 2021. The project sought to develop resources that could support greater incorporation of capital (embodied) carbon emissions into transportation models and scenarios.

Owing to a number of challenges related to data access, data quality and processing resource requirements, the project failed to deliver the primary intended outcome – an open and extendable prototype web resource on capital carbon emissions in transportation projects. However, the project did develop a large novel dataset and successfully delivered a number of the intended secondary outcomes. Subsequently, the links forged and insights gained throughout the project ultimately resulted in a successful funding bid to support further development in collaboration with key stakeholders.

Datasets compiled under the project were incorporated into development of a new database and spatial tool under the Department for Transport's Shared Digital Carbon Architecture (SDCA) programme, in turn informing strategic decision making within Government departments and Arm's-Length Bodies. The opportunity to deliver this subsequent high-impact project would not have arisen without stakeholder engagement supported by the DecarboN8 Seedcorn fund and the Centre for Research into Energy Demand Solutions (CREDS).

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Introduction

Transforming the North of England requires increased investment in new transport infrastructure whilst meeting ambitious national carbon reduction targets. Data on the carbon emissions from construction and maintenance of infrastructure assets (known as 'embodied emissions' or 'capital carbon') are increasingly routinely gathered during construction projects but not incorporated into the long-term modelling and scenario analyses that inform strategic plans as there is no comprehensive single data source for modelers to reference. These capital carbon emissions in infrastructure already exceed 10 $MtCO_2e/yr$ and are likely to increase with future infrastructure development [1]. As well as increasing in absolute terms with record levels of anticipated investment, under highly decarbonised 'net zero' scenarios such embodied emissions increase in relative significance over time as emissions from the operation and use of infrastructure assets decline. Therefore, quantifying the scale and potential for mitigation of capital carbon, is an important, but currently poorly understood, component of scenario analysis.

This seedcorn project sought to develop the prototype of an open extendable tool for the transport modelling community, including a database detailing the capital carbon embodied in different construction materials, products, components, projects and asset types. The project team intended to demonstrate the tool through estimation of the impacts of future scenarios for transport infrastructure in the North, including both the construction of new assets and maintenance of existing roads and railways. The primary objective was to develop a prototype which could subsequently be developed (with further funding) into an impactful resource that could support a range of stakeholders, including national and sub-national transport bodies, in integrating capital carbon into their scenario analyses and strategic planning.

This project report provides further details on the context, activities undertaken, results and subsequent developments, including further funding.

Context

The project was proposed and undertaken against a backdrop of four key trends, in addition to the global Covid-19 pandemic:

1. Growing stakeholder focus on decarbonization of infrastructure
2. Increasing investment driving increased capital carbon
3. Mixed progress in carbon assessment and reporting
4. Lack of integration of capital carbon into strategic models

This section briefly recaps the key features of these trends, placing the seedcorn project in context.

Growing stakeholder focus on decarbonization of infrastructure

The greenhouse gas emissions associated with the development, operation, use and subsequent disposal of infrastructure assets are significant. In 2013 HM Treasury's Infrastructure Carbon Review (ICR) estimated that infrastructure emissions accounted for over half of the UK's total carbon footprint in 2010 [2]. Data compiled for a 2020 update of this estimate by the Institution of Civil Engineers, suggests infrastructure emissions still accounted for 54% of the UK's carbon footprint [3]. Of this estimated ~420 $MtCO_2e$/annum, around 100 $MtCO_2e$ arises directly from the construction, operation and maintenance of infrastructure assets, with a further 320 $MtCO_2e$/annum arising from the use of these assets. Although these emissions have reduced over the past decade, they are not declining at a rate that is consistent with achievement of the UK's 5^{th} & 6^{th} Carbon Budgets over the coming decade [3]. A recent 7 year on review of the ICR by the Green Construction Board – titled 'Good progress but not fast enough' [4] – neatly encapsulated recent developments in carbon management and mitigation within the sector.

The growing urgency of decarbonization is reflected in the recent strengthening of national and organizational targets and a spate of associated strategies. In addition to the UK's target of achieving net zero greenhouse gas emissions by 2050, the Government published a number of key strategies and plans throughout the duration of this project. At the outset, the Department for Transport had commenced development of its Transport Decarbonisation Plan [5]. However, as indicated in the initial white paper, the greenhouse gas emissions associated with construction of transport infrastructure were declared outside of scope, "noting their consideration in other policy areas". The subsequent plan [6] consequently predominantly focused on emissions from operation and use of transportation infrastructure. Many of the Arm's-Length Bodies (ALBs) also recently developed and moved into the early stages of implementing long term sustainability or 'net zero' strategies, such as National Highways [7] and Network Rail [8]. Leading sub-national bodies, such as Transport for the North (TfN), were also in the early stages of developing detailed decarbonization strategies at the outset of this project (subsequently published as [9]). The construction industry and its supply chains have also engaged in development of a number of increasingly ambitious decarbonization initiatives, such as the Construction Leadership Council's CO2nstruct Zero programme [10] and the Net-Zero Infrastructure Industry Coalition [11].

The Infrastructure and Projects Authority have been at the forefront of promoting additional assessment and mitigation of whole life carbon emissions on Government projects. For example, implementing new requirements for whole life carbon assessment set out in the 2020 Construction Playbook [12], and issuing additional guidance on Best Practice in Benchmarking on Government projects [13]. Their efforts to improve the quality of carbon measurement and management and facilitate best practice sharing have been supported through recently formed fora such as the Government Construction Metrics Working Group and initiatives such as the Transport Infrastructure Efficiency Strategy (TIES) Living Lab programme [14].

Collectively all of these strategies, guidance and knowledge sharing platforms are indicative of a growing focus upon decarbonization of infrastructure assets. This is expected to further accelerate in the years to come as these strategies are translated into additional policies, client requirements and practical actions.

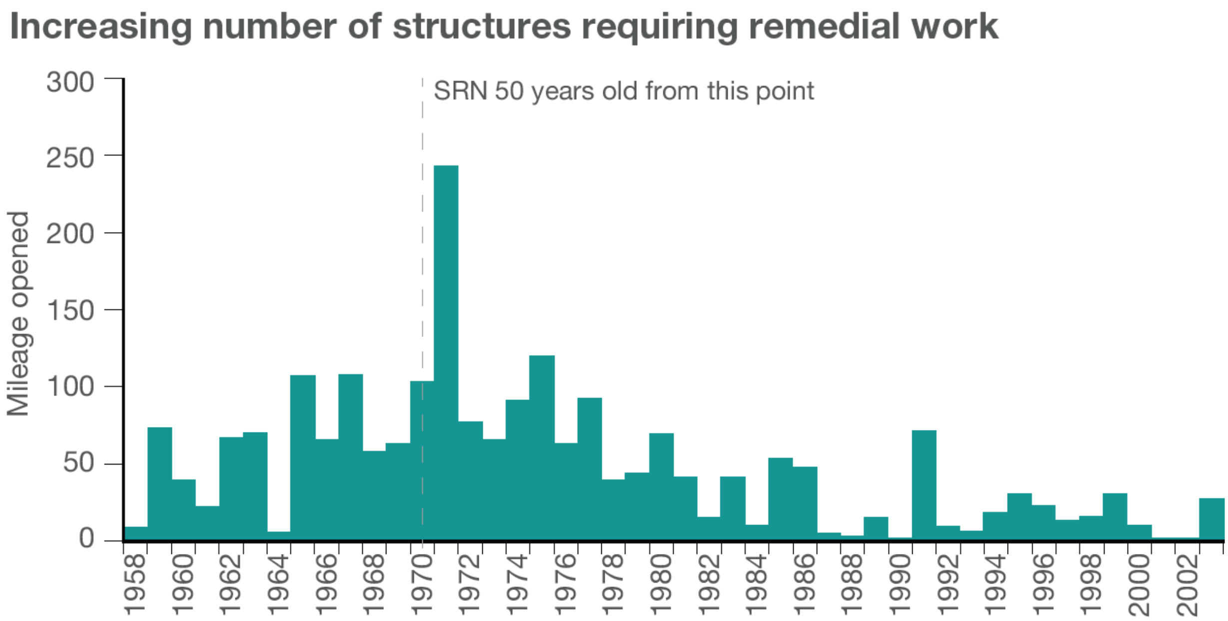
Increasing investment driving increased capital carbon

Nationally, the UK Government is currently undertaking – and expects to continue – a significant expansion in infrastructure investment [15], [16], for example, through record levels of investment in roads [17]. Indeed, according to analysis by the Climate Change Committee (CCC), all net zero pathways for the UK require extensive changes and investment in new infrastructure [18]. Others groups, such as the Net Zero Infrastructure Industry Coalition, have highlighted the increased capital carbon anticipated to accompany these record levels of expenditure [1].

More locally, rail demand in the north of England has more than doubled in the past two decades, with road trips also increasing by 8% in the 5 years up to 2019 [19, p. 64]. Prior to the pandemic, TfN's Northern Transport Demand Model scenarios anticipated a further 26-54 % road growth and 60-327 % rail growth to 2050 [19, p. 69]. Overcoming existing capacity constraints and improving connectivity will require significant investments in new and existing infrastructure assets. For instance, TfN have suggested a Long Term Investment Programme in major road and rail projects of the order of £60-70bn in the period up to 2050; supplemented by increased investment in local transport of £50-60bn [20].

In addition to this, works must be undertaken to maintain and improve the North's existing assets - including 85,580km of roads, 3,800km of rail track, and 575 rail stations. The age profiles of existing infrastructure assets also suggest significant phases of additional maintenance activities in the years ahead, corresponding to past cohorts of investment. For instance, the Strategic Road Network saw a significant expansion within the 1970s which is expected to require substantial remedial works (see Figure 1).

FIGURE 1 – MILEAGE OPENED ON STRATEGIC ROAD NETWORK BY YEAR [17]



Collectively this combination of increased new construction and additional maintenance activities are expected to drive an increase in construction works, material use and associated capital carbon emissions.

Critics have already questioned the consistency of planned investments with stated decarbonization objectives [21] and a number of proposed schemes have been subject to legal challenges to the associated Development Consent Orders (DCOs). Balancing the need for new and refurbished infrastructure to support growing transport service demands within the ever tightening constraints of carbon budgets thus presents an increasingly difficult challenge for policy makers. An effective and legally robust response necessitates the full consideration of associated impacts (including capital carbon) within strategic scenarios and routine detailed calculation of impacts from the earliest stages of all project business cases.

Mixed progress in carbon assessment and reporting

The measurement and mitigation of capital carbon has been increasingly embedded into project processes in recent years by organisations responsible for the delivery and maintenance of road and rail assets. However, these processes are still far from routine and there is substantial variability in the standards, tools, and underlying data sets that are used in practice. Recent carbon measurement and management standards, building upon BS EN 15978, have sought to bring greater consistency. One of the most prominent examples is PAS 2080 [22], a publicly available specification and associated guidance [23] describing best practice in carbon management on infrastructure projects. The current PAS 2080 stages are set out in Figure 2 for reference – though it should be noted that a revised version of the PAS is under development at the time of writing and is expected to refer to the upcoming standard BS EN 17472.

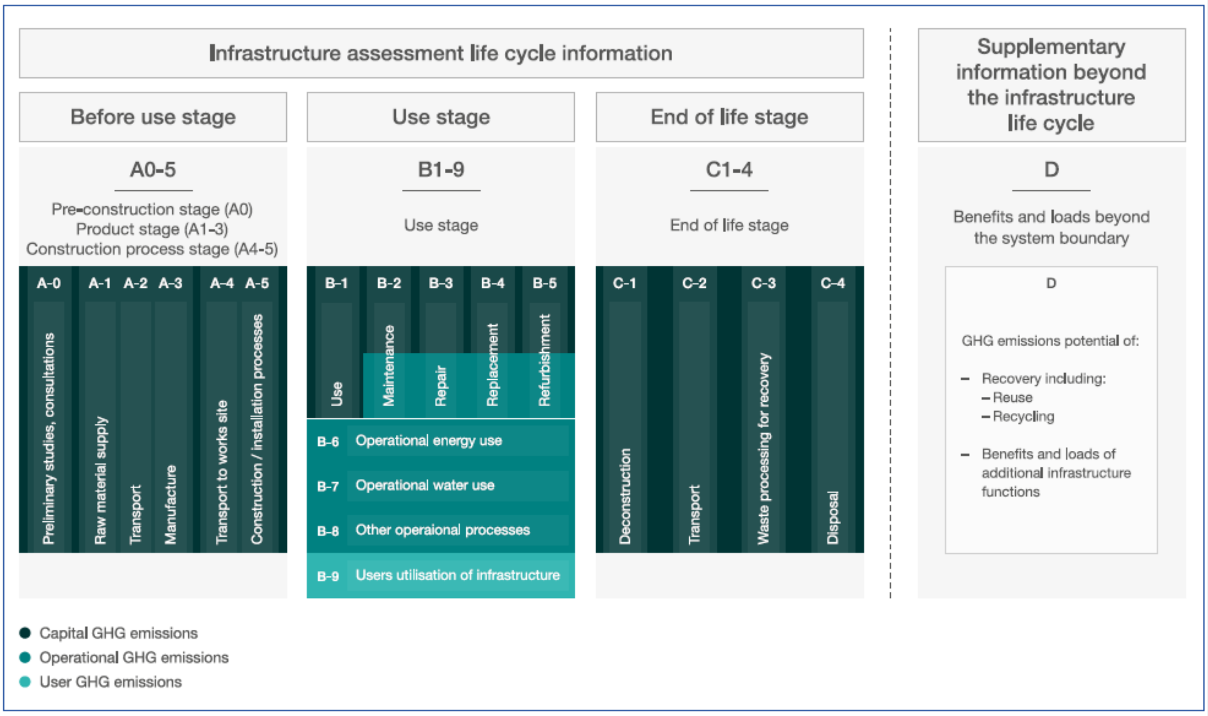


FIGURE 2 – INFRASTRUCTURE LIFE CYCLE STAGES AND INFORMATION MODULES BASED ON PAS2080:2016

These modules increasingly represent the routine way of reporting emissions for infrastructure projects. However, it should be noted that even this specification allows a degree of flexibility, for example in the reporting of emissions from the use stage, which may be designated as either capital or operational emissions in accordance with the roles and responsibilities of the organization conducting the assessment. Beneath this, the classification of particular assets, components and materials can accord with a variety of different, and often bespoke, standards. Recent efforts to produce greater consistency in the presentation of construction life cycle emissions, such as ICMS3 [24] – a cost measurement standard endorsed by an international coalition of 49 surveying institutions – have yet to be implemented. In the meantime, many organisations (such as National Highways) have proceeded with embedding their own classification systems within reporting mechanisms. The granularity and internal consistency of these classifications varies according to the carbon maturity of the organization. See the recent Green Construction Board review [4] for a more detailed description of the present mixed picture of carbon maturity across the industry.

The picture is further complicated by ongoing efforts to update the underlying European standards, such as EN 15978, and recent attempts to ensure greater consistency in the approach used across buildings and infrastructure assets. For example, through the ongoing update of the RICS Professional Statement on Whole Life Carbon Assessment for the Built Environment [25] and the revision of IEMA's guidance on assessing greenhouse gas emissions and evaluating their significance [26]. Though the rapid evolution of these standards should support more robust and consistent carbon assessment, reporting and management in future, in the short term it is challenging for many stakeholders to navigate this evolving standards landscape without specialist support. These rapid changes also present challenges with interpretation of historic datasets (discussed further in the 'Results & reflection' section of this report).

The project stage at which the measurement of carbon is undertaken is also of critical importance as the ability to influence reductions typically declines throughout a project's progression (as indicated in Figure 3).

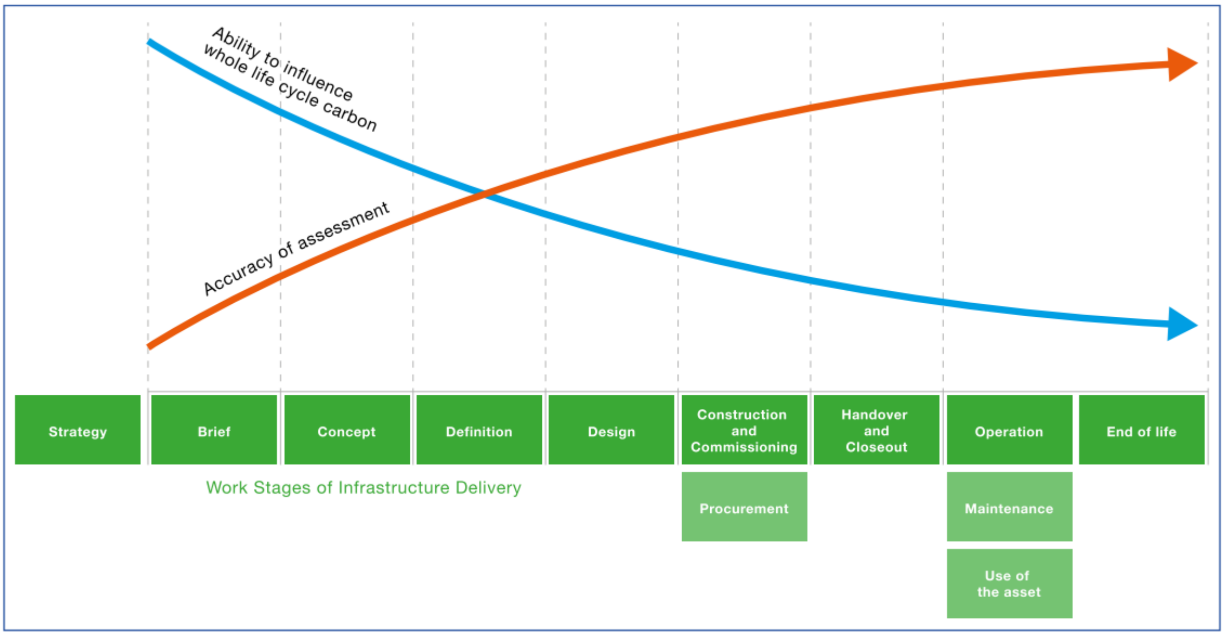


FIGURE 3 – CONCEPTUAL DIAGRAM SHOWING THE ABILITY TO INFLUENCE CARBON REDUCTION ACROSS THE DIFFERENT WORK STAGES OF INFRASTRUCTURE DELIVERY FROM PAS 2080:2016

In practice, estimates of the capital carbon associated with project development are often only compiled at late project work stages, typically after a single preferred option has been determined, with the first estimate typically forming part of the environmental statement submitted to secure planning permission. This estimate may be subsequently revised, however, often the largest opportunities to reduce capital carbon (e.g. through optimized route alignment) have already passed. There are also numerous current examples of projects wherein the estimate of capital carbon at this stage is of a very crude nature. For instance, the recent capital carbon assessment for the Portishead Branch Line of the MetroWest programme (currently under examination by the Secretary of State) was based entirely upon a single benchmark of 42 tCO_2e/£100k from 2013 covering only the A1-A3 life cycle stages [27].

Much of the more detailed reporting of capital carbon typically occurs after construction, for example through supplier returns.

Collectively these evolving standards, classification systems, and differences in organizational carbon maturity, make it challenging for non-carbon specialists (such as transport modelers or policy analysts) to easily interpret the information arising from carbon assessments.

Lack of integration of capital carbon into strategic models

Although the average carbon intensity of UK construction works declined substantially throughout the 1990s and early 2000s, analysis by the UKGBC suggests that gains over the past decade have been marginal at best [28]. Future roadmaps for the construction sector and its supply chains anticipate substantial reductions in the carbon intensity of key materials, such as cement and steel, can be delivered through the adoption of new production technologies. However, given the relative immaturity, high capital costs, long asset lifetimes and slow production stock turnover, it is not anticipated that these technologies will deliver deep reductions until well into the 2030s [28]. Therefore the opportunities to mitigate the impending increase in capital carbon emissions due to increased investment (outlined in prior section of this report) primarily depend upon strategic decisions around the level of service provision and corresponding asset requirements, transport mode, project route, design and specification. As per the CCC's analyses, major infrastructure decisions *"need to be made in the near future and quickly implemented"*, but *"just how much infrastructure will need to be developed in each sector will depend on decisions on the pathway to achieving net-zero emissions"* [18]. Policy makers thus have a range of strategic choices which will be the primary determinant of capital carbon emissions over the coming decade or more. However, whilst assessment of capital carbon has become increasingly routine on construction projects (as per previous section) it is rarely incorporated into transport models and long-term scenarios. A brief review of key models informing strategic decision making at the outset of this project, failed to identify any substantive incorporation of capital carbon within the models that matter.

The data to support such integration is scattered across a range of sources and no central resource exists for the modelling community. This seedcorn project thus set out to transform the currently disparate data on the capital carbon of products and projects into a single go-to open source resource that can be used by the modelling community. A similar approach has previously been applied to materials for building projects with marked success – the Inventory of Carbon and Energy (ICE database), having >25,000 users. Indeed the ICE outputs are foundational to many of the ALBs' current carbon assessment tools.

DecarboN8 CREDS

Project overview

This section provides a brief overview of the project team, aims and objectives and the methods applied.

Project team

The project had a small part time team comprised of two members with expertise in life cycle assessment within the construction industry and one data scientist with an expertise in geospatial data analysis and transport modelling (see Table 1). Additional support was provided by the Centre for Research into Energy Demand Solutions (CREDS – grant reference number EP/R035288/1) through additional researcher time and support from a research assistant.

TABLE 1 – PROJECT TEAM

Individual	Organisation	Role
Dr Jannik Giesekam	University of Leeds *(now University of Strathclyde)*	Research Fellow *(now Chancellor's Fellow)*
Dr Jonathan Norman	University of Leeds	Senior Research Fellow
Dr Robin Lovelace	University of Leeds	Associate Professor of Transport Data Science
Samuel Betts-Davies	University of Leeds	Research Assistant

Aims & objectives

Upon commencement, the project had four principal objectives:

1. Compile an open and extendable prototype resource detailing capital carbon emissions factors for products, components, projects and asset types.
2. Generate capital carbon benchmarks[1] for physical assets, capital investments, and units of service provision.
3. Demonstrate application of these benchmarks to a future scenario.
4. Develop understanding of stakeholder needs through engagement, with the intention of developing a final product through a future funding bid.

The primary outcome was intended to be delivery of the open source prototype resource of capital carbon data for transportation infrastructure. This resource was intended to be of

[1] It was envisaged that the benchmarks may need to be expressed through a mix of physical (e.g. $kgCO_2e$/km of road or $kgCO_2e/m^2$ Net Internal Area for transport hubs) and financial units (e.g. $kgCO_2e$/£ of contract value). The ultimate aspiration was to express benchmarks for assets relative to service provision (e.g. embodied $kgCO_2e$/passenger km) where sufficient data could be sourced.

potential use to a range of stakeholders, including the transport modelling community (within academia and government), strategic planners, regulators and those involved in the delivery and maintenance of transport assets. The secondary outcomes focused upon identification of future development opportunities, partnerships, and applications.

Stakeholder engagement

The project's delivery hinged upon the quality of the stakeholder engagement and participation. Key organisations engaged directly through calls and workshops are listed in Table 2. Additional exchanges were made by email with a number of local authorities, transport operators, consultants and contractors.

TABLE 2 – KEY STAKEHOLDERS ENGAGED

Organisation	
Department for Transport	Infrastructure and Projects Authority
Network Rail	Skanska
Highways England	BAM Nuttall
RSSB	Arcadis
Transport for London	Mott MacDonald

Initial engagements sought to understand the details of any relevant procedures, tools and information held in relation to estimation or reporting of capital carbon emissions. Subsequent exchanges centered around securing access to relevant data sources. Feedback on the intended project outputs was also sought, including potential user needs.

Efforts were also made to publicize the project aims and outputs through relevant working groups (such as the Net Zero Infrastructure Industry Coalition Embodied Carbon Working Group) and through a series of invited presentations including: a Department for Transport Symposium for Transport Decarbonisation; a meeting of the Department for Transport Scientific Advisory Council; and a Department for Transport Executive Committee meeting. A secondary goal of these presentations was to raise the profile, and prompt further consideration, of capital carbon amongst these stakeholders.

Results & reflections

This section summarizes the results and the challenges encountered in project delivery.

Data compilation

Data was compiled from 92 sets of sources[2] including a wide range of academic studies, project environmental statements, industry studies (including roadmaps, reporting & sustainability strategies), carbon factor databases (e.g. Inventory of Carbon and Energy) and bespoke carbon assessment tools (e.g. Highways England Carbon Tool). To the authors' knowledge, the resulting dataset represented the most comprehensive inventory of capital carbon data on UK transportation projects compiled to that point in time[3].

The majority of the data sources were in the public domain with additional data sourced from stakeholders engaged throughout the project. Typically this focused upon a small number of specific projects or data compiled across an organization on key materials (e.g. sprayed concrete) or average emissions intensities of different work types across a portfolio (e.g. earthworks). Some stakeholders identified datasets which they were willing to make available for validation purposes but which could not be released into the public domain (i.e. through the intended repository). Some primary datasets were also developed based upon cross-sections of common simple assets that accorded with design standards (e.g. the quantities and mixes of asphalt required for sub-base, binder and surface courses for a typical section of pedestrian-only pavement in accordance with DMRB CD 239 - Footway and cycleway pavement design [27]).

Approaches were made to secure access to the only other comparable datasets in scale and scope – those held internally by ALBs (e.g. National Highways carbon tool returns) and a multi-modal set compiled under the Transport Infrastructure Efficiency Strategy (TIES) Living Lab. The TIES carbon dataset itself suffers from a number of well documented limitations [29]. Access to these sources could not be secured in the project timeframe, and initial discussions with stakeholders often highlighted additional challenges (such as a lack of back-end platforms for automated data compilation or split ownership of data between clients, assessment tool providers and users). For instance, the RSSB Rail Carbon Tool[4] – which has become the default tool for the majority of large rail industry projects (excluding high speed projects such as HS2) – contains data representing in excess of 1000 projects. However, permission to access the data is required from each user under the terms of the tool – making it exceptionally difficult to obtain a large sample without a new mass approach to securing

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[2] Each set comprised the range of resources available from a single source. For example, the project Environmental Statements available through the PINS site would constitute a set.
[3] This was subsequently superseded by the dataset assembled under the Department for Transport's Shared Digital Carbon Architecture programme – discussed in the section on 'Subsequent development & funding'
[4] Available with a registered account at: www.railindustrycarbon.com

permission or amending existing user agreements. The data itself contains a mix of forecast, retrospective, full and partial assessments. A sizeable minority of the projects are also likely to be dummy and sandbox projects, placeholders used for testing the tool or impromptu backups or variations prepared by users. Furthermore, the project trees within the tool do not share a common format (as the tool allows for layers specified by the user) making comparison between projects (e.g. for benchmarking) exceptionally difficult.

Much of the data gathering required time consuming manual data extraction owing to the evolution, and in some cases lack, of standardized project carbon reporting. For instance, amongst the transport schemes designated as Nationally Significant Infrastructure Projects (NSIPs), for which data was held within the Planning Inspectorate's database, 7 different assessment standards were adopted and 7 different headline assessment boundaries were observed. This high degree of variation, and evolution of reporting templates over time, prevented automated extraction, significantly increasing the human resource required for data extraction. Much of the project resource was consequently expended trying to compile and standardize data into common formats within each set. For example, the data for all transport projects within the PINS database was compiled to the common structure outlined in Table 3 overleaf.

The example in Table 3 is indicative of the challenges in compiling such historic data in a consistent manner as standards have evolved considerably. In this example the reporting (although relatively comprehensive for a carbon assessment conducted in 2014), does not provide a breakdown by EN15978 life cycle stages, instead using the CCMP categories that were common for highway carbon assessments of that period. This results in either no classification of A4 & A5 emissions for comparison purposes, or an incorrect simplification of all 'transport and logistics' emissions being attributed to A4 – despite this total including HGV movements on-site that would now typically be considered under A5. Numerous similar challenges that required common assumptions or additional interpretation of granular results were encountered across each set of sources.

Owing to the wide range of formats and content, no attempt was made to combine all sets of sources into a universal data taxonomy. Based upon the data gathered, the development of such a taxonomy would be a substantial undertaking in its own right, even if building upon international standards such as ICMS3 [24]. It is unclear whether retrospectively applying such a taxonomy would enable sufficiently greater extraction of value from historic datasets to justify the corresponding resource. However, the value of moving swiftly towards adoption of such a consistent taxonomy for new projects is abundantly clear.

TABLE 3 – EXAMPLE PROJECT ENTRY INDICATING CHALLENGES WITH HISTORIC DATA

Metadata	Example
Lead organisation	Highways England
Project name	A14 Cambridge to Huntingdon Improvement Scheme
Project summary	The A14 Cambridge to Huntingdon improvement scheme involves the improvement and upgrading of a 23-mile length of strategic highway between Cambridge and Huntingdon, the widening of a 2-mile stretch of the A1 between Alconbury and Brampton, and the modification and improvement of the associated local-road network within this corridor
Link to documentation	Environmental Statement Appendix 13.2: Carbon assessment - https://infrastructure.planninginspectorate.gov.uk/wp-content/ipc/uploads/projects/TR010018/TR010018-000797-A14%206.3%20ES%20Appendix%2013.02.pdf Also summarised in Report 3 Carbon emissions - https://infrastructure.planninginspectorate.gov.uk/wp-content/ipc/uploads/projects/TR010018/TR010018-001914-HE-A14-EX-30%20ExAQ1%20Report%203%20Carbon%20Emissions.pdf
Type of project	Road (improvement)
Project stage	Decided
Notes	Breakdown provided by CCMP categories only (waste, transport, materials, energy) not EN15978 modules. Therefore A1-A3 total assumed to be combination of waste, materials and excavation categories; A4 corresponding to transport and logistics; A5 to energy (site offices and other fuel use).
Carbon assessment standard used	Highways Agency Carbon Calculation for Major Projects 2013
Carbon assessment tool used	Highways Agency Carbon Calculation Tool
Carbon assessment tool version	Not stated – assessment conducted in 2014 and tool version uses ICE v2

Life cycle stages included within capital carbon assessment	A1-A5
Assessment coverage	Waste, transport and logistics, materials and excavation, energy
Total capital carbon (tCO_2e)	981432
Materials (A1-A3 tCO_2e)	740343
Transport (A4 tCO_2e)	235979
Construction processes (A5 tCO_2e)	5110
Assessment of capital carbon significance	0.025% of 3rd carbon budget https://infrastructure.planninginspectorate.gov.uk/wp-content/ipc/uploads/projects/TR010018/TR010018-001811-Highways%20England%20-%20HE-A14-EX-26%20-%20Impact%20of%20the%20scheme%20against%20UK%20Government%20Carbon%20Budget.pdf
Expected cost (£m)	1500
Construction period	11/2016-05/2020

A project GitHub repository was established and populated with some R code and initial datasets. These primarily focused on spatial data representing the North's transport infrastructure stock – with the intent of combining this with the carbon data in a subsequent scenario analysis. This includes compilation of appropriate boundary data for the TfN region, extraction of linear assets like motorways, A-roads, B-roads etc and their key parameters (e.g. average width) – see Figure 4 for a summary of the area covered. Some limited work was also undertaken on other aspects of the intended prototype package such as documentation. Unfortunately, owing to the challenges encountered in carbon data gathering and processing, the seedcorn project ran out of resource to complete the public repository (see further discussion in section on 'Challenges encountered').

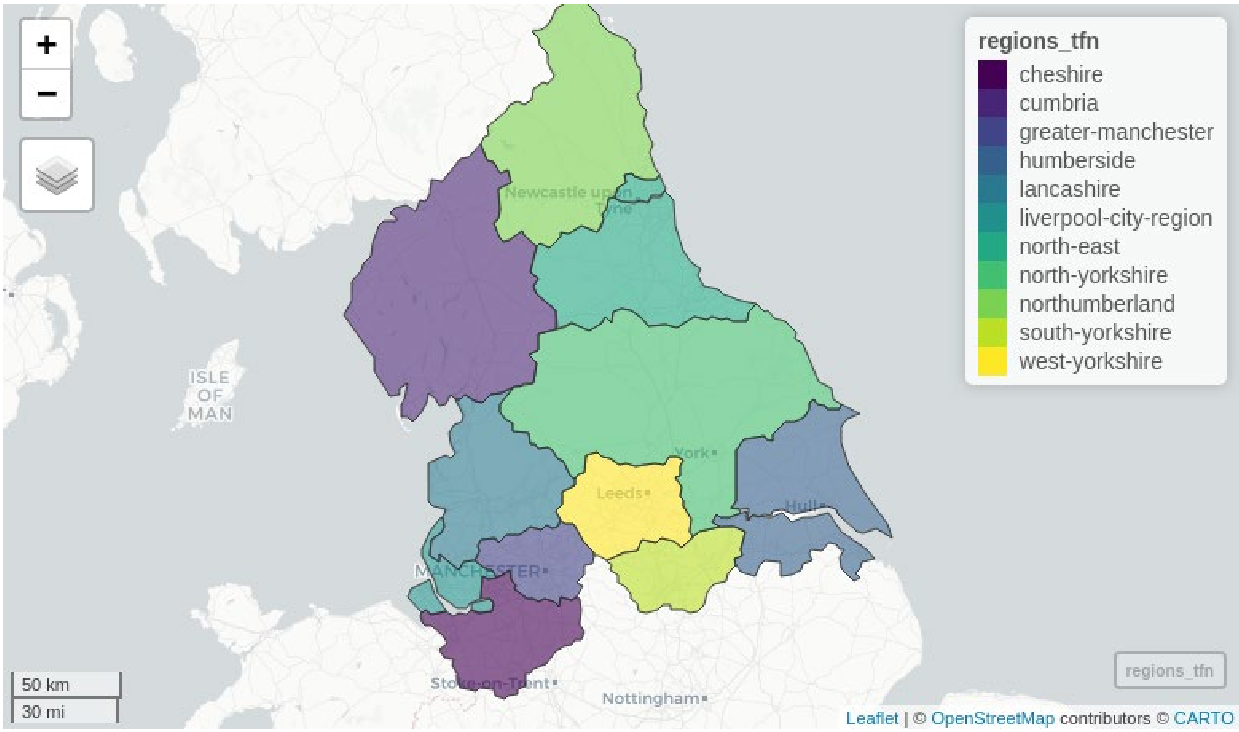

FIGURE 4 – REGIONS FOR WHICH SPATIAL DATA ON INFRASTRUCTURE ASSETS WAS EXTRACTED

Challenges encountered

As indicated in the prior section, the primary challenges centered around access to data, data quality and processing resource requirements. This consequently heavily impacted upon the project timeline and resulted in a significantly reduced scope and set of outputs.

The datasets were typically subject to a greater level of sensitivity than anticipated at the project outset, with recent legal challenges potentially prompting a more cautious approach from key stakeholders. Unlocking such datasets to extract their latent value may require active endorsement or coordination by a major client or regulatory body such as the Department for Transport.

The intent at the project outset was to generate normalised benchmarks for components, projects and asset types. In practice, the generation of benchmarks proved particularly challenging owing to the lack of granularity in carbon reporting and the common absence of corresponding asset or project parameters (i.e. information on the physical characteristics of each project). The parameters against which assets and projects were being benchmarked in practice also appeared to vary substantially between organisations. Any such normalization in further research projects must include greater consideration of spatially explicit elements, as much of the observed variance between projects of a similar type appeared to be due to earthworks, transportation requirements and other factors that are specific to a given site. This significantly limits the ability to generalize without a more detailed approach or spatial model that can routinely account for these differences. Construction of such a model was beyond the scope of this project.

These challenges were further exacerbated by the Covid-19 pandemic, which resulted in a number of key staff members at stakeholder organisations being furloughed or refocused. Most depended upon a relatively small number of carbon specialists whose knowledge was not replicated across the wider organisation. Similarly, given the challenging operating context, many stakeholders who were generally supportive of the project's aims had more immediate priorities and reduced capacity to engage with external research projects.

The failure to secure timely access to data at the project outset meant we were not able to effectively leverage the full skillset of the project team, as much of the intended geospatial processing of data for scenario analysis hinged upon the successful compilation of sufficiently granular input data on associated materials and emissions. Consequently, the focus of the project turned towards assembling as much data as practicable in the available timeframe and establishing links that could support further development. The intended online resource remains unfinished at the time of writing and will remain so with the subsequent incorporation of datasets into another tool (discussed in the section on 'Subsequent development & funding').

Opportunities identified by stakeholders

Throughout the project, stakeholders repeatedly reaffirmed the need for better resources to support capital carbon assessment, particularly in earlier project development stages and within strategic models. Many noted that when a carbon assessment is undertaken, it often occurs too late in the planning process to enable significant changes in design. Some stakeholders also reflected that the data they had previously gathered was primarily for reporting and had not been leveraged for other purposes. There is a clear opportunity to extract some of the latent value from these datasets provided appropriate access (with suitable disclosure agreements etc.) can be arranged.

Though unsuccessful in delivering its intended primary outcome, the seedcorn project confirmed that there is an opportunity to better mitigate the capital carbon impacts of transport infrastructure by producing tools that help decision-makers understand the impacts earlier, drawing on the body of assessment data produced to date.

Subsequent development & funding

Following expiration of the seedcorn project funds, a small amount of additional time for further data processing was provided by CREDS. All of the project delivery team were also separately funded by CREDS for other research projects at the time.

Subsequently, much of the project data was incorporated into the development of a new spatial tool for whole life carbon estimation within the Department for Transport's Shared Digital Carbon Architecture (SDCA) programme. The SDCA is a 2 year cross-government project funded by HM Treasury's Shared Outcomes Fund intended to support a more joined-up approach to infrastructure decarbonisation across Government. The project is led by the Department for Transport with a broad range of Partners including National Highways, Network Rail, Environment Agency, Department for Business, Energy and Industrial Strategy, Infrastructure and Projects Authority, Department for Levelling Up, Housing and Communities, Homes England, Department for Education and others. It is focused on reducing legal challenge, delivering sustainable communities, visualising carbon policy trade-offs and harmonising carbon reporting across government. The SDCA will pilot a shared carbon system amongst Partners through development of a primary reporting platform and a range of secondary tools.

Researchers from the University of Leeds with input from the University of Strathclyde, Oxford University & several consultancies are developing one of the secondary tools. Development of the tool was funded with an award of £358,149.72 in response to an invited tender from the Department for Transport to produce a 'Digital platform to visualize cross-sectoral infrastructure carbon impacts'. The project will benefit from combining datasets and contacts established during the DecarboN8 seedcorn funded project with the active involvement of a range of SDCA Partners, and the significant influence of the Department for Transport. It is anticipated that this will assist in overcoming a number of the challenges encountered in the seedcorn project around access and resource. The project also builds upon other outputs from CREDS including the Place-Based Carbon Calculator[5].

Work on the new tool commenced in October 2021, with an alpha version scheduled for completion in 2022. A full overview of work undertaken in the initial development phase can be found in a recent paper presented at the 54th Annual Conference of the Universities' Transport Study Group [30]. An example screenshot from the tool can be seen in Figure 5 overleaf. In this example the tool user is estimating the whole life carbon impact of a new cycle scheme. The tool combines a typical material build-up based on historic project data with context-specific geospatial data (such as transport demand and terrain) to estimate the construction, maintenance, and use emissions for various types of infrastructure. A wide

[5] Free tool available at https://www.carbon.place/

range of contextual data is also incorporated into the tool under the 'explore data layers' dropdown. In this example the user has turned on flood zones to assist in route design. Following input of all associated assets in the design pages of the tool, headline results are presented back to the user on the summary tab. Results are broken down in further detail on adjacent tabs by type, time of occurrence, and the details of the calculation (e.g. all individual material inputs, carbon factors etc.). Though access to the tool and primary datasets are restricted under the terms of development, much of the code that underpins calculations conducted within the tool is open-source and freely available[6]. Further development of the tool is anticipated throughout 2023.

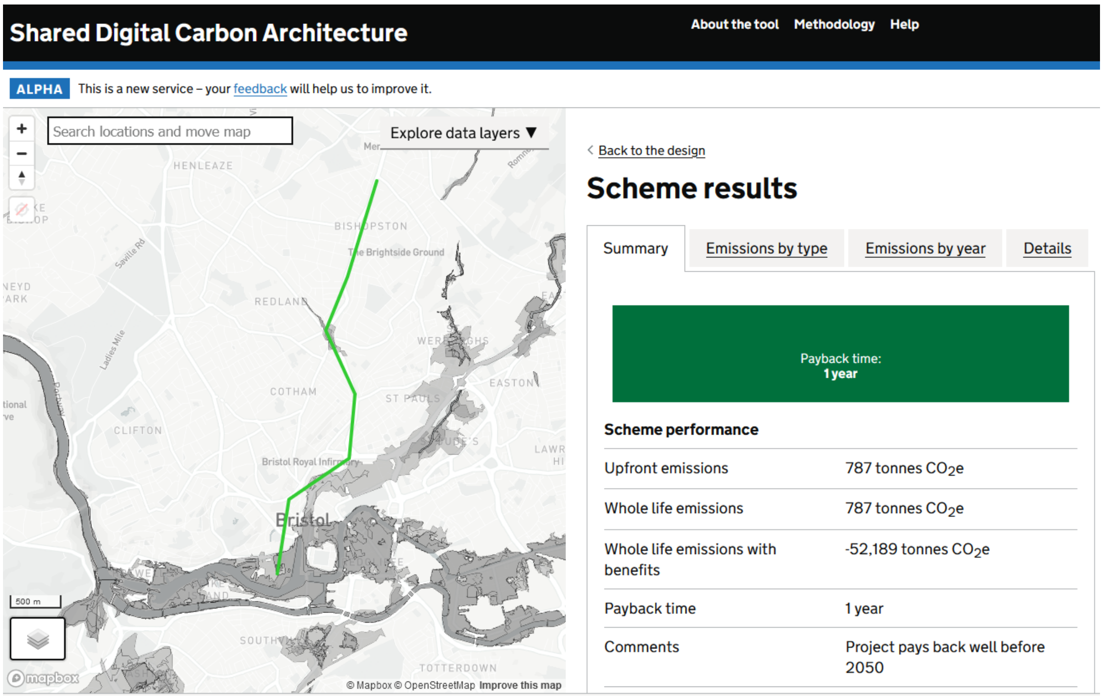

FIGURE 5 - SCREENSHOT FROM THE PROTOTYPE TOOL SUBSEQUENTLY DEVELOPED UNDER THE SDCA PROGRAMME.

[6] Repository available at https://github.com/SDCA-tool

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