Carbon Infrastructure Transformation Tool Project

EXECUTIVE SUMMARY REPORT – NOVEMBER 2019

HOSTED BY **VOLVO CONSTRUCTION EQUIPMENT**

CONSTRUCTION CLIMATE CHALLENGE™

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About the Project

THIS REPORT PRESENTS the main findings from the Carbon Infrastructure Transformation Tool (CITT) research project. The project was funded by the Construction Climate Challenge (CCC), an initiative hosted by Volvo Construction Equipment. The research activities have been performed in collaboration between the Centre for Business and Climate Change at the University of Edinburgh Business School and industry partner Costain Group plc, with input from software experts EnableMyTeam.

The project is made-up of the following five packages:

- **Work package 1** is the development and trialling of an embodied carbon calculator for infrastructure projects
- **Work package 2** tests the completeness of the tool for identifying reduction opportunities
- **Work package 3** identifies possible social and institutional barriers to the tool's adoption, and identifies solutions
- **Work package 4** explores different potential frameworks for incentivising supply chain carbon management
- **Work package 5** investigates uncertainty representation strategies and develops decision support models

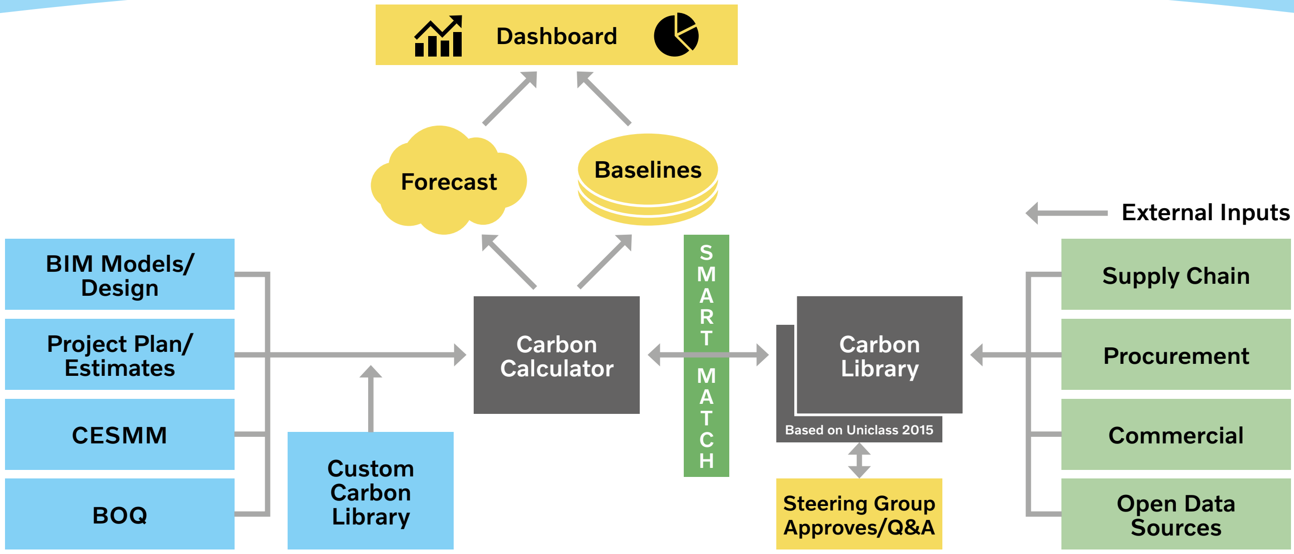
WE EXPECT THAT the results from the project will be useful for clients, design teams, estimators and contractors for specifying, measuring, and reporting carbon reductions. The results of the research will also be useful to developers of carbon calculation tools, for identifying areas for future development, and understanding the wider sectoral context for maximizing the effectiveness of tools.

Research Team
Centre for Business and Climate Change, University of Edinburgh Business School: Dr Matthew Brander; David Jackson (PhD candidate); Dr Kathi Kaesehage; Dr Francisco Ascui; Professor Roberto Rossi.
Costain: Dr Noemi Arena; Zoë Rogers; Tim Embley
EnableMyTeam: Sandeep Jain

Work Package 1. Carbon Infrastructure Transformation Tool

Researchers: Noemi Arena, Sandeep Jain, Zoë Rogers, Tim Embley

THE CARBON INFRASTRUCTURE TRANSFORMATION TOOL (CITT) measures the embodied carbon emissions of infrastructure projects, i.e. the emissions associated with producing the materials used, by integrating emissions data with outputs from estimators, planners and BIM technicians. This provides a bottom up, granular assessment of the carbon impacts of an infrastructure project at the resource level, with the aim of simplifying carbon assessment and intervention processes for all users. Whilst there are several carbon management tools available to industry, few integrate with contractors' costing and planning processes. The consequence is that assessments are either too high level for any reliable insight or lead to increased labour costs for data input. The intention with the CITT solution is that no additional time is taken to identify the "hot-spots" of a project, delivering a step change in carbon management on infrastructure projects (see BIM: Building Information Modelling; CESMM: Civil Engineering Standard Method of Measurement; BOQ: Bill of Quantities below for an overview of the structure of the tool).



BIM: Building Information Modelling; CESMM: Civil Engineering Standard Method of Measurement; BOQ: Bill of Quantities

Figure 1. Structure, inputs and outputs for the tool and carbon library.

Benefits

- **Focus on resources:** The CIT tool provides granularity of key impact areas and associated costs, making business case development simple.

- **Rapid calculations:** Integrated data sets mean carbon impacts are quantified as the cost profiles are built, taking no additional time.

- **Supply chain engagement:** Linking carbon to cost allows for a quick assessment of commercial benefits linked to low carbon interventions, leading to quick and easy engagement with suppliers.

- **Managing carbon through time:** Integration of data from the schedule of activities allows for carbon impacts to be tracked and managed on a monthly basis in the same way that cost is, significantly reducing reporting time during project delivery.

Trials

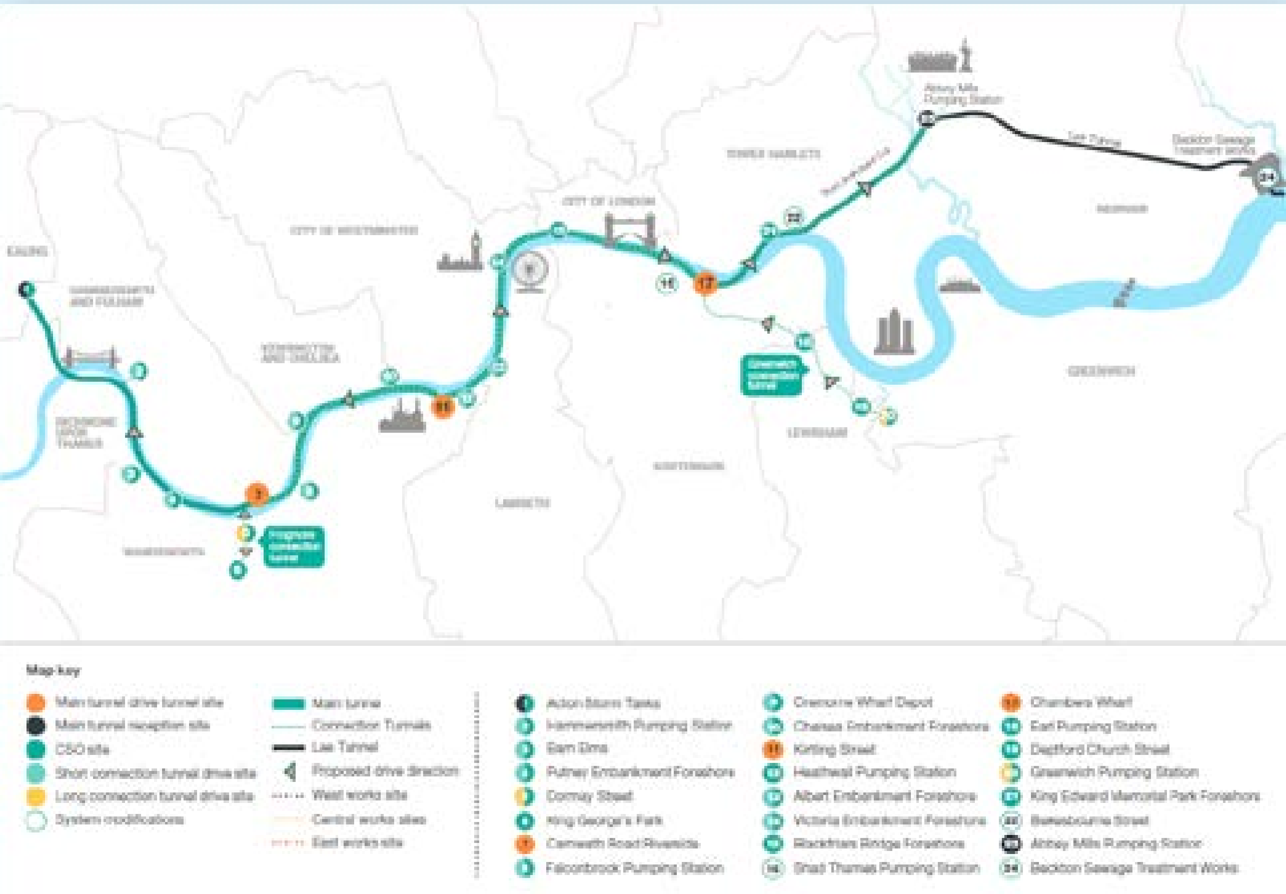
The tool has been trialled and tested throughout various stages of the development, using a wide range of stakeholders to do so. Some examples are listed below:

Thames Tideway, UK

The Thames Tideway project is building a 25km tunnel or 'super sewer' underneath the Thames to help with pollution due to overflowing with high rainfall levels. The initial collaboration with the site was through Costain's carbon managers, who had previously been manually calculating, and re-calculating, carbon for the project. The CITT project team were able to provide a matching process to help take items from the Bill of Quantities and match with a carbon factor. These results provided an appreciation of the scope 1, 2 & 3 carbon sources. This project provided the initial discussions highlighting the need to develop tools which are user friendly and can measure carbon in more detail.

Costain site engineers

The new intake of Costain site engineering graduates trialled the process of collecting a small Bill of Quantities (BoQ) from their projects, uploading them to the tool and testing the matching process. This was useful to understand how user-friendly the tool was and how to add carbon factors of products from suppliers.



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Future Development

- **Smart matching**: A function for automatically matching the BoQ with emission factors has gone through the initial stages of development. This is a key area for future development to ensure the function works on all data sets.
- **Standardising carbon in infrastructure projects:** The project identified the value of developing a standardised carbon library, which can be populated by suppliers or from open source or commercial databases. For example, suppliers of low carbon materials should be able to upload emission factors, allowing planners and estimators to model the reductions achieved by using those materials. This is envisaged as an area for future development.
- **Whole life cycle assessment:** Future development will look to integrate other life cycle stages, e.g. site operation and use-phase emissions.

Further Information

For further information and to register interest in using the CIT tool please visit:
https://carbon.enablemyteam.com/

Work Package 2. The Risk of Burden Shifting from Embodied Carbon Calculation Tools

Researchers: David Jackson and Matthew Brander

Purpose

THIS WORK COMPLEMENTS the development of the CIT tool by addressing the risk that focusing only on embodied carbon may lead to 'burden shifting', i.e. reducing impacts in one part of an infrastructure project's life cycle (e.g. embodied emissions) but increasing impacts elsewhere (e.g. the use phase).

The focus on embodied carbon is common for many tools currently available within the infrastructure sector, and this research is therefore expected to have broad applicability.

Method

TO EXPLORE the possibility of burden shifting due to the use of an embodied carbon calculator we compared the results from the Carbon Infrastructure Transformation Tool (CITT) with a whole-of-life approach for four decision cases aimed at reducing embodied emissions on a rail project.

Findings

IN ALL FOUR CASES the CIT tool calculated a reduction in embodied emissions, thus suggesting that the proposed changes aimed at reducing emissions should be implemented. In three of the four cases, the suggested changes did not have an impact on emissions in other life cycle stages meaning that any reduction in embodied emissions had a net benefit over the asset's lifetime.

However, in the fourth case, where changes were made to reduce the diameter of a train tunnel the results show that the initial reduction in embodied emissions is quickly offset by the increased energy demand of trains going through the tunnel. Depending on the scenario it would take between 6 and 13 years for the upfront emissions 'benefit' to be lost.

These results show that embodied carbon calculators can identify emission reduction opportunities in some cases, but not in all cases.

Recommendations

A PROPOSED SOLUTION to this problem is to combine the use of embodied carbon calculators with a set of heuristics or 'rules-of-thumb' for identifying when burden shifting effects are more likely to occur, and therefore when the use of an embodied carbon calculator would need to be supplemented with a whole-of-life approach (see Figure 2 below).

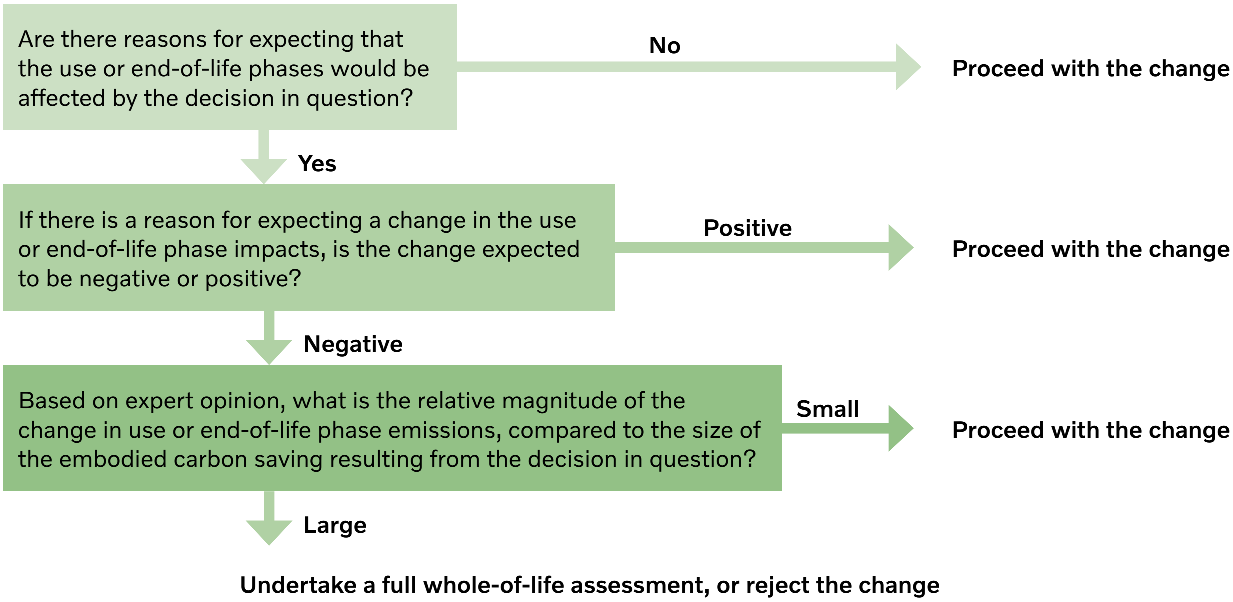
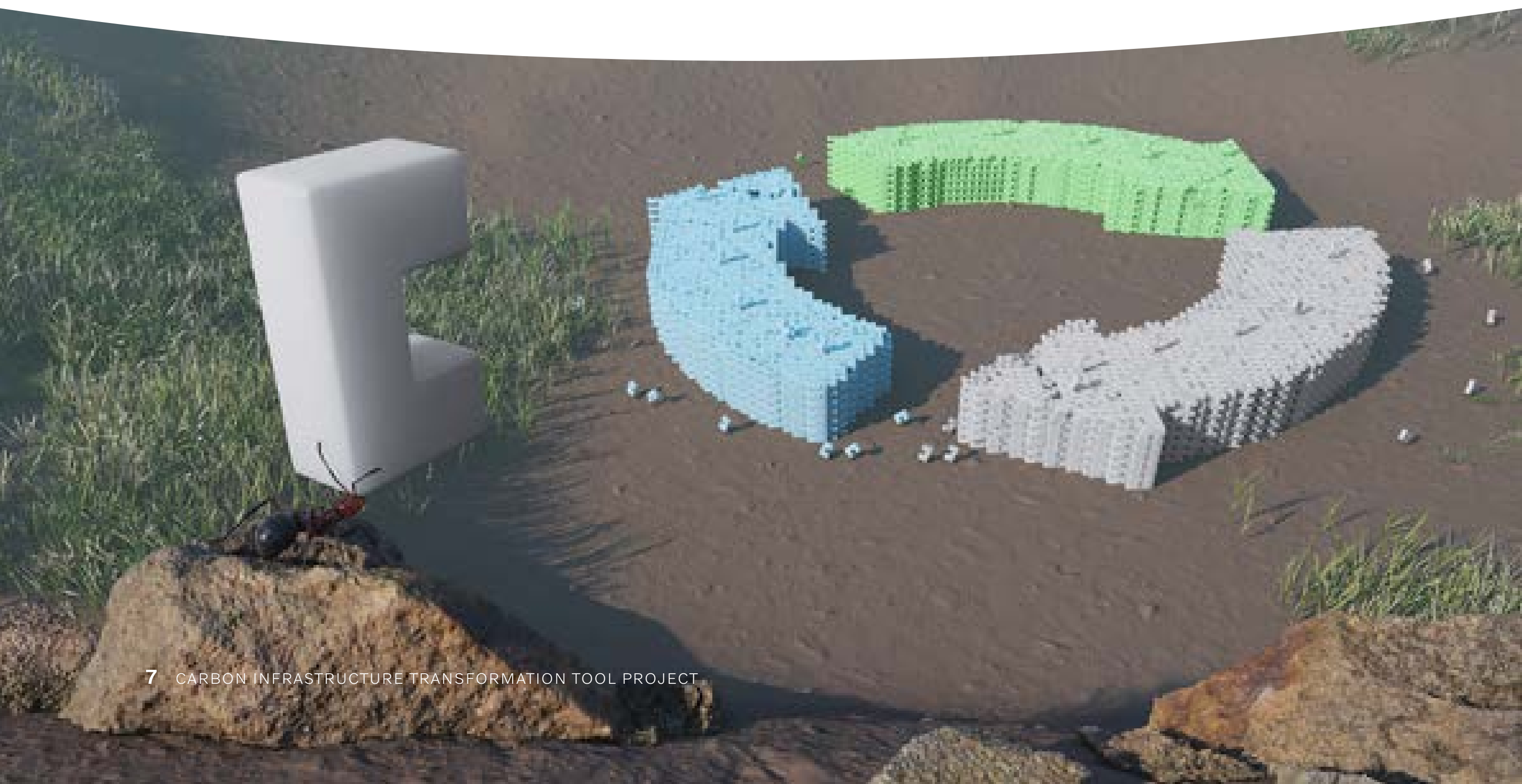


Figure 2. Heuristics for identifying and avoiding burden shifting.

WE RECOMMEND that over time, as skills and capacity for carbon measurement increase, there should be a transition from relatively simple embodied carbon calculators to whole-of-life assessment, and subsequently from whole-of-life attributional life cycle assessment to consequential methods, as such methods aim to capture all changes in emissions caused by a decision, and therefore fully address the problem of burden shifting.

Further Information

FOR THE FULL research article, please visit: https://doi.org/10.1016/j.jclepro.2019.03.171



Work Package 3. Enabling Carbon Management within the Construction Industry

Researchers: David Jackson and Kathi Kaesehage

Purpose

THIS WORK PACKAGE seeks to enhance the use of the CIT tool by exploring the possible social and institutional barriers to the adoption of carbon calculators, and identifying possible solutions.

Method

DATA WERE INITIALLY gathered from two industry workshops where the primary objective was to identify the barriers that hindered the adoption of carbon management practices within the construction industry, and to develop solutions for how to overcome these. To gain a better understanding of the challenges specifically faced within an organisation, 10 interviews were performed with the intention of discovering how carbon management could be implemented within the organization.

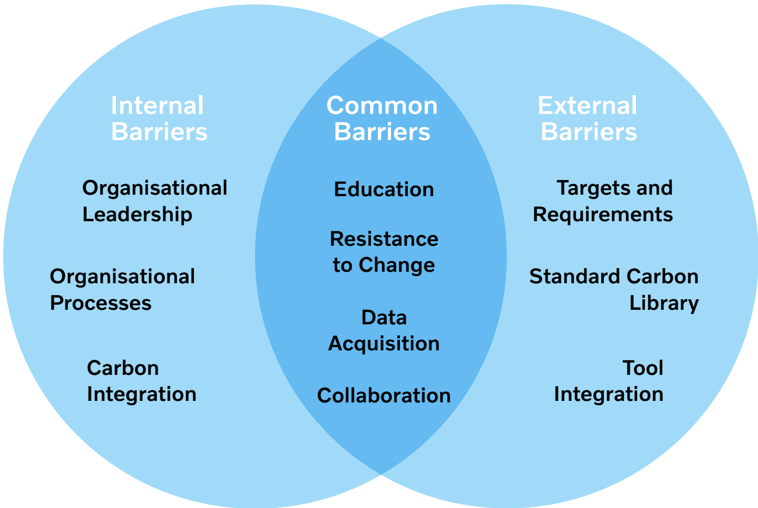


Figure 3. Typology of barriers

Findings

BARRIERS TO THE ADOPTION of carbon management practices were analysed and categorised into three broad areas: External Barriers; Internal Barriers; and Common Barriers (see Figure 3 above). External Barriers are those that the focal organisation has little or no control over, such as government regulation or client drive. Internal Barriers describe issues that can be overcome by the organisation such as leadership or strategy. Common Barriers are issues that require attention both within the organisation and the wider industry, such as overcoming resistance to change and data collection.

Recommendations

TO OVERCOME THESE BARRIERS, we propose the framework shown in Figure 4 below, and suggest three steps for an organisation to adopt carbon management practices:

- **Firstly**, to start there must be external motivation for the organisation to consider carbon management, e.g. through new regulations demanding action or through a client incentivising the organisation to reduce their emissions.
- **Secondly**, the organisation's leadership must take responsibility for carbon management, ensuring that the organisation's strategy aligns to low carbon targets, and encourages collaboration with other members of the supply chain.
- **Thirdly**, carbon management must be fully integrated within each team in the organisation, so that carbon management is not just the responsibility of the environment team, but everyone is taking action to reduce the organisation's carbon impact.

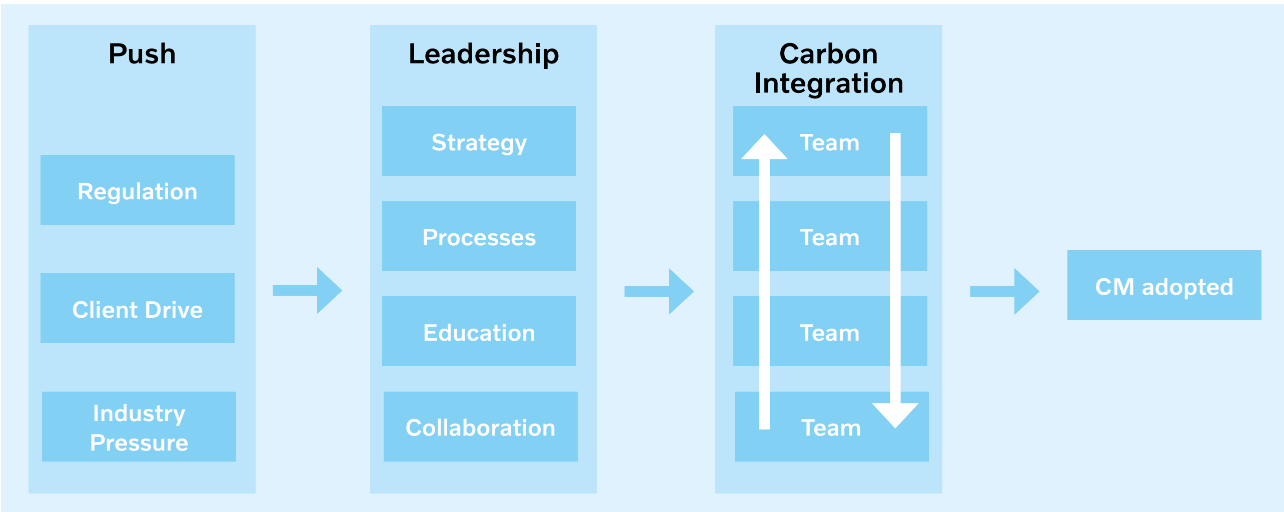


Figure 4. Typology of barriers

Further Information

FOR THE FULL research article, please visit: https://onlinelibrary.wiley.com/doi/full/10.1002/bse.2551

Work Package 4. Achieving Infrastructure Emission Reductions through Supply Chain Collaboration: Challenges and Opportunities

Researchers: David Jackson and Francisco Ascui

Purpose

THIS WORK PACKAGE seeks to enhance the use of the CIT tool by identifying collaborative frameworks for carbon reduction across the life cycle of an asset. Achieving ambitious cuts in carbon emissions on an infrastructure asset will require significantly enhanced collaboration across the supply chain, for the simple reason that infrastructure project emissions arise in many areas over the lifetime of a project, including direct emissions from construction of the asset, emissions embodied in the materials used, emissions from operation and decommissioning of the asset, and emissions associated with third-party users of the asset. As well as carbon reduction, other considerations such as cost, standards and regulatory requirements, and stakeholder engagement provide further challenges that must be overcome to achieve efficient low-carbon solutions.

Method

SEVERAL CASE STUDIES were examined to highlight the challenges of reducing emissions throughout the supply chain, and to discover how organisations had collaborated to overcome these challenges. These case studies highlight several collaborative factors that are required in order to improve emission reductions throughout the supply chain. Of particular importance are leadership, information sharing and incentive mechanisms.

Findings

THE ORGANISATIONS WHICH succeeded in reducing emission through their supply chains were the ones who demonstrated strong leadership by communicating with their suppliers, providing training and resources to help measure emissions, and working closely with their suppliers to reduce emissions. To manage carbon emissions throughout the infrastructure supply chain it is critical that key decision makers have data to be able to make informed choices. This requires the supply chain to gather and share information regarding their emissions.

However, some suppliers may be reluctant to share their data if there is no immediate benefit for them. For this reason, it is important to incentivise suppliers to encourage them to engage. There are several ways that a company can incentivise suppliers, such as long-term contracts, paying prices above the market value, or by providing training and education. However, it is important to make sure that incentives are aligned to the shared vision of the collaborating parties to reduce emissions.

Recommendations

KEY RECOMMENDATIONS ARE:

- **The industry** needs to work together to improve collaboration throughout the infrastructure supply chain.
- **We propose** a move away from the traditional 'design-bid-build' business model towards a client-centric model where the client acts as a trusted leader to encourage information sharing and incentivise other stakeholders to collaborate (as shown in Figure 5).
- **Incentive mechanisms** should be designed to consider system-wide reductions in emissions rather than just through the project delivery.

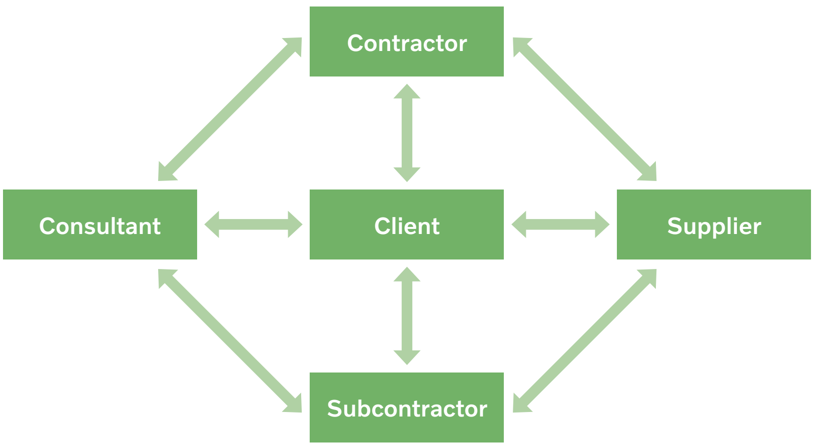


Figure 5. Client-centric model

Further Information

FOR THE FULL research article, please visit: https://www.bccas.business-school.ed.ac.uk/sites/cbccs/files/2020-09/Working-Paper-Achieving-infrastructure-emission-reductions-through-supply-chain-collaboration.docx

Work Package 5. Decision Analytics for Infrastructure Project Design under Uncertainty

Researchers: Roberto Rossi and David Jackson

Purpose

THIS WORK PACKAGE provides an analysis of uncertainty to inform the future development of the CIT tool. Carbon calculators generally use single-point estimates for input data and emissions factors, but ignoring uncertainty may lead to significant underestimation or overestimation of carbon emissions.

Method

WE EXTENDED THE trade-off analysis in Work Package 2 between the embodied and use phase carbon emissions for a train tunnel, and built a decision-support model based on the techniques illustrated in Rossi et al. (2017). The model considers random concrete emissions, instead of a constant average emission factor and random train speeds in the tunnel, instead of a constant average speed.

Findings

THIS ANALYSIS REVEALS that a larger tunnel leads not only to a 5% average carbon reduction over 30 years of service, but also to a 44% reduction in uncertainty (i.e. variability) associated with lifetime emissions, see Figure 6. This result is surprising as in contrast to other settings (e.g. investment portfolio management) in which an improvement in expected return on investment, generally leads to higher variability (i.e. risk) associated with returns; we here observe that the decision which leads to lower expected emissions, i.e. opting for a larger tunnel, has also the advantage of reducing uncertainty on these future emissions, that is the risk of emitting substantially more or less than predicted (Figure 6 illustrates the findings).

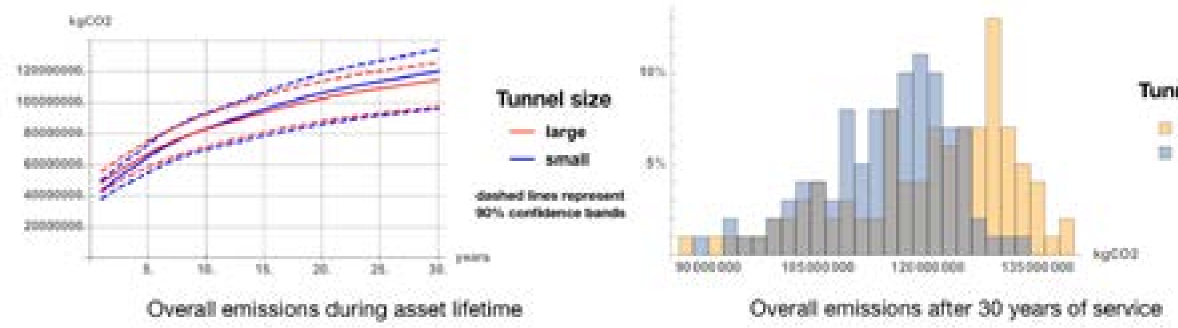


Figure 6. Integrated (embodied + operational) analysis

Recommendations

WE RECOMMEND THAT as the sophistication of carbon calculators develops over time, uncertainty analysis should be included to fully represent the likelihood of different outcomes from decisions aimed at reducing emissions.

Further Information

For the theoretical research article, please visit: https://arxiv.org/pdf/1708.01829.pdf
For the case study application, please visit: https://www.bccas.business-school.ed.ac.uk/sites/cbccs/files/2020-11/Case-study-Decision-analytics-for-infrastructure-project-design-under-uncertainty.docx
For the Open Source declarative statistics library, please visit: https://gwr3n.github.io/syat-choco/

Overarching Concluding Statement

The CIT tool provides a number of useful functions for managing carbon, and trialling the tool, and the supporting research, has identified a number of areas for further development, including: whole-of-life and consequential assessment; uncertainty analysis; and the need for automatic matching of data to emission factors in a standardised carbon library. The research also indicates how this future development should be undertaken in order to achieve maximum impact, namely through industry collaboration. The delivery of this report underpins the development of a User Club, to bring partners from across the infrastructure sector together to achieve further collaboration.

THE CONSTRUCTION CLIMATE CHALLENGE (CCC) is an initiative hosted by Volvo Construction Equipment to promote sustainability throughout the entire construction industry value chain and provide funding for environmental research. The Construction Climate Challenge is a part of the Volvo CE commitment to WWF's Climate Savers Program. Volvo Construction Equipment is a Corporate Advisory Board member of the World Green Building Council.

For more information about the Construction Climate Challenge, please visit www.constructionclimatechallenge.com

THE CENTRE FOR BUSINESS AND CLIMATE CHANGE at the University of Edinburgh's Business School provides academic expertise to understand how climate change creates risks and opportunities for business, and how businesses can play a vital role in mitigating and adapting to climate change. We do this through interlinking world-leading academic research, high-level corporate and policy engagement, and specialised teaching programmes.

For more information please visit: https://www.bccas.business-school.ed.ac.uk/impact-and-collaboration/carbon-infrastructure-transformation-tool/

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