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# TRANSFORMING CONSTRUCTION CHALLENGE EVALUATION

## Phase 2: Impact Evaluation

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## ACKNOWLEDGEMENTS

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The secondary data analysis was produced using statistical data from the Office for National Statistics (ONS). The use of the ONS statistical data in this work does not imply the endorsement of the ONS in relation to the interpretation or analysis of the statistical data. This work uses research datasets which may not exactly reproduce ONS aggregates.

ONS agrees that the figures and descriptions of results in the attached document may be published. This does not imply ONS's acceptance of the validity of the methods used to obtain these figures or of any analysis of the results.

# EXECUTIVE SUMMARY

## CONTEXT OF THE EVALUATION

The Transforming Construction Challenge (TCC) aims to radically reshape the UK's construction sector by increasing research and development (R&D) investment; establishing new business models and accelerating technology adoption; shifting demand away from 'lower cost'; and expanding research and increasing knowledge dissemination.

In 2018, Frontier Economics with its partner BMG Research (BMG) was commissioned by Innovate UK to carry out an evaluation of the TCC. This report presents findings from the final phase of the evaluation, the **impact evaluation**.

The evaluation adopts a **contribution analysis approach** which aims to come to a considered view on the contribution that the TCC has made to a range of indicators underpinning seven **themes** or **evaluation questions** identified from the logic model agreed for TCC in 2019. Our evaluation draws on **mixed methods** tailored to each question: analysis of monitoring data; a primary survey of organisations that engaged TCC in some way; case studies (comprising 19 activity-based case studies and a thematic case study focused on procurement); analysis of secondary data; and an expert panel review. Our analysis focused on understanding, as far as possible, the **counterfactual** of what would have been different for each thematic evaluation question absent the TCC. Our approach to counterfactual assessment involved a combination of self-reported counterfactuals through questions asked in the survey and case studies, trend analysis, and comparisons of the construction sector and value chain with 'control groups' in adjacent sectors in analysing a range of secondary data sources.

## OVERALL FINDINGS

The TCC has been delivering a wide range of activities and outputs and has exceeded its internal targets on the projects it has influenced which achieve productivity improvements as well as reductions to whole-life costs, delivery time and emissions.

The evidence we gathered suggests that those engaged with the TCC have high awareness of TCC concepts and are adopting them. The TCC has helped to deepen and improve the understanding and adoption of TCC concepts for those engaged. This is through the TCC's role in strengthening collaboration, 'de-risking' investment and providing proof of TCC concepts.

Further, there is strong evidence that the use of TCC concepts will have positive impacts for firms and the sector as a whole, and will provide wider benefits (such as to the environment). To the extent that TCC can successfully promote TCC concepts (and thereby realise the benefits referred to above), these benefits will be partly attributed to the Challenge, although there are clearly wider drivers of change. As yet, there is relatively limited evidence on the wider impact of the Challenge beyond the organisations directly engaged. This is expected given the stage of delivery and the TCC's current focus on demonstration.

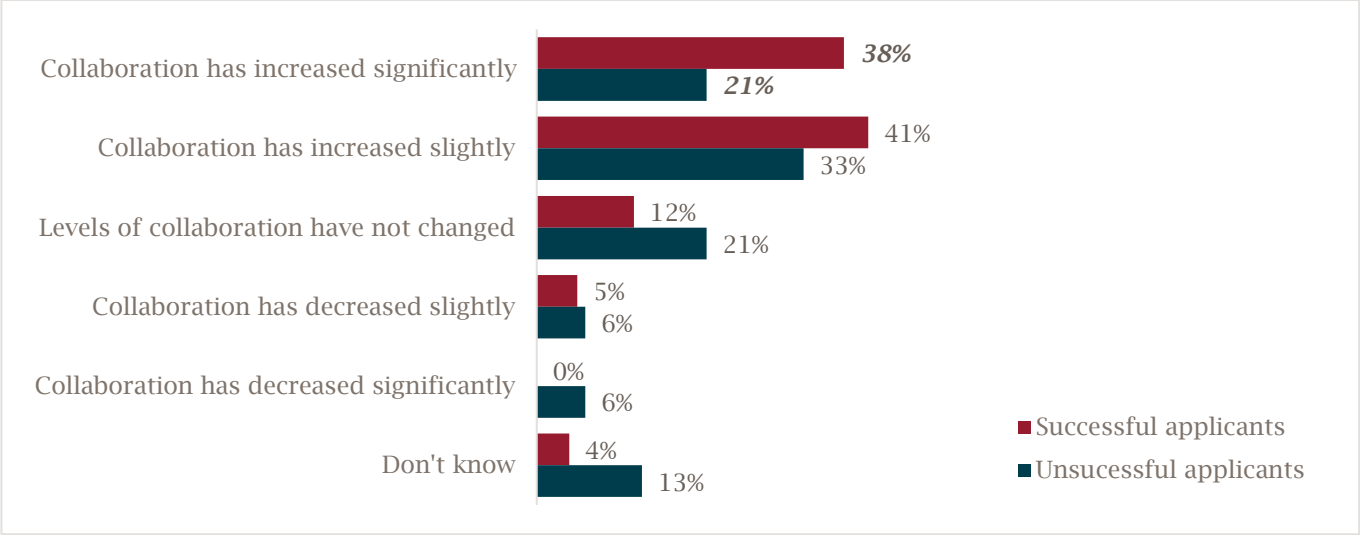
It is clear from the thematic case study on procurement that the TCC has begun to shape thinking around procurement in the public sector, including through its significant contributions to the Construction Playbook. However, further tangible change, including change across the commercial sector, will take time to deliver.

A summary of the main findings for each thematic evaluation question is provided below.

## THEME 1 – FIRMS, PUBLIC BODIES AND ACADEMICS ENGAGING IN PROJECTS RELATING TO TCC CONCEPTS

There has been an increase in collaboration related to TCC concepts since the TCC was established.[1] The primary survey found an increase in collaboration to develop or use new ways of working on construction projects compared with the baseline survey (conducted in 2019).

### FIGURE 1 CHANGE IN COLLABORATION ON PROJECTS OR GRANTS CONCERNING CONSTRUCTION SINCE 2018 – SUCCESSFUL VS. UNSUCCESSFUL APPLICANTS




*Source: Beneficiaries survey. C22. How do you think collaboration in general on projects or grants concerning construction has changed since 2018?*
*Note: Base: Successful applicants (76), unsuccessful applicants (52). Figures in **bold and italics** are statistically significantly different for successful and unsuccessful applicants.*

The expert panel agreed with the evidence that there has been an increase in collaboration and in the quality of collaboration for organisations that the TCC has engaged with, and that this is at least partly attributable to the TCC. The expert panel suggested the presence of wider factors that have driven collaboration within the construction industry. For instance, there has been an industry-wide movement to improve collaboration which pre-dates the TCC, and Covid-19 has helped foster collaboration across the industry and has accelerated access to digital tools.

The case studies show many examples of interdisciplinary collaboration across organisations. Those we consulted in the case studies often suggested that the TCC can be credited with improving collaboration across the sector, in the following ways:

- **By acting as a facilitator of collaboration** through providing a hub for like-minded organisations to get together and share knowledge and learnings;
- **By using its high profile and strong reputation** throughout the construction sector to help organisations which engage with the TCC to increase their profile and activities; and

[1] Critical to meeting the TCC's aims is the demonstration and dissemination of a number of construction technology concepts across the construction sector. Throughout this report, these are referred to as 'TCC concepts' and include the following: integrated energy capture and storage systems; integrated thermal solutions; off-site manufacturing; digital twin and assurance tools; Information Management Framework/UK BIM Framework; standardisation of product data; digital compliance; improving the whole-life value of buildings; and quality and validation process for modern methods of construction.

- **By de-risking activities through providing matched funding and resource**. This has allowed organisations to collaborate in 'high-risk' areas for which it would have been difficult to receive funding. The TCC has enabled organisations to pool risk both with the TCC and across other organisations involved in the activity.

There is variation in the role of the TCC in promoting collaboration. Some case studies suggest that without the TCC collaboration would not have gone ahead (e.g. Behind the Meter Billing and Trend Basin). In contrast, a number of case studies suggest that the collaboration would have happened in some form without the involvement of the TCC (e.g. Aquila, Digital Accelerator and FASTtruss). Where this is the case, the case studies frequently credit the TCC with accelerating the collaboration or improving the quality of collaboration.

However, there are limited examples of the interviewed parties having other interactions with the Challenge, such as with different TCC activities or across the TCC strands. Further, we find limited evidence of the TCC impacting collaboration across the wider sector (i.e. beyond organisations that directly engage with the TCC).

## THEME 2 – CONSTRUCTION SECTOR CLIENTS ENABLE TCC CONCEPTS TO BE USED IN THE PROCUREMENT PROCESS

Since the implementation of the TCC there has been a change in the overall strategy within procurement to consider a wider range of impacts, such as on people and the environment, rather than just on costs. The procurement case study highlights that this can, in part, be attributed to the TCC. For example, government interviewees highlighted that the TCC was having a clear, strategic impact on procurement:

> *"Overall, we are seeing a big cultural change which is guided towards outcomes rather than inputs … we are expecting a very positive impact from it." (BEIS stakeholder)*

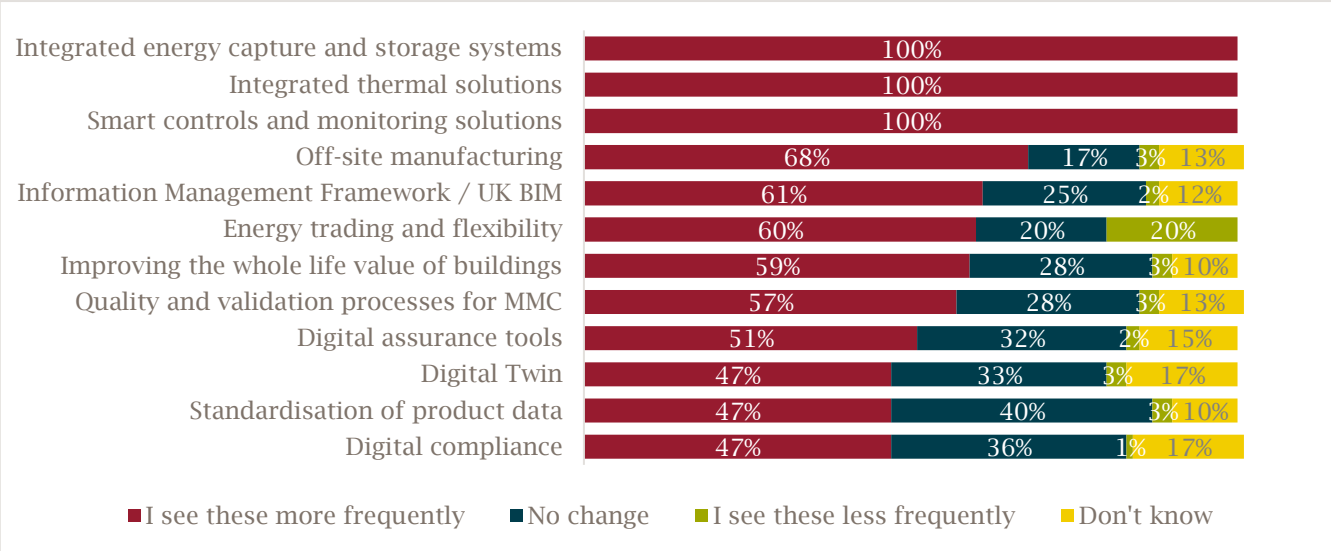
This is reflected in the results of the primary survey. Figure 2 shows that survey responses suggest there has been a material change in the presence of concepts in major private infrastructure procurement. However, the extent of the change depends on the concept analysed.

Both the expert panel and thematic case study noted the importance of the Construction Playbook in changing public sector procurement, including via the incorporation of TCC concepts. The TCC has been heavily involved in developing aspects of the Playbook relating to TCC concepts. A number of experts suggested that the TCC had picked up on these concepts, which pre-date the Challenge, and acted as an accelerator for their consideration in procurement:

> *"A whole load of things are driving cultural change (e.g. worries about global warming), but TCC is an important element of it and without TCC we wouldn't see progress in quite the same way. TCC is good at bringing the industry and government together." (BEIS stakeholder)*

However, at this stage of the TCC, there is limited evidence of change in the TCC concepts actually being included in private and public sector procurement, largely due to the time required to implement change.

## FIGURE 2 PERCEPTIONS OF CHANGE IN THE PRESENCE OF CONCEPTS IN MAJOR PRIVATE INFRASTRUCTURE PROCUREMENT FRAMEWORKS SINCE 2018



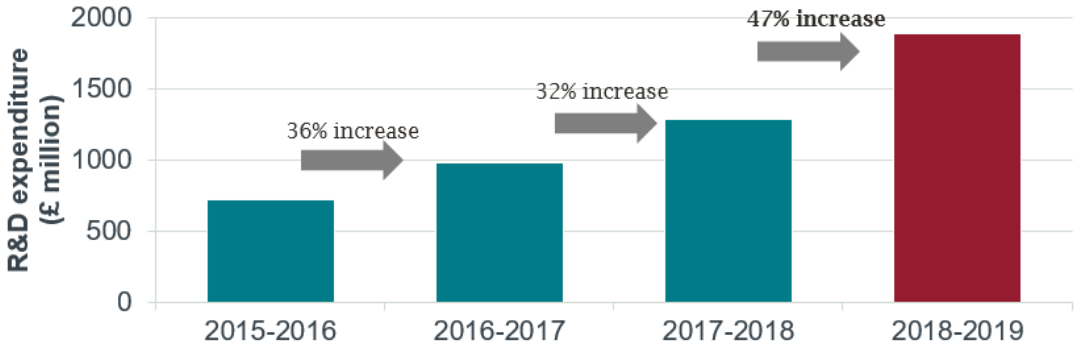

*Source: Beneficiaries survey. Q20A. Have you noticed any changes at all in the presence of the following tools, technologies, and concepts in major private infrastructure clients' procurement frameworks since 2018?*
*Note: Base: Impact survey business respondents whose main engagement was with CR&D, CIH, N+ or RL (115)*

## THEME 3 – CONSTRUCTION INDUSTRY AND ASSOCIATED VALUE CHAIN INCREASE INVESTMENT IN R&D RELATED TO TCC CONCEPTS

The TCC has fostered R&D and investment in TCC concepts in the short term through providing matched funding and has a target to achieve a cumulative co-investment value of £250 million by 2027. The benefits data suggests that the TCC is on track to meet this target by 2023.

Secondary data suggests increasing levels of overall investment across the construction sector. The Office for National Statistics (ONS) Business Enterprise Research and Development (BERD) data provides evidence of increases in both absolute intramural and extramural R&D spending and the share of R&D relative to total UK R&D spend. Further, HM Revenue and Customs (HMRC) R&D Tax Credits Statistics show that claims of R&D tax credits by firms whose primary activity is construction grew by 47% in the financial year 2017/2018 (compared to 32% in the previous year).

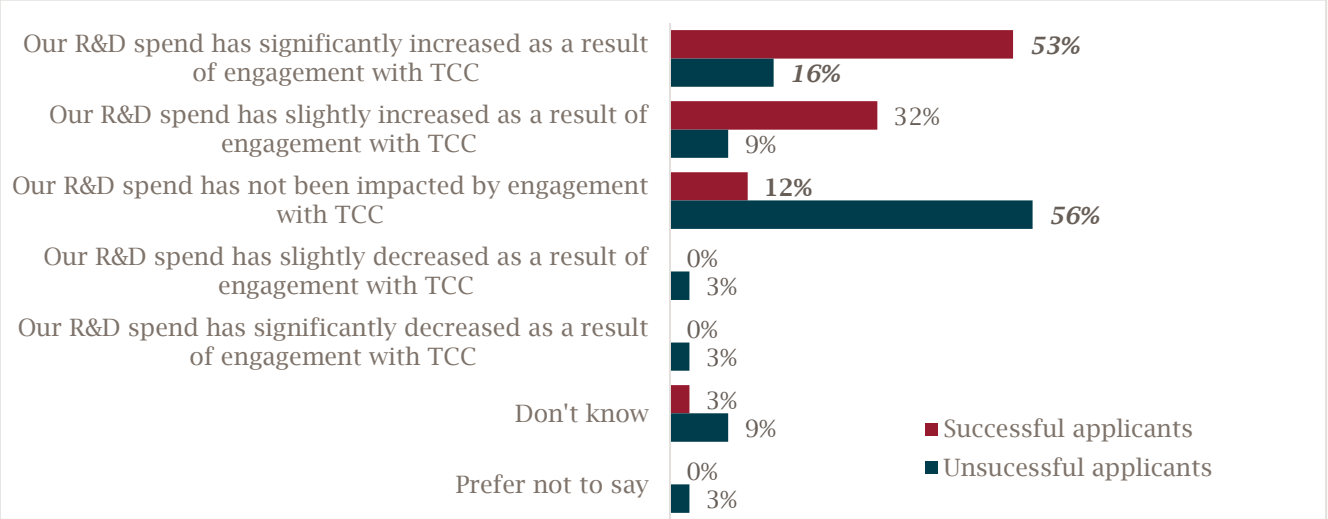
## FIGURE 3 HMRC TAX CREDIT – CONSTRUCTION SECTOR R&D EXPENDITURE




*Source: Frontier Economics based on HMRC*

The primary survey and case studies provide some evidence of an increased level of investment in TCC concepts among firms engaged by the Challenge, and this can be largely attributed to the Challenge. Figure 4 shows that 53% of 'successful' applicants reported that that R&D spend had increased significantly as a result of engagement with the TCC. The cases studies suggest this is mostly as a result of the TCC's 'de-risking' role through matched funding. By pooling risk across organisations through matched funding for those engaging with collaborative R&D (CR&D), the TCC has enabled more investment in 'higher risk' areas that relate to TCC concepts.

## FIGURE 4 PERCEIVED IMPACT OF TCC ON R&D SPEND – SUCCESSFUL VS. UNSUCCESSFUL APPLICANTS




*Source: Beneficiaries survey. Q2F. Which of the following best describes how your engagement with TCC has impacted your organisation's R&D spend?*
*Note: Base: Successful business applicants (34), unsuccessful business applicants (32). Figures in **bold and italics** are statistically significantly different for successful and unsuccessful applicants.*

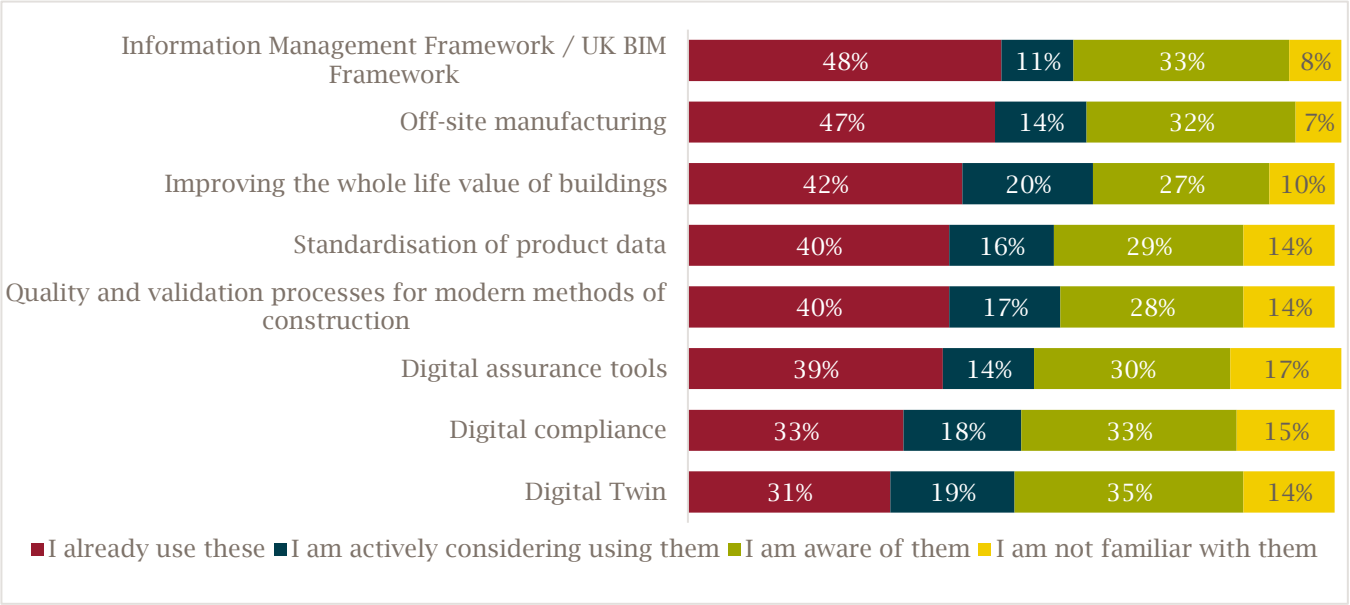
There is mixed evidence on the extent to which investment in R&D related to TCC concepts is expected to increase further in the future. There are examples of investment continuing after the initial TCC funding has ended (e.g. the Challenging Space Frontiers in Hospitals project) as well as investment in new projects resulting from previous TCC engagement (e.g. the West Midlands DfMA project). However, generally there were limited discussions of follow-on funding in the case studies. The expert panel warned that without

longer-term public support, R&D focused on TCC concepts may not take off further, with construction sector firms likely to focus on 'business as usual' activities.

## THEME 4 – CONSTRUCTION SECTOR AND ITS SUPPLY CHAIN ADOPT TCC CONCEPTS

In the activity case studies, we found that organisations that had engaged with the TCC tended to have high awareness of TCC concepts prior to engagement. As shown in Figure 5, the primary survey indicated that a high proportion of those that had engaged with the TCC (whether or not they had been successful in receiving funding) were already aware of or using TCC concepts: at least 83% of respondents were using, considering using, or were aware of each TCC concept asked about. This is to be expected given that organisations that have engaged with the CR&D have applied to receive funding for the development of a TCC concept.

### FIGURE 5 AWARENESS OF AND USE OF TCC CONCEPTS




*Source: Beneficiaries survey. Q18. Please describe your familiarity with the following tools, technologies and concepts.*
*Note: Base: Impact survey respondents whose main engagement was with CR&D, CIH, N+ or RL (155)*

However, the activity case studies suggest that the TCC has had a role in improving awareness of TCC concepts among those organisations it has engaged to date. This has occurred through the role the TCC plays in introducing organisations to the concepts and allowing them to better focus their application of TCC concepts, and by providing a standardisation role through publishing how concepts are being used. For example, those interviewed for the Value Toolkit case study showed a general consensus that TCC concepts would have been used with or without the TCC's involvement. Nonetheless, interviewees believed that the TCC had increased the speed of take-up of these concepts.

The case studies and expert review panel suggest there is limited evidence to date on the extent to which the wider industry is adopting TCC concepts, although this was felt to be consistent with the stage the Challenge has reached. Many of the projects are at a proof-of-concept/demonstrator stage, where technology is tested within real-world industry settings but is not yet widespread or fully commercialised.

The activity case studies do provide insights on the extent to which future adoption is expected, and where change is more likely to occur:

- **GenZero:** There was an expectation that TCC concepts will be adopted by the wider industry in the future. However, this adoption was expected to be at a slower pace in comparison to TCC beneficiary firms.
- **Value Tookit:** There was an expectation that the use of TCC concepts will continue to grow and that this is related to the TCC's standardisation role. There was also a general agreement that use of the concepts in the industry will continue to grow and they are important to the future of the industry.
- **Digital Accelerator:** There was uncertainty over when wider concepts will be adopted in the construction sector. TCC concepts were suggested to be the 'hot topic' in the industry, but interviewees suggested that the rate of adoption varies significantly across the industry. They suggested that it is too early to state the extent of the adoption of concepts across the industry as they are at an early stage.

## THEME 5 – INCREASED PERFORMANCE OF CONSTRUCTION SECTOR FIRMS AND THEIR SUPPLIERS

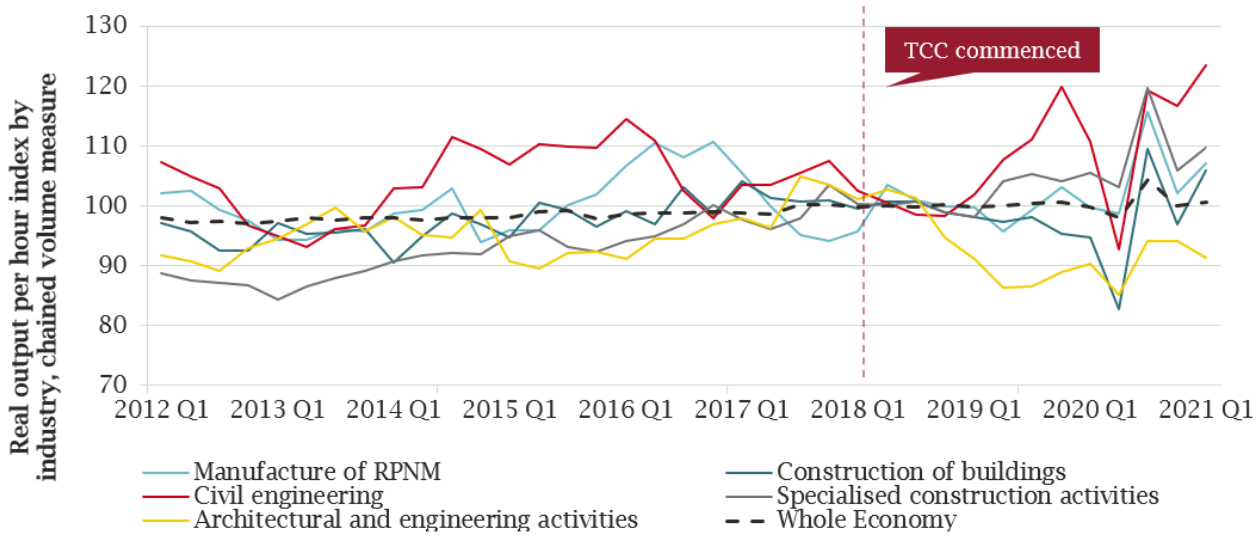
The evidence gathered suggests that there is an expected impact of TCC support on the economic performance of the sector in the future but this has not yet been fully realised .

The TCC set a target of influencing a total of £10 billion of projects which achieve productivity improvements of around 13.5%. As of 2021, internal TCC data shows that the funding target has already been surpassed, with a cumulative committed project value of £29.3 billion.

There is clear recognition of the economic potential for using TCC concepts in business performance. The primary survey shows strong evidence that applying TCC concepts has a positive impact on annual revenue, profit, productivity and speed of delivery. Sixty-one percent of survey respondents who were already using TCC concepts said that their use had had a large positive impact on annual revenue, and 79% reported a positive impact on their organisation's profit.

However, the evidence is more limited in terms of the impact of the TCC on performance, as the survey data gathered focused on the use of TCC concepts rather than the direct impact of engagement with the TCC. The secondary data analysis provides evidence for a slight increase in sector (and relevant supply chain) productivity performance in the period after the TCC was set up. For example, ONS Labour Productivity data shows that, from 2018 onwards, construction-related activities have tended to have a higher annual growth rate compared with UK-wide productivity with the exception of architectural and engineering activities, which have experienced lower growth (see Figure 6). Overall, this suggests that the TCC is operating in an environment of modestly increasing productivity in the sector but, given other evidence and the time lags involved, it is not in itself evidence that the TCC has influenced sector-wide productivity.

## FIGURE 6 ONS – REAL OUTPUT PER HOUR INDEX BY INDUSTRY, CHAINED VOLUME MEASURE




*Source: Frontier Economics*
*Note: RPNM relates to manufacture of rubber and plastics products, & other non-metallic mineral products*

Despite this, there is strong evidence from organisations on the benefits of using TCC concepts. This suggests that, to the extent that TCC can increase the use and adoption of TCC concepts, we would expect economic benefits to follow. We found that more than 70% of respondents reported a positive impact, both observed and expected, of using TCC concepts for annual revenue, profit, productivity and speed of delivery. The activity case studies and panel review also support the idea that a longer timeframe will be needed to see the impact of the TCC on the performance of the construction sector firms and their suppliers. The activity case studies illustrate numerous activities that show potential to improve the performance of the construction sector through the integration of TCC concepts. However, many of the TCC activities remain at demonstration/proof-of-concept stages. As such, it is not possible to demonstrate a direct impact of the TCC on the performance of construction sector firms and their suppliers at this stage. Nonetheless, the adoption of TCC concepts is expected to be transformative to performance in the future.

### THEME 6 – IMPROVED DELIVERY OF BUILT ASSETS (TIME, QUALITY AND WHOLE-LIFE COSTS)

As with the economic impact (Theme 5), we also found some early evidence of a potential future positive impact of the use of TCC concepts on the improved delivery of built assets in terms of quality, whole-life costs and speed of delivery, as shown in Table 1.

## TABLE 1 CHANGE IN PERFORMANCE METRIC SINCE ENGAGEMENT WITH TCC FOR 'SUCCESSFUL' APPLICANTS

| PERFORMANCE METRIC | IMPROVED | STAYED THE SAME | WORSENED |
|---|---|---|---|
| Construction projects delivered on time or in advance | 27% | 65% | 9% |
| Construction costs per $m^2$ | 27% | 41% | 12% |

| PERFORMANCE METRIC | IMPROVED | STAYED THE SAME | WORSENED |
|---|---|---|---|
| Labour hours spent on site per $m^2$ | 30% | 53% | 3% |

*Source: Beneficiaries survey*

*Note: Improved includes responses reporting that the performance metric had 'got significantly better' or 'got slightly better' since engagement with the TCC. Worsened includes responses reporting that the performance metric had 'got worse' and had 'got significantly worse' since the engagement with the TCC. In addition to the above, there were also survey responses which reported 'don't know'. Further breakdowns of the results are provided in the full report. Full details of the sample size are provided in the full report.*

The case studies show examples of projects with potential to improve the delivery of built assets through the integration of TCC concepts. Together, this provides an indication of future impact through the TCC's role of disseminating TCC concepts.

- The **Advanced Industrialised Methods for the Construction of Homes Initiative** (AIMCH) aims to provide comparative cost data on new manufacturing approaches compared to traditional methods. The concepts have helped cut costs and delivery times, resulting in higher expected future profits.
- The **West Midlands DfMA** activity involves the design and build of a prototype house which can easily be scaled up. To optimise the installation of the prototype, the consortium developed a knowledge-based engineering (KBE) tool which would estimate where the greatest emissions and costs come from across both the lifecycle of the build and home once in use and which would adjust the design to minimise investment and carbon footprint. The activity is at proof-of-concept stage and so it is too early to see any quantified impacts. However, all of the parties interviewed agreed that they expected the whole-life costs to be reduced
- The **Government Soft Landings** (GSL) activity provides evidence for potential improvement of cost and time predictability. GSL is an open-source framework which aims to smooth the transition between the design and construction of a building to its operation and use, and which helps to ensure a building is easy to operate and maintain. A comparison of key performance indicators of the projects that are using GSL to industry norms by an interviewee suggests performance above industry expectations, particularly for cost and time predictability.

However, many of the TCC activities remain at the demonstration/proof-of-concept stage. As such, it is not possible to demonstrate a direct impact of the TCC on the delivery of built assets at this stage. The experts agreed that changes to the delivery of built assets in terms of time, quality and whole-life costs is a lagging metric, and therefore we would not expect to see an impact of the TCC at this stage of its implementation.

## THEME 7 – IMPROVED ENVIRONMENTAL PERFORMANCE OF BUILT ASSETS

There is clear optimism about the role of TCC concepts in improving the environmental performance of built assets. This is suggested across the internal TCC data, activity case studies and primary survey.

- **Internal TCC monitoring data** shows that the TCC has a target of influencing a total of £3 billion of projects that reduce greenhouse gas emissions. As of 2021, this target had already been surpassed, with a cumulative committed project value of £22.8 billion.
- The **activity case studies** show examples of projects with potential to improve the environmental performance of built assets through the integration of TCC concepts. For example, the **Active Office** programme sought to build a prototype building using cutting-edge off-site manufacturing techniques and incorporating innovative technologies that generate, store and release solar energy. The **Optimised Retrofit Programme** has successfully measured the impact of retrofitting on the environmental performance of affordable housing.

- The **primary survey** suggests that TCC concepts have the potential to have a positive impact on the environmental performance of built assets, with a high proportion (more than 70%) of survey respondents reporting a positive impact from adopting TCC concepts on carbon dioxide emissions, energy consumption and waste produced on site.

However, the evidence does not suggest that the TCC is currently having a significant impact on the environmental performance of built asset across the sector. Similarly for Themes 5 and 6, this is to be expected given the stage of the programme. To the extent that the TCC will drive wider adoption of relevant concepts, some of the environmental benefits will be attributable to the Challenge, although stakeholders also stressed the critical role of wider factors including net zero commitments and consumer preferences in driving change.

# 1 INTRODUCTION

## 1.1 ABOUT THE EVALUATION

This report presents findings from the final phase of a multi-year evaluation of the Transforming Construction Challenge (TCC).

As part of what was previously known as the Industrial Strategy,[2] the government launched the Industrial Strategy Challenge Fund (ISCF), which seeks to invest in sectors across the UK economy to strengthen the UK's base of highly innovative businesses. This fund is administered by UK Research and Innovation (UKRI) and the TCC is one of its largest programmes.

The TCC aims to radically reshape the UK's construction sector. The Challenge involves a £170 million public investment over four years (2018-22) and has a target to match industry investment of £250 million by 2027. The broad aim of the TCC is to 'eliminate the productivity gap between construction and the rest of the economy and pave a faster route to building safer, healthier and more affordable places to live and learn that use dramatically less energy'.[3] Specifically, the TCC aims to:[4]

- **Increase research and development (R&D) investment,** including further additional follow-on R&D investments, even after the TCC is completed;
- **Establish new business models and accelerate technology adoption** such as new digital manufacturing approaches and better information management frameworks to reduce misalignments across different phases of construction. In parallel, the Challenge is also working to encourage firms to put energy efficiency and reducing whole-life costs at the centre of their design strategy;
- **Shift demand away from 'lowest cost'**, working closely with clients, especially in the public sector, to shift the focus from 'lower cost' to 'whole-life value'; and
- **Expand research and increase knowledge dissemination** – the Challenge funds R&D projects designed to demonstrate, at scale, the benefits of adopting new construction methods and supports the development and diffusion of academic knowledge which may help accelerate the transformation of the sector.

Critical to meeting the TCC's aims is the demonstration and dissemination of a number of construction technology concepts across the construction sector. Throughout this report, these are referred to as 'TCC concepts' and include the following list identified in earlier phases of the evaluation:

- Integrated energy capture and storage systems
- Integrated thermal solutions
- Off-site manufacturing
- Digital Twin and assurance tools

[2] The Industrial Strategy White Paper (2017) is available online at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/664563/industrial-strategy-white-paper-web-ready-version.pdf

[3] https://innovateuk.blog.gov.uk/2018/04/13/the-future-of-construction/

[4] Please note the stated aims above are not exhaustive and highlight the key areas of focus for the Challenge and the principal ways in which it hopes to transform the industry. Further details of the aims and TCC programme are provided in the evaluation framework.

- Information Management Framework/UK BIM (Building Information Modelling) Framework
- Standardisation of product data
- Digital compliance
- Improving the whole-life value of buildings
- Quality and validation process for modern methods of construction (MMC)

To achieve the above aims, the TCC was set up with three distinct strands, which address different but complementary aspects of the Challenge. They are the Construction Innovation Hub (CIH) (a consortium of the Building Research Establishment (BRE), Manufacturing Technology Centre (MTC) and Centre for Digital Built Britain (CDBB)); the Active Building Centre (ABC); and Collaborative R&D (CR&D) including grant funding for academic research (provided through Network Plus and the Research Leaders programme). These key strands are supported by a wider set of stakeholders linked to the TCC.

In 2018, Frontier Economics (Frontier), with its partner BMG Research (BMG), was commissioned by Innovate UK to carry out the evaluation. The evaluation comprised multiple phases: an **evaluation framework,** delivered in 2019, which informed the methods deployed in this report; a **process evaluation,** delivered in 2019, which highlighted aspects of the delivery of the Challenge which were working well and less well; and a **summer update,** delivered in 2020, which reviewed and updated the evaluation framework in the light of the Covid-19 pandemic. This impact evaluation is the final phase of the evaluation, with work carried out between May 2021 and December 2021.

We adopted a 'contribution analysis' approach to the evaluation (see next section) and applied a mix of quantitative and qualitative methods to evidence findings. The contribution analysis aims, based on the evidence, to come to a considered view on the contribution that the TCC has made to different thematic evaluation questions and triangulates across different approaches to understand what the **counterfactual** – what would have happened without the TCC – looks like.

The methods deployed were:

1. **A primary survey** completed by 162 respondents who have engaged with the TCC in various ways;
2. Two types of in-depth case studies:
    a. **Activity-level case studies** involving 19 studies of particular projects and activities conducted by the TCC. The case studies were informed by 38 interviews with stakeholders involved in the selected activities.
    b. A specific **procurement case study** focusing on the extent to which TCC concepts are integrated throughout public procurement processes and regulatory frameworks. This included four interviews with public sector stakeholders;
3. **Secondary analysis** of data held by the TCC (including internal monitoring and benefits realisation data) and data collected by industry and public data sources which inform some of the evaluation indicators;
4. A review of interim findings by an independent **expert panel** comprising seven experts from business, academia and the public sector with an understanding both of the TCC and of wider trends in the construction sector.

Senior TCC stakeholders and representatives from the TCC and UKRI also reviewed and provided feedback on a draft version of this report. We also presented preliminary conclusions to the Challenge and wider UKRI stakeholders for comment before drafting this report.

More details of the methods can be found in Section 3 and some of the Annexes to this report.

# 2 THE FRAMEWORK USED FOR THIS EVALUATION

This impact evaluation implements and builds on the impact evaluation framework for the TCC developed by Frontier and BMG between 2019 and 2020.

## 2.1 THE TCC LOGIC MODEL AND EVALUATION THEMES

The framework was based on a logic model relating the TCC's activities to economic and social outcomes. The Challenge-wide logic model is shown in Figure 7 and has the following key features:

- **Strand activities and outputs, Challenge-wide outcomes and impacts** – The TCC is composed of three distinct strands, each with a different focus and managed by different organisations. This means that the activities and outputs of each strand are distinct. By contrast, many of the intended outcomes and impacts of the Challenge are not strand-specific and only likely to be achieved because of the outputs from all strands. As a result, the impact evaluation is *not* conducted at the strand level. Instead, a thematic approach is more appropriate (as described below).
- **Emphasis on collaboration** – Collaboration between different TCC strands, segments of the supply chain, and between industry and wider stakeholders both in academia and government are highlighted throughout each stage of the logic model. This emphasis reflects the TCC's diagnosis of what is currently hampering progress in the industry, in particular its fragmentation and lack of coordination.
- **Centrality of early adoption and stakeholder buy-in** – To achieve the longer-term industry-wide impacts that the TCC aims to realise, it will be critical for early adopters to convince the wider industry to change its ways. The logic model identifies the importance of obtaining buy-in from policy makers, public procurement bodies and, ultimately, consumers. This recognises the importance of *demand* in spurring innovation and technology adoption.
- **Timeframe for outcomes and impacts** – In distinguishing short-term outcomes, long-term outcomes and impacts, the logic model highlights the long-term horizon between when TCC activities take place and when benefits are expected to be realised.

Separate logic models for each TCC strand are provided in the evaluation framework.

In line with the Challenge-wide nature of the outcomes and impacts, we distilled the logic model into a set of **seven themes** which structure this evaluation:

1 Firms, public bodies and academics are engaging in projects relating to TCC concepts;

2 Construction sector clients enable TCC concepts to be used in the procurement process;

3 Construction industry and its associated value chain increase investment in R&D related to TCC concepts;

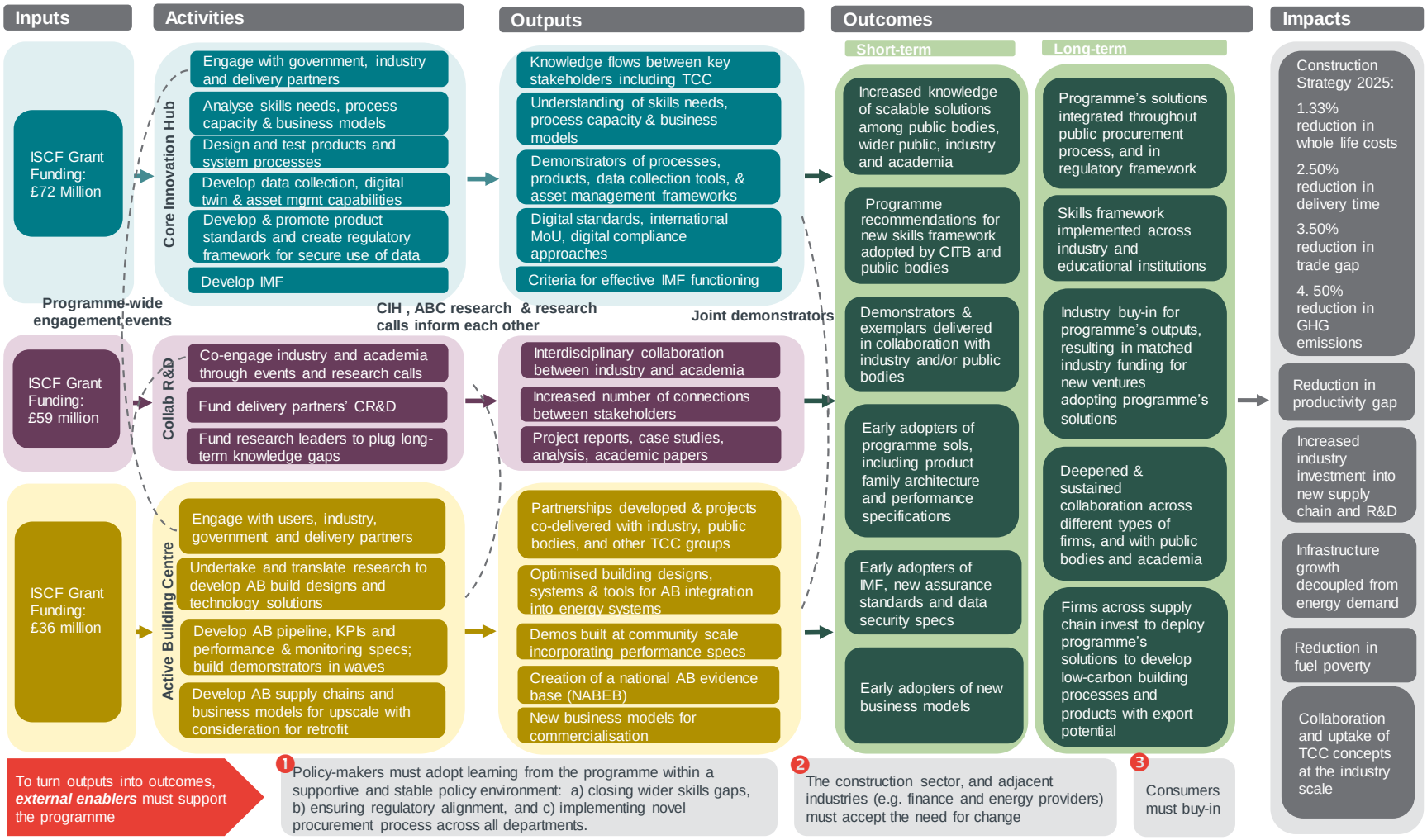
4 Construction sector and its supply chain adopt TCC concepts;

5 Increased performance of construction sector firms and their suppliers;

6 Improved delivery of built assets (time, quality and whole-life costs); and

7 Improved environmental performance of built assets.

## FIGURE 7 CHALLENGE-WIDE LOGIC MODEL




*Source: Frontier Economics*

*Abbreviations: Active Buildings (AB), Key performance indicators (KPIs), Information Management Function (IMF), GHG (Greenhouse gases), Memorandum of understanding (MOU), Construction Industry Training Board (CITB)*

## 2.2 THE EVALUATION INDICATORS

For each theme, we developed a set of 'success indicators' (see below), divided into:

- **monitoring** indicators (relating mostly to activities and outputs);
- **short-term outcome** indicators; and
- **long-term outcome and impact** indicators.

### TABLE 2 MONITORING INDICATORS FOR EACH EVALUATION THEME

| TCC THEME | MONITORING INDICATORS |
|---|---|
| Firms, public bodies and academics are engaging in projects related to TCC concepts | Number and type of external engagements with firms, public bodies and academics |
| Construction sector clients enable TCC concepts to be used in the procurement process | External engagement with construction sector clients |
| Construction industry and associated value chain increase investment in R&D related to TCC concepts | Matched firm R&D funding (UKRI Definitions 1 and 2)[5] |
| Construction sector and its supply chain adopt TCC concepts | *The evaluation of this theme is concerned with industry adoption of technologies and concepts developed during the early phases of the Challenge. As such, there are no monitoring indicators for this theme.* |
| Increased performance of construction sector firms and their suppliers | Challenge outputs provide evidence that TCC concepts have the *potential* to improve firm performance |
| Improved delivery of built assets (time, quality and whole-life costs) | Programme outputs provide evidence that TCC concepts have potential to decrease construction delivery time and construction and whole-life costs |
| Improved environmental performance of built assets | Challenge outputs provide evidence of expected environmental benefits arising from adoption of TCC concepts |

*Source: Frontier Economics*

[5] **Definition 1:** The amount of money, materials, resources (with overheads) that a particular consortium has spent on a project in line with the project plan minus grant recovery.

**Definition 2:** In addition to definition 1, the extra contributions made to a project over and above those agreed in the project plan/costs.

## TABLE 3 SHORT-TERM OUTCOME INDICATORS FOR EACH EVALUATION THEME

| TCC THEME | SHORT-TERM OUTCOME INDICATORS |
|---|---|
| Firms, public bodies and academics engaging in projects relating to TCC concepts | Change in number and type of collaborations engaged in by TCC beneficiaries shortly after participation |
| Construction sector clients enable TCC concepts to be used in the procurement process | Change in construction sector clients' intention to adopt TCC concepts in their procurement processes |
| Construction industry and associated value chain increase investment in R&D related to TCC concepts | Change in value of R&D linked to TCC concepts (UKRI Definitions 3 and 4)[6] |
| Construction sector and its supply chain adopt TCC concepts | Change in use of TCC concepts by Challenge beneficiaries post Challenge |
| | Industry and government usage of evidence bases developed by TCC |
| Increased performance of construction sector firms and their suppliers | Change in performance of TCC beneficiary firms post participation |
| Improved delivery of built assets (time, quality and whole-life costs) | Demonstrators of TCC concepts improve on construction costs and delivery times |
| Improved environmental performance of built assets | Extent to which demonstrators of TCC concepts improve on environmental impact of built assets |

*Source: Frontier Economics*

[6] **Definition 3:** Additional aligned investment in a technology area around the project but not part of the project as a result of increased confidence in the technology area created by the policy focus and ISCF challenge funding. Additional investment as a result of capitalising on the growth in competency gained through participation in ISCF.

**Definition 4:** Follow-on investment by companies to take the project to market or exploit the project outcomes. Often involves combining with other IP/technology to achieve commercial product.

## TABLE 4 LONG-RUN OUTCOME AND IMPACT INDICATORS FOR EACH EVALUATION THEME

| TCC THEME | SUCCESS INDICATOR |
|---|---|
| Firms, public bodies and academics engaging in projects related to TCC concepts | Change in number and type of collaborations between ex-TCC beneficiaries in the longer term |
| Construction sector clients enable TCC concepts to be used in the procurement process | Change in number/value of major private infrastructure clients' procurement frameworks which incorporate TCC concepts |
| | Change in number/value of government procurement frameworks which adopt TCC concepts |
| Construction industry and associated value chain increase investment in R&D related to TCC concepts | Additional aggregate R&D spending in construction sector and key suppliers |
| | Change in industry investment in key sub-sets of the industry |
| Construction sector and its supply chain adopt TCC concepts | Number/proportion of firms in relevant sectors adopting CIH and ABC concepts |
| Increased performance of construction sector firms and their suppliers | Year-on-year change in sector (and relevant supply chain) productivity performance |
| | Year-on-year change in value of exports of construction products and services |
| Improved delivery of built assets (time, quality and whole-life costs) | Change in predicted costs (construction and whole-life) and delivery time across industry |
| Improved environmental performance of built assets | Estimated environmental impact of built assets |

*Source: Frontier Economics*

## 2.3 THE APPROACH TO DEVELOPING COUNTERFACTUALS

This evaluation draws on different approaches to determining the 'counterfactual' – that is, what would have happened in the absence of TCC?

Building on the methodology developed in the evaluation framework, we employ a **contribution analysis**, an example of a **theory-based evaluation**. The logic model sets out the critical pathways through which the economic and wider impacts of the TCC are expected to be realised. The evaluation indicators identify the metrics and measures that will help determine whether the TCC's activities are generating observable changes in line with those pathways. The contribution analysis then seeks to identify evidence from a range of methodologies that help to derive a narrative conclusion about the extent to which the TCC (rather than external factors) has been the driver of changes observed in the indicators over time.

We do not attempt to derive a single 'impact estimate' (quantitative or qualitative), given the nature of the intervention and the complex set of objectives that the TCC is working towards. We employ different approaches, both qualitative and quantitative, and then seek to *triangulate* across them to determine the

contribution narrative (see Section 11). Where different pieces of evidence about the indicators or the TCC's contribution suggest different conclusions, we assess the relative strengths and weaknesses of each in determining our views based on the data available.

The methodologies we use to consider counterfactuals are:

- Self-reported counterfactuals from the beneficiary survey in which respondents were asked to reflect on what had happened *as a result of their engagement* with the TCC and the mechanisms through which the TCC had contributed to particular reported benefits;
- Comparing reported outputs, outcomes and impacts from the beneficiary survey between those with different forms of engagement, in particular comparing those who had received project funding with those who had sought but were not successful in obtaining funding;
- Secondary analysis of data relating to key metrics, including trend analysis (pre and post TCC) and comparing metrics for sub-sectors that are the closest proxies for those the TCC is supporting or influencing with other similar, non-supported sub-sectors.
- Detailed evaluative case studies of specific interventions run by the TCC, where beneficiaries were asked to reflect in detail on what they had achieved or expected to achieve that could not otherwise have happened (or at least would not have happened as effectively) and the mechanisms through which the TCC's support had yielded benefits; and
- Expert stakeholder views on the impact the TCC is having on the overall sector and other factors that had influenced the sector.

## 2.4 THE STRUCTURE OF THIS REPORT

The rest of this report is organised as follows:

- Section 3 provides more detail on the various methodologies used to provide evidence for this phase of the evaluation. More detail can also be found in various Annexes to the report.
- Sections 4 to 10 respectively provide the evidence base relating to the evaluation indicators, organised by the seven evaluation themes. Sub-sections are used to organise the evidence against specific indicators.
- Section 11 provides an overall contribution narrative, drawing on the evidence and conclusions from previous Sections and reflecting on the evaluation findings against the TCC business case objectives.
- Section 12 sets out some lessons learned and recommendations for future evaluation.

# 3 METHODOLOGY FOR THE EVALUATION

## 3.1 THE EVIDENCE BASE FOR THE EVALUATION

A high-level description of the evaluation methods is given below. Further detail on the evaluation methods is provided in the Annexes.

### 3.1.1 MONITORING DATA

The evaluation involved an analysis of monitoring data collected internally by the TCC. This data provided evidence for all TCC activities across the three TCC strands.

We used three types of monitoring data for the evaluation.

1 **Benefits data:** TCC internal data designed to capture the extent to which the initial activities and outputs derived benefits for participating organisations. This includes data provided by all the TCC strands on their projects related to defined benefits such as reduction in project whole-life costs or reduction in greenhouse gas emissions;

2 **Project completion form (PCF) data:** Survey data collected by the monitoring team of Innovate UK on completed Innovate UK projects. This survey only includes projects completed by the CR&D strands. It contains project-specific questions answered by project leads (23), collaborators (31) and academics (13); and

3 **Challenge applicants data:** The TCC strands provide applicant-level contact data for successful and unsuccessful applicants of TCC support for the primary survey. It provides descriptive evidence on the number and types of organisations the strands have been engaging with.

### 3.1.2 PRIMARY SURVEY

#### SURVEY METHODOLOGY

A bespoke survey was developed to explore issues aligned to the logic model and evaluation indicators. A slightly different survey script was developed for academic and business respondents.

An online link to the survey was sent out to contacts, followed by two email reminders to those who had not completed the survey. To maximise response rates, telephone chasing was also used to encourage participation for those for whom telephone numbers were available. In total, 117 interviews were completed by telephone and 45 were completed online.

Fieldwork took place between 23 August and 1 October 2021.

#### DESIGN PROCESS

The survey aimed to capture information for the impact evaluation which could not be captured elsewhere in the evaluation. It was designed in partnership with representatives from across the TCC, including with attendees at a design workshop held in early August 2021.

The survey repeats some key questions from the baseline survey (conducted to 2019) to understand the progress and impact of the TCC over time. These relate to awareness and use of TCC concepts, organisations' turnover, R&D spend and collaborations. Aside from this, new questions specific to this phase of the evaluation were added to measure the impact of the TCC in more detail.

### SAMPLE COMPOSITION AND SURVEY ANALYSIS

The survey sought to gather the experiences and opinions of businesses and academics who had engaged with the TCC in a meaningful way. Contact details for the survey sample were collected from each of the TCC strands: CR&D, CIH, ABC, Network + and Research Leaders.

The sample for the surveys included:

- Those who had been successful in their application to the Challenge for funding (referred to as 'successful applicants');
- Those who had applied for TCC funding but had not been awarded it (referred to as 'unsuccessful applicants'); and
- Those who had been involved with CIH, ABC, Network + or Research Leaders activities, but had not necessarily applied for any funding via TCC competitions

The full, de-duplicated sample for the survey consisted of 859 individuals. A total of 162 respondents completed the survey. Table 5 shows the response rates against the different strands.

### TABLE 5 RESPONSE RATE BY MAIN STRAND WHICH THE RESPONDENT ENGAGED WITH

| STRAND | NUMBER OF CONTACTS | COMPLETE | RESPONSE RATE |
|---|---|---|---|
| ABC | 32 | 7 | 22% |
| CIH | 33 | 11 | 33% |
| Network+ | 17 | 5 | 29% |
| CR&D | 773 | 138 | 18% |
| Research Leaders | 4 | 1 | 25% |
| Total | 859 | 162 | 19% |

*Source: Primary survey*

It is important to note there are some limitations to the achieved sample which should be borne in mind when interpreting the data:

- The majority of the responses in the 2021 survey (138 of the total 162 interviews) came from individuals who had primarily engaged with the CR&D strand of TCC. The relatively small number of completed interviews by individuals who had primarily engaged with ABC (7), CIH (11), N+ (5) and Research Leaders (1) means that analysis by individual strand was not possible. As a result, the reported primary survey results are aggregated across the TCC strands but should be considered most 'representative' of the CR&D strand of the Challenge.

- Only 56 responses were received to the baseline survey conducted in 2019. This survey used a different methodology as it was not possible to obtain a contact database from the TCC strands at the time of the baseline survey. As such, the baseline survey was delivered online, with a link being sent to each strand for dissemination to its contacts and beneficiaries. This method had more potential for self-selection bias and did not allow for the representativeness of the surveyed individuals to be assessed. Comparisons were made to the baseline survey where possible, but these should be treated as indicative only due to these limitations.

A high proportion of survey respondents were either project leaders (30%) or collaborators (40%). Organisations that were most represented in the survey sample included consultancy and professional services (32%), academic/research institutions (23%) and main/lead contractors (14%). More information on the survey respondents by project role and organisation is provided in Annex A -

### 3.1.3 IN-DEPTH CASE STUDIES

#### ACTIVITY CASE STUDIES

We conducted 19 in-depth activity case studies of projects and activities that the TCC has engaged with. The TCC provided a longlist of a possible 53 case studies in July 2021 from the Stronger Stories dashboard.[7]

BMG, Frontier, the TCC and UKRI jointly identified a set of preferred case studies that gave broad coverage across the TCC strands and types of organisation involved. Later checks also confirmed broad coverage in terms of funding amount (where relevant) and project objectives across those selected.

The agreed list of case studies is shown in Table 6. Each case study involved interviews with one or more stakeholder participant and, where relevant, desk review of documents or materials related to the chosen case. The interviewees for the case studies were identified through the relevant TCC strands. The interviews followed a semi-structured topic guide (see Annex C - ) and case study protocol which was discussed with the TCC and UKRI in a workshop in August 2021.

All evidence relating to each case was combined to provide an overall narrative summary of each case study. Insights from each case study have been extracted throughout this report and used to illustrate examples relevant to each of the evaluation themes and indicators.

The full narrative write-ups of each case study are provided in Annex D - For each evaluation theme we also highlight relevant findings from the case studies in the main body of the report.

### TABLE 6 ACTIVITY CASE STUDIES

| TCC STRAND | ACTIVITY | ACTIVITY OBJECTIVES | NUMBER OF INTERVIEWS |
|---|---|---|---|
| CR&D | West Midlands DfMA | ■ Provide proof of concept for using modern methods of construction (MMC) for small site residential homes<br>■ Reduce life costs of residential social housing stock | 3 |

[7] The Stronger Stories dashboard is available here: https://tc-catalogue.strongerstories.org/mentor-gifts/innovate-uk-non-tcc/

| | | | |
|---|---|---|---|
| | | ■ Reduce emissions of residential social housing stock | |
| CR&D | Aquila | ■ Develop a tool that allows emissions on construction sites to be accurately measured<br>■ Reduce emissions on construction sites | 1 |
| CR&D | HIPER Pile | ■ Develop lighter cement-free concrete piles that have the same bearing capacity, in order to reduce carbon emissions by up to 80%<br>■ Embrace off-site manufacturing in building foundations to increase safety and speed up delivery<br>■ Create wireless sensors that can measure the properties of the piles in terms of strength and durability so that piles can be re-used for new buildings in the future, thus reducing waste<br>■ Incorporate renewable technologies into the void of the piles so that the piles are able to produce, manage and store energy as part of an active building | 3 |
| CR&D | IDEMA Panel House | ■ Provide a proof of concept of easy to assemble, pre-manufactured homes that are well insulated to improve productivity and reduce costs<br>■ Produce affordable net zero homes that can generate energy to meet their own energy requirements and charge an electric vehicle<br>■ Speed up the delivery times of construction projects by adopting an off-site manufacturing approach | 2 |
| CR&D | AEC Delta Mobility | ■ Create a data exchange standard for the industry that allows design teams to exchange data with greater efficiency and assurance | 2 |
| CR&D | AIMCH | ■ Scale up and make MMC a viable approach to building houses for the same price as traditional building costs | 2 |
| CR&D | Fabrication Automation for Steel Lattice Trusses (FASTtruss) | ■ Produce a robotically-welded demonstrator that can automate the design and manufacture of steel lattice trusses<br>■ Transform the way superstructures are constructed | 1 |
| CR&D | PLASMA | ■ Provide a technology platform to improve supply chain management and productivity in construction projects | 2 |
| CR&D and N+ | Challenging Space Frontiers in Hospitals | ■ Challenge the way hospitals are built by looking at how MMC could be applied in hospital operation theatres. | 1 |
| CIH | GenZero | ■ Create new and improved design standards for school buildings that will facilitate a shift towards MMC and whole-life value<br>■ Support the move to net zero emissions for schools | 1 |
| CIH | Value Toolkit | ■ Provide the sector with a tool to help embed value-based decision making<br>■ Provide a consistent, consensus-based process for defining value | 5 |

| | | | |
|---|---|---|---|
| | | ■ Support a shift towards smarter, better decision making which ensures that buildings are delivering whole-life value | |
| CIH | Construction Quality Planning (CPQ) Tool | ■ Shift construction to off-site manufacturing methods to improve industry productivity and quality of built assets<br>■ Create a quality assurance tool that moves from defect checking once the building is complete to a defect-prevention approach<br>■ Reduce remediation costs and waste by preventing defects<br>■ Promote whole-life value by incorporating quality, safety, durability, servicing and sustainability factors at the design stage | 2 |
| CIH | Digital Accelerator | ■ Understand the need for an accelerator programme for construction start-ups focused on digital technology<br>■ Design an accelerator programme to train deep technology start-ups to have a higher degree of success when they grow | 3 |
| CIH | Government Soft Landings (GSL) | ■ Provide a modern method of procurement and project management to enable clients to get the maximum value from their investments | 1 |
| CIH and N+ | Data Capture for Whole Lifecycle Compliance Checking | ■ Reduce time and cost of compliance checking by digitising data capture processes where possible<br>■ Increase confidence on accuracy of compliance data<br>■ Enable continuous inspections to track compliance of a building throughout its lifecycle to ensure remediation happens as errors occur rather than at completion or not at all | 1 |
| ABC | Active Office | ■ Test and prove the 'Active Buildings' concept with a range of building uses<br>■ Build a prototype to showcase the benefits of MMC and integrated technologies<br>■ Deliver a building that can optimise operation and make energy use as efficient as possible | 2 |
| ABC | Behind the Meter Billing and Trent Basin | ■ Understand the impact of real-time energy supply and cost data on behaviour change in terms of energy usage at home<br>■ Blend on-site renewables and grid energy to improve energy trading and flexibility, and reduce costs of utility bills for residents<br>■ Reduce emissions of residential homes by generating, storing and using renewable energy in the local community | 3 |
| ABC | Optimised Retrofit Programme (ORP) | ■ Evaluate how well new retrofit measures have performed<br>■ Overarching aim of improving affordable warmth in homes, reducing emissions, and creating 15,000 new jobs in Wales | 1 |
| ABC | Active Building Research Centre (ABRC) | ■ Provide research facilities to allow active building solutions to be tested in combination with other parts of an active building solution | 2 |

#### THEMATIC CASE STUDY – PROCUREMENT

In addition to the activity-level case studies, a specific thematic case study on procurement was undertaken as part of the evaluation. This case study provides the main evidence for Theme 2 – 'Construction sector clients enable TCC concepts to be used in the procurement process'. This approach was agreed in the evaluation framework, reflecting the relative lack of evidence from other sources relating to procurement.

The procurement case study covered the following themes:

- **Engagement with TCC**. The engagement that has occurred with the TCC and TCC concepts, including the nature and depth of the engagement;
- **Benefits from TCC engagement**. The extent to which the engagement has resulted in improvements to awareness and understanding of TCC concepts across procuring bodies in a way that has potential to create demand incentives for the private sector; and
- **Impact of the TCC**. The extent to which there been a change in the incorporation of TCC concepts that can be attributed to the Challenge, and whether the impact has been affected by Covid-19.

The procurement thematic case study involved four semi-structured interviews, with the following bodies:

- Two interviews with central government representatives from the Department for Business, Energy and Industrial Strategy (BEIS) and the Infrastructure and Projects Authority (IPA); and
- Two interviews with representatives from devolved and central government departments. Both representatives had roles linked to procurement within their respective department.

The case study focuses on the public sector. We supplemented the targeted evidence collected as part of this thematic case study with evidence from interviews supporting the activity-level case studies where relevant to the procurement theme, including an individual from a large commercial sector client. The full reporting of the procurement case study is included in Annex E - However, the key findings are included in the findings for Theme 2 (see section 5).

### 3.1.4 SECONDARY DATA ANALYSIS

The approach to the secondary data analysis varied according to data availability (see Table 7 below for a summary of alternative analytical methods deployed). The data comprise a mix of propriety industry datasets, such as periodic surveys of their members conducted by professional associations, and public datasets. A complete list of the datasets analysed is provided in Table 8.

The available data largely refers to wider sectoral/industry data. Given the early stages of the TCC programme and the wider evidence gathered in the evaluation, we think it is too soon to expect the TCC to have driven any trends or changes observed in these datasets in practice. As a result, we present the secondary data analysis largely to provide relevant context for the evaluation and a sense of key industry trends but suggest it provides, at best, tentative evidence relating to attribution. This is particularly true in the light of Covid-19, which has affected key industry metrics, and therefore the interpretation of this data needs to be considered with some care (as outlined in our summer update report in 2020, which emphasised the increased importance of qualitative and primary data given Covid).

## TABLE 7 METHODS ADOPTED AS PART OF THE SECONDARY DATA ANALYSIS

| METHOD | DESCRIPTION | ROBUSTNESS |
|---|---|---|
| **Before versus after** | A comparison of the outcomes and/or behaviours of the affected organisations (the so-called 'treatment group') before and after a Challenge intervention had taken place. In effect, the outcome observed before the Challenge's intervention is used to approximate the counterfactual outcome.<br>Low data requirements: requires a data point pre and post intervention. | Level one on the Maryland Scientific Methods Scale.*<br>From the results of before and after analysis, it is difficult to disentangle any changes seen from wider contextual factors and understand the direct impact of the TCC. Therefore, before and after analysis is interpreted descriptively, rather than attributing impact directly to the TCC. |
| **Trend analysis** | Post-intervention outcomes are compared with a projection of the historical trend that they followed prior to the introduction of an intervention.<br>Trend analysis supposes that the future projection of the outcome's historical trend is used to approximate the counterfactual, and therefore that the historical trend would have continued absent the Challenge intervention. | Level one on the Maryland Scientific Methods Scale.<br>As with before and after analysis, it is difficult to disentangle any changes seen from wider contextual factors and understand the direct impact of the TCC from the results of any trend analysis. Therefore, the trend analysis conducted does not directly project historical trends and attribute differences to the TCC. |
| **Weakly identified difference-in-difference analysis** | The change in an outcome of the treatment group (e.g. a beneficiary) is compared over time to the change in that same outcome observed in another otherwise comparable control group.<br>Any change in the treatment group more than that observed in the control group is then attributed to the intervention. | Level two on the Maryland Scientific Methods Scale.<br>This approach is potentially a more powerful method for attributing the contribution of the Challenge but depends on the identification of the treatment and control groups. See Annex F - for more information on the method for identifying treatment and control groups. |

*Source: Frontier Economics*

*Note: * The Maryland Scientific Methods Scale ranks quantitative evaluation methods on their robustness, increasing from level one to level five.*

## TABLE 8 SECONDARY DATA SOURCES

| DATASET TYPE | DATA SOURCE | DESCRIPTION | RELEVANT EVALUATION THEMES |
|---|---|---|---|
| Public | HMRC tax credits | Statistics on total R&D expenditure per sector compiled through tax credit claims data in the UK | Theme 3 |

| DATASET TYPE | DATA SOURCE | DESCRIPTION | RELEVANT EVALUATION THEMES |
|---|---|---|---|
| | ONS Business Investment by Industry and Asset | The ONS Business investments are published estimates of UK net capital expenditure | Theme 3 |
| | ONS Labour Productivity by Industry Division | Statistics on productivity hours and output per hour by industry division | Theme 5 |
| | HMRC OST | UK national statistics concerning international trade of goods | Theme 5 |
| | BEIS | UK national statistics concerning the construction products industry | Theme 5 |
| | ONS Pink Book | ONS estimates of the balance of payments of the UK | Theme 5 |
| | Ministry of Housing, Communities & Local Government | Energy Performance of Buildings Data (EPC) reports on the energy efficiency of domestic and non-domestic buildings in England and Wales | Theme 7 |
| Public data – secure access | ONS BERD | Statutory survey that collects information about employment and expenditure R&D performed within UK businesses | Theme 3 |
| | ONS ABS | Structural business survey conducted by ONS that crosses most business sectors | Themes 3, 5 |
| | ONS BSD | The ONS Business Structure Database is part of the collection of microdata on firms registered for VAT and/or PAYE in the UK | Theme 5 |
| Private | CPA Survey | Survey comprising between 120 and 150 construction sector manufacturers | Themes 3, 5 and 6 |
| | Glenigan | Statistics on the performance of the UK construction industry based on survey data, in addition to government data | Themes 5 and 6 |
| | ACE Survey | Survey data gathered from members of the Association for Consultancy and Engineering (ACE) | Theme 5 |
| | BRE SmartSite | Data collected through measurement products (SmartWaste, SmartSite) | Theme 7 |

*Source: Frontier Economics*

### 3.1.5 EXPERT PANEL REVIEW

Interim findings, based on initial analysis of the surveys, case studies and secondary data by evaluation theme were discussed and tested with external sector experts. The role of these experts was to:

- provide critical challenge to our early interpretation of the evidence;
- help contextualise evidence around wider trends affecting the construction sector;
- help identify additional data sources that might inform the evaluation; and
- provide their own reflections on the contribution of the TCC so far.

Working with the TCC, we identified a long list of experts who we invited to participate in the review process. These experts spanned industry bodies, Tier 1 construction companies, consultants and construction sector clients.

Experts were invited to attend a review meeting lasting one and a half hours. The meeting was held virtually and was facilitated by the Frontier and BMG team based on the themes identified in the interim report. Two separate expert review sessions were held, with a total of seven external sector experts in attendance.

Individuals from the TCC did not attend the meeting so that the experts would feel comfortable to offer their honest views. A summary of findings from the panel is reported in Annex B. Where relevant, key points of view from the expert panel are also highlighted in the main body of the report.

A summary note of the views (without individual attribution) was prepared and shared with attendees for review and sign-off. Any comments or feedback received will be included as part of the final report circulated in January 2022.

### 3.1.6 DEVELOPING THE CONTRIBUTION ANALYSIS

The overall contribution narrative, based on the evidence gathered, is reported in Section 11.

Evidence from the different evaluation methods discussed above was analysed and mapped against the evaluation themes and indicators. The Frontier and BMG team conducted a review of the findings for each of the evaluation themes and indicators. Where multiple sources of evidence were found for specific indicators (particularly where the messages from different sources about the impact of the TCC were potentially contradictory), we discussed our view on the overall findings and strength of the evidence for that indicator to support a shared and agreed contribution narrative. In addition, the results of the contribution narrative weresummarised against each TCC business case objective.

An initial draft of the narrative was written and presented at a meeting attended by representatives from the TCC and UKRI. The presentation was based on the initial contribution narrative for each evaluation theme along with the key supporting evidence. Feedback and comments were taken from those attending the meeting. Frontier reviewed this feedback and used it to revise the initial draft report and contribution narrative.

### 3.1.7 STRUCTURE OF THE FINDINGS SECTION

Sections 4 to 10 respectively outline the evidence for each evaluation theme. Sub-sections are used to organise the evidence against specific indicators.

For each theme, we first outline the activities undertaken by the TCC relating to the theme and then summarise the evidence for each indicator type.

It is important to note that the TCC activities included as part of this evaluation are a sub-set of all of those conducted by the Challenge to date. The survey and case studies were designed to provide a broadly representative reflection of the work of the TCC, but may not have captured all key activities. The monitoring data, including TCC benefits data, provides complete data across all TCC strands and projects.

# 4 FINDINGS: THEME 1 – FIRMS, PUBLIC BODIES AND ACADEMICS ENGAGING IN PROJECTS RELATING TO TCC CONCEPTS

## KEY MESSAGES

- This theme is a key component of the TCC objective to increase interdisciplinary collaboration between industry and academia.

**Number and type of external engagements with firms, public bodies and academics**

- We used contact detail information provided as part of the primary survey to derive a proxy assessment of the number of organisations by type that the TCC has engaged with to date. The majority of the contacts (74%) relate to business organisations in the private sector, with academics and researchers being the second largest group.

**Change in number and type of collaborations engaged in by TCC beneficiaries shortly after participation**

The primary survey found an increase in collaboration to develop or use new ways of working on construction projects in comparison to the baseline survey (conducted in 2019). Sectors which reported the largest increase in collaboration in the primary survey were research and technology organisations and businesses in manufacturing sectors. The majority of 'successful' TCC applicants (57%) reported that the TCC had increased collaboration significantly.

The case studies show examples of interdisciplinary collaboration across academic institutions; consultancy; businesses in the construction and digital sectors; technology specialists; and government departments. Those we consulted in the case studies often suggested that the TCC can be credited with improving collaboration across the sector through acting as a facilitator of collaboration, its high-profile nature and de-risking activities by providing matched funding.

Experts agreed with the evidence that there had been an increase in collaboration and in the quality of collaboration for organisations that the TCC had engaged with, and that this was partly attributable to the TCC.

Experts agreed with evidence from the case studies that organisations engaged by the Challenge often do not have full visibility of the wider TCC. The experts suggested that organisations often had awareness of CIH and/or ABC, but were not aware that they were part of the same programme.

**Change in number and type of collaborations between ex-TCC beneficiaries in the longer term**

- The case studies provide mixed evidence on the change and type of collaborations between ex-TCC beneficiaries in the long term, likely due to the recent completion of activities:
  - A number of case studies highlight optimism for long-term improvements in collaboration as a result of the TCC. By facilitating effective collaboration during TCC activities, it is expected that elements of this collaboration will continue in the future.
  - A number of case studies illustrate learnings for the TCC in order to better foster long-term collaboration. For example, interviewees suggested that the TCC could improve by providing channels for future engagement post Challenge participation for new projects.

This theme is a key component of the TCC objective to increase interdisciplinary collaboration between industry and academia (the 'supply side'). The theme is relevant to all TCC strands. Through this theme, the TCC is expected to create lasting links between the construction sector and the R&D community which will be critical for the long-term success of the Challenge.

This section provides the evidence base relating to the evaluation indicators for Theme 1, which are summarised in the table below. The section first outlines the activities undertaken by the TCC relating to this theme and then summarises the evidence for each indicator type below.

### TABLE 9 THEME 1 – SUMMARY OF EVALUATION APPROACH

| INDICATOR TYPE | SUCCESS INDICATOR | DATA SOURCES |
|---|---|---|
| Monitoring | Number and type of external engagements with firms, public bodies and academics | Contact data analysis |
| Short-term outcomes | Change in number and type of collaborations engaged in by TCC beneficiaries shortly after participation | Primary survey<br>Activity case studies<br>Expert review |
| Long-term outcomes and impacts | Change in number and type of collaborations between ex-TCC beneficiaries in the longer term | Primary survey<br>Activity case studies |

*Source: Frontier Economics*

## 4.1 ACTIVITIES UNDERTAKEN BY THE TCC

Activities that the TCC has undertaken in relation to this theme include the following:

- Engagement with government, industry and delivery partners in order to increase connections and knowledge flows between stakeholders;
- Development of demonstrators of processes, products, data collection tools and asset management frameworks. This largely links to the work of CIH;
- Development of collaborations between industry and academia through events and research calls in order to develop interdisciplinary partnerships; and
- Partnerships developed and projects co-delivered with industry, public bodies and other TCC centres.

## 4.2 MONITORING

### 4.2.1 NUMBER AND TYPE OF EXTERNAL ENGAGEMENT WITH FIRMS, PUBLIC BODIES AND ACADEMICS

#### TCC INTERNAL BENEFITS DATA

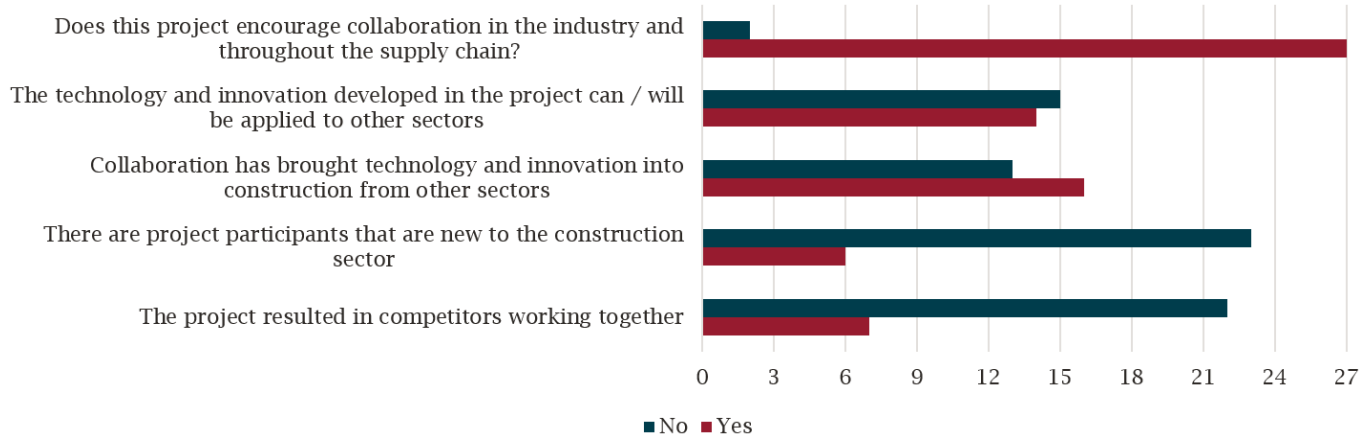
Internal TCC monitoring data includes survey answers by organisations linked to projects influenced by CR&D. Figure 8 shows the answers related to collaboration.

The survey was answered 29 organisations linked to 21 CR&D projects:

- The majority of respondents (27 out of 29) suggested that participation in the project was encouraging collaboration across the industry.

- Around half of the respondents answered that the technology/innovation developed could be applied to other sectors or that collaboration had brought technology/innovation from other sectors.
- Few respondents answered that there were project participants who were new to the construction sector (6 out of 29) or that projects resulted in competitors working together (7 out of 29).

## FIGURE 8 MONITORING DATA – CR&D SURVEY ON COLLABORATION




*Source: Frontier Economics based on TCC internal benefits data*

## CONTACT DATA ANALYSIS

The TCC strands provided contact data for successful and unsuccessful applicants of TCC support. This data was given to provide respondents for the primary survey conducted as part of this evaluation.

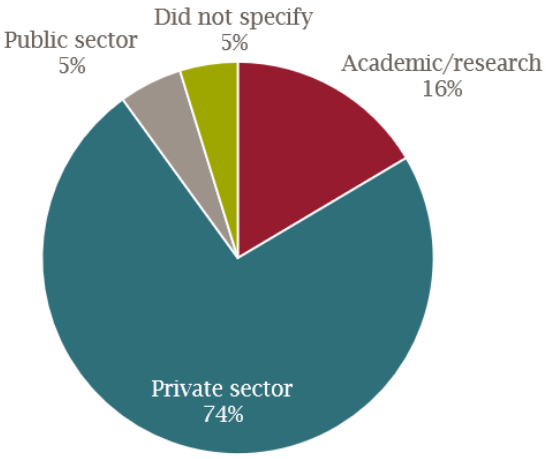
The contacts dataset comprised 878 organisations.[8] Figure 9 sets out the distribution of the contact data provided by all strands, by type of organisation:

- The majority of the contacts (74%) related to business organisations in the private sector.
- The second largest group (16%) concerned contacts from academics and researchers.
- The remaining contacts related to public sector organisations (5%) or did not specify their organisation type (5%).

The majority of the contacts (787) related to CR&D, such that the distribution in Figure 9 mainly reflects engagements with this strand. Most contacts from N+ and RL related to academics and researchers, while contacts from CIH mainly related to private sector organisations.

[8] This data does not include contacts who did not give permission for their details to be passed on to BMG/Frontier for the evaluation. We are not aware of how many contacts did not provide permission. The method of collecting contact details varied slightly by strand: for CR&D we asked for all successful and unsuccessful applicants across all competitions, and we received some contacts who had started their application but had not completed it or had withdrawn their application. For ABC and CIH, we asked for all those who had engaged with the Challenge in a meaningful way and excluded those who had only had very limited contact, such as attending one webinar.

FIGURE 9 DISTRIBUTION OF APPLICANT-LEVEL CONTACT DATA BY ORGANISATION TYPE




*Source: Frontier Economics based on primary survey contacts*

This database provides a proxy assessment of the number of organisations by type that the TCC has engaged with to date. We note that it is not comprehensive of all engagements, both because some organisations declined to have their details shared for the purpose of the survey and because we deliberately sought contacts from more meaningful or substantive engagements (e.g. sought to exclude organisations that had engaged TCC only through attending a single webinar or signing up to mailing lists) to support the impact evaluation survey.

## 4.3 SHORT-TERM OUTCOMES

### 4.3.1 CHANGE IN NUMBER AND TYPE OF COLLABORATIONS ENGAGED IN BY TCC BENEFICIARIES SHORTLY AFTER PARTICIPATION

#### PRIMARY SURVEY

The primary survey provides evidence of the extent to which there has been a change in the number and type of collaborations engaged in by TCC beneficiaries for the following metrics:

- Types of organisation which beneficiaries are collaborating with on new ways of working;
- Perceived changes in collaboration on projects or grants concerning construction; and
- Perceived impact of TCC on collaboration.

Overall, we find evidence of increases in collaboration, particularly with research and technology organisations. A material proportion of 'successful' TCC applicants experienced increased collaboration and attributed this to the TCC.

##### TYPES OF ORGANISATION WHICH BENEFICIARIES ARE COLLABORATING WITH ON NEW WAYS OF WORKING

The primary survey found that collaboration to develop or use new ways of working on construction projects was common. Ninety-eight percent of survey respondents had collaborated with at least one type of organisation to develop or use new ways of working on construction projects. This compares to 93% of

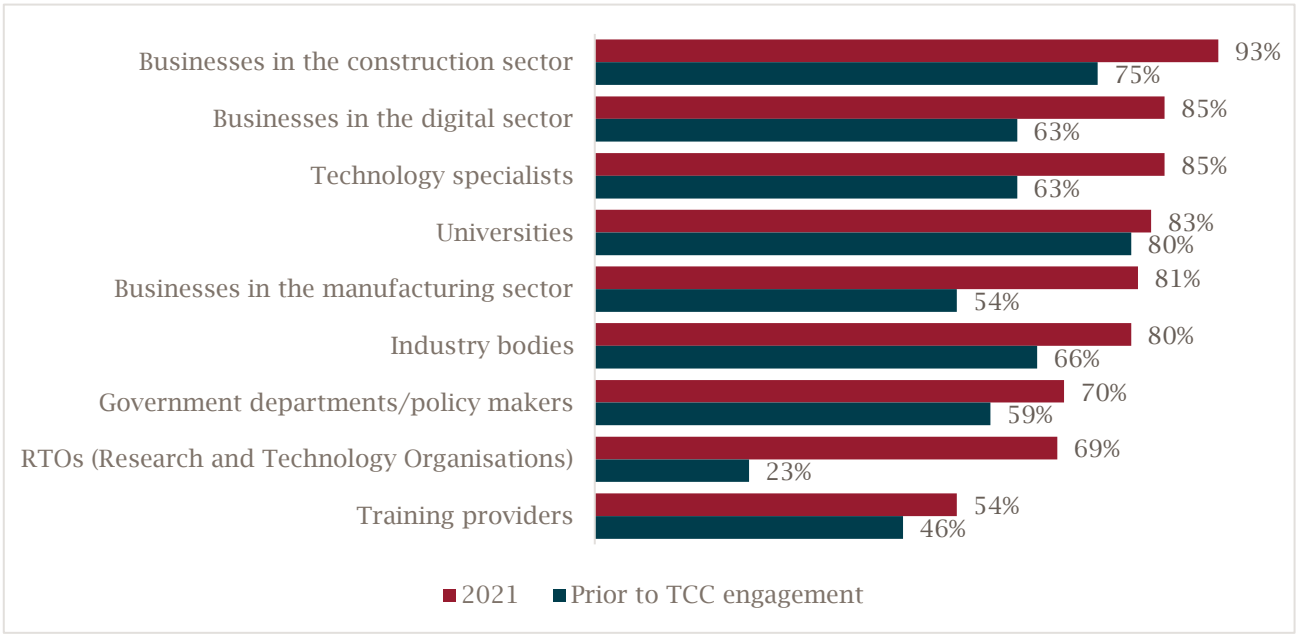
respondents to the baseline survey (conducted in 2019) who had collaborated with at least one type of organisation in the year prior to TCC engagement.

The most common type of organisation that survey respondents had collaborated with was businesses in the construction sector (93% had collaborated with this group), followed by businesses in the technology sector and technology specialists (both 85%). Around four in five had collaborated with universities (83%), businesses in the manufacturing sector (81%) and industry bodies (80%). Collaboration with government departments/policy makers (70%), research and technology organisations (RTOs) (69%) and training providers (54%) were less common but had still been undertaken by the majority of survey respondents.

The proportion of TCC beneficiaries surveyed who were involved in collaborations had increased compared to the baseline for each group measured, as shown in Figure 10. It is worth noting that the baseline survey only asked about collaborations in the year prior to TCC engagement, whereas the impact survey did not specify a time frame for collaborations. However, the two can be compared to give a rough estimation of the increase in collaboration.

The group where the biggest increase in collaboration can be seen is RTOs: 23% were collaborating with this group a year prior to their TCC engagement, compared to 69% who have ever collaborated with an RTO in the impact survey. Other groups where substantial increases in the proportion collaborating can be seen include businesses in the manufacturing sector (54% prior to TCC engagement, compared to 81% in the impact survey), businesses in the digital sector (63% prior to TCC engagement, compared to 85% in the impact survey) and technology specialists (63% prior to TCC engagement, compared to 85% in the impact survey).

## FIGURE 10 TYPES OF UK ORGANISATIONS WHICH BENEFICIARIES ARE COLLABORATING WITH ON NEW WAYS OF WORKING ON CONSTRUCTION PROJECTS COMPARED TO BASELINE



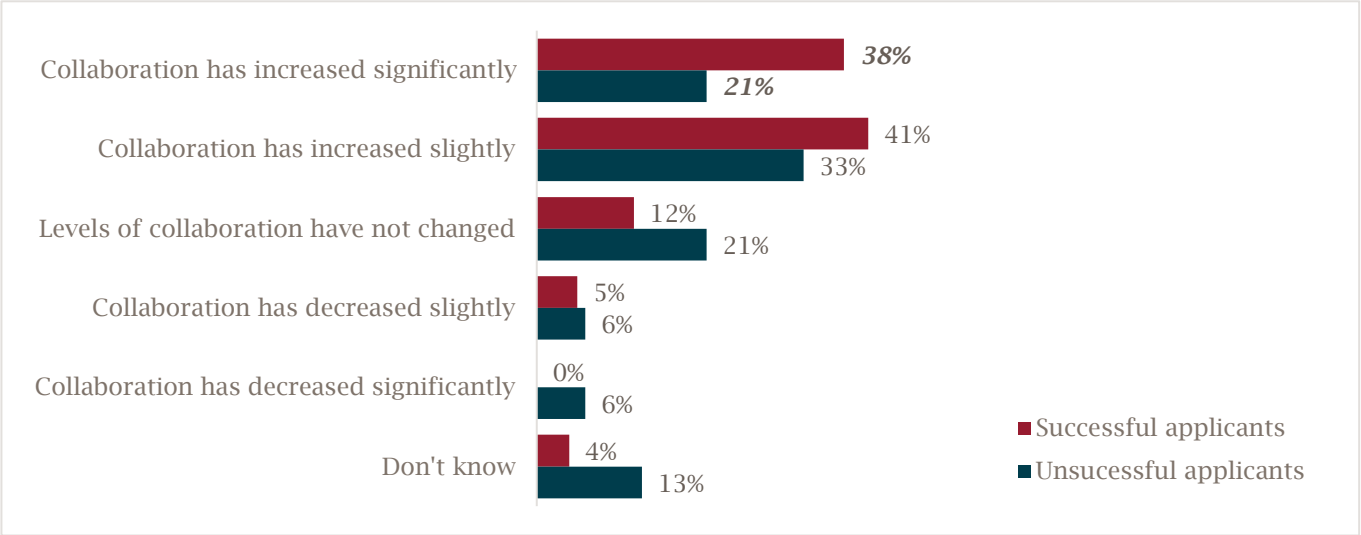

*Source: Beneficiaries surveys. Q10. In the year prior to your TCC engagement had your organisation/you collaborated with any of the following in the UK to develop or use new ways of working on construction projects? C21. Has your organisation/Have you collaborated with any of the following in the UK to develop or use new ways of working on construction projects?*

*Note: Base: All baseline survey respondents (56) all impact survey respondents (162)*

### PERCEIVED CHANGES IN COLLABORATION ON PROJECTS OR GRANTS CONCERNING CONSTRUCTION

Figure 11 shows the survey respondents' views of changes in collaboration on construction projects since 2018. Thirty-eight percent of 'successful' applicants reported that collaboration had increased significantly compared to 21% of 'unsuccessful' applicants.[9]

## FIGURE 11 CHANGE IN COLLABORATION ON PROJECTS OR GRANTS CONCERNING CONSTRUCTION SINCE 2018 – SUCCESSFUL VS. UNSUCCESSFUL APPLICANTS



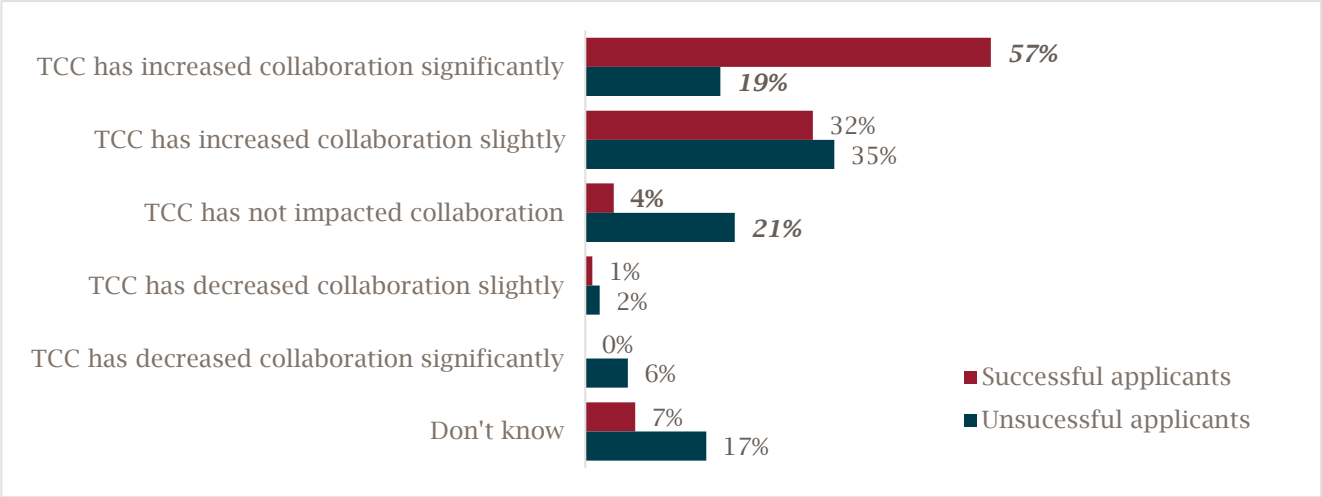

*Source: Beneficiaries survey. C22. How do you think collaboration in general on projects or grants concerning construction has changed since 2018?*
*Note: Base: Successful applicants (76), unsuccessful applicants (52). Figures in **bold and italitcs** are statistically significantly different for successful and unsuccessful applicants.*

### PERCEIVED IMPACT OF TCC ON COLLABORATION

Figure 12 shows the perceived impact of the TCC on collaborations. More than half of 'successful' TCC applicants (57%) reported that the TCC had increased collaboration significantly; only 19% of 'unsuccessful' applicants reported this. Only 5% of 'successful' applicants reported that the TCC had either not impacted collaboration or had decreased collaboration.

[9] Those who had been successful in their application to the Challenge for funding are referred to as 'successful applicants' and those who applied for TCC funding but had not been awarded it are referred to as 'unsuccessful applicants'.

## FIGURE 12 PERCEIVED IMPACT OF TCC ON COLLABORATIONS – SUCCESSFUL VS. UNSUCCESSFUL APPLICANTS




*Source: Beneficiaries survey. C23. How much to do you think the Transforming Construction Challenge has impacted collaboration in general on projects or grants aimed at any of the following: lowering costs, speeding up delivery, lowering emissions or improving exports?*
*Note: Base: Successful applicants (76), unsuccessful applicants (52). Figures in **bold and italics** are statistically significantly different for successful and unsuccessful applicants.*

### ACTIVITY CASE STUDIES

The case studies show many examples of interdisciplinary collaboration across academic institutions, consultancy, businesses in the construction and digital sectors technology specialists and government departments.

Overall, those we consulted in the case studies often suggested that the TCC can be credited with improving collaboration across the sector. The case studies highlight how the TCC has enabled collaboration by:

- **Acting as a facilitator of collaboration** through providing a hub for like-minded organisation to get together and share knowledge and learnings;
- **Using its high profile and strong reputation** throughout the construction sector to help organisations which engage with the TCC to increase their profile and activities; and
- **De-risking activities through providing matched funding and resource**. This has allowed organisations to collaborate in 'high-risk' areas for which it would have been difficult to receive funding. The TCC has enabled organisations to pool risk both with the TCC and across other organisations involved in the activity.

Nonetheless, there is variation in the role of the TCC in promoting collaboration. Some case studies suggest that without the TCC collaboration would not have gone ahead (e.g. Behind the Meter Billing and Trend Basin). In contrast, a number of case studies suggest that the collaboration would have happened in some form without the involvement of the TCC (e.g. Aquila, Digital Accelerator and FASTtruss). However, where this is the case, the case studies frequently credit the TCC with accelerating the collaboration or improving the quality of collaboration.

The case studies highlight that the TCC has increased the quality of the collaborations overall, allowed collaboration with more 'unlikely' partners and enabled organisations to take on additional activities or to have progressed activity to a later stage as a result of the collaboration.

A minority of case studies (including the Value Toolkit) highlight the role of Covid-19 in encouraging collaboration. Interviewees suggested that Covid-19 has been transformative in terms of ways of working and has thereby enabled more organisations to collaborate virtually. This volume of collaboration would have been difficult to coordinate prior to the pandemic, when in-person meetings were the norm.

It is important to note that for many of the case studies, engagement with the TCC, and consequently collaboration, was limited to specific activities. There are limited examples of the interviewed parties having other interactions with the Challenge outside of these, such as with different TCC activities or across the TCC strands.

A summary of relevant insights for the change in the number and type of collaborations from the activity case studies are presented in the below table. A full write-up of the case studies is provided in Annex D -

## TABLE 10 ACTIVITY CASE STUDY INSIGHTS – COLLABORATION SHORTLY AFTER TCC PARTICIPATION

| ACTIVITY | INSIGHTS |
|---|---|
| **Aquila** | **There was mixed attribution of the collaboration seen in the activity to the TCC.** The project involved collaboration between Build Stream, Northumbria University, BIM Academy and Walters Group. Interviewees felt the collaboration had worked well. However, this collaboration had started before TCC and hence the Challenge was less impactful in harnessing these collaborations.<br>However, the interviewees highlighted that **the Challenge had positioned the organisation as an 'innovative partner'**, making it attractive to other companies, and had fostered new relationships and partnerships with different organisations and customers, and thus had created wider collaboration beyond the activity partners. |
| **Behind the Meter Billing and Trent Basin** | **The TCC had encouraged collaboration between partners by de-risking activities through providing funding.** The parties involved (University of Nottingham and SmartKlub) felt that it would have been unlikely for the consortium to work together without TCC involvement or engagement. It would have been hard for the academic partners to convince commercial organisations to take the risk involved in proving a concept without external funding. Similarly, it would have been difficult for commercial partners to develop this concept by themselves**.** |
| **GenZero** | **The TCC had changed the form and increased the quality of collaborations.** Interviewees highlighted collaboration as critical to future proofing consulting services offered around MMC. Collaborations with other stakeholders such as academics, government departments, construction companies, CIH, and design consultants had proved very valuable for business networking and development. The TCC was deemed instrumental in these collaborations, both |

| | |
|---|---|
| | by providing funding and a hub for like-minded organisations to get together, as opposed to a decentralised network of collaboration. While the frequency of such collaborations had not changed, the interviewee credited TCC for better quality collaborations. |
| **Value Toolkit** | **It was suggested that Covid-19 had increased the levels of collaboration.** A number of interviewees suggested that the levels of collaboration might not have been possible without Covid-19. The activity had easily been able to progress while other construction work had been limited and the use of remote collaboration tools had worked really well for the activity. |
| **Active Building Research Centre** | **The TCC had acted as an effective bridge between academics and the wider industry.** The academic institution considered its collaboration with ABC to have been 'very valuable' and noted that it had allowed it to do things, such as planning courses that it would otherwise not have been able to do. Collaboration with ABC had helped the academic institution to attract companies to its institution and increase its collaboration with other organisations. It described the ABC as 'crossing the divide' between it as an academic organisation and companies which can bring forward technologies. |
| **Digital accelerator** | **The TCC had helped with developing new collaboration and accelerating others.** CIH funding had provided the opportunities for new collaborations to be formed. It was thought that some of these collaborations would have happened without the TCC's input as they were the result of existing personal connections, but others had been accelerated by the TCC's involvement. |
| **PLASMA** | **There were mixed views on the impact of collaboration, depending on the organisation interviewed.**<br>■ The interviewee from the technology company had very little awareness of the impact the TCC had had. They were unsure whether the project would have gone ahead without the Challenge, and felt it was too early to say whether engagement with TCC had impacted their organisation due to the stage of the project.<br>■ The interviewee from the construction company felt the project had only gone ahead because of the TCC and, while this was largely because of funding, the Challenge had also improved access to partners and had brought people together. |
| **FASTtruss** | **Collaboration enabled by the TCC had allowed the activity to reach a more developed stage.** Although, there had already been collaborations between the companies, the project would not have gone ahead to the extent it had without the funding and would have been a more theoretical model if done internally. The TCC had enabled them to reach the physical demonstration stage. |

*Source: Activity case studies*
*Note: This is a summary of the case study activity included. More detail is provided in the case study-specific annex.*

## VIEWS OF THE EXPERT PANEL

Overall, the expert panel agreed with the evidence that there has been an increase in collaboration and in the quality of collaboration for organisations that the TCC has engaged with and that this is partly

attributable to the TCC. A number of experts suggested that the TCC has acted as a critical focal point for organisations across the construction sector.

Experts agreed with evidence from the case studies that organisations engaged by the Challenge often do not have full visibility of the wider TCC. Experts suggested that organisations often had awareness of CIH and/or ABC but were not aware that they were part of the same programme, for example. The experts had mixed views about whether this visibility mattered. Some suggested that, in practice, it might not be necessary for organisations to be aware of other parts of the TCC programme. However, others suggested that the lack of wider programme visibility limited the extent of collaboration across the whole programme.

Experts did suggest that the communication between the TCC and wider industry could be improved to foster collaboration better. They highlighted that the wider industry often does not have visibility of the outputs and products being produced by the TCC and their timelines. As a result, the engagement with the wider industry was felt not to be sufficiently structured.

With regard to collaboration, other views expressed by those we consulted included:

- **A number of experts believed that there had been more limited engagement with policy makers and academia.** It was recognised that engagement with policy makers was difficult and required the right people in government to show a desire to be engaged. An expert highlighted that the links between the TCC and the wider government were not as effective as they could be, particularly those with BEIS and the IPA It was suggested that the TCC often had similar objectives to government, e.g. promoting modernised construction but in a way that was affordable and compatible with budgets, but that in practice there could be greater collaboration
- **An expert suggested that there were limited examples of pre-commercial collaboration in the wider industry.** An expert suggested that there had been limited changes in pre-commercial collaboration across the construction sector. They suggested that the TCC had not been able to influence this yet but that this was a critical area. However, the expert highlighted that this was an area with broader behavioural and cultural issues.

The expert panel suggested that there were a number of wider factors that had driven collaboration within the construction industry:

- **There had been an industry-wide movement to improve collaboration which pre-dated the TCC.** It was suggested that there was a movement towards greater collaboration in 2015-2016 driven by the Construction Leadership Council. This was matched by a distinct shift in academic research requirements around collaboration from research councils to collaborate with industry.
- **Covid-19 had increased collaboration.** A number of experts suggested that Covid-19 had helped foster collaboration across the industry and had accelerated access to digital tools, in line with some of the case study evidence.

## 4.4 LONG-TERM OUTCOMES AND IMPACTS

### 4.4.1 CHANGE IN NUMBER AND TYPE OF COLLABORATIONS BETWEEN EX-TCC BENEFICIARIES IN THE LONGER TERM

#### ACTIVITY CASE STUDIES

The case studies provide mixed evidence on change to and the type of collaborations between ex-TCC beneficiaries in the long term, likely due to the recent completion of activities:

- A number of case studies highlighted optimism about long-term improvements in collaboration as a result of the TCC. By facilitating effective collaboration during TCC activities, it was expected that elements of this collaboration would continue into the future.
- A number of case studies illustrated learnings for the TCC to better foster long-term collaboration. For example, interviewees suggested that the TCC could improve by providing channels for future engagement post Challenge participation for new projects.

A summary of relevant insights for the change in long-term collaboration from the activity case studies is presented in the table below. A full write-up of the activity case studies is provided in Annex D -

### TABLE 11 ACTIVITY CASE STUDY INSIGHTS – COLLABORATION IN THE LONG TERM

| ACTIVITY | INSIGHTS |
|---|---|
| **AIMCH** | **Optimism for future, more long-term collaboration.** The TCC had increased the number of collaborations for both parties interviewed (a house developer and a house builder) and had linked them to other organisations. This had increased their scope to form other types of partnership in the future. |
| **Data capture for whole lifecycle compliance checking** | **Through its creation of a network, it is expected that the TCC has facilitated future collaborations.** The TCC was seen as critical in developing a network for the activity and providing a platform to bring the consortium together. It was expected that there would be future collaboration across this consortium. |
| **Aquila** | **Evidence suggests there is potential for improving long-term collaboration following closure of a project.** Interviewees felt there had been little engagement in how to leverage the work of the project and collaboration for the future. They felt it would be beneficial for the TCC to be more involved in providing support with commercialisation, connecting partners and identifying funding opportunities or pipelines. |
| **GenZero** | **Improvements in processes for promoting spin-off projects.** There was an example of a spin-off project to GenZero, which was a classroom prototype. The interviewee felt it would have been beneficial to look at what other projects could have followed the same suit. However, there were no channels for this type of engagement. Therefore, the interviewee suggested that better engagement could be fostered through having a forum within CIH which would address this. |

*Source: Activity case studies*
*Note: This is a summary of the case study activity included. More detail is provided in the case study-specific annex.*

# 5 FINDINGS: THEME 2 – CONSTRUCTION SECTOR CLIENTS ENABLE TCC CONCEPTS TO BE USED IN THE PROCUREMENT PROCESSES

## KEY MESSAGES

- This theme relates to investment by firms engaged in R&D activities which facilitate the discovery of new processes or improvement of existing ones, with the result of improving within-firm productivity, and with the potential to create positive spillovers to the wider industry.

**External engagements with construction sector clients**

- The procurement case study highlighted a wide number of TCC programmes and TCC organisations that interviewees were actively aware of and had engaged with, showing clear knowledge of and engagement with the Challenge. Further, the procurement case study highlighted that engagement with the TCC had not been isolated to specific projects or activities. The TCC was seen as a focal point of innovation within the sector and a body they would seek to work with when pursuing innovation within procurement.

**Change in the intention of construction sector clients to adopt TCC concepts in their procurement processes**

- The primary survey provided evidence of high awareness of TCC concepts by large-scale construction businesses across all TCC concepts. Awareness was less than 85% for no concepts.
- The thematic case study found that individuals had had a high level of awareness of TCC concepts prior to engagement with the TCC. However, it was considered that the TCC had helped to increase knowledge of specific concepts and their potential and had opened their eyes to other concepts.

**Change in number/value of major private infrastructure clients' procurement frameworks which incorporate TCC concepts**

- The primary survey found that there was a perception that TCC concepts were more frequently seen in major private infrastructure procurement frameworks in 2021 in comparison to 2018. Further, many respondents believed that TCC concepts would be requested more frequently by both public and private sector clients in the future.
- The thematic case study found that, at this stage of the implementation of the TCC, the level of impact on procurement was at a strategic level rather than having a direct impact on individual procurement decisions. That is, the TCC's impact had broadened procurement strategy to consider wider outcomes rather than simply the inputs (i.e. costs). It was expected that there would be a change to the number of TCC concepts incorporated into procurement processes and regulatory frames in the next five years.
- The expert panel agreed that there had been a change in overall procurement strategy to consider a wider range of impacts (e.g. on people and the environment). However, they suggested that this could not be attributed directly to the TCC because of other factors, such as wider environmental pressures, and the work of other organisations, such as the Infrastructure Client Group.

This theme relates to the long-term outcome to integrate TCC solutions throughout public procurement processes and regulatory frameworks. This outcome is supported by outputs from the CIH and ABC strands, which aim to increase adoption of TCC technologies and methods in government programmes and by the sector.

This theme captures outputs that are necessary to enable the adoption of TCC concepts by construction companies, their clients as well as wider industry. The adoption of new concepts is likely to be costly to firms, and there will initially need to be demand-side incentives, i.e. through the implementation of TCC concepts in procurement frameworks.

This section provides the evidence base for the evaluation indicators for Theme 2, which are summarised in the table below. The section first outlines the activities undertaken by the TCC which relate to this theme and then summarises the evidence for each indicator type.

### TABLE 12 THEME 2 – SUMMARY OF EVALUATION APPROACH

| INDICATOR TYPE | SUCCESS INDICATOR | DATA SOURCES |
|---|---|---|
| Monitoring | External engagement with construction sector clients | Thematic case study |
| Short-term outcomes | Change in construction sector clients' intention to adopt TCC concepts in their procurement processes | Primary survey<br>Thematic case study |
| Long-term outcomes and impacts | Change in number/value of major private infrastructure clients' procurement frameworks which incorporate TCC concepts | Primary survey<br>Thematic case study<br>Expert review |

*Source: Frontier Economics*

## 5.1 ACTIVITIES UNDERTAKEN BY THE TCC

Activities that the TCC has undertaken in relation to this theme include the following.

- Engagement with government, industry and delivery partners in order to increase connections and knowledge flows between stakeholders;
- Development and promotion of demonstrators of processes, products, data collection tools and asset management frameworks. This largely links to the work of CIH; and
- Development and promotion of active buildings demonstrators and models for commercialisation. This relates to the work of ABC specifically.

For example, we understand that as part of the GenZero project, CIH has influenced the Department of Education to improve the design standards for school buildings by incorporating modern methods of construction. This includes a whole-life approach and digital off-site manufacturing methods.[10] Further, CIH and ABC noted their contributions to the development of government policy through, for example, CIH's significant input to the Construction Playbook in areas related to TCC concepts. [11]

[10] https://tc-catalogue.strongerstories.org/stories/genzero/

[11] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/941536/The_Construction_Playbook.pdf

## 5.2 MONITORING

### 5.2.1 EXTERNAL ENGAGEMENT WITH CONSTRUCTION SECTOR CLIENTS

#### THEMATIC CASE STUDY

##### ENGAGEMENT WITH THE TCC ON PROCUREMENT ISSUES

The procurement case study highlighted a large number of TCC programmes and TCC organisations that interviewees were actively aware of and had engaged with, showing clear knowledge of and engagement with the Challenge. These programmes included the Value Toolkit (CIH), Digital Twin (CIH), Government Soft Landings (GSL), AutoBIM, and the Active Building Research Centre (ABC). Details of these programmes are included in the full procurement case study write-up (see Annex E -

Further, the procurement case study highlighted that engagement with the TCC had not been isolated to specific projects or activities. A number of interviewees spoke highly of the TCC and the respective organisations they had engaged with. They suggested that the TCC was seen as a focal point of innovation within the sector and a body they would seek to work with when pursuing innovation within procurement.

> *"There was little sense of industry-wide innovation with the objective of improving the industry (e.g. making the industry more stable). TCC has changed that, creating something that people gravitate towards (…) TCC has had a significant impact on raising awareness and encouraging innovation."*

Interviewees highlighted that the demonstrator elements of TCC engagement were working particularly well. It was suggested that there was often an element of doubt or uncertainty when incorporating a new concept into procurement and that demonstrators were a critical mechanism for reducing these barriers, showing how TCC concepts can work in practice.

> *"When we can demonstrate things, e.g. walk through a building and show what works, it makes it easier to shift people's mindsets."*

## 5.3 SHORT-TERM OUTCOMES

### 5.3.1 CHANGE IN CONSTRUCTION SECTOR CLIENTS' INTENTION TO ADOPT TCC CONCEPTS IN THEIR PROCUREMENT PROCESSES

#### PRIMARY SURVEY

The primary survey provides evidence for the awareness of TCC concepts by large-scale construction business. Overall, we find a high level of awareness across all TCC concepts.

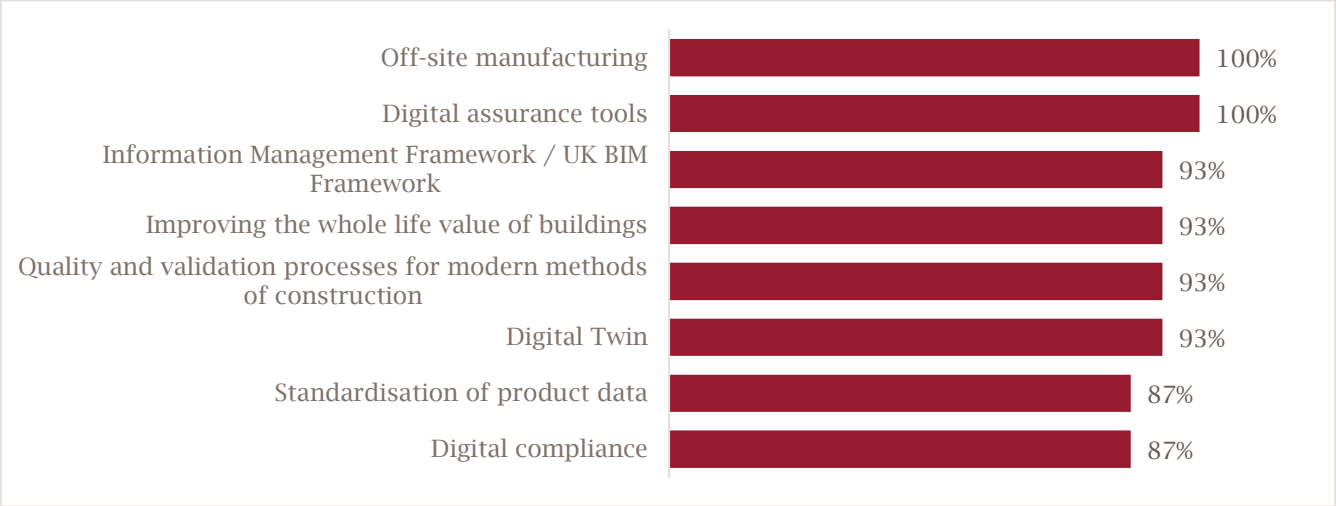
A summary of the relevant primary survey evidence is provided below, with the full write-up in Annex B -

##### AWARENESS OF TCC CONCEPTS BY LARGE-SCALE CONSTRUCTION BUSINESS

Figure 13 shows respondent awareness of TCC concepts by large-scale construction businesses. The concepts shown to each respondent varied depending on the main TCC strand they had engaged with. For this theme, we analysed the awareness of TCC concepts for the companies with the largest turnover (£25 million or more).

The figure illustrates high overall awareness of TCC concepts by large construction sector businesses. The majority of these businesses were aware of all of the concepts measured. All were aware of off-site manufacturing and digital assurance tools. The concepts with the lowest levels of awareness were standardisation of product data and digital compliance. However, these were still known by the vast majority of the large businesses surveyed.

## FIGURE 13 AWARENESS OF TCC CONCEPTS BY LARGE-SCALE CONSTRUCTION BUSINESSES




*Source: Beneficiaries survey. Q18. Please describe your familiarity with the following tools, technologies and concepts.*
*Note: Base: Impact survey respondents whose main engagement was with CR&D, CIH, N+ or RL with turnover of at least £25 million (15)*

## THEMATIC CASE STUDY

### AWARENESS OF TCC CONCEPTS

The interviewees all showed a clear understanding of TCC concepts (the Value Toolkit and MMC were frequently mentioned) and the benefits that they have versus traditional construction methods. Interviewees illustrated a wide range of views on the extent to which the TCC had increased their understanding of TCC concepts. By and large, this varied depending on the individual's role and previous level of knowledge of TCC concepts prior to engagement with the TCC. All interviewees suggested that the nature of their role meant they had had a high level of awareness of TCC concepts prior to the TCC's introduction. This was particularly the case for the interviewee from the commercial sector. However, government representatives expressed that the TCC had helped increase their knowledge of specific concepts and their potential, and had opened their eyes to other concepts. In particular, this was linked to innovations related to the environmental sustainability of buildings and Information Management, which interviewees suggested were often theoretical but which the TCC had made more digestible.

Interviewees also offered views on the overall awareness of TCC concepts in wider government procuring bodies. It was suggested that the more experienced individuals with an influence on procurement had a high level of awareness and understanding of the TCC and its concepts. This was the case in central government departments and private sector bodies. However, one interviewee noted that government procurement is broad and includes a wide range of departments and arms-length bodies. The interviewee questioned the extent to which there was widespread awareness of the TCC and TCC concepts across government and arms-length bodies. Nonetheless, it was suggested that the TCC's current focus on influencing senior procurement stakeholders in government bodies was appropriate.

*"Where procurers are sufficiently involved and senior enough in order to influence things, there is usually quite good awareness and understanding of TCC and TCC concepts. However, people are less aware of TCC lower down the chain."*

The individuals in government that we interviewed were particularly aware and had engaged with the TCC. We approached other potential interviewees in government, who declined to participate as they felt they had insufficient knowledge of or familiarity with the TCC, perhaps supporting the view that there is still a gap in widespread awareness of the Challenge and TCC concepts across government.

## 5.4 LONG-TERM OUTCOMES AND IMPACTS

### 5.4.1 CHANGE IN NUMBER/VALUE OF MAJOR PRIVATE INFRASTRUCTURE CLIENTS' PROCUREMENT FRAMEWORKS WHICH INCORPORATE TCC CONCEPTS

#### PRIMARY SURVEY

The primary survey provides evidence for the level of change in the number and value of major private infrastructure clients' procurement frameworks that incorporate TCC concepts for the following metrics:

- Perceived changes in the presence of concepts in major private infrastructure procurement frameworks; and
- Expected use of TCC concepts for public and private sector clients.

Overall, we found that, for a number of TCC concepts, there was a perception that these were seen more frequently in major private infrastructure procurement frameworks in 2021 in comparison to 2018. Further, many respondents believed that TCC concepts will be requested more frequently by both public and private sector clients.

A summary of the primary survey evidence is provided below, with the full write-up in Annex B -

##### PERCEIVED CHANGES IN THE PRESENCE OF CONCEPTS IN MAJOR PRIVATE INFRASTRUCTURE PROCUREMENT FRAMEWORKS

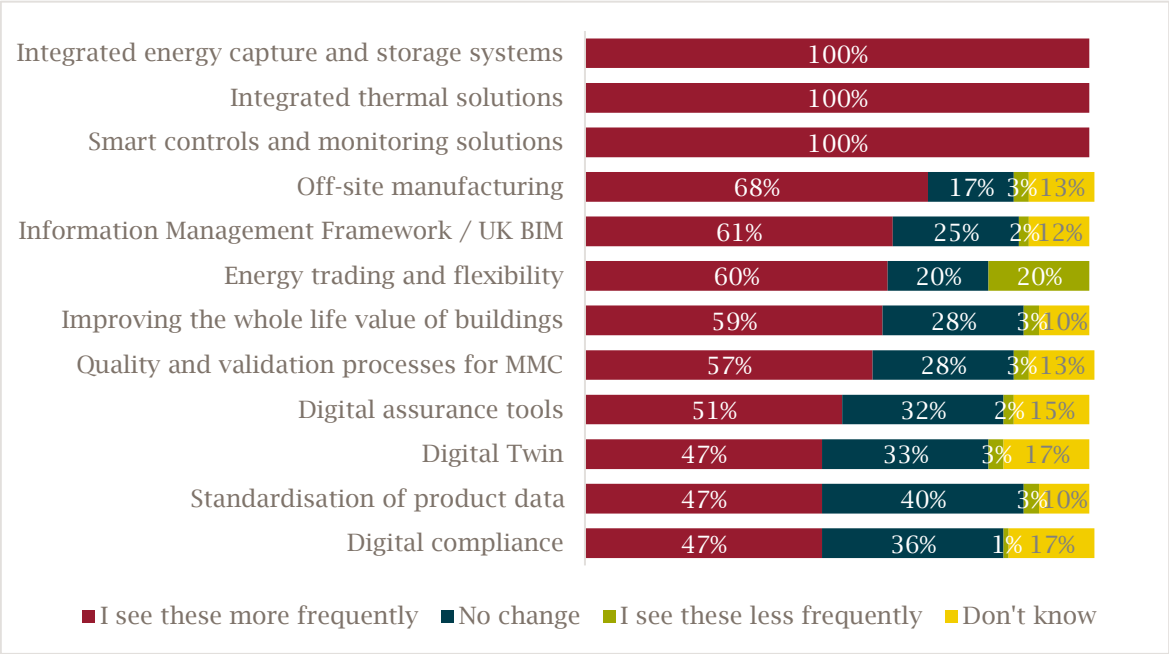
Figure 14Figure 14 shows the survey responses on whether business had noticed a change in the presence of TCC concepts in major private infrastructure clients' procurement frameworks compared to 2018. This question was asked specifically to businesses.[12] As above, the concepts respondents were asked about depended on the TCC strand they had had the most engagement with.

The figure illustrates that there has been a material change in the presence of concepts in major private infrastructure procurement. However, the extent of the change depends on the concept analysed. For example, all respondents reported more frequently seeing integrated energy capture and storage systems, integrated thermal solutions, and smart controls and monitoring solutions. However, just under half (47%) said they had seen an increase in Digital Twin, standardisation of product data and digital compliance.

[12] Only five businesses stated that their main engagement had been with ABC. As such, there is not enough evidence from the surveys to comment on perceptions of the change in the presence of ABC concepts in major private infrastructure procurement frameworks.

It is important to note that the 'successful' TCC funding applicants surveyed were more likely to have seen digital assurance tools (63%), Digital Twin (59%) and digital compliance (58%) more frequently.

## FIGURE 14 PERCEPTIONS OF CHANGE IN THE PRESENCE OF CONCEPTS IN MAJOR PRIVATE INFRASTRUCTURE PROCUREMENT FRAMEWORKS SINCE 2018




*Source: Beneficiaries survey. Q20A. Have you noticed any changes at all in the presence of the following tools, technologies, and concepts in major private infrastructure clients' procurement frameworks since 2018?*
*Note: Base: Impact survey business respondents whose main engagement was with CR&D, CIH, N+ or RL (115)*

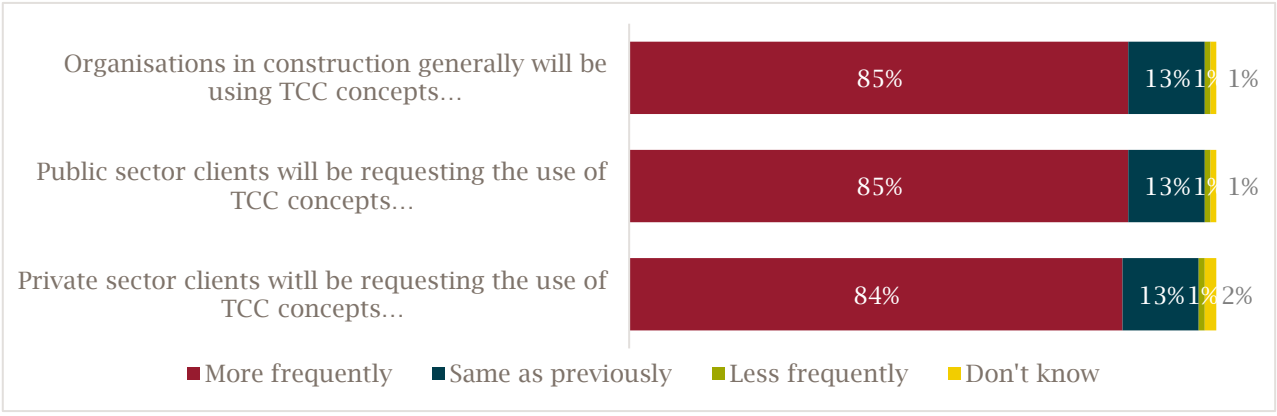
### EXPECTED USE OF TCC CONCEPTS FOR PUBLIC AND PRIVATE SECTOR CLIENTS

Businesses which were aware of at least one of the TCC concepts measured were asked whether they expected public sector and private clients to be requesting the use of TCC concepts more frequently, based on their knowledge of TCC and its activities.

Figure 15 shows that there was high expected use of TCC concepts in the future. Specifically, 85% expected construction organisations to be generally using TCC concepts more frequently. The same proportion (85%) expected public sector clients to be requesting the use of TCC concepts more frequently, and a similar proportion (84%) expected private sector clients to be requesting their use more frequently.

Those whose organisations were typically involved with cladding were more likely to expect both public and private sector clients to be requesting the use of TCC concepts more frequently (97% for both), as were those whose organisations were typically involved with superstructure (95% for public and 93% for private clients).

## FIGURE 15 EXPECTATIONS OF USE OF TCC CONCEPTS




*Source: Beneficiaries survey. Q20. Based on your knowledge and experience of the Transforming Construction Challenge, do you expect as a result of its activities to see the following things more frequently, less frequently, or same as previously?*
*Note: Base: Impact survey business respondents aware of at least one TCC concept measured (158)*

## THEMATIC CASE STUDY

### CHANGES TO PROCUREMENT PROCESSES AND ATTRIBUTION TO THE TCC

Overall, interviewees offered a number of areas where there had been changes to public procurement processes and regulatory frameworks, including the concepts being procured. However, at this stage of the implementation of the TCC, they suggested that the level of impact was at the strategic level rather than having a direct impact on individual procurement decisions. That is, the TCC's impact had broadened procurement strategy to consider wider outcomes rather than simply the inputs (i.e. costs). The interviewees noted that this was to be expected given the timeframe required to influence the concepts used in public procurement processes and regulatory frameworks. This is explored in more detail in this sub-section, focusing first on the current impact of the TCC and the potential future impact.

- **Government interviewees highlighted that the TCC was having a clear, strategic impact on procurement.** This impact was linked to the overall engagement individuals in procurement were having with the TCC, and particularly with the Value Toolkit and the Digital Twin projects. Interviewees highlighted the role of the TCC in changing the overall approach to procurement to consider wider factors. Prior to the TCC, projects' objectives were mainly focused on the costs and the direct delivery of the project (e.g. number of schools or hospitals built). The TCC had widened the strategic thinking in procurement to consider the 'whole value' of the project, including impacts on people (such as via employment), social impacts, natural impacts (such as those on emissions and biodiversity) and the manufacturing impacts. As a result, a number of interviewees cited the TCC as being critical in changing the current strategy within procurement processes:

*"Overall, we are seeing a big cultural change which is guided towards outcomes rather than inputs, so we are expecting a very positive impact from it."*

- **The TCC was having a clear influence on government thinking. This had the potential for additional spillovers to the sector.** A number of interviewees suggested that the TCC was influencing wider government thinking, as can be seen in the latest Construction Playbook with its emphasis on digitalisation and decarbonisation. These areas have been key features of the TCC. As

a result, it was expected that TCC concepts would have an impact on large-scale public sector procurement.

- **The interviewees suggested that the TCC had helped accelerate change, but that there were wider factors contributing to the changes seen.** Interviewees suggested that the TCC had begun to change culture and influence government thinking, although the extent to which that change could be attributed to the TCC was not clear. Interviewees suggested that the changes were being driven by a wider range of factors, such as concerns about global warming and the pressure to decarbonise. Overall, interviewees agreed that the TCC had been an important factor in contributing to the change seen in government culture due to its role in bringing industry and government together, which had accelerated the pace of change:

*"A whole load of things are driving cultural change (e.g. worries about global warming), but TCC is an important element of it and without TCC we wouldn't see progress in quite the same way. TCC is good at bringing the industry and government together."*

- **Overall, interviewees across the commercial, government procurement and central government groups agreed that there had been a limited impact on the number of TCC concepts incorporated in procurement process and regulatory frameworks to date.** Interviewees suggested that this was as expected given the short timeframe since implementation of the TCC. Nonetheless, interviewees noted that they expected a future impact, both due to the TCC and the wider pressures linked to decarbonisation and digitisation strategies:

*"In terms of TCC concepts being included in the procurement process, I don't think that has been the case yet. However, it is to be expected in the future."*

- **Interviewees suggested they expected to see a change in the number of TCC concepts incorporated in procurement processes and regulatory frames in the next five years.** They suggested this timeframe for both the incorporation of TCC concepts in government and commercial procurement. They expected these changes to include the changed strategy for procurement; procurement objectives moving beyond cost; digitalisation; MMC; waste minimisation and decarbonisation. The interviewees suggested that the TCC would be a critical enabler of the adoption of these concepts in the future.

### SECTOR-WIDE BARRIERS

A number of sector-wide and procurement-related barriers were identified as part of the thematic case study, limiting the impact that the TCC had been having and would continue to have on incorporating TCC concepts into procurement process and frameworks.

- **The frequent separation between innovation and procurement within organisations.** A number of interviewees flagged difficulties in integrating innovation concepts due to the general separation of innovation and procurement activities. It was suggested that this was a common problem within a range of organisations and prevented the adoption of innovative concepts in procurement, or, at a minimum, created significant time delays. This was flagged, in particular, by government procuring bodies. One interviewee suggested that the TCC acted as an effective link between innovation and procurement, but there was still an existing gap to close:

*"The problem, which is common to most organisations, is that the people responsible for R&D/innovation and the people responsible for procurement are not the same, and are not connected".*

- **Skills shortages in the industry.** Interviewees suggested that skills shortage were a critical barrier that would likely delay the adoption of TCC concepts in procurement processes and regulatory frameworks. There was uncertainty about whether the industry had the skills and capabilities to adopt many of these technologies linked to TCC concepts in a short timeframe. Therefore although the TCC was creating incentives to improve the supply of the TCC concepts in the construction industry through increasing demand, the gap in skills in the supply side was likely to cause delays in the wider adoption of TCC concepts and, thereby, the ability of organisations to include TCC concepts in procurement processes.

- **In general, the interviewees did *not* suggest that Covid-19 had limited the adoption of TCC concepts in procurement processes and regulatory frameworks.** On the contrary, a number of interviewees stated that Covid-19 had motivated change across the industry by, for example, placing more emphasis on off-site construction.

### VIEW OF THE EXPERT PANEL

Overall, the expert panel agreed that there had been a change in the overall strategy within procurement to consider a wider range of impacts (e.g. on people and the environment). However, they suggested that this could not be attributed directly to the TCC due to the presence of other factors, such as wider environmental pressures and the work of other organisations. The experts instead suggested that the TCC was an enabler of a movement towards TCC concepts being adopted in public sector procurement processes.

A number of experts suggested that the TCC had picked up on concepts that were being discussed within procurement prior to the TCC and had acted as a 'broadcast mechanism' to promote their adoption further. Other bodies such as the Infrastructure Client Group were also influencing the adoption of TCC concepts in procurement. Therefore, the TCC had added to this voice and thus the impact could not be directly attributed to it. This was particularly the case for platform-based approaches.

The experts noted the importance of the Construction Playbook in changing public sector procurement, including via the incorporation of TCC concepts. However, the experts had mixed views and understanding of the extent to which the TCC had engaged with the development of the Construction Playbook. One expert questioned the causal mechanism between the TCC and the outputs of the Construction Playbook. They highlighted that the TCC had been involved in the development of the Construction Playbook but the extent to which the TCC had been driving the thinking behind the content included was not clear. Another expert suggested we should be careful not to underestimate the role that the TCC, and in particular the CIH, had played in the outputs included in the Construction Playbook. Further, it was expected that the TCC would be similarly involved in the creation of a construction playbook for the private sector.

An expert suggested that there should have been a greater focus on procurement in practice and, further, that they were not aware of the extent to which the focus on procurement processes was a true focus of the TCC. The expert suggested that a focus on government procurement had the wider benefit of enabling and incentivising wider market adoption of TCC concepts. However, the expert felt that changing mindsets within the public sector was challenging and was not an expected output of the TCC at this stage of the programme.

# 6 FINDINGS: THEME 3 – CONSTRUCTION INDUSTRY AND ASSOCIATED VALUE CHAIN INCREASE INVESTMENT IN R&D RELATED TO TCC CONCEPTS

## KEY MESSAGES

- This theme relates to investment by firms in R&D activities that facilitate the discovery of new processes, or improve existing ones, with the result that they improve within-firm productivity, and have the potential to create positive spillovers to the wider industry.

**Matched firm R&D funding**

- The TCC has a target of achieving a cumulative co-investment value of £250 million by 2027. The benefits data suggests that the TCC is on track to meet this target by 2023. As of 2021, cumulative committed co-investment amounted to £132.77 million, representing 53% of the target for 2027.

**Change in value of R&D linked to TCC concepts**

- The primary survey shows similar levels of R&D spending in comparison to before the TCC was established, across all organisations surveyed. The average R&D spend as a proportion of turnover was 30% for the previous financial year. This is similar to the average of 29% seen in the year prior to TCC engagement.
- However, the primary survey does suggest that increases in R&D spending can be attributed in part to the TCC. Fifty-three percent of those with 'successful' TCC applicants reported that R&D spend had increased significantly as a result of engagement with the TCC, and a further 32% reported that the TCC had increased R&D slightly as a result of engagement with the TCC.

**Additional aggregate R&D spending in construction sector and key suppliers**

- The case studies highlight the importance of the 'de-risking' role that the TCC has played in encouraging investment. By pooling risk across organisations through matched funding for those engaging with CR&D, the TCC has enabled more investment in 'higher risk' areas that relate to TCC concepts. Further, the TCC's involvement provides organisations with external validation, giving a positive signal for wider investment.
- The experts echoed the view that the TCC provides an important route for de-risking R&D as well as a source of external validation. The experts questioned whether the industry's current focus on short-term R&D investment in the sector was appropriate. They felt that the TCC helped organisations to focus on longer-term type R&D activities, and more so than would be possible in a purely commercial context. The experts commented that they did not expect the R&D focused on TCC concepts to continue in the long term without continual government support.

**Change in industry investment in key sub-sets of the industry**

- The secondary data analysis provides evidence for an increase in additional aggregate R&D spending and investment in the construction sector and key suppliers. This suggests that the TCC is operating in an environment of increasing R&D expenditure and investment.

This theme relates to investment by firms in research and development activities that facilitate the discovery of new processes or improvement of existing ones, with the result that they improve within-firm productivity, and have the potential to creating positive spillovers on the wider industry.

In the short term, R&D investment is supported by matched funding (in-kind and cash) for businesses in receipt of ISCF support (funding for the CR&D strand and access to expertise, technology, and facilities for

CIH and ABC) . In the longer term, the Challenge's outcomes are intended to attract further follow-on investments.

This section provides the evidence base relating to the evaluation indicators for Theme 3, which are summarised in the table below. The section first outlines the activities undertaken by the TCC relating to this theme and then summarises the evidence for each indicator type.

### TABLE 13 THEME 3 – SUMMARY OF EVALUATION APPROACH

| INDICATOR TYPE | SUCCESS INDICATOR | DATA SOURCES |
|---|---|---|
| Monitoring | Matched firm R&D funding (UKRI Definitions 1 and 2) | TCC benefits data |
| Short-term outcomes | Change in value of R&D linked to TCC concepts (UKRI Definitions 3 and 4) | Primary survey<br>Activity case studies |
| Long-term outcomes and impacts | Additional aggregate R&D spending in construction sector and key suppliers | Secondary data analysis |
| | Change in industry investment in key sub-sets of the industry | Secondary data analysis<br>Expert review |

*Source: Frontier Economics*

## 6.1 ACTIVITIES UNDERTAKEN BY THE TCC

The TCC has fostered R&D and investment in TCC concepts in the short term through providing matched funding (in-kind and cash) for businesses in receipt of ISCF support (funding for the CR&D strand and access to expertise, technology, and facilities for CIH and ABC). In the longer term, the activities and outputs of the TCC are intended to attract further follow-on investment. These activities include the following:

- The development and demonstration of new models for commercialisation;
- Development and promotion of demonstrators of processes, products, data collection tools and asset management frameworks. This largely links to the work of the CIH; and
- Undertaking and translating research to develop Active Building build designs and technology solutions and the creation of a National Active Building Evidence Base (NABEB). This links to the work of the ABC.

## 6.2 MONITORING

### 6.2.1 MATCHED FIRM R&D FUNDING

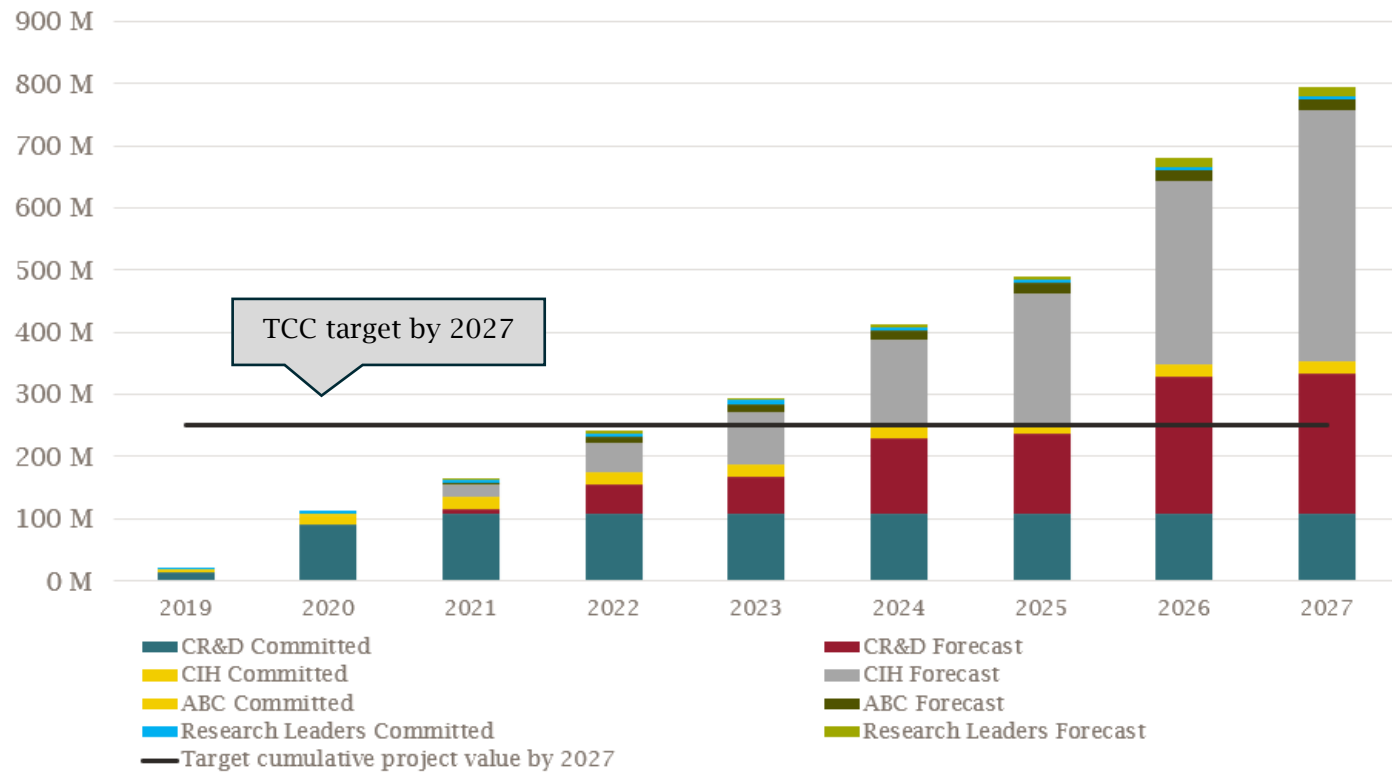
#### TCC BENEFITS DATA

Figure 16 shows total industry matched funding by TCC strand for four types of co-investment:

- **Form 1 ('Upfront, committed' co-investment):** Participant contribution committed as part of the project application.
- **Form 2 ('Additional, committed' co-investment):** Additional contribution over and above that committed as part of the project application.
- **Form 3 ('Induced' or 'aligned' co-investment):** Investment from additional activity thematically aligned to TCC but not directly associated with the project.
- **Form 4 ('Follow-on' co-investment):** Investment to take to market and achieve a commercial product.

The TCC has a target of achieving a cumulative co-investment value of £250 million by 2027. The benefits data suggests that the TCC is on track to meet this target by 2023. As of 2021, cumulative committed co-investment amounted to £132.77 million, representing 53% of the 2027 target.

### FIGURE 16 INDUSTRY MATCHED FUNDING




*Source: Frontier Economics based on TCC's benefits survey data*

*Note: Forecast amounts are based on a proportion of the identified pipeline; committed amounts are based on value of projects influenced. The exact definitions of forecast and committed vary by strand.*

## 6.3 SHORT-TERM OUTCOMES

### 6.3.1 CHANGE IN VALUE OF R&D LINKED TO TCC CONCEPTS

#### PRIMARY SURVEY

The primary survey provides evidence for the change in the value of R&D linked to TCC concepts following the metrics:

- Current investment in R&D;
- Proportion of spend related to TCC areas of focus; and
- Perceived impact of the TCC on R&D spend.

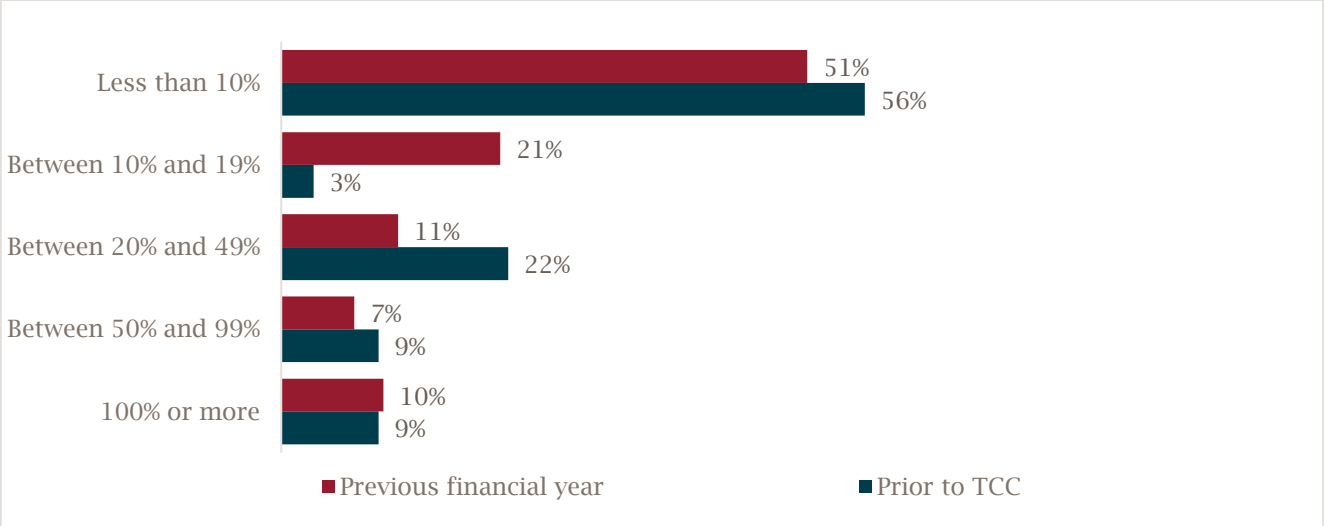
Overall, we find similar levels of R&D expenditure in 2020/21 compared to the baseline survey (2018-19). However, a material number of 'successful' TCC applicants attributed increases in R&D expenditure to the TCC. A summary of the findings is provided below, with all figures presented in Annex B -

### CURRENT INVESTMENT IN R&D

Survey respondents that were businesses were asked about their organisations' level of investment in R&D in the previous financial year (2020/21). For most of the businesses surveyed the 'previous financial year' indicator includes at least some of the Covid-19 pandemic.

Figure 17 shows current investment in R&D as a proportion of turnover in comparison to the baseline. The average R&D spend as a proportion of turnover was 30% for the previous financial year. This is similar to the average of 29% seen in the year prior to TCC engagement. The majority of businesses continued to spend less than 10% of their turnover on R&D (51% for the previous financial year, and 56% for the year prior to engagement with TCC). Around one in ten continued to spend 100% or more of their turnover on R&D (10% in the previous financial year and 9% in the year prior to engagement with TCC).

## FIGURE 17 CURRENT INVESTMENT IN R&D AS A PROPORTION OF TURNOVER COMPARED TO BASELINE




*Source: Beneficiaries survey. Q2Di. What was your organisation's level of investment in research and development in the previous financial year?*
*Note: Base: Impact survey business respondents (82)*

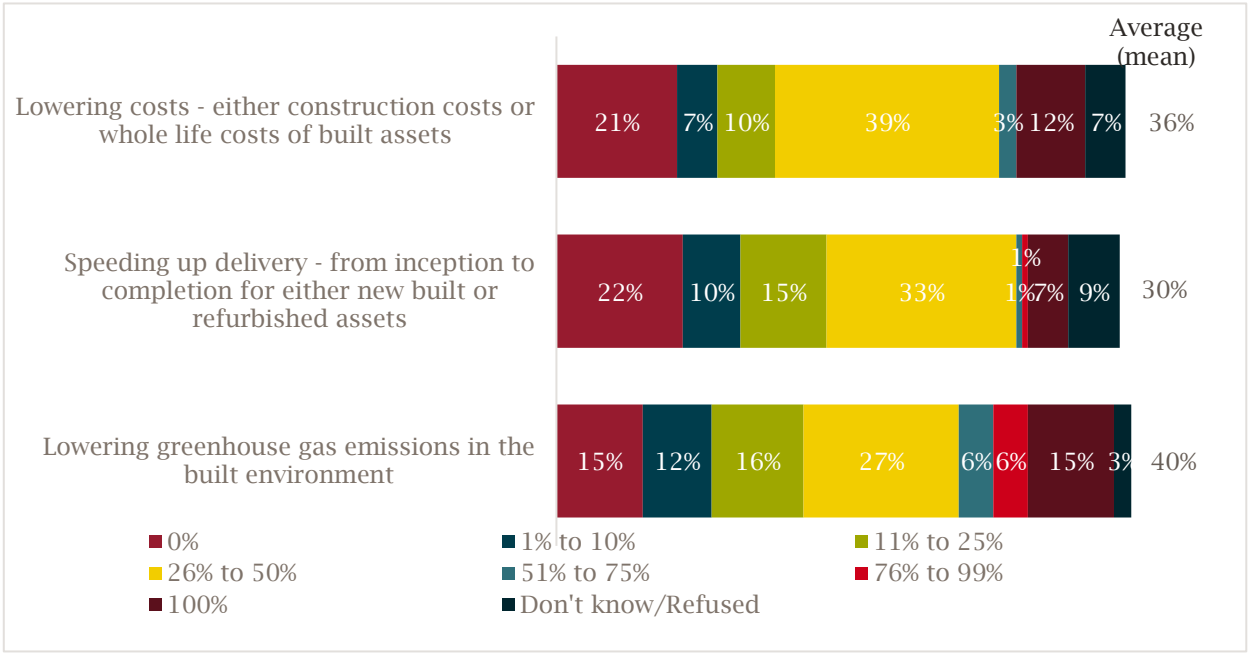
### PROPORTION OF SPEND RELATED TO TCC AREAS OF FOCUS

Figure 18 shows the proportion of spend related to TCC areas of focus. There are similarities in the distribution of R&D spend across lowering cost, speeding up delivery and lowering greenhouse gas emissions in the built environment.

The area with the highest average proportion of R&D spend (40%) is lowering greenhouse gas emissions in the built environment. The average proportion of R&D allocated to lowering costs, either construction

costs or whole-life costs of built assets, is over a third (36%). The average proportion of R&D allocated to speeding up delivery is 30%.

## FIGURE 18 PROPORTIONS OF SPEND RELATED TO TCC AREAS OF FOCUS

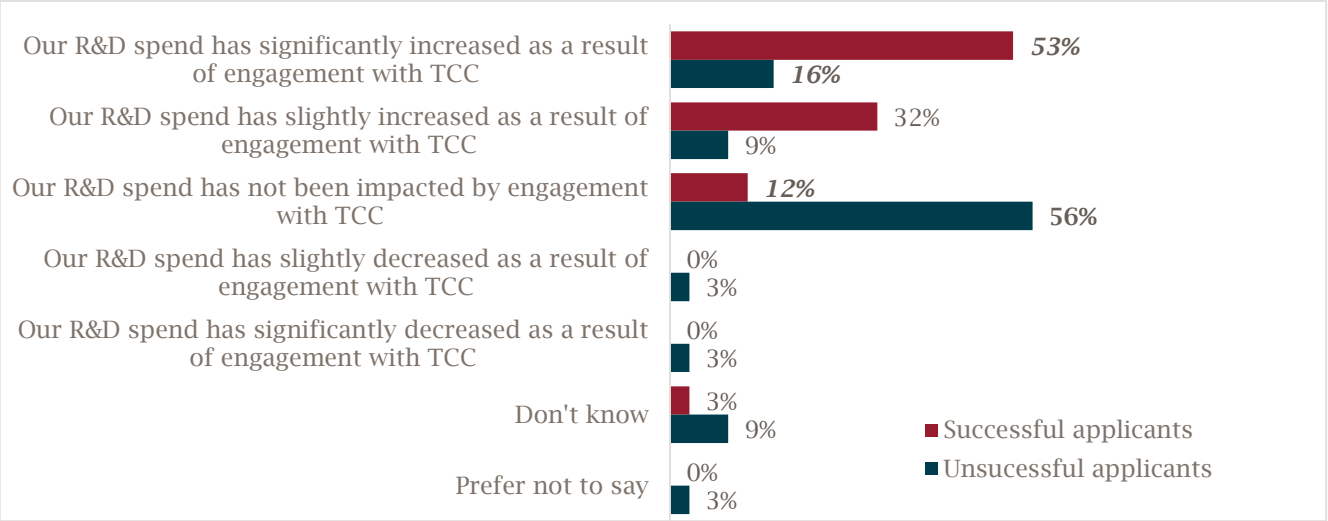



*Source: Beneficiaries survey. C18. And what proportion of this spend was related to each of the following?*
*Note: Base: Impact survey business respondents with R&D spend (67)*

### PERCEIVED IMPACT OF THE TCC ON R&D SPEND

Survey respondents suggested a high level of impact of the TCC on R&D spend. Figure 19 shows the perceived impact of the TCC on R&D spend for successful versus unsuccessful applicants. Fifty-three percent of those with 'successful' TCC applications reported that R&D spend had increased significantly as a result of engagement with the TCC, and a further 32% reported that the TCC had increased R&D slightly as a result of engagement with the TCC.

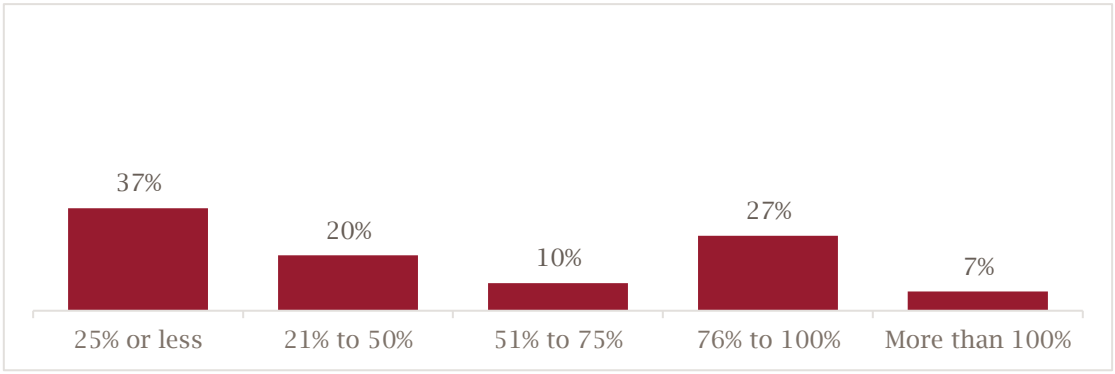
## FIGURE 19 PERCEIVED IMPACT OF TCC ON R&D SPEND – SUCCESSFUL VS. UNSUCCESSFUL APPLICANTS




*Source: Beneficiaries survey. Q2F. Which of the following best describes how your engagement with TCC has impacted your organisation's R&D spend?*
*Note: Base: Successful business applicants (34), unsuccessful business applicants (32). Figures in **bold and italitcs** are statistically significantly different for successful and unsuccessful applicants.*

Figure 20 illustrates the proportional increases in R&D spend for respondents as a result of TCC engagement.[13] The average increase for these businesses, as a proportion of total R&D spend, is 60%. However, there is clear variation in the proportional changes in terms of R&D spend across respondents. Seven percent of respondents reported that R&D spend had increased by more than 100% as a result of the TCC, whereas 37% of respondents reported that R&D spend had increased by 25% or less.

## FIGURE 20 PROPORTIONAL INCREASE IN R&D SPEND AS A RESULT OF TCC ENGAGEMENT




*Source: Beneficiaries survey. Q2G. How much has your organisation's R&D spend increased as a result of your engagement with TCC? Q2Di. What was your organisation's level of investment in research and development in the previous financial year?*
*Note: Base: Impact survey business respondents with increased R&D spend who provided amounts for total R&D and increase in R&D as a result of TCC engagement (30)*

### ACTIVITY CASE STUDIES

The activity case studies provide insights on the role of the TCC in fostering earlier investment in TCC concepts. As discussed in Section 4, the TCC has enabled and changed the nature of collaboration for

[13] This figure only includes responses from those that did report an increase in R&D spend and were able to quantify this.

organisations it has engaged with. This has resulted in additional investment in TCC concepts that, without the TCC, is unlikely to have occurred. The additional investment has been enabled through the 'de-risking' role that the TCC has provided. By pooling risk across organisations through matched funding for those engaging with CR&D, the TCC has enabled more investment in 'higher risk' areas that relate to TCC concepts.

A number of those interviewed as part of the case studies suggested the presence of optimism for future investment resulting from their initial engagement with the TCC. This stemmed from both the TCC acting as a source of external validation, giving a positive signal to investors, and success in demonstrating the commercial viability of innovations.

There were examples of investment continuing after the initial TCC funding has ended (e.g. the Challenging Space Frontiers in Hospitals project) as well as investment in new projects resulting from previous TCC engagement (e.g. the West Midland DfMA project).

There were limited discussions of follow-on funding in the case studies. However, a number of interviewees did highlight that they would appreciate the TCC providing a route for follow-on funding or assisting with sourcing alternative funding.

A summary of relevant insights for R&D linked to TCC concepts from the activity case studies is presented in the table below. The full write-up of the case studies is provided in Annex D -

### TABLE 14 ACTIVITY CASE STUDY INSIGHTS – R&D LINKED TO TCC CONCEPTS

| ACTIVITY | INSIGHTS |
|---|---|
| **AIMCH** | **The TCC has fostered earlier investment in TCC concepts.** Interviewees stated that without the TCC investment R&D activities would have taken longer than they had in practice. The TCC was seen to have had a vital role in 'de-risking' investment in innovations linked to TCC concepts. |
| **AEC Delta Mobility** | **The TCC has provided external validation, increasing investment opportunities.** Interviewees agreed that the activity would not have gone ahead without the input of the TCC. The engineering consultancy interviewed articulated that the TCC had provided an external validation that had increased the confidence of businesses to invest in technology. |
| **Data capture for whole lifecycle compliance** | **There is optimism for future follow-on funding.** The case study highlights a positive perception of follow-on research that could be obtained in the future as a result of the successful engagement with the TCC. The engagement had allowed for the successful development of digital prototypes in automating compliance. |
| **Challenging space frontiers in hospitals** | **Investment has continued after TCC funding has ended.** Organisations interviewed believed that they had invested above and beyond what was required by the TCC as they saw value in the project. Further, since the delivery of the project, the academic institution interviewed had been teaching the concepts at university, directly translating the work into student research |

| ACTIVITY | INSIGHTS |
|---|---|
| | projects and had continued its engagement with other parties that were involved in the project, which had been unfunded. |
| **West Midlands DfMA** | **There were additional investment spillovers following on from the activity.** One of the partners of the activity had taken the concept and early prototypes from the activity and had adapted it so that it could be used as part of a new project. This new project involved off-site manufacture of houses, similar to the original design for the West Midlands DfMA activity but on a platform that was designed to rise and fall in line with predictions of flooding levels. This would allow residential housing to be built on sites that had a risk of flooding. The project was currently at the stage of building a proof of concept. This project was fully funded by the activity partner following on from the success of the West Midland DfMA project. |

*Source: Activity case studies*
*Note: This is a summary of the case study activity included. More detail is provided in the case study-specific annex.*

## 6.4 LONG-TERM OUTCOMES AND IMPACTS

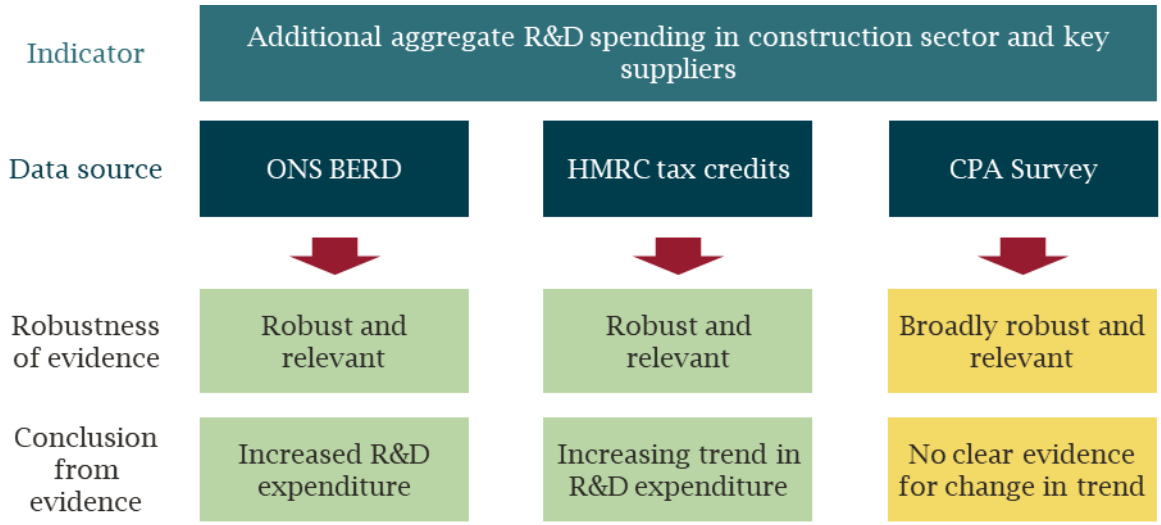
### 6.4.1 ADDITIONAL AGGREGATE R&D SPENDING IN CONSTRUCTION SECTOR AND KEY SUPPLIERS

#### SECONDARY DATA ANALYSIS

Overall, the secondary data analysis provides evidence for an increase in additional aggregate R&D spending in the construction sector and key suppliers. This suggests that the TCC is operating in an environment of increasing R&D expenditure. Figure 21 below summarises the conclusions from the analysis of each of the metrics and indicates their robustness and relevance for the context of the evaluation.

- ONS BERD data provides evidence for the change in annual intramural and extramural R&D spending. The data shows increases in both absolute intramural and extramural R&D spending and the share of R&D relative to total UK R&D spend.
- HMRC R&D Tax Credits Statistics evidences that claims of R&D tax credits by firms whose primary activity is construction grew by 47% in the financial year 2017/2018 (compared to 32% in the previous year).
- Data from the Construction Products Association (CPA) survey does not provide clear evidence for increases in R&D. However, we consider this data to be less robust for the purposes of the evaluation relative to data from ONS BERD and HMRC tax credits as the metric only provides information on the balance of construction sector manufacturers reporting increases or decreases in R&D expenditure, rather than total absolute levels of R&D expenditure.

## FIGURE 21 SUMMARY OF RESULTS FROM SECONDARY DATA ANALYSIS




*Source: Frontier Economics*

A sub-section of the analysis conducted is included in the main report, while a complete set of analysis and assessment of the relevance and robustness of the data is provided in Annex G -

### ONS BERD

The ONS BERD analysis is conducted at two levels: (i) at the sector level, and (ii) at the sub-sector level. We present the results of both analyses below.

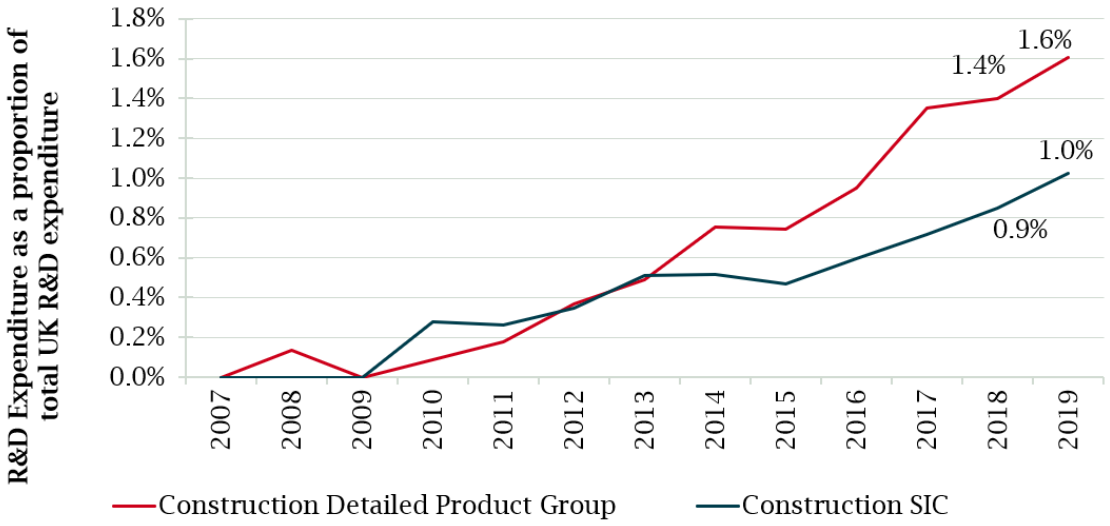
#### i. Sector-level analysis

Figure 22 below sets out intramural and extramural R&D expenditure as a proportion of total UK R&D economy expenditure.[14] From 2018 to 2019, intramural and extramural R&D expenditure increased from 1.4% of total UK economy R&D expenditure to 1.6% for the construction detailed product group. Similar growth was also seen for the Construction SIC code, with an increase from 0.9% to 1.0% of the UK economy.

We conducted separate analysis of the absolute intramural and extramural R&D expenditure (i.e. expenditure in £s rather than as a proportion of the UK R&D expenditure). The results of the analysis are consistent with the above. That is, there is evidence of an increase in R&D intramural and extramural expenditure. Therefore, this suggests evidence of increasing R&D expenditure across the construction sector.

[14] Intramural expenditure is expenditure on in-house R&D. Extramural expenditure is expenditure on purchased R&D. See ONS: https://www.ons.gov.uk/economy/governmentpublicsectorandtaxes/researchanddevelopmentexpenditure/methodologies/ukgovernmentexpenditureonscienceengineeringandtechnologyqmi

FIGURE 22 ONS BERD – CONSTRUCTION R&D EXPENDITURE AS A PROPORTION OF TOTAL UK R&D EXPENDITURE




*Source: Frontier Economics based on ONS BERD*

### ii. Subsector-level analysis

The subsector-level analysis uses a weakly defined difference-in-difference approach to assess the impact of the TCC on intramural and extramural R&D spending. This approach is explained in further detail in Annex F - , including the definitions used as treatment and benchmark groups.

Our approach identifies the treatment group (i.e. where we expect TCC to impact) and benchmark groups on the basis of SIC codes. The benchmark groups are a benchmark in the same sub-sector, but not identified to be related to TCC; a benchmark in a similar sector; and a whole-economy benchmark.

We conducted this analysis for three treatments groups: core construction (e.g. organisations focused on the construction of buildings or bridges); construction product manufacturers (e.g. organisations focused on the manufacture of cement or concrete); and professional services for the construction industry (e.g. organisations focused on architectural or engineering activities). The results for each are set out in the table below.

Overall, we find evidence for increases in total intramural and extramural R&D expenditure for core construction and for professional services for the construction industry over and above the increases observed in the treatment groups. However, this is not observed for construction manufacturers.

The detailed sub-sector-level analysis, including graphical outputs, is provided in Annex G -

## TABLE 15 ONS BERD SUB-SECTOR ANALYSIS

| TREATMENT GROUP | CHANGE IN INTRAMURAL AND EXTRAMURAL EXPENDITURE |
|---|---|
| Core construction | There is evidence of increases in the total of intramural and extramural R&D expenditure for the core construction treatment group post 2018, with larger increases in comparison to the sub-sector and sector benchmark groups. |
| Construction product manufactures | Extramural and intramural R&D expenditure for the construction product manufacturers treatment group has followed a similar trend to the sub-sector benchmark and has not followed the increased trend seen in the sector and whole-economy benchmarks. |
| Professional services for the construction industry | There is evidence of increases in R&D expenditure for the professional services treatment group post 2018, with larger increases in comparison to the sector and whole-economy benchmark groups.[15] |

*Source: Frontier Economics based on ONS BERD data*

### HMRC R&D TAX-CREDITS

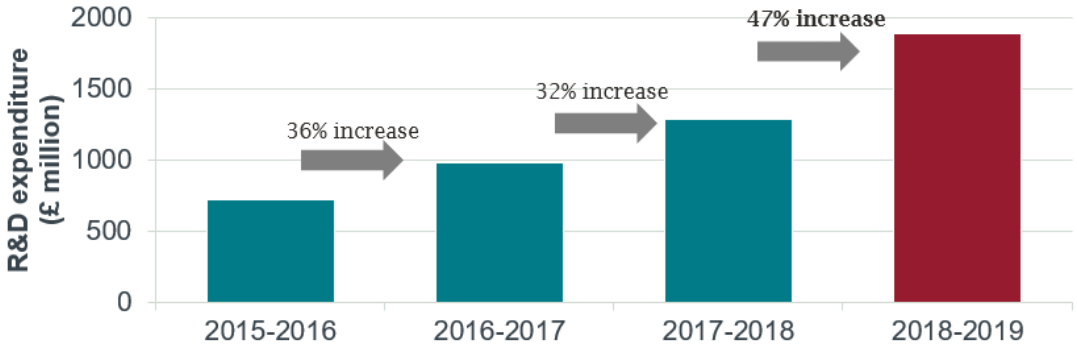
Figure 23 illustrates the level of R&D expenditure submitted by construction firms in the UK for the purposes of claiming R&D tax credits from HMRC.

This analysis provides positive evidence of an accelerating trend in R&D expenditure in the construction sector after 2019. Claims of R&D tax credits by firms whose primary activity is construction grew by 36% and 32% in the financial years 2016/2017 and 2017/2018. This growth rate increased to 47% in financial year 2018/2019.

The data enables measurement of construction sector firms. However, claims are grouped by the primary activity of the business rather than by the nature of the R&D activity itself. As such, investment by non-construction sector firms in R&D in construction sector activities is not captured.

[15] There is no sub-sector level control available for the treatment group relative to professional services for the construction industry as all the relevant digit SIC codes are part of the treatment group. More detail on how the treatment and control groups are defined is provided in Annex G.

FIGURE 23 HMRC TAX CREDIT – CONSTRUCTION SECTOR R&D EXPENDITURE




*Source: Frontier Economics based on HMRC*

### 6.4.2 CHANGE IN INDUSTRY INVESTMENT IN KEY SUB-SETS OF THE INDUSTRY

#### SECONDARY DATA ANALYSIS

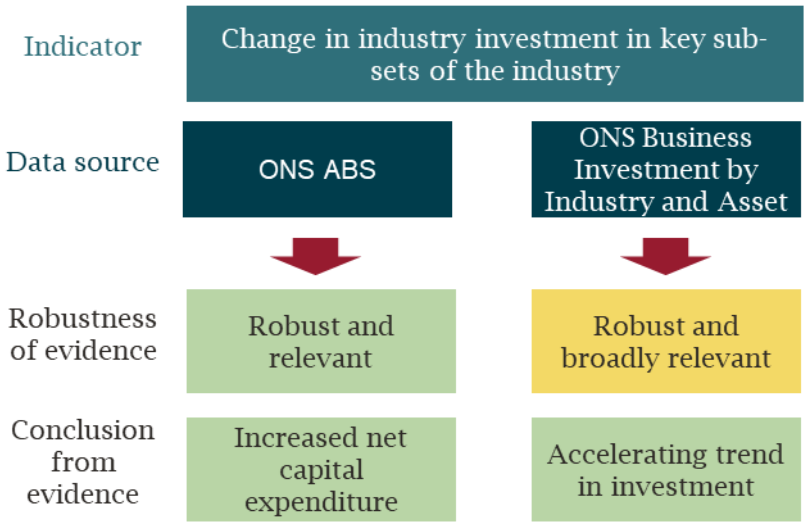
This indicator focuses on the increase in the value of capital expenditure in existing technologies (whether TCC-related or otherwise) that leads to improved productivity performance of the construction sector more broadly.

Overall, our secondary data analysis provides evidence for an increase in industry investment in key sub-sets of the industry. This suggested that the TCC is operating in an environment of increasing investment. Figure 24 below summarises the conclusions from the analysis:

- ONS Annual Business Survey (ABS) data on annual net capital expenditure of sub-sets of construction-related activities shows that, from 2018 to 2019, there is evidence of an increase in net capital expenditure across the construction sector as a whole, with increasing trends to varying degrees in specialised construction activities, civil engineering and the construction of buildings.
- ONS Business Investment by Industry and Asset shows an acceleration in total business investment in the construction sector. From 2012 Q1 to 2018 Q1, the compound annual growth rate (CAGR) was of 11%, compared with 22% from 2018 Q1 to 2021 Q1. However, we consider this data to be broadly relevant for the purposes of the evaluation as it is sector-level data and may capture investment that is unrelated to TCC evaluation and exclude relevant ones (e.g. construction product manufacturers).

The following sub-sections provide further details on the analysis conducted for these two metrics. A full write-up of the secondary data analysis conducted as part of the evaluation is included in Annex G -

## FIGURE 24 SUMMARY OF RESULTS FROM SECONDARY DATA ANALYSIS




*Source: Frontier Economics*

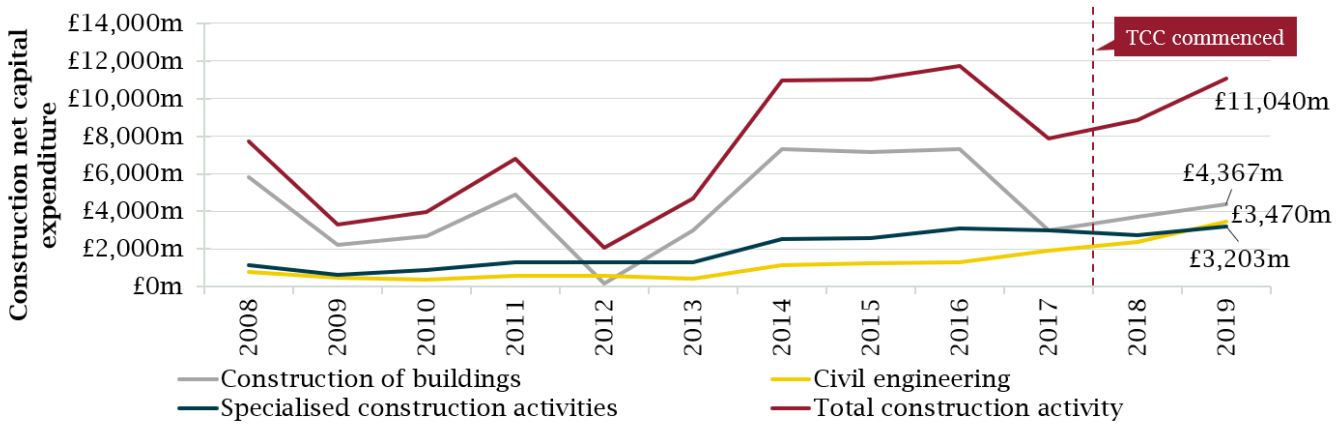
### ONS ABS

We conducted analysis using ONS ABS data at two levels: (i) at the sector level, and (ii) at the sub-sector level. We present the results of both analyses below.

**i. Sector-level analysis:**

Figure 25 shows changes to the annual net capital expenditure of sub-sets of construction-related activities at a 2-digit SIC code level. We find that from 2018 to 2019 there is evidence of an increase in net capital expenditure across the construction sector as a whole, with increasing trends to varying degrees in specialised construction activities, civil engineering and the construction of buildings.

## FIGURE 25 ONS – NET CAPITAL EXPENDITURE BY SUB-SECTOR OF ACTIVITY




*Source: Frontier Economics based on ONS ABS*

**iii. Sub-sector-level analysis:**

The sub-sector-level analysis uses a weakly defined difference-in-difference approach to assess the impact of the TCC on annual net capital expenditure. This approach is explained in further detail in Annex F - , including the definitions used as treatment and benchmark groups.

Our approach identifies the treatment group (i.e. where we expect TCC to impact) and benchmark groups on the basis of SIC codes. The benchmark groups are a benchmark in the same sub-sector, but not identified to be related to TCC, a benchmark in a similar sector, and a whole-economy benchmark.

We conducted this analysis for three treatments groups: core construction (e.g. organisations focused on the construction of buildings or bridges); construction product manufacturers (e.g. organisations focused on the manufacture of cement or concrete); and professional services for the construction industry (e.g. organisations focused on architectural or engineering activities). The results for each are set out in the table below.

Overall, we find that after 2018 the three treatment groups followed increasing trends in annual net capital expenditure, similarly to those in the benchmark groups. The results for each treatment group are presented in Table 16.

The detailed sub-sector-level analysis, including graphical outputs, is provided in Annex G -

### TABLE 16 ONS SRS ABS SUB-SECTOR ANALYSIS – ANNUAL NET CAPITAL EXPENDITURE

| TREATMENT GROUP | CHANGE IN NET CAPITAL EXPENDITURE |
|---|---|
| Core construction | Net capital expenditure fell for the core construction treatment group relative to all benchmarks in 2017 and has since followed a similar overall increasing trend to the benchmark groups. |
| Construction product manufactures | Net capital expenditure increased significantly between 2013 and 2015 for the construction product manufacturers treatment group. Since 2016/17 the treatment group has followed similar groups to the sector and whole-economy benchmark. |
| Professional services for the construction industry | Net capital expenditure has followed similar trends to the sector and whole-economy benchmarks. |

*Source: Frontier Economics based on ONS BERD data*

#### ONS BUSINESS INVESTMENT BY INDUSTRY AND ASSET

The ONS Business Investment by Industry and Asset data includes a breakdown of business investment by industry and asset type for the private sector.

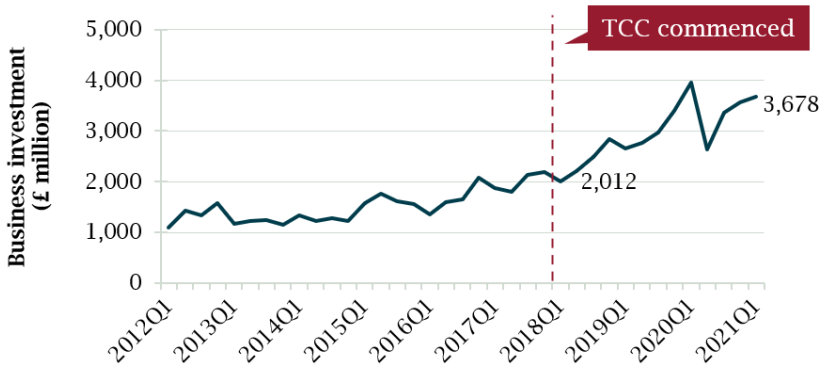
Figure 26 below shows the evolution of business investment in the construction sector. We find an acceleration in total business investment in the construction sector from 2018 onwards:

- From 2012 Q1 to 2018 Q1, the CAGR of business investment (£ million) was of 11%; and
- From 2018 Q1 to 2021 Q1, the CAGR of business investment (£ million) was of 22%.

The decline in the second quarter of 2020 followed by a surge in the following quarters is likely associated with Covid-19.

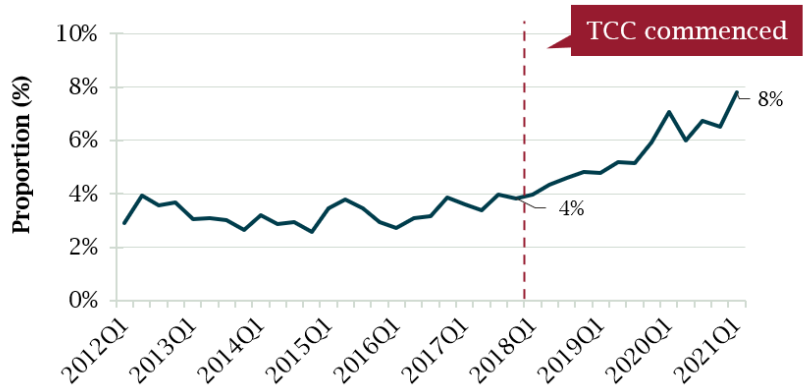
Figure 27 presents business investment in the construction sector as a proportion of total non-manufacturing business investment. In this figure, we see an increase in the share of total non-manufacturing business investment attributable to the construction sector (CAGR of 5% and 25% between 2012 Q1 and 2018 Q1, and 2018 Q1 and 2021 Q1, respectively).

## FIGURE 26 ONS – CONSTRUCTION SECTOR BUSINESS INVESTMENT




*Source: Frontier Economics based on ONS Business Investment by Industry and Asset*

## FIGURE 27 ONS – CONSTRUCTION SHARE OF TOTAL NON-MANUFACTURING BUSINESS INVESTMENT




*Source: Frontier Economics based on ONS Business Investment by Industry and Asset*

### VIEW OF THE EXPERT PANEL

The expert panel broadly agreed that there had been increases in investment due to the TCC for firms that the TCC had directly engaged with, but less so for the wider industry.

An expert highlighted links between this theme's focus on investment and the focus in Theme 1 on collaboration. They suggested that the collaboration was a critical first step for investment and provided an important route for de-risking R&D as well as being a source of external validation, giving a positive signal to investors, and success in demonstrating the commercial viability of innovations.

The experts questioned whether the industry's current focus on short-term R&D investment in the sector was appropriate:

- There was a perception that current R&D investment was focused on near-term or 'fire-fighting' activities in order to provide solutions to immediate problems, compared to R&D focused on longer-term goals. It was suggested that the TCC helped organisations to focus on longer-term type R&D activities, and more so than would be possible in a purely commercial context.
- An expert suggested that ABC may have duplicated work that was already ongoing in academia prior to the implementation of the TCC.
- There was a suggestion that, while the TCC had delivered benefits with respect to R&D in the commercial construction sector, there could have been a more optimised approach.

The experts commented that they did not expect the R&D focused on TCC concepts to continue in the long term without continual government support. They highlighted that the TCC's impact on R&D investment had been focused on short-term R&D projects. Despite this, the levels of investment in the industry were relatively low compared to where the experts believed they should be. Further, the experts questioned the extent to which the investment would continue in the longer term. One suggested that, without future TCC funding, it was unlikely that industry would be able to continue the increased level seen of R&D in TCC concepts, as organisations tend to be too focused on 'business as usual' activities.

An expert highlighted that there was potential for a future TCC project to build on the learnings from the current TCC programme, such as the increasing focus on industry strategy developed in the latter stages of the TCC.

# 7 FINDINGS: THEME 4 – CONSTRUCTION SECTOR AND ITS SUPPLY CHAIN ADOPT TCC CONCEPTS

## KEY MESSAGES

- This theme relates to the TCC objective of increased adoption of digital manufacturing approaches and active energy technologies in new construction projects.

**Change in use of TCC concepts by programme beneficiaries post programme**

- In the primary survey, we find that a high proportion of survey respondents were either using or were aware of TCC concepts. At least 83% of respondents were using, considering using or were aware of each TCC concept. Further, there had been an increase in use across the TCC concepts since the baseline survey, particularly for information management frameworks, digital compliance and improving the whole-life value of buildings.
- The activity case studies find that organisations that had engaged with the TCC tended to have had high awareness of TCC concepts prior to engagement. However, the case studies do highlight how the TCC has helped organisations develop their understanding of TCC concepts by increasing their understanding of concepts they were already aware of; introducing organisations to new concepts; allowing organisations to better focus their application of TCC concepts; and providing a standardisation role.

**Number/proportion of firms in relevant sectors adopting CIH and ABC concepts**

- In the primary survey, we found that organisations were using the concepts on a large number of contracts, indicating a high degree of embeddedness of TCC concepts once adopted. Further, there was an expectation that TCC concepts would be used more frequently in the future.
- The activity case studies provide limited evidence on the extent to which the wider industry is adopting TCC concepts. This is expected given the stage of the TCC and the activities being at a proof-of-concept/demonstration stage. As a result, there has been limited dissemination of the outputs of TCC activities across the wider industry.
- The experts suggested that the adoption of TCC concepts was occurring in a small sub-sector of organisations but that the majority of the sector was reluctant to implement change in the absence of a clearly articulated business case. There were mixed views across the experts on the uptake of TCC concepts, with the suggestion that uptake varied across concepts. The experts highlighted the importance of the TCC building a legacy in order to encourage longer-term adoption of TCC concepts and change in the wider industry.

This theme relates to the TCC objective of increased adoption of digital manufacturing approaches and active energy technologies in new construction projects. This theme is specifically supported by the activities of the ABC and CIH.

The early adoption of TCC concepts gives the Challenge traction with the construction sector. In the long term, the TCC's success depends on wider buy-in from the construction sector and its supply chain. As the TCC is a limited exercise in scope and time, diffusion of TCC concepts is crucial to have a significant impact in the industry.

This section provides the evidence base relating to the evaluation indicators for Theme 4, which are summarised in the table below. The section first outlines the activities undertaken by the TCC relating to this theme and then summarises the evidence for each indicator type.

## TABLE 17 THEME 4 – SUMMARY OF EVALUATION APPROACH

| INDICATOR TYPE | SUCCESS INDICATOR | DATA SOURCES |
|---|---|---|
| Monitoring | The evaluation of this theme is concerned with industry adoption of technologies and concepts developed during the early phases of the Challenge. As such, there are no monitoring indicators for this theme. | |
| Short-term outcomes | Change in use of TCC concepts by programme beneficiaries post programme | Primary survey<br>Activity case studies<br>Expert review |
| | Industry and government usage of evidence bases developed by TCC | Primary survey<br>Activity case studies<br>Expert review |
| Long-term outcomes and impacts | Number/proportion of firms in relevant sectors adopting CIH and ABC concepts | Primary survey<br>Activity case studies<br>Expert review |

*Source: Frontier Economics*

### 7.1 ACTIVITIES UNDERTAKEN BY THE TCC

Activities that the TCC has undertaken in relation to this theme include the following:

- Demonstrators of TCC concepts to highlight commercial viability;
- Development of a richer understanding of skills needs, process capacity and business models for the adoption of TCC concepts. This is largely supported by the work of CIH;
- Development of an effective information management framework. This is largely supported by the work of CIH; and
- Development of new active building business models and demonstrators for commercialisation. This links to the work of the ABC.

In this context, projects at a demonstrator/proof-of-concept phase refer to projects where a technology is tested within real-world industry settings but is not yet widespread market practice or fully commercialised. Example projects at a demonstrator/proof-of-concept phase include the following:

- **Active Office**, which involved the construction of a two-storey prototype office using only commercially available technologies and existing supply chains in order to demonstrate the viability of active office buildings. The prototype included MMC and integrated technologies.[16]
- **Transport Infrastructure Efficiency Strategy (TIES) Living Lab**, a large-scale programme for demonstrating a more efficient model for infrastructure builds. The project involves a number of demonstrators including:

[16] https://tc-catalogue.strongerstories.org/stories/active-office/

- the AVA footbridge, which is an adaptable metal footbridge designed for use over rail infrastructure stations; and
- a structure designed to reduce heating issues in the tube network which is being trialled at Herne House (Acton), at a disused station near Tower Hill and in an operational environment in Knightsbridge station.[17]

- The **West Midlands DfMA** activity, which utilises MMC and off-site manufacture to demonstrate a modular steel-frames house design and how it can be adapted to different settings, in this case being bult on a flood responsive platform. [18]
- The **FASTtruss** TCC activity being undertaken by Tat Steel UK, Bryden Wood and AMRC, which will produce a robotically welded demonstrator that can automate the design and manufacture of steel lattice trusses. [19]

## 7.2 MONITORING

The evaluation of this theme is concerned with industry adopting technologies and concepts developed during the early phases of the Challenge. As such, there are no monitoring indicators for this theme.

## 7.3 SHORT-TERM OUTCOMES

### 7.3.1 CHANGE IN USE OF TCC CONCEPTS BY PROGRAMME BENEFICIARIES POST PROGRAMME

#### PRIMARY SURVEY

The primary survey provides evidence for the change in use of TCC concepts by programme beneficiaries for the following metrics:

- Awareness and use of TCC concepts; and
- Change in TCC concepts awareness and use.

Overall we find that a high proportion of survey respondents were either using or were aware of TCC concepts. Further there has been an increase in use across the TCC concepts since the baseline survey, particularly for information management frameworks and digital compliance.

A summary of the findings is provided below, with all figures presented in Annex B -

##### AWARENESS AND USE OF TCC CONCEPTS

Figure 28 shows the levels of awareness of TCC concepts. Overall, there were high levels of awareness of TCC concepts with all concepts having at least 83% of respondents answering that they were using or considering using the concept, or were aware of the concept. The most common TCC concepts currently in use by these survey respondents were Information Management Framework (48% were currently using) and off-site manufacturing (47% were currently using). The least commonly used concept was Digital Twin,

[17] https://tc-catalogue.strongerstories.org/stories/transport-infrastructure-efficiency-strategy-ties-living-lab/

[18] https://homebyhadley.co.uk/introducing-the-hadley-floodsafe-house/

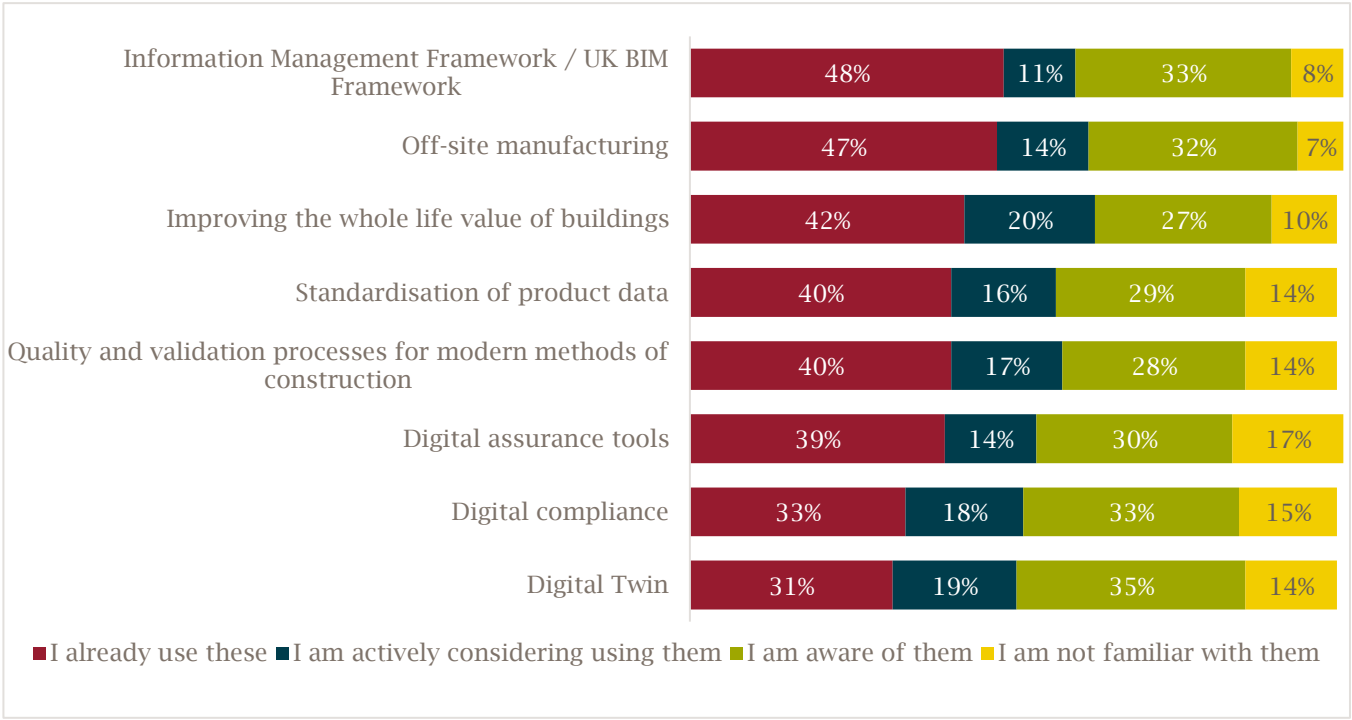
[19] https://tc-catalogue.strongerstories.org/stories/fabrication-automation-for-steel-lattice-trusses-fasttruss/

where a little under a third (31%) were currently using it. However, a further 19% were actively considering using this concept and only 14% of these survey respondents were not familiar with the concept.

The primary survey also finds a variation in the use and knowledge of TCC concepts depending on the respondent type:

- Respondents who were involved with Ministry of Defence building functions were more likely to be currently using off-site manufacturing (74%), improving the whole-life value of buildings (59%), standardisation of product data (56%), quality and validation processes for MMC (62%), digital assurance tools (62%) and digital compliance (47%).
- Respondents who were involved with Ministry of Justice building functions were more likely to be currently using Information Management Framework/UK BIM (71%), off-site manufacturing (65%), improving the whole-life value of buildings (58%), digital assurance tools (65%) and digital compliance (48%).
- Respondents who were involved with industrial building functions were more likely to be currently using off-site manufacturing (58%) and digital assurance tools (55%).
- Respondents who were involved with retail building functions were more likely to be currently using Information Management Framework/UK BIM (60%) and digital assurance tools (60%).

## FIGURE 28 AWARENESS OF AND USE OF TCC CONCEPTS




*Source: Beneficiaries survey. Q18. Please describe your familiarity with the following tools, technologies and concepts.*
*Note: Base: Impact survey respondents whose main engagement was with CR&D, CIH, N+ or RL (155)*

### CHANGE IN TCC CONCEPTS AWARENESS AND USE

Table 18 shows the changes in TCC concept awareness and usage in comparison to the baseline survey. The proportions who were currently using each concept had increased compared to the baseline for all of the concepts. In particular, the increases were notably large for Information Management Framework (48% currently using, compared to 25% in the baseline), improving the whole-life value of buildings (42%

currently using, compared to 20% in the baseline) and digital compliance (33% currently using, compared to 5% in the baseline).

However, it is important to note that in the baseline survey only respondents who had primarily engaged with CIH were asked about them. This only comprised 20 respondents in the baseline survey.

## TABLE 18 CHANGE IN TCC CONCEPT AWARENESS AND USAGE

| | BASELINE | | 2021 | |
|---|---|---|---|---|
| Concept | % currently using | % actively considering | % currently using | % actively considering |
| Information Management Framework/UK BIM* | 25% | 15% | 48% | 11% |
| Off-site manufacturing | 35% | 15% | 47% | 14% |
| Improving the whole-life value of buildings | 20% | 25% | 42% | 20% |
| Quality and validation processes for MMC | 15% | 35% | 40% | 17% |
| Digital assurance tools | 25% | 15% | 39% | 14% |
| Digital compliance | 5% | 20% | 33% | 18% |
| Digital Twin | 25% | 15% | 31% | 19% |

*Source: Beneficiaries survey. Q18. Please describe your familiarity with the following tools, technologies and concepts.*

*Note:Base: Impact survey respondents whose main engagement was with CR&D, CIH, N+ or RL (155). Baseline survey respondents whose main engagement was with CIH (20). *Text shown to respondents in the baseline survey was 'Information Management Framework'*

### ACTIVITY CASE STUDIES

The activity case studies provide evidence on general awareness of TCC concepts and the extent to which the TCC beneficiary firms have adopted these concepts following engagement with the TCC.

Overall, those we consulted in the case studies often suggested that organisations that had engaged with the TCC had tended to have high awareness of TCC concepts prior to engagement. This is to be expected given that organisations that had engaged with the CR&D had applied to receive funding for the development of a TCC concept.

However, the case studies do highlight how the TCC has helped organisations to develop their understanding of TCC concepts by increasing their understanding of concepts they were already aware of, introducing organisations to new concepts, allowing organisations to better focus their application of TCC concepts and providing a standardisation role. This standardisation was suggested particularly for activities relating to 'Digital Twin'.[20]

There was a mixed view across the case studies on the impact that the TCC had had on the uptake of TCC concepts. Some interviewees questioned the additionality of the TCC, as the work on the concepts would

[20] A Digital Twin involves the creation of a digital representation of a construction project or site.

have continued without the TCC. However, there was a general perception that the TCC was accelerating adoption even where it had not directly caused the adoption of the TCC concepts for the beneficiary organisations. In particular, the case studies provide evidence that the TCC has had a more significant impact on increasing adoption of frameworks such as BIM and off-site manufacturing.

The case studies highlighted that Covid-19 has had a limited impact to date on the uptake of TCC concepts by beneficiary firms due to the stage of activities that the TCC is engaged with. The case studies did suggest a positive impact from environmental pressures and wider supply chain issues on the uptake of TCC concepts. The lack of availability and increasing cost of some materials such as concrete was likely to cause organisations to seek to use alternatives and introduce new innovations, such as TCC concepts.

A summary of relevant insights for the change in use of TCC concepts by beneficiary firms from the activity case studies is presented in the table below.

### TABLE 19 ACTIVITY CASE STUDY INSIGHTS – CHANGE IN USE OF TCC CONCEPTS BY BENEFICIARY FIRMS

| ACTIVITY | INSIGHTS |
|---|---|
| **West Midlands DfMA** | **Although interviewees showed high general awareness of TCC, this could not be attributed to the TCC.** However, some interviewees, outside of those that were involved in the activity, were not aware of which concepts TCC was focusing on. Generally, this awareness of the concepts was not attributed to the TCC but was something that the parties had prior to engagement.<br>**There was an expectation that the concepts would continue to be used in the future.** All the parties interviewed expected to be using the concepts in the future, but they differed in terms of whether they considered themselves to be early adopters or not. One of the parties had embraced the concept fully, saw lots of opportunities in the near future and expected 50% of their businesses in the next three years to be accounted for by projects involving the TCC concepts that were incorporated into the activity. |
| **Optimised retrofit programme** | **The TCC has directly increased the knowledge and awareness of TCC concepts.** Knowledge and use of such concepts were largely attributed to TCC as well as engagement with other stakeholders working in the field, such as energy networks and the Welsh government, through involvement in the activity. |
| **GenZero** | **The TCC has increased understanding for particular concepts.** Awareness of TCC concepts was high, and these will be increasingly adopted within the organisation. There was familiarity with some concepts, such as MMC and off-site manufacturing, owing to the nature of the interviewees' work. Awareness of other concepts which were less familiar, such as Digital Twin and digitisation, had increased since involvement with TCC,. |
| **Construction quality planning tool** | **Although the TCC had not introduced the organisations to the concepts, it has helped to increase their understanding of TCC concepts.** Generally, this awareness of the concepts was not attributed to TCC, as parties were already aware of these before TCC came along. However, one of the partners attributed their increased understanding of some of these concepts to TCC |

| ACTIVITY | INSIGHTS |
|---|---|
| | through their involvement in this activity: "*Without [the funding] we wouldn't know nowhere near what we know right now.*" |
| **Value Toolkit** | **The TCC has accelerated the adoption of TCC concepts for organisations involved and has provided a useful standardisation role.** There was a general consensus that these concepts would be being used anyway, without the TCC's involvement. However, some felt that the TCC had increased the speed of take-up of these concepts and had helped them to be more standardised. |
| **HIPER Pile** | **Use of TCC concepts was said to be critical to remain competitive in the industry and meet government net zero targets.** All the commercial parties interviewed expected to be using the concepts in the future, albeit to different degrees depending on the type of company they were and how they operated. One of the parties had embraced the concepts that were relevant to their area of expertise, while the other commercial partner was currently in the process of having internal conversations to adopt these concepts. |
| **Active Office** | **This specific activity has not increased the organisations' use of TCC concepts.** The lead organisation was already familiar with the concepts being used in Active Office: integrated energy capture and storage systems, integrated thermal solutions, smart controls and monitoring solutions, and energy trading and flexibility. These concepts had previously been used in earlier prototype active buildings (Active Pod and Active Classroom), particularly smart controls and monitoring solutions. Their work already focused on these concepts and would have continued to do so without engagement with TCC. |

*Source: Activity case studies*
*Note: This is a summary of the case study activity included. More detail is provided in the case study-specific annex.*

## 7.4 LONG-TERM OUTCOMES AND IMPACTS

### 7.4.1 NUMBER AND PROPORTION OF FIRMS IN RELEVANT SECTORS ADOPTING CIH AND ABC CONCEPTS

#### PRIMARY SURVEY

The primary survey provides evidence for the number and proportion of firms in relevant sectors adopting CIH and ABC concepts for the following metrics:

- Average number and value of contracts using TCC concepts; and
- Expectations of use of TCC concepts for organisations in construction.

Overall, we find that organisations were using the concepts on a large number of contracts, indicating a high degree of embeddedness of TCC concepts once adopted. Further, there was an expectation that TCC concepts would be used more frequently in the future.

A summary of the findings is provided below, with all figures presented in Annex B -

### AVERAGE NUMBER AND VALUE OF CONTRACTS USING TCC CONCEPTS

Table 20 shows respondent estimates on the average number of contracts using each concept and the value of these contracts. Organisations were typically using the concepts on a large number of contracts, indicating a high degree of embeddedness of TCC concepts once adopted. We also find:

- The highest average number of contracts per organisation was for Information Management Framework/UK BIM where, on average, each organisation that was using this concept was using it on 70 contracts. The average value of these contracts was £170 million.
- Where organisations used digital assurance tools, they were also typically used on a large number of contracts: the average was 63. The average value of these contracts was £437 million.
- For off-site manufacturing and Digital Twin, the concepts with the lowest average number of contracts, where they were being used by respondent organisations, were typically used on more than 20 contracts.
- For quality and validation processes for MMC, even though the average number of contracts this concept was being used on by each organisation was relatively low (22), the average value of these contracts was noticeably high at £2.1 billion, indicating a number of high-value contracts.

## TABLE 20 AVERAGE NUMBER AND VALUE OF CONTRACTS USING TCC CONCEPTS

| CONCEPT | NUMBER CURRENTLY USING | MEAN NUMBER OF CONTRACTS | MEAN VALUE OF CONTRACTS |
|---|---|---|---|
| Information Management Framework/UK BIM* | 52 | 70 | £170 million |
| Off-site manufacturing | 56 | 21 | £90 million |
| Improving the whole-life value of buildings | 51 | 53 | £835 million |
| Standardisation of product data | 50 | 54 | £101 million |
| Quality and validation processes for MMC | 47 | 22 | £2.1 billion |
| Digital assurance tools | 48 | 63 | £437 million |
| Digital compliance | 41 | 57 | £889 million |
| Digital Twin | 32 | 20 | £92 million |

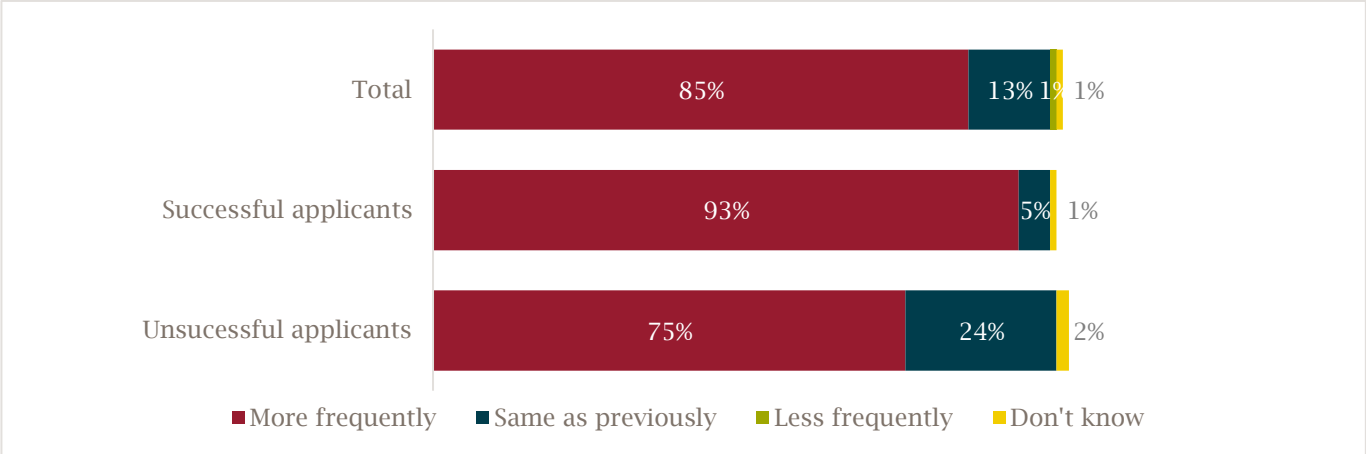
*Source: Beneficiaries survey. Q18A. You said that you/your organisation is already using some of these tools, technologies and concepts. Can you please indicate how many of your contracts use these and what the overall values of the contracts are?*

*Note:Base: Impact survey business respondents whose main engagement was with CR&D, CIH, N+ or RL and are currently using TCC concepts (base sizes shown in table)*

### EXPECTATIONS OF USE OF TCC CONCEPTS FOR ORGANISATIONS IN CONSTRUCTION

The survey also provides evidence on the use of TCC concepts more generally across the wider industry. Figure 29 shows that the majority of survey respondents expected that organisations in construction would generally be using TCC concepts more frequently (85%). Those that had been successful in their TCC application for funding were more likely to expect to see the concepts used more frequently (93%), compared to those who had been unsuccessful in their application (75%).

## FIGURE 29 EXPECTATIONS OF USE OF TCC CONCEPTS FOR ORGANISATIONS IN CONSTRUCTION GENERALLY




*Source: Beneficiaries survey. Q20. Based on your knowledge and experience of the Transforming Construction Challenge, do you expect as a result of its activities to see the following things more frequently, less frequently, or same as previously? I expect organisations in construction generally to be using TCC concepts*
*Note: Base: Impact survey business respondents aware of at least one TCC concept measured (158), successful applicants (76), unsuccessful applicants (51)*

### ACTIVITY CASE STUDIES

The activity case studies provide limited evidence on the extent to which the wider industry is adopting TCC concepts. This is expected given the stage of the TCC and the activities being at a proof-of-concept/demonstration stage. As a result, there has been limited dissemination of the outputs of TCC activities across the wider industry. We define and provide examples of concepts at a demonstrator/proof-of-concept phase in section 7.1 above.

Despite the more limited adoption of TCC concepts across the wider industry, the case studies show that the TCC is still providing a value role for the wider industry. The expectation is that the use of TCC concepts will continue to grow in the future, and this is related to the TCC raising industry-wide awareness of TCC concepts and providing a standardisation role for the use of TCC concepts.

As a result, there is an expectation that the wider industry will adopt TCC concepts in the future. However, the case studies provide a mixed view on the timelines for industry-wide adoption.

A summary of relevant insights for the wider adoption of TCC concepts from the activity case studies are presented in the table below.

## TABLE 21 ACTIVITY CASE STUDY INSIGHTS – WIDER ADOPTION OF TCC CONCEPTS IN RELEVANT SECTORS

| ACTIVITY | INSIGHTS |
|---|---|
| **Government Soft Landings** | **The TCC has raised awareness of TCC concepts across the industry.** The TCC has had a positive impact on the wider construction industry, with the interviewee noting that more people in the supply chain were aware of TCC concepts. |

| ACTIVITY | INSIGHTS |
|---|---|
| **Optimised retrofit programme** | **There has been limited adoption in the wider industry, but the TCC is providing a valuable role to the wider industry.** There was acknowledgement that TCC concepts were being adopted by other organisations in the construction industry, although it was perceived that these were mostly in the early stages. The TCC had been valuable in providing standardisation, and the concepts were crucial to the construction industry overall, particularly in relation to energy savings, and were empirical in achieving the UK's decarbonisation ambitions. |
| **AEC Delta Mobility** | **The TCC is raising awareness of concepts, but adoption levels are not sufficiently advanced.** Interviewees agreed that the wider adoption of TCC concepts was not yet happening enough. They suggested that it would take years for tangible benefits to be seen. However, interviewees also suggested that the TCC was raising awareness of concepts, whether companies were adopting them or not, and this was seen as a positive: |
| **Value Toolkit** | **There was an expectation that the use of TCC concepts will continue to grow and that this is related to the TCC's standardisation role.** There was also a general agreement that use of the concepts in the industry will continue to grow and they are important to the future of the industry. |
| **GenZero** | **There was an expectation that TCC concepts will be adopted by the wider industry in the future.** However, this adoption was expected to be at a slower pace in comparison to TCC beneficiary firms. This expected wider industry adoption was attributed to the TCC by the interviewee through the TCC bringing together different organisations with similar but competing aims. |
| **Digital Accelerator** | **There was uncertainty over when wider concepts will be adopted in the construction sector.** Interviewees suggested that TCC concepts were the 'hot topic' in the industry but that the rate of adoption varied significantly across the industry. It was suggested that it is too early to determine the adoption of concepts across the industry as they were at an early stage. As the activities that the TCC was investing in were innovative, it was not clear when the concepts would become part of the wider industry. |

*Source: Activity case studies*
*Note: This is a summary of the case study activity included. More detail is provided in the case study-specific annex.*

### VIEW OF THE EXPERT PANEL

The degree of adoption of TCC concepts across the wider industry was lower than the experts' initial expectations. However, given the landscape of the construction sector and the current levels of awareness of TCC concepts, the lower levels of adoption across the industry were not a surprise. The experts suggested that the adoption of TCC concepts was occurring in a small sub-sector of organisations but that the majority of the sector was reluctant to implement change in the absence of a clearly articulated business case.

There were mixed views across the experts on the uptake of TCC concepts, with uptake suggested to vary across concepts. An expert suggested that there were examples of disconnect between TCC frameworks and reality. Information management frameworks were highlighted as an example of this. However, other

experts highlighted the successful adoption of other TCC concepts, for example off-site manufacturing in housing, although this was highlighted not always to be pioneering and digitalised. Similarly, it was suggested that construction platforms had moved forward and framed what the supply chains were doing and their role in platform-based systems. For both of these cases, the TCC was credited with raising awareness of the concepts and promoting their adoption by industry.

The experts highlighted the importance of the TCC building a legacy to encourage longer-term adoption of TCC concepts and change in the wider industry. The experts noted a need for a longer-term delivery vehicle for change in the construction sector to continue the progress made by the TCC. They suggested it is critical that this is supported by government, given the barriers to investment and adoption of TCC concepts in the purely commercial setting. This is not unexpected given that wide-scale adoption takes a significant period of time. An expert suggested this delivery vehicle should create change via 'disruption' rather than organic development.

The experts highlighted the following barriers to wider-sector adoption of TCC concepts:

- TCC concepts are expensive for organisations to adopt, with high upfront costs; and
- The commercial sector is risk-averse, and so the timeframes for change are slow.

# 8 FINDINGS: THEME 5 – INCREASED PERFORMANCE OF CONSTRUCTION SECTOR FIRMS AND THEIR SUPPLIERS

## KEY MESSAGES

- This theme captures the longer-term ambition of the TCC to improve performance across the wider construction industry. Performance in this context ultimately refers to the productivity, revenue and employment of the sector.

**There is evidence that TCC concepts have the potential to improve firm performance if adopted, but less direct evidence so far on the impact of the TCC on firm performance**

- The TCC has a target of influencing a total of £10 billion of projects which achieve productivity improvements of around 13.5%. In this context, projects 'influenced' by the TCC are those that are linked to the TCC but whose productivity improvements achieved are not necessarily attributable to the TCC's involvement. Internal TCC data shows that this target has already been surpassed, with a cumulative committed project value of £29.3 billion in 2021.
- The primary survey shows positive evidence of TCC concepts having an impact on annual revenue, profit, productivity and speed of delivery. Over three in five (61%) of survey respondents who were already using TCC concepts said that their use had had a large positive impact on annual revenue, with four in five (79%) survey respondents reporting a positive impact on their organisation's profit. Over half (51%) of survey respondents who were already using at least one TCC concept reported a large positive impact on their organisation's productivity, with nearly three-quarters (71%) of survey respondents reporting a positive impact in speed of delivery.
- The case studies show a number of examples of projects with potential to improve the performance of the construction sector through the integration of TCC concepts. However, many of the TCC activities remain at demonstration/proof-of-concept stages. As such, it is not possible to demonstrate a direct impact of the TCC on the performance of construction sector firms and their suppliers at this stage. Nonetheless, the adoption of TCC concepts is expected to be transformative to performance in the future.
- The experts suggested that changes to the performance of the construction sector is a lagging metric, particularly when compared to collaboration and R&D investment. As a result, the experts did not expect to see a clear impact of the TCC at this stage both for beneficiary firms and the wider industry. The experts' views reflect the optimism in the case studies in indicating that the TCC will be a critical driver of future change in the performance of the construction sector as a result of incorporating TCC concepts. The experts suggested that change is likely to be realised in the next 5 to 10 years.

**Year-on-year change in sector (and relevant supply chain) productivity performance**

- Secondary data provides evidence for a slight increase in sector (and relevant supply chain) productivity performance in the period after the TCC was set up. This suggests that the TCC is operating in an environment of modestly increasing productivity in the sector but, given other evidence and the time lags involved, this is not in itself evidence that the TCC has influenced sector-wide productivity.

**Year-on-year change in value of exports of construction products and services**

- Secondary data provides some evidence for an increase in the value of exports of construction products and services following the introduction of the TCC. ONS Pink Book data shows that construction service exports grew at a CAGR of 14% from 2018 to 2020, compared with a CAGR rate of 9% from 2012 to 2018. As with the productivity data, this provides contextual data for the

environment in which the TCC has operated rather than strong evidence of the TCC's sector-wide impact.

This theme captures the longer-term ambition of the TCC to improve performance across the wider construction industry. It is supported by all strands of the TCC programme.

This theme follows from the stated objective of Construction 2025 to achieve higher productivity through more efficient construction of assets to make progress in closing the UK's productivity gap.[21] Improved construction productivity is expected to lead to infrastructure savings across transport, energy networks and social infrastructure such as schools and hospitals.

This section provides the evidence base relating to the evaluation indicators for Theme 5, which are summarised in the table below. The section first outlines the activities undertaken by the TCC relating to this theme and then summarises the evidence for each indicator type.

### TABLE 22 THEME 5 – SUMMARY OF EVALUATION APPROACH

| INDICATOR TYPE | SUCCESS INDICATOR | DATA SOURCES |
|---|---|---|
| Monitoring | Challenge outputs provide evidence that TCC concepts have the *potential* to improve firm performance | TCC benefits data |
| Short-term and long-term outcomes | Change in performance of TCC beneficiary firms post participation | Primary survey<br>Activity case study<br>Secondary data analysis |
| Long-term outcomes and impacts | Year-on-year change in sector (and relevant supply chain) productivity performance | Secondary data analysis |
| | Year-on-year change in value of exports of construction products and services | Secondary data analysis |

*Source: Frontier Economics*

## 8.1 ACTIVITIES UNDERTAKEN BY THE TCC

A critical aim of the TCC is to increase the performance of the UK construction sector and, therefore, all of the activities undertaken by the TCC are relevant to Theme 5. These activities include the development and dissemination of TCC concepts across organisations directly engaging with the TCC and the wider industry.

[21] https://www.gov.uk/government/publications/construction-2025-strategy

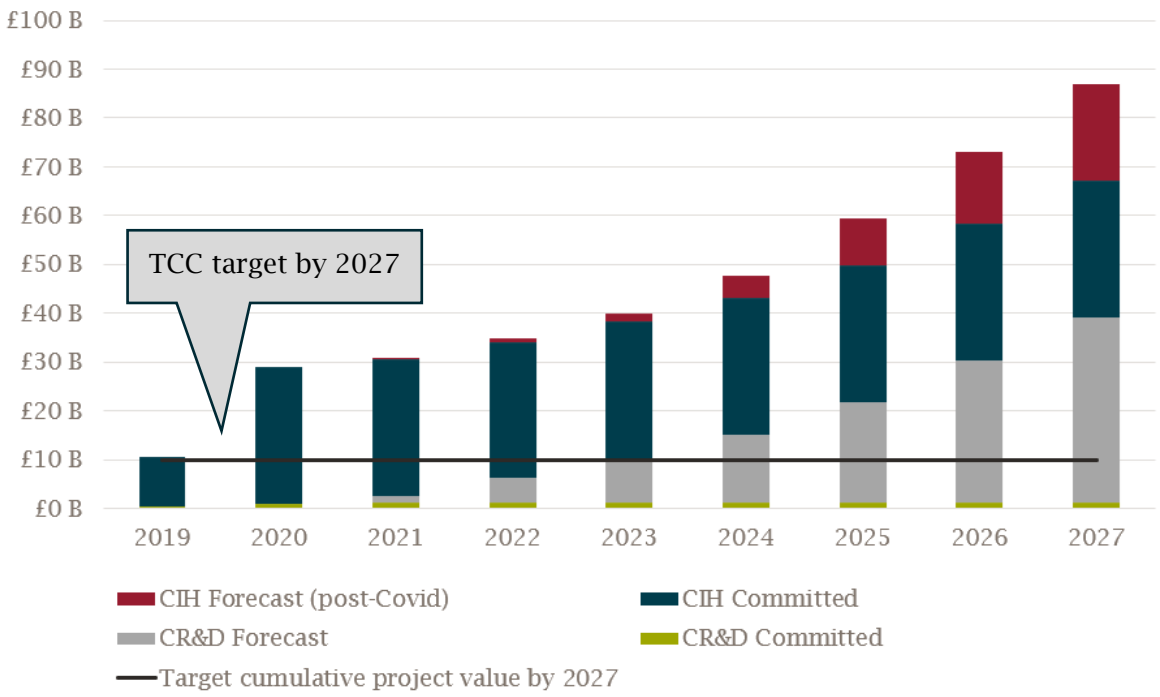
## 8.2 MONITORING

### 8.2.1 PROGRAMME OUTPUTS PROVIDE EVIDENCE THAT TCC CONCEPTS HAVE THE POTENTIAL TO IMPROVE FIRM PERFORMANCE IF FIRMS ADOPT THEM

#### TCC INTERNAL BENEFITS DATA

Internal TCC monitoring data from the strands on the productivity gap provides evidence for productivity improvements as a result of the TCC. Figure 30 sets out the cumulative committed (actual) and forecasted contracted project value of projects influenced by the TCC which achieve productivity improvements of around 13.5%. In this context, projects 'influenced' by the TCC are those that are linked to the TCC but whose achieved productivity improvements are not necessarily attributable to the TCC's involvement. The TCC has a target of influencing a total of £10 billion of projects which achieve productivity improvements of around 13.5%. As of 2021, this target had already been surpassed, with a cumulative committed project value of £29.3 billion.

### FIGURE 30 PROJECTS INFLUENCED BY THE TCC WITH PRODUCTIVITY IMPROVEMENTS




*Source: Frontier Economics based on TCC's benefits survey data*

*Note: Forecast amounts are based on a proportion of the identified pipeline; committed amounts are based on value of projects influenced. The exact definitions of forecast and committed vary by strand.*

Activities relating to expected productivity improvements as a result of TCC funding and seen in the TCC benefits data presented in Figure 30 include:

- **Aquila**: The BIM Academy led a team to develop a digital platform that could better plan the use of plant equipment. The result is more streamlined projects and safer, cleaner and more productive sites.

- **Construction quality planning tool:** The tool is intended to shift the industry from a culture of quality control and defect checking, to one of defect prevention – helping to increase productivity and leading to a better quality built environment.
- **Optimising Equipment-Use in Construction**: A digital platform visualises data on the use of construction machinery and makes recommendations about ways to improve utilisation, reducing costs and increasing productivity.

## 8.3 SHORT-TERM AND LONG-TERM OUTCOMES

### 8.3.1 CHANGE IN PERFORMANCE OF TCC BENEFICIARY FIRMS POST PARTICIPATION

#### PRIMARY SURVEY

The primary survey provides evidence for the change in performance of TCC beneficiary firms for the following metrics:

- **Annual revenue:** change in annual revenue since engagement with the TCC, observed impact of using TCC concepts on annual revenue and expected impact of the TCC on annual revenue;
- **Profit:** observed and expected impact of the TCC concepts on profit;
- **Productivity:** observed and expected impact of TCC concepts on productivity; and
- **Speed of delivery:** observed and expected impact of TCC concepts on speed of delivery.

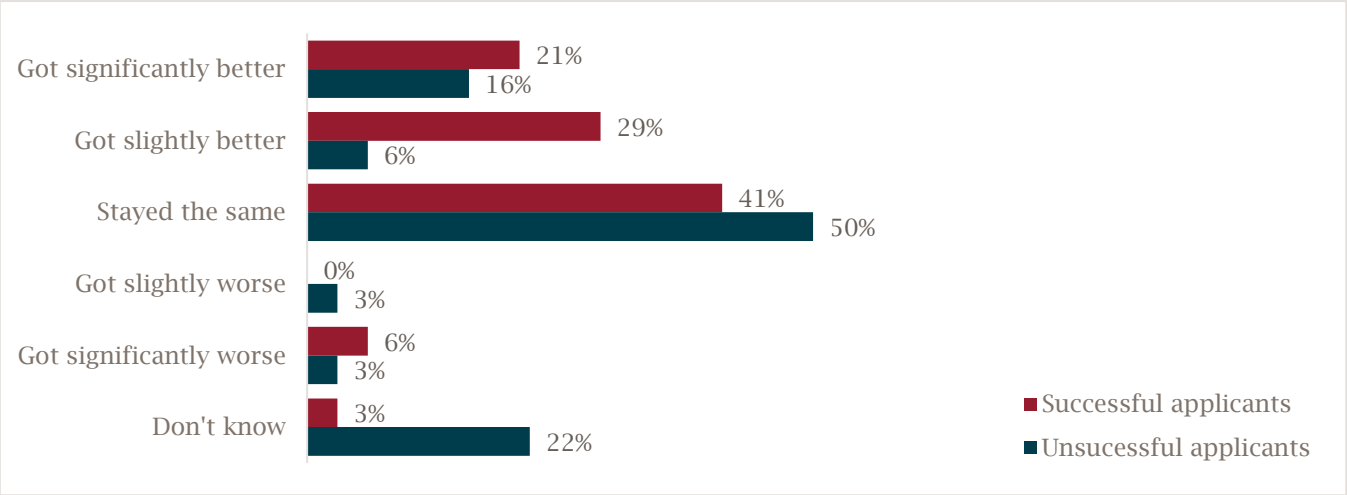
Overall, we find positive evidence of TCC concepts having an impact on annual revenue, profit, productivity and speed of delivery. A summary of the findings is provided below, with all figures presented in Annex B -

#### ANNUAL REVENUE

Figure 31 shows the change in annual revenue since engagement with the TCC, by 'successful' and 'unsuccessful' TCC applicants. We find evidence of 'successful' applicants showing increases in annual revenue following engagement: 50% of 'successful' applicants reported that their revenue had got significantly better or slightly better following engagement with the TCC. This compares to 22% of 'unsuccessful' applicants. However, 41% of 'successful' applicants reported that their annual revenue had stayed the same, and a further 9% of 'successful' applicants reported decreases in annual revenue.

There is evidence that the increases in annual revenue can be attributed to the TCC for 'successful' applicants. Over three-quarters (76%) of businesses surveyed which had been successful in their TCC application for funding reported that the TCC had had a positive impact on their annual revenue, including 29% who reported that the TCC had had a large positive impact. Just under one in five (19%) of 'unsuccessful' businesses reported that the TCC had positively impacted their annual revenue.

## FIGURE 31 CHANGE IN ANNUAL REVENUE SINCE ENGAGEMENT WITH TCC – SUCCESSFUL VS. UNSUCCESSFUL APPLICANTS

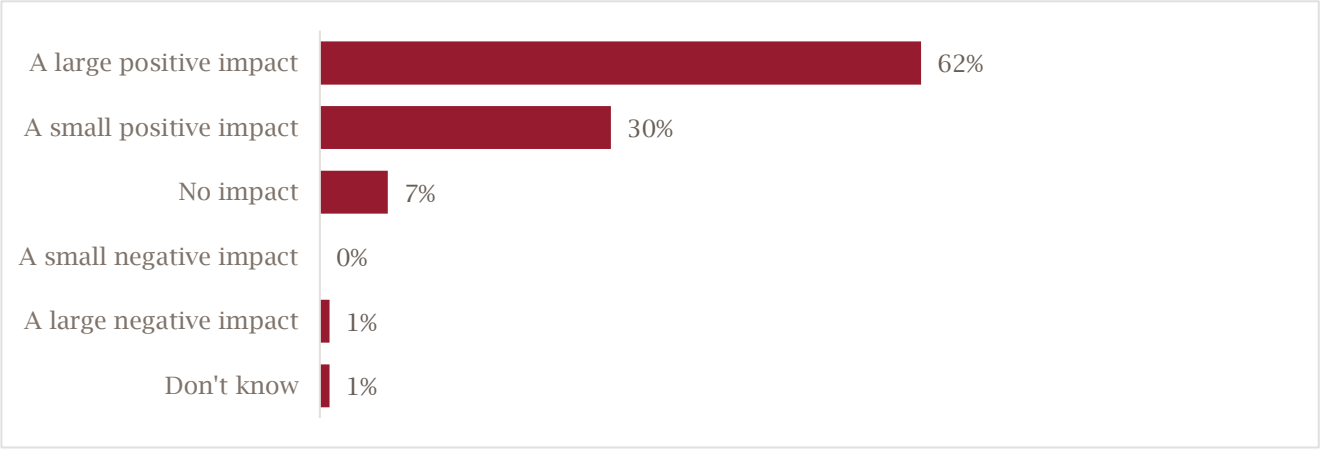



*Source: Beneficiaries survey. Q21. How, if at all, have the following changed for your organisation since your engagement with TCC?: Annual revenue*
*Note: Base: Successful business applicants (34), unsuccessful business applicants (32)*

Figure 32 shows the observed impact of using TCC concepts on annual revenue, for all respondents. We found that the use of TCC concepts has had a positive impact on annual revenue. Over three in five (61%) survey respondents who were already using TCC concepts said that their use had had a large positive impact on annual revenue. A further 30% of respondents expected TCC concepts to have a small positive impact.

We also found that the survey respondents expected the use of TCC concepts to have a positive impact on annual revenue. Over half (52%) of survey respondents who were actively considering using at least one of the TCC concepts expected the use of TCC concepts to have a large positive impact on their organisation's annual revenue. A further 40% expected the use of TCC concepts to have a small positive impact. None of those who were actively considering using at least one of the TCC concepts expected their use to have a negative impact.

## FIGURE 32 OBSERVED IMPACT OF USING TCC CONCEPTS ON ANNUAL REVENUE




*Source: Beneficiaries survey. Q18B. What impact, if any, do you think using these tools, technologies and concepts has had on your organisation's performance in the following areas?: Your organisation's annual revenue*

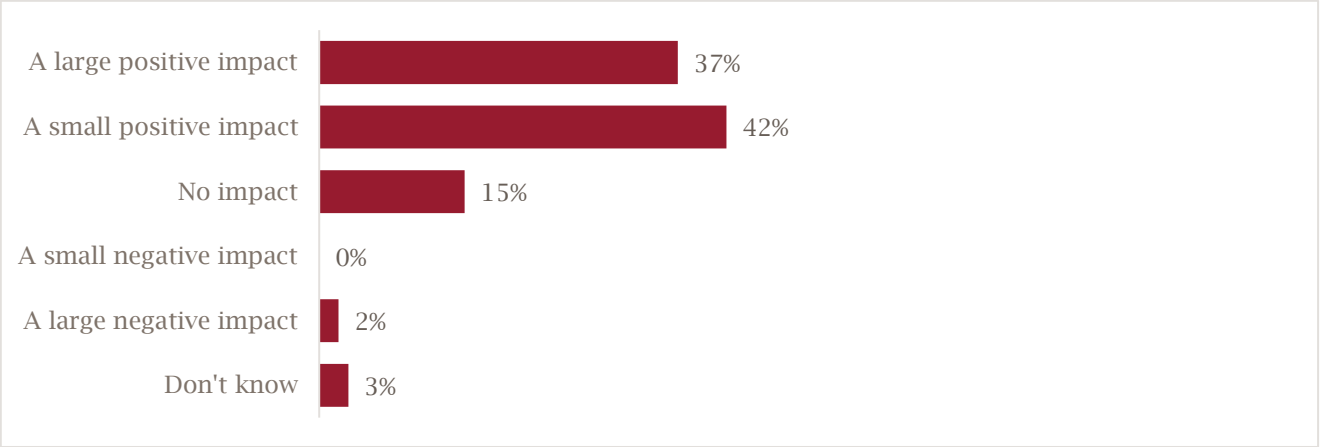
*Note: Base: Impact survey respondents already using TCC concepts (91)*

### PROFIT

Figure 33 shows the observed impact of using TCC concepts on profit for both 'successful' and 'unsuccessful' applicants. We find that TCC concepts are having a positive impact on profit. Nearly four in five (79%) survey respondents who were already using at least one TCC concept reported a positive impact on their organisation's profit. Over a third (37%) said this positive impact had been large. Two percent said the use of TCC concepts had had a large negative impact on profit.

These findings are similar to those for the expected impact of using TCC concepts on profit. Over a third (35%) of survey respondents who were actively considering using at least one TCC concept expected the use of TCC concepts to have a large positive impact on their organisation's profit. A further 40% expected the use of TCC concepts to have a small positive impact.

## FIGURE 33 OBSERVED IMPACT OF USING TCC CONCEPTS ON PROFIT



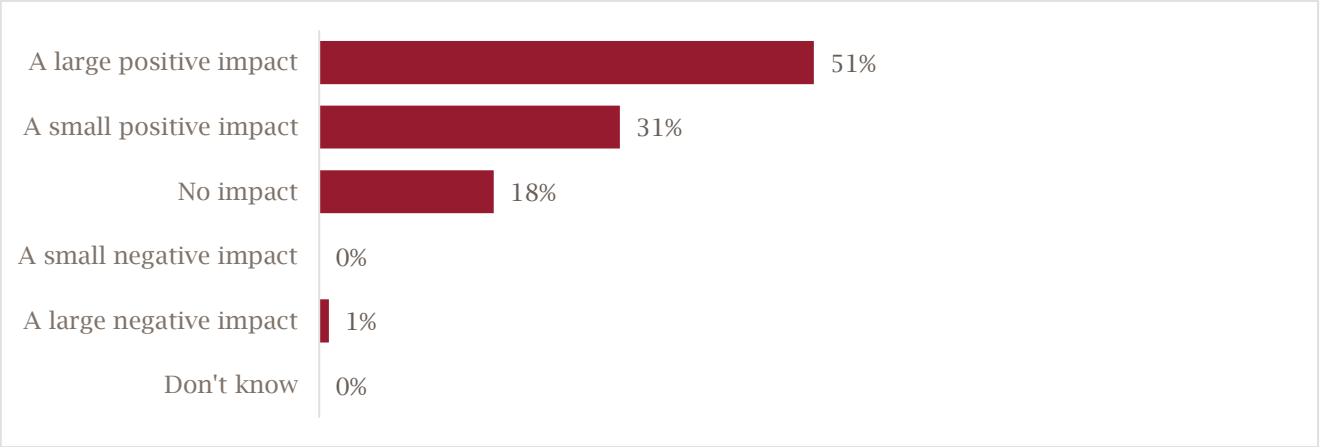

*Source: Beneficiaries survey. Q18B. What impact, if any, do you think using these tools, technologies and concepts has had on your organisation's performance in the following areas?: Your organisation's profit*
*Note: Base: Impact survey respondents already using TCC concepts (91)*

### PRODUCTIVITY

Figure 34 shows the observed impact of using TCC concepts on productivity for both 'successful' and 'unsuccessful' applicants. We find that TCC concepts are having a positive impact on productivity. Over half (51%) of survey respondents who were already using at least one TCC concept reported a large positive impact on their organisation's productivity. A further 31% reported a small positive impact.

These proportions are similar to those for respondents who were actively considering using TCC concepts and expected a positive impact on productivity. Forty-seven percent of survey respondents who were actively considering using at least one TCC concept expected the use of TCC concepts to have a large positive impact on their organisation's productivity and a further 35% reported a small positive impact.

## FIGURE 34 OBSERVED IMPACT OF USING TCC CONCEPTS ON PRODUCTIVITY



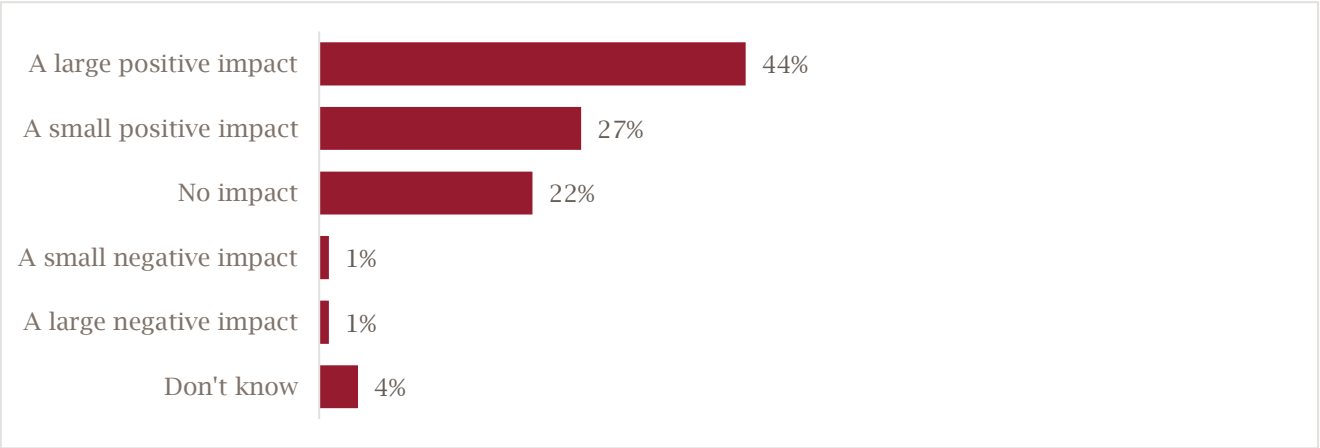

*Source: Beneficiaries survey. Q18B. What impact, if any, do you think using these tools, technologies and concepts has had on your organisation's performance in the following areas?: Your organisation's productivity*
*Note: Base: Impact survey respondents already using TCC concepts (91)*

### SPEED OF DELIVERY

Figure 35 shows the observed impact of using TCC concepts on speed of delivery for both 'successful' and 'unsuccessful' applicants. We find that TCC concepts are having a positive impact on speed of delivery. Nearly three-quarters (71%) of survey respondents who were already using at least one TCC concept reported a positive impact in speed of delivery. This includes 44% who reported a large positive impact.

These proportions are similar to those who were actively considering using TCC concepts and expected a positive impact on speed of delivery. Nearly three-quarters (71%) of survey respondents who were actively considering using at least one TCC concept expected the use of TCC concepts to have a positive impact on their organisation's speed of delivery.

## FIGURE 35 OBSERVED IMPACT OF USING TCC CONCEPTS ON SPEED OF DELIVERY




*Source: Beneficiaries survey. Q18B. What impact, if any, do you think using these tools, technologies and concepts has had on your organisation's performance in the following areas?: Your organisation's speed of delivery – from inception to completion for either new built or refurbished assets*
*Note: Base: Impact survey respondents already using TCC concepts (91)*

### ACTIVITY CASE STUDIES

The case studies give a number of examples of projects that show potential to improve the performance of the construction sector through the integration of TCC concepts. These examples are provided in the table below. The concepts developed as part of these projects include BIM, Information Management, MMC and off-site manufacturing. However, as discussed in Section 7.1, many of the TCC activities remain at demonstration/proof-of-concept stages. As such, it is not possible to demonstrate a direct impact of the TCC on the performance of construction sector firms and their suppliers at this stage.

Many of the concepts developed were expected to be transformative for a number of the case study organisations. There was general agreement that the activities would not have been able to go ahead without the TCC and therefore any future transformation can be attributed to the TCC. However, the interviewees were not able to quantify the future impact of the TCC precisely.

### TABLE 23 ACTIVITY CASE STUDY INSIGHTS – CHANGE IN PERFORMANCE OF TCC BENEFICIARIES

| ACTIVITY | INSIGHTS |
|---|---|
| **Aquila** | **As a result of the TCC, the Aquila activity has been able to demonstrate the use of BIM and artificial intelligence to improve on-site productivity.** The BIM Academy led a team to develop a digital platform that could better plan the use of plant equipment. The result is Aquila, which improves plant and equipment utilisation in real time, giving everyone the ability to view plant and equipment in a project by linking live data in a 3D model with time or schedule-related information. Aquila uses artificial intelligence to process information to synchronise activity and create a sequence for what equipment is needed and when. The result is more streamlined projects and safer, cleaner and more productive sites.<br>Funding has allowed for the development of a demonstrable product that can be used within the industry. Interviewees that were part of this case study suggested that this activity would not have gone ahead without the TCC. |
| **Construction quality planning tool** | **The activity is at too early a stage to understand impact, but future positive impacts on revenue are expected.** The activity created a tool to shift the construction industry from a defect remediation approach once buildings are completed to a quality assurance prevention approach from the outset. |
| **Behind the Meter Billing and Trent Basin** | **The integrated use of TCC concepts has resulted in optimism for future revenue prospects.** The Behind the Meter experiment allows partners to test different scenarios in terms of energy supply and billing. The interviewed commercial partner was already seeing interest in the concept from developers and expected this to positively impact the company's revenue in the future. |
| **AEC Delta Mobility** | **The implementation of TCC concepts makes businesses more competitive in the market and offers incremental value to customers.** This was suggested by the interviewees in relation to BIM and Information Management Frameworks. |

| ACTIVITY | INSIGHTS |
|---|---|
| **IDEMA Panel House** | **Although this activity is still at proof-of-concept stage there was optimism about the financial benefits for the activity partners.** One partner mentioned that their involvement in the activity had helped them 'win additional contracts', but the value of these was unknown. |

*Source: Activity case studies*
*Note: This is a summary of the case study activity included. More detail is provided in the case study-specific annex.*

#### VIEWS OF THE EXPERT PANEL

Overall, the experts suggested that changes to the performance of the construction sector was a lagging metric, particularly when compared to collaboration and R&D investment. As a result, the experts did not expect to see a clear impact of the TCC at this stage both for beneficiary firms and the wider industry.

The experts reflected the optimism in the case studies in indicating that the TCC will be a critical driver of future change in the performance of the construction sector as a result of incorporating TCC concepts. The experts suggested that change is likely to be realised in the next 5 to 10 years due to the cycle of construction projects. That is, the projects that the TCC aims to impact tend to be larger-scale construction projects with long delivery lead times.

## 8.4 LONG-TERM OUTCOMES

### 8.4.1 YEAR-ON-YEAR CHANGE IN SECTOR (AND RELEVANT SUPPLY CHAIN) PRODUCTIVITY PERFORMANCE (LONG-TERM OUTCOME)

#### SECONDARY DATA ANALYSIS

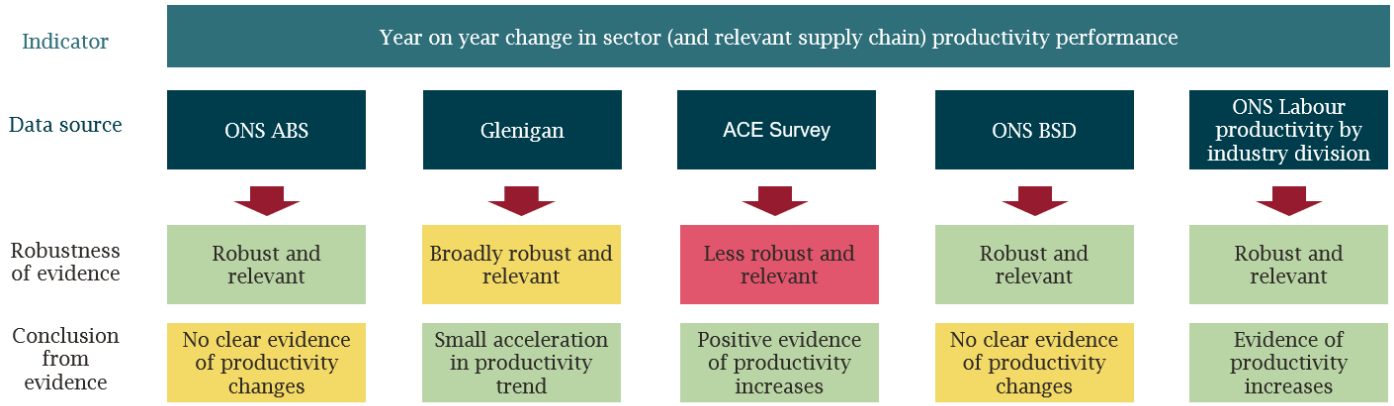
The secondary data analysis conducted provides evidence for a slight increase in sector (and relevant supply chain) productivity performance in the years after the TCC was established. This suggests that the TCC is operating in an environment of modestly increasing productivity. Figure 36 below summarises the conclusions from the analysis of each of the metrics, indicating both their robustness and relevance for the context of the evaluation.

- ONS ABS data provides evidence on annual gross value added (GVA) of sub-sectors of construction-related activities per £ of employment. We find that GVA per worker in these sectors has been relatively constant and in line with the UK non-financial business economy average, with the exception of construction of buildings where we see a slight increase relative to the benchmark groups.
- Glenigan data provides evidence on annual self-reported median value added per full-time equivalent employed. We find evidence for a slightly accelerating trend in the CAGR of mean GVA per employee after 2018 (CAGR of 2.6% from 2012 to 2017; CAGR of 2.9% from 2017 to 2020). However, the data is from a sample based on construction projects that appear in publicly available local planning applications. Therefore data variation may be due to changes in the sample rather than industry trends.
- The Association for Consultancy and Engineering (ACE) survey indicates that, from 2017 to 2019, GVA per worker has increased for firms with over 250 employees. However, we consider the ACE survey to be less robust due to its low sample size (14-15 firms).

- ONS Business Structure Database (BSD) shows that turnover per employee has followed broadly the same trend for the relevant construction sub-sectors compared with the benchmark sector.
- ONS Labour Productivity data shows that, from 2018 onwards, construction-related activities have tended to have a higher annual growth rate compared with UK-wide productivity, with the exception of architectural and engineering activities, which have experienced lower growth.

Below we present some of the key analysis; a complete set of analysis and assessment of the relevance and robustness of the data is provided in Annex G -

## FIGURE 36 SUMMARY OF RESULTS FROM SECONDARY DATA ANALYSIS




*Source: Frontier Economics*

### ONS ABS

The ONS ABS is the main structural business survey conducted by ONS and crosses most business sectors. To obtain productivity estimates in this dataset, annual GVA is divided by total employment cost.

We used a weakly defined difference-in-difference approach to assess the impact of the TCC on this productivity metric at a sectoral level. Our approach identified the treatment group (i.e. where we expect TCC to impact) and benchmark groups on the basis of SIC codes (see Annex F - ). The benchmark groups are a benchmark in the same sub-sector, but not identified to be related to TCC; a benchmark in a similar sector; and a whole-economy benchmark.

We conducted this analysis for three treatments groups: core construction (e.g. organisations focused on the construction of buildings or bridges); construction product manufacturers (e.g. organisations focused on the manufacture of cement or concrete); and professional services for the construction industry (e.g. organisations focused on architectural or engineering activities).

The results of the analysis are presented in Table 24. Overall, the ONS ABS analysis suggests that productivity has followed similar trends to the benchmark groups for core construction and professional services for the construction industry. This suggests that the sub-sectors that the TCC is operating within are following similar levels of productivity increase to the benchmark groups. We find that there has been a slight decrease in productivity for the construction product manufactures treatment group.

The detailed sub-sector-level analysis is provided in Annex G -

## TABLE 24 ONS ABS SUB-SECTOR ANALYSIS

| TREATMENT GROUP | CHANGE IN GVA PER £ OF EMPLOYMENT COSTS |
|---|---|
| Core construction | GVA per £ of employment costs for the core construction treatment group has followed a similar trend to all benchmark groups post 2018. |
| Construction product manufacturers | There has been a slight decrease in GVA per £ of employment costs post 2018, while this metric has remained mostly stable for the benchmark groups. |
| Professional services for the construction industry | There is no evidence of differences in the evolution of GVA per £ of employment costs post 2018 for the treatment and benchmark groups. |

*Source: Frontier Economics based on ONS ABS data*

### ONS BSD

The ONS BSD includes firm-level data on turnover per employee as a measure of productivity. As per the analysis for ONS ABS, we used a weakly defined difference-in-difference approach to assess the impact of the TCC on turnover per employee at a sectoral level. The same definitions of treatment groups and benchmark groups are used as for the ONS ABS analysis above.

The results of the analysis are presented in Table 25. Overall, the ONS BSD analysis does not show larger increases in turnover per employee than those experienced in the benchmark groups. This suggests that the sub-sectors within which the TCC is operating are following similar levels of productivity increase (measured by turnover per employee) to the benchmark groups.

The detailed sub-sector-level analysis is provided in Annex G -

## TABLE 25 ONS BSD SUB-SECTOR ANALYSIS

| TREATMENT GROUP | CHANGE IN TURNOVER PER EMPLOYEE |
|---|---|
| Core construction | Following an increase from 2016 to 2018 over and above the increases in the benchmarks groups, from 2019-2020 there has been a slight decrease in turnover per employee for core construction that is not seen in the benchmark groups. |
| Construction product manufacturers | For the construction product manufacturers treatment group, turnover per employee has broadly followed the same trends as the sub-sector and sector benchmark groups. |
| Professional services for the construction industry | For the construction product manufacturers treatment group, turnover per employee has broadly followed the same trends as the benchmark groups. |

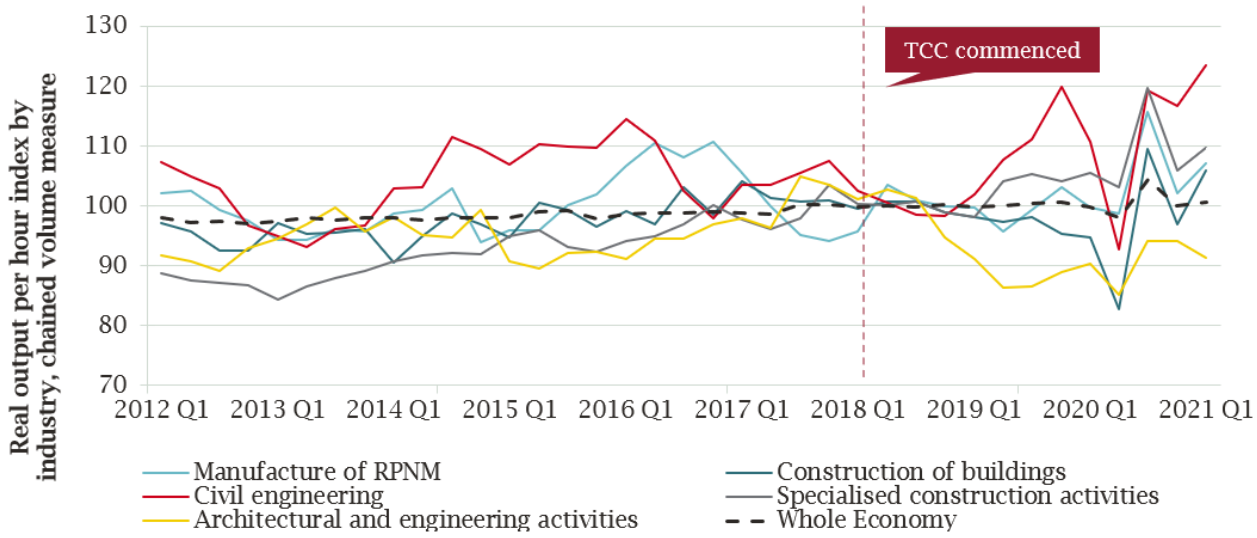
*Source: Frontier Economics based on ONS BSD data*

### ONS LABOUR PRODUCTIVITY BY INDUSTRY DIVISION

The ONS Labour Productivity by Industry Division source defines productivity as output per hour for different industries.

Figure 37 shows the evolution of real output per hour (productivity) of sub-sets of construction-related activities, at a 2-digit SIC code level, indexed at 2018. The analysis shows that from 2018 until the first quarter of 2021, all construction-related activities (with the exception of architectural and engineering activities) outperformed the whole economy. The data also indicates that the pandemic's initial impact of on productivity for many construction-related sectors was very sharp, followed by a rapid recovery.

## FIGURE 37 ONS – REAL OUTPUT PER HOUR INDEX BY INDUSTRY, CHAINED VOLUME MEASURE




*Source: Frontier Economics*
*Note: RPNM relates to Manufacture of rubber and plastics products, & other non-metallic mineral products*

Table 26 sets out the CAGR of the same productivity metric for different periods. This figure shows evidence for an increase in labour productivity for construction-related activities following 2018. This suggests that the TCC is operating in an environment with increasing productivity.

- Productivity of construction-related activities generally grew faster than the whole economy (with the exception of architecture and engineering activities) across the medium term, from 2012 Q1 to 2021 Q1.
- Over 2015-18, Manufacture of rubber and plastics products and other non-metallic mineral products and civil engineering underperformed relative to whole economy.
- Over 2018-21, all construction-related activities (with the exception of architecture and engineering activities) grew faster than the whole economy. Out of these activities, the best performance is seen for the civil engineering and manufacture of RPNM. However, this is likely to relate to the negative growth observed in the previous period analysed (2015-18).

## TABLE 26 ONS – COMPOUND ANNUAL GROWTH RATE OF REAL OUTPUT PER HOUR INDEX BY INDUSTRY, CHAINED VOLUME MEASURE

| TIMEFRAME | | MANUFACTURE OF RPNM* | CONSTRUCTION OF BUILDINGS | CIVIL ENGINEERING | SPECIALISED CONSTRUCTION ACTIVITIES | ARCHITECTURAL AND ENGINEERING ACTIVITIES | WHOLE ECONOMY |
|---|---|---|---|---|---|---|---|
| Medium-term comparison | CAGR 2012-21 | 0.2% | 0.4% | 0.6% | 0.9% | 0.0% | 0.1% |
| Short-term comparison | CAGR 2015-18 | 0.0% | 0.5% | -0.4% | 0.5% | 1.0% | 0.2% |
| | CAGR 2018-21 | 1.2% | 0.6% | 1.9% | 0.9% | -1.0% | 0.1% |

*Source: Frontier Economics*

*Note: *RPNM relates to Manufacture of rubber and plastics products, & other non-metallic mineral products*

### 8.4.2 YEAR-ON-YEAR CHANGE IN THE VALUE OF EXPORTS OF CONSTRUCTION PRODUCTS AND SERVICES

#### SECONDARY DATA ANALYSIS

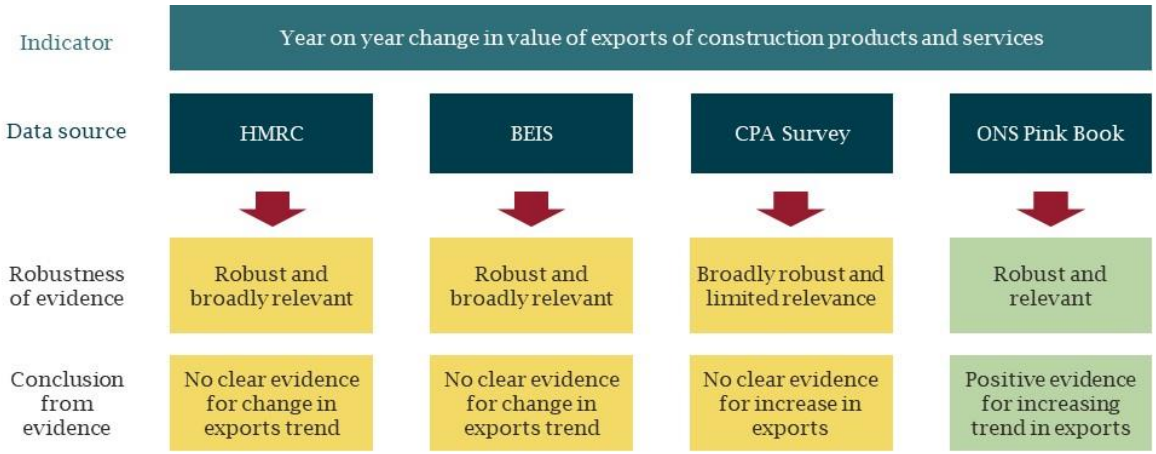
Overall, the secondary data analysis conducted provides some evidence for an increase in the value of exports of construction products and services following the introduction of TCC. Figure 38 summarises the conclusions from the analysis of each of the metrics, as well as their robustness and relevance for the evaluation.

- HMRC and BEIS data on exports provides limited evidence for changes in the exports of pre-fabricated buildings or concrete increasing after 2018.[22]
- CPA Survey data provides no evidence for an acceleration in the trend of exports of construction manufacturers from 2018 onwards. However, we consider this metric to be less robust for the purposes of the evaluation as the CPA is only able to ask respondents to report percentage increases in variables (rather than the underlying cash values). In addition, it does not capture engineering consultancy firms, which is a key group that the TCC programme expects to impact.
- ONS Pink Book data shows that construction service exports grew at a CAGR of 14% from 2018 to 2020, in comparison to a CAGR of 9% from 2012 to 2018. As the TCC has a greater focus on services, we consider this dataset to be particularly relevant for the evaluation.

Below we present some of the key analysis; a complete set of analysis and assessment of the relevance and robustness of the data is provided in Annex G -

[22] We note that the TCC aims to influence pre-fabricated products given the focus on off-site construction. We therefore consider exports of these goods to be particularly relevant.

## FIGURE 38 SUMMARY OF RESULTS FROM SECONDARY DATA ANALYSIS



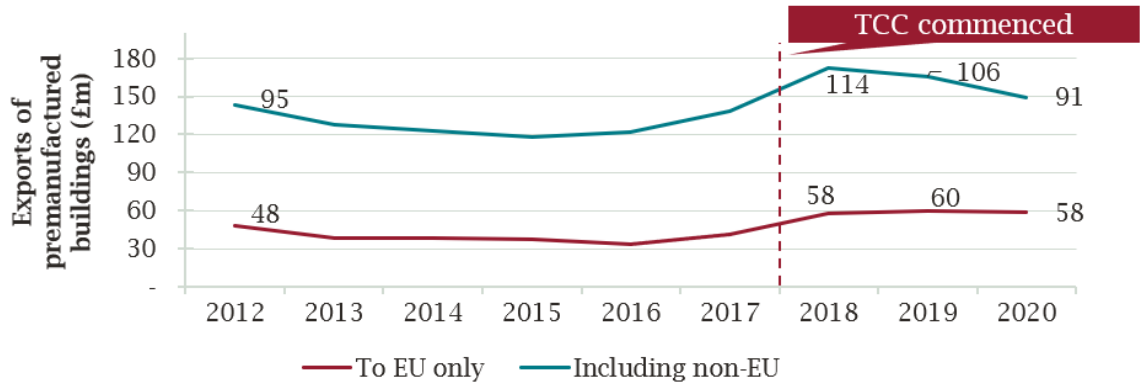

*Source: Frontier Economics*

### HMRC

HMRC Overseas Trade statistics are compiled monthly from trade declarations using 8-digit commodity codes. Businesses whose annual value of dispatches exceeds £250,000 are required to report monthly declarations, covering roughly 97% of trade for dispatches. The data allows for measurement of trade value by product categories.

Figure 39 shows the value of exports of pre-manufactured buildings. Overall, there is no clear evidence for an increase in the trend of exports of pre-manufactured buildings after 2018. Since 2016 there has been a gradual increase in the value of UK exports in pre-manufactured buildings. This increase stabilised in 2019 and decreased in 2020 (particularly when including non-EU exports).

## FIGURE 39 HMRC – VALUE OF EXPORTS OF PRE-MANUFACTURED BUILDINGS




*Source: Frontier Economics based on HMRC OTS data*

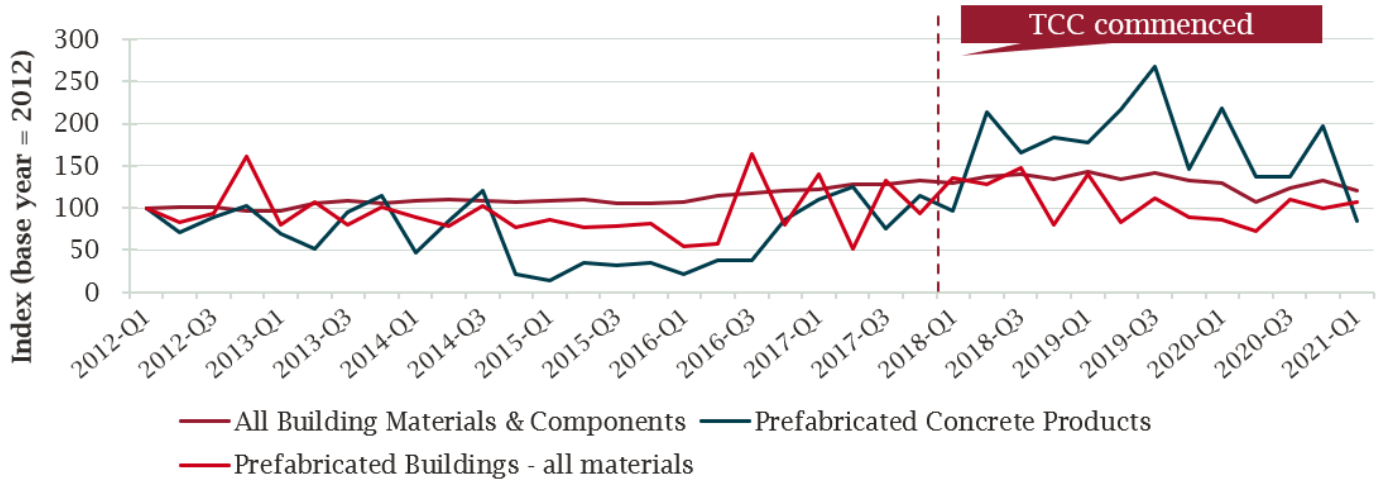
### BEIS

The Building Materials and Components statistics are UK national statistics concerning the construction products industry. The data allows for measurement of trade value by categories of product.

Figure 40 shows the overall annual exports in all building materials and components, pre-fabricated concrete products and pre-fabricated buildings. Overall, there is no clear evidence that exports of pre-fabricated products have increased since 2018:

- Exports of overall building materials and components have had a slightly increasing trend since 2012.
- Exports of pre-fabricated concrete products decreased in 2015 by 69% in comparison to 2012 but then increased to 222% of 2012 exports in 2019, suggesting a clear resurgence of pre-fabricated concrete product exports.

## FIGURE 40 BEIS – ANNUAL EXPORTS IN SELECTED CONSTRUCTION MATERIALS AND COMPONENTS




*Source: Frontier Economics based on BEIS*

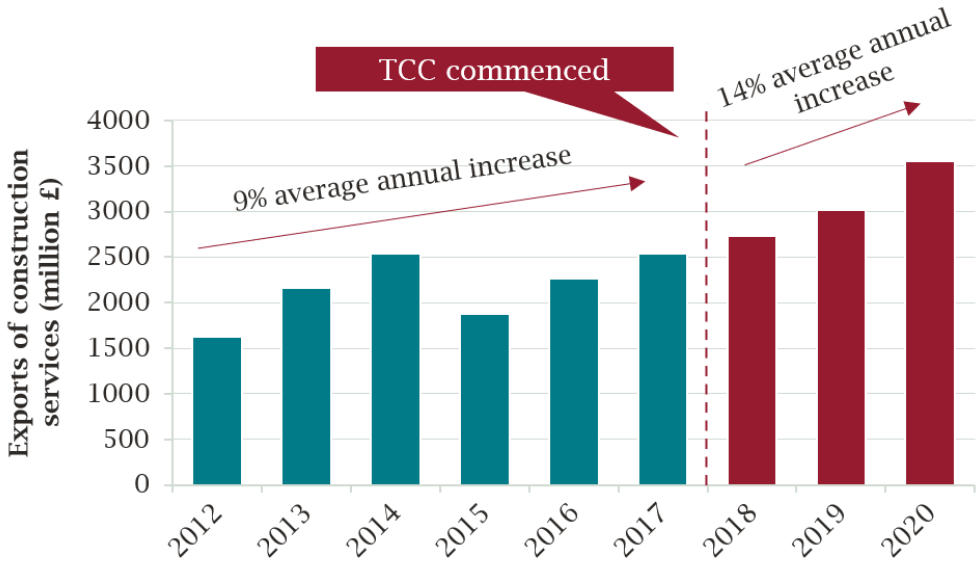
### ONS PINK BOOK

Figure 41 sets out exports of services for the construction sector compiled in the Pink Book and sourced from the UK Balance of Payments.

There is positive evidence of an accelerating trend in construction service exports in the construction sector after 2018:

- Construction service exports grew at a CAGR of 9% from 2012 to 2018.
- From 2018 to 2020 the CAGR increased to 14%, despite any potential negative effects from Covid. We note that the TCC aims to have an impact on the export of construction services. Therefore, this dataset is particularly relevant for analysis of exports.

## FIGURE 41 ONS PINK BOOK – EXPORTS OF CONSTRUCTION SERVICES IN THE UK




*Source: Frontier Economics based on ONS Pink Book*

# 9 FINDINGS: THEME 6 – IMPROVED DELIVERY OF BUILT ASSETS (TIME, QUALITY AND WHOLE-LIFE COSTS)

## KEY MESSAGES

- This theme links the development and incorporation of TCC concepts into the construction process and its associated supply chain with the results of better delivery and performance of built assets. These effects will include, but are not limited to, a lowering of predicted and actual costs of delivery of built assets, as well as lower whole-life costs of buildings that incorporate TCC concepts.

**Programme outputs provide evidence that TCC concepts have potential to decrease construction delivery time and construction and whole-life costs**

- The TCC has a target of influencing a total of £3 billion of projects which achieve reductions in whole-life costs of around 33%. In this context, projects 'influenced' by the TCC are those that are linked to the TCC but whose achieved productivity improvements are not necessarily attributable to the TCC's involvement. As of 2021, internal TCC data shows that this target has already been surpassed, with a cumulative committed project value of £21.2 billion. In terms of delivery time, the TCC has a target of influencing a total of £3 billion of projects which achieve reductions in delivery time of around 50%. As of 2021, internal TCC data shows that this target has already been surpassed, with a cumulative committed project value of £14.6 billion.

**Demonstrators of TCC concepts improve on construction costs and delivery times**

- The case studies have a number of examples of projects that show potential to improve the delivery of built assets through the integration of TCC concepts. However, many of the TCC activities remain at demonstration/proof-of-concept stages. As such, it is not possible to demonstrate a direct impact of the TCC on the delivery of built assets at this stage.

**Change in predicted costs (construction and whole-life) and delivery time across industry**

- Overall, we find mixed evidence on changes in projects delivering on time or in advance, construction costs and labour hours spent on site. For the majority of survey respondents, we find that the indicator has stayed the same in comparison to the baseline survey.
- Overall, the secondary data analysis does not provide evidence that the TCC is operating in an environment with improvements in predicted costs or delivery times. However, data from the secondary data is limited for this theme and, as such, the evaluation for this theme draws primarily on evidence from the remaining evaluation methods (primary survey and case studies).
- The experts agreed that changes to the delivery of built assets in terms of time, quality and whole-life costs is a lagging metric, and therefore we would not expect to see an impact of the TCC at this stage of its implementation. However, there is optimism about change in the future as a result of the TCC, which is expected to be realised in approximately 5 to 10 years.

This theme links the development and incorporation of TCC concepts into the construction process and its associated supply chain with the intended results of better delivery and performance of built assets. These effects will include, but are not limited to, a lowering of predicted and actual costs of delivery of built assets, as well as lower whole-life costs of buildings that incorporate TCC concepts. These objectives are supported by the activities and outputs of all strands, particularly ABC and CIH.

This theme is supported by the stated objective of Construction 2025 to reduce the time taken to deliver new buildings and refurbished assets by 50% and costs, both delivery and whole life, by 33%, targeting £3bn of asset value during TCC.

This section provides the evidence base relating to the evaluation indicators for Theme 6, which are summarised in the table below. The section first outlines the activities undertaken by the TCC relating to this theme and then summarises the evidence for each indicator type below.

### TABLE 27 THEME 6 – SUMMARY OF EVALUATION APPROACH

| INDICATOR TYPE | SUCCESS INDICATOR | DATA SOURCES |
|---|---|---|
| Monitoring | Programme outputs provide evidence that TCC concepts have potential to decrease construction delivery time and construction and whole-life costs | Self-reported counterfactual<br>Completion form data |
| Short-term and long-term outcomes | Demonstrators of TCC concepts improve on construction costs and delivery times | Primary survey<br>Activity case studies |
| Long-term outcomes and impacts | Change in predicted costs (construction and whole-life) and delivery time across industry | Activity case studies<br>Secondary data analysis |

*Source: Frontier Economics*

## 9.1 ACTIVITIES UNDERTAKEN BY THE TCC

A critical aim of the TCC is to increase the delivery of built assets by the UK construction sector and, therefore, all of the activities undertaken by the TCC are relevant to Theme 6. These activities include the development and dissemination of TCC concepts across organisations directly engaging with the TCC and the wider industry.

## 9.2 MONITORING

### 9.2.1 PROGRAMME OUTPUTS PROVIDE EVIDENCE THAT TCC CONCEPTS HAVE POTENTIAL TO DECREASE CONSTRUCTION DELIVERY TIME AND CONSTRUCTION AND WHOLE-LIFE COSTS

#### TCC INTERNAL BENEFITS DATA

Internal TCC monitoring data relating to the reduction of whole-life costs and reduction of delivery time provides evidence for reduction of project whole-life costs and project delivery times, respectively.

##### REDUCTION IN WHOLE-LIFE COSTS

Figure 42 sets out the cumulative committed (actual) and forecasted contracted project value of projects influenced by the TCC where calculated lifetime cost is reduced by around 33%. In this context, projects 'influenced' by the TCC are those that are linked to the TCC but whose whole-life cost reductions achieved are not necessarily attributable to the TCC's involvement. The TCC has a target of influencing a total of £3 billion of projects which achieve reductions in whole-life costs of around 33%. As of 2021, this target had already been surpassed, with a cumulative committed project value of £21.2 billion.

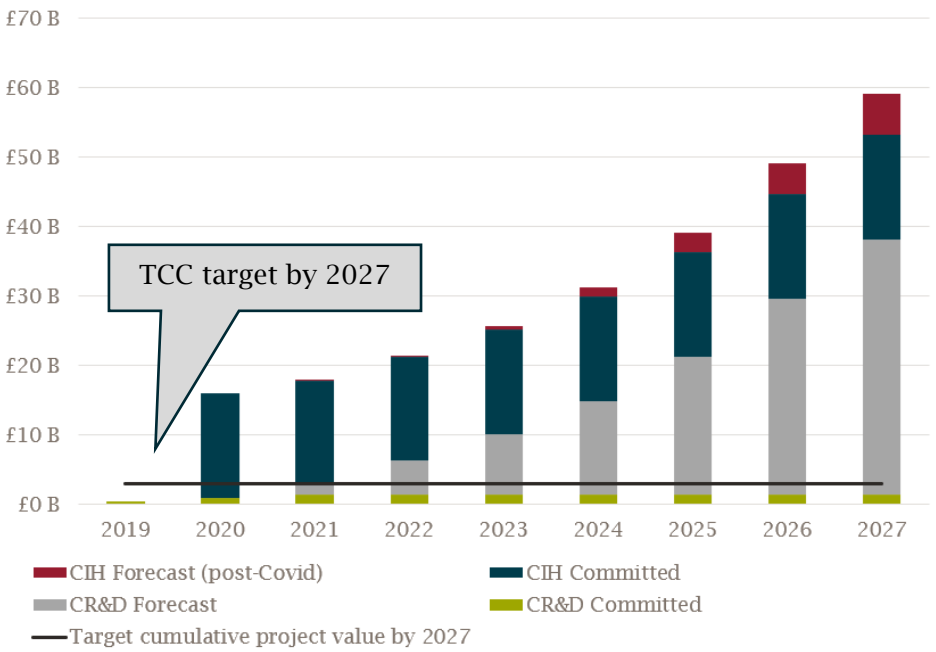
## FIGURE 42 PROJECTS INFLUENCED BY THE TCC WITH REDUCTION IN WHOLE-LIFE COSTS


*Source: Frontier Economics based on TCC's benefits data*

### REDUCTION IN DELIVERY TIME

Figure 43 sets out the cumulative committed (actual) and forecasted contracted project value of projects influenced by TCC where calculated delivery time is reduced by around 50%. In this context, projects 'influenced' by the TCC are those that are linked to the TCC but whose achieved delivery time reductions are not necessarily attributable to the TCC's involvement. The TCC has a target of influencing a total of £3 billion of projects which achieve reductions in delivery time of around 50%. As of 2021, this target had already been surpassed, with a cumulative committed project value of £14.6 billion.

## FIGURE 43 REDUCTION IN DELIVERY TIME




*Source: Frontier Economics based on TCC's benefits data*

### RELATED ACTIVITIES INCLUDED IN BENEFITS DATA

Activities relating to expected improvements to the delivery of built assets as a result of TCC funding and seen in the TCC benefits data presented in Figure 42 and Figure 43 include:

- **AIMCH**: The Advanced Industrialised Methods for the Construction of Homes Initiative (AIMCH) aims to provide comparative cost data on new manufacturing approaches compared to traditional methods. The concepts have helped cut costs and delivery times, resulting in higher expected future profits.
- **Government Soft Landings:** Government Soft Landings (GSL) is an open-source framework that aims to smooth the transition between the design and construction of a building to its operation and use, and helps to ensure a building is easy to operate and maintain, with the ultimate goal of improving cost and time predictability.
- **STELLAR:** This programme aims to allow smaller housebuilders and contractors to access MMCs by reducing capital costs. The ultimate goal of the activity is for SMEs to be able to benefit from lower cost, increased productivity and quality, and help deliver social homes using MMCs that meet community needs.

### COMPLETION FORM DATA

Project completion form (PCF) data is collected by the monitoring team of Innovate UK operations on all projects completed by CR&D. Twenty-two project leads involved with different CR&D projects answered the PCF survey.

Out of these 22 projects:

- 23% had a delayed start (with an average delay time of 2 months);
- 41% required an extension to the end date (the average termination delay was 4.2 months); and
- 36% are expected to generate cost savings.

## 9.3 SHORT-TERM AND LONG-TERM OUTCOMES

### 9.3.1 DEMONSTRATORS OF TCC CONCEPTS IMPROVE CONSTRUCTION COSTS AND DELIVERY TIMES

Note that the indicator 'demonstrators of TCC concepts improve construction costs and delivery times' relates to both short-term and long-term impacts.

#### ACTIVITY CASE STUDIES

The case studies show a number of examples of projects that have the potential to improve the delivery of built assets through the integration of TCC concepts. The concepts developed as part of these projects include off-site manufacturing, improving the whole-life value of buildings, and quality and validation process for MMC. The expected improvements to the delivery of built assets include the following:

- Expected future reductions in whole-life costs (e.g. see the West Midland DfMA activity case study); and
- Future benefits on costs and delivery times (e.g. see the AIMCH, FASTtruss, Government Soft Landings and Data Capture for Whole Lifecycle Compliance Checking activity case studies).

However, as discussed in section 7.1, many of the TCC activities remain at demonstration/proof-of-concept stages. It is important to note that the evidence collected for this theme is limited in comparison to the other evaluation themes. As such, it is not possible to demonstrate a direct impact of the TCC on the delivery of built assets at this stage.

A summary of relevant insights for improvements to the delivery of built assets from the activity case studies is presented in the below table. The full write-up of the case studies is provided in Annex D -

### TABLE 28 ACTIVITY CASE STUDY INSIGHTS – IMPROVE CONSTRUCTION COSTS AND DELIVERY TIMES

| ACTIVITY | INSIGHTS |
|---|---|
| **West Midland DfMA** | **There are expected future reductions in whole-life costs, but these are yet to be realised.** The activity included the design and build of a prototype house that could be easily scaled up. To optimise the installation of the prototype, the consortium developed a knowledge-based engineering (KBE) tool which would estimate where the greatest emissions and costs come from across both the lifecycle of the build and home once in use and which would adjust the design to minimise investment and carbon footprint. The activity is at proof-of-concept stage and so it is too early to see any quantified impacts. However, all of the parties interviewed agreed that they expected the whole-life costs to be reduced. |
| **AIMCH** | **There are expected future benefits on costs and delivery times for the construction of homes.** The Advanced Industrialised Methods for the |

| ACTIVITY | INSIGHTS |
|---|---|
| | Construction of Homes Initiative (AIMCH) aims to provide comparative cost data on new manufacturing approaches compared to traditional methods. The concepts have helped cut costs and delivery times, resulting in higher expected future profits. |
| **FASTtruss** | **There is initial evidence of improvement of costs and time taken to manufacture from the incorporation of robotics.** Tata Steel UK is working with Bryden Wood and the Advanced Manufacturing Research Centre (part of University of Sheffield) to produce a robotically welded demonstrator called FASTtruss which can automate the design and manufacture of steel lattice trusses. The FASTtruss project has almost been completed and was expected to finish in December 2021. It is at proof-of-concept stage and a full-scale trial was being rolled out in October 2021. The project has demonstrated the potential of the FASTtruss concept. |
| **Government Soft Landings** | **There is evidence of improvement of cost and time predictability from the incorporation of frameworks**. Government Soft Landings (GSL) is an open-source framework that aims to smooth the transition between the design and construction of a building to its operation and use and helps to ensure a building is easy to operate and maintain. In terms of the impact of GSL on the interviewees organisation, they have compared key performance indicators of the projects that are using various TCC frameworks to industry norms and, encouragingly, all are exceeding those norms, particularly for cost and time predictability. |
| **Data capture for whole lifecycle compliance checking** | **A future impact on cost savings is expected due to the activity.** Although the activity has not yet completed, it is expected to result in a reduction in wasted time relating to the re-submittance of compliance checks, which will translate into cost savings. |

*Source: Activity case studies*

*Note: This is a summary of the case study activity included. More detail is provided in the case study-specific annex.*

### 9.3.2 CHANGE IN PREDICTED COSTS (CONSTRUCTION AND WHOLE-LIFE) AND DELIVERY TIMES ACROSS INDUSTRY

#### PRIMARY SURVEY

The primary survey provides evidence for the change in the predicted cost and delivery time of TCC beneficiary firms for the following metrics:

- **Proportion of construction projects delivered on time or in advance:** the change in the proportion of construction projects delivered on time or in advance since TCC engagement and the impact of the TCC;
- **Construction costs per metre squared ($m^2$):** change in construction costs per $m^2$ since engagement with the TCC and impact of the TCC; and
- **Labour hours spent on site per $m^2$:** change in labour hours spent on site per $m^2$ since engagement with the TCC and impact of the TCC.

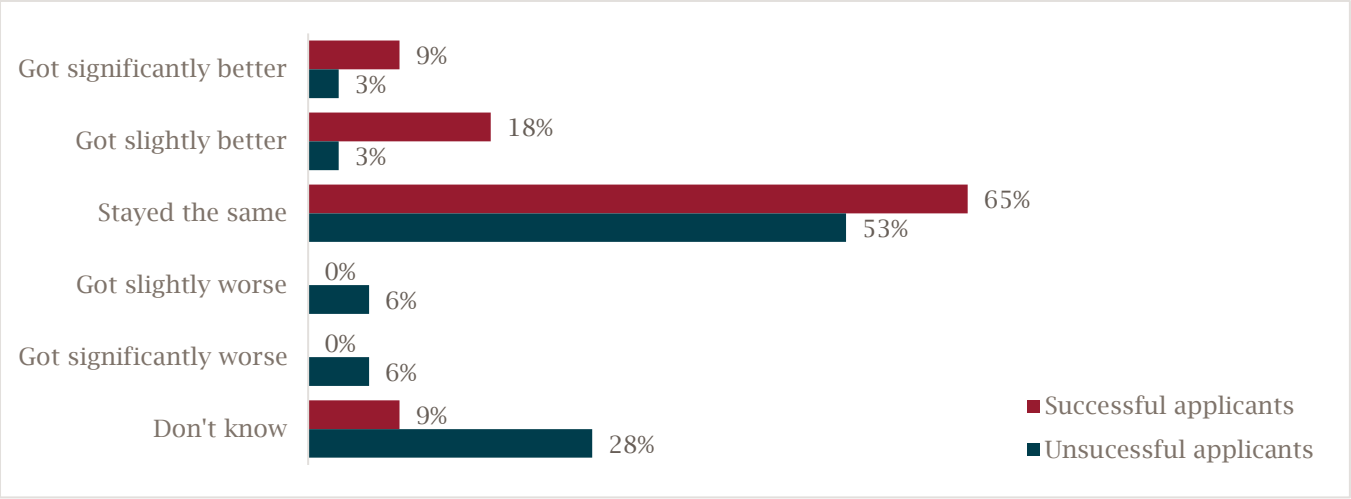
Overall, we find mixed evidence on changes in projects delivered on time or in advance, construction costs and labour hours spent on site. For the majority of survey respondents, we find that the indicator has stayed the same in comparison to the baseline survey.

### PROPORTION OF CONSTRUCTION PROJECTS DELIVERED ON TIME OR IN ADVANCE

Figure 44 shows the change in the proportion of construction projects delivered on time or in advance since engagement with the TCC, split by 'successful' and 'unsuccessful' TCC applicants. For the majority of 'successful' TCC applicants (65%), the proportion of construction projects delivered on time or in advance since engagement with the TCC was reported to have stayed the same. However, businesses whose application for TCC funding was successful were more likely to say that the proportion of projects delivered on time or in advance had got better since their engagement with TCC: 9% reported that it had got significantly better and 18% reported that it had got slightly better. None of these 'successful' TCC applicant businesses reported that the proportion of construction projects delivered on time or in advance had decreased.

There is evidence of businesses attributing changes to construction projects delivered on time or in advance to the TCC. Over half (59%) of businesses whose applications for TCC funding were successful reported TCC having a positive impact on the proportion of projects delivered on time or in advance. This includes 15% who reported the TCC had had a large positive impact and 44% who reported the TCC had had a small positive impact. However, 35% of business whose applications for TCC funding were successful reported that the TCC had had no impact.

### FIGURE 44 CHANGE IN THE PROPORTION OF CONSTRUCTION PROJECTS DELIVERED ON TIME OR IN ADVANCE SINCE ENGAGEMENT WITH TCC – SUCCESSFUL VS. UNSUCCESSFUL APPLICANTS




*Source: Beneficiaries survey. Q21. How, if at all, have the following changed for your organisation since your engagement with TCC?: The proportion of construction projects delivered on time or in advance*

*Note: Base: Successful business applicants (34), unsuccessful business applicants (32)*

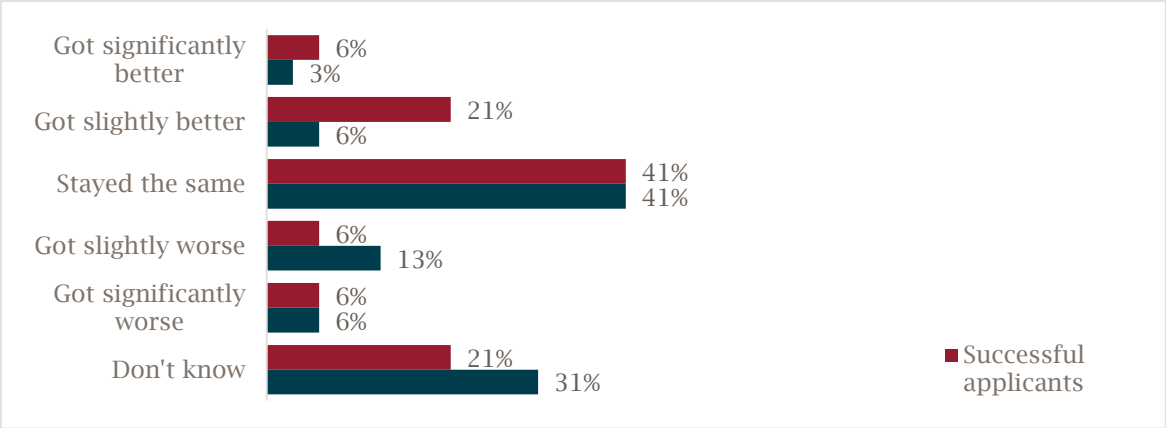
### CONSTRUCTIONS COSTS PER METRE SQUARED

Figure 45 shows the change in construction costs per $m^2$ since engagement with the TCC, split by 'successful' and 'unsuccessful' TCC applicants. We find that 41% of businesses whose TCC applications had been successful reported that construction costs per $m^2$ since engagement with the TCC had stayed the same. However, businesses which had been successful in their applications for TCC funding were more

likely to report that their construction costs per $m^2$ had got better (26%) than those which had been unsuccessful (9%).

There is evidence of businesses attributing changes to construction costs per $m^2$ to the TCC. Half (50%) of surveyed businesses which had been successful in their TCC applications for funding reported that the TCC had had a positive impact on constructions costs, including 21% which reported that the TCC had had a large positive impact. None of these respondents reported that the TCC had had a negative impact on construction costs.

## FIGURE 45 CHANGE IN CONSTRUCTION COSTS PER M² SINCE ENGAGEMENT WITH TCC – SUCCESSFUL VS. UNSUCCESSFUL APPLICANTS



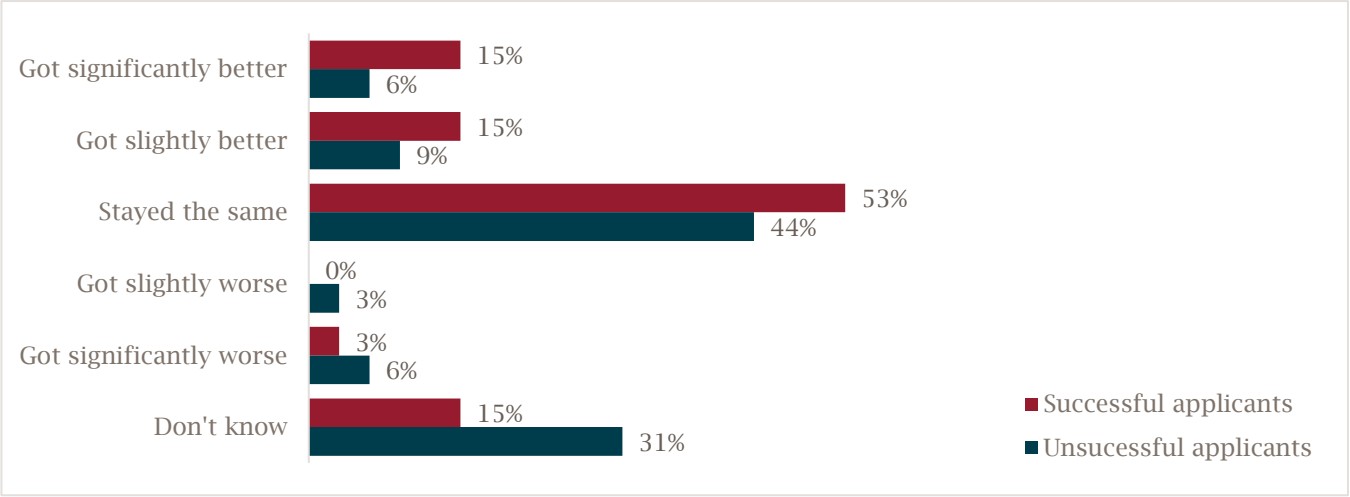

*Source: Beneficiaries survey. Q21. How, if at all, have the following changed for your organisation since your engagement with TCC?: Construction costs per $m^2$*
*Note: Base: Successful business applicants (34), unsuccessful business applicants (32)*

### LABOUR HOURS SPENT ON SITE PER METRE SQUARED

Figure 46 shows the change in the proportion of construction projects delivered on time or in advance since engagement with the TCC, split by 'successful' and 'unsuccessful' TCC applicants. Around the majority of 'successful' TCC applicants (53%) reported that the change in labour hours spent on site per $m^2$ had stayed the same following engagement with the TCC. Businesses which had been successful with their application for TCC funding were more likely to say this had got better (30%, compared to 15% for those which had been unsuccessful with their applications).

There is mixed evidence on the impact of the TCC on site labour hours. Over two in five (44%) businesses surveyed that had been successful in their TCC application reported that the TCC had positively impacted labour hours, including 18% who felt that the TCC had had a large positive impact. However, 44% of the 'successful' businesses surveyed reported that the TCC had had no impact on labour hours.

## FIGURE 46 CHANGE IN LABOUR HOURS SPENT ON SITE PER M² OF INTERIOR FLOOR SPACE SINCE ENGAGEMENT WITH TCC – SUCCESSFUL VS. UNSUCCESSFUL APPLICANTS




*Source: Beneficiaries survey. Q21. How, if at all, have the following changed for your organisation since your engagement with TCC?: Labour hours spend on site per m² of interior floor space*
*Note: Base: Successful business applicants (34), unsuccessful business applicants (32)*

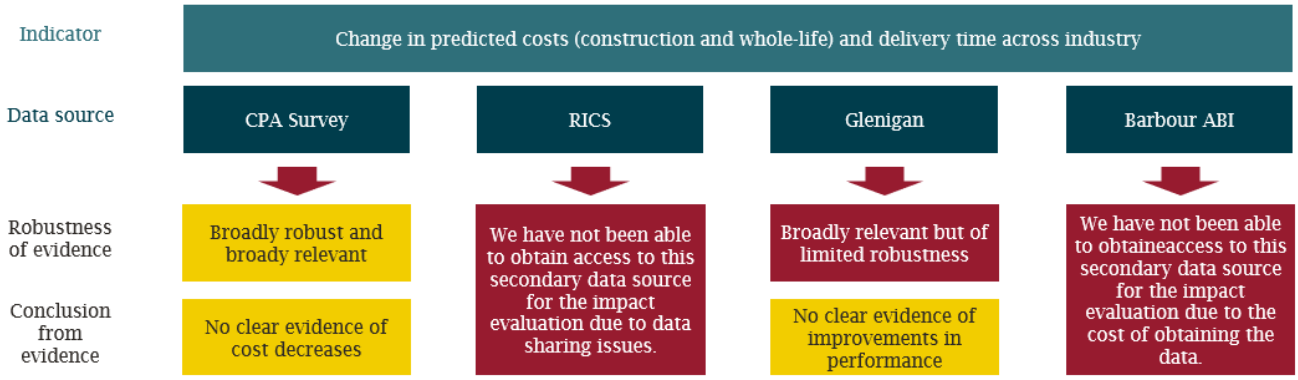
### SECONDARY DATA ANALYSIS

Overall, the secondary data analysis does not provide evidence that the TCC is operating in an environment with improvements in predicted costs or delivery time. However, data from the secondary data is limited for this theme and as such, the evaluation for this theme draws primarily on evidence from the remaining evaluation methods (primary survey and case studies). Figure 47 summarises the conclusions from the analysis of each of the metrics, as well as their robustness and relevance for the evaluation.

- The CPA Survey reports percentage increases in variables rather than the underlying cash values, affecting the ability to interpret the data. The cost measure included does not account for changes in cost due to inflation, nor by fluctuations in prices of raw materials. Nonetheless, we can draw some inferences from the available data, which shows limited evidence of reductions in the actual unit costs of construction manufacturers from 2018 onward.
- The Glenigan data relies on data from publicly available local planning applications. The types of firms included each year change with the types of projects. Therefore, the data presented is expected to be significantly impacted by the types of projects included in the data sample in each year, rather than uniquely by variation caused by wider industry factors or policy interventions. There is no clear evidence that the proportion of projects delivered on time or better increased from 2018 onwards.
- We were not able to obtain access to the datasets from Royal Institute of Charted Surveyors (RICS) and Barbour ABI.

Below we present some of the key analysis; a complete set of analysis and assessment of the relevance and robustness of the data is provided in Annex G -

## FIGURE 47 SUMMARY OF RESULTS FROM SECONDARY DATA ANALYSIS




*Source: Frontier Economics*

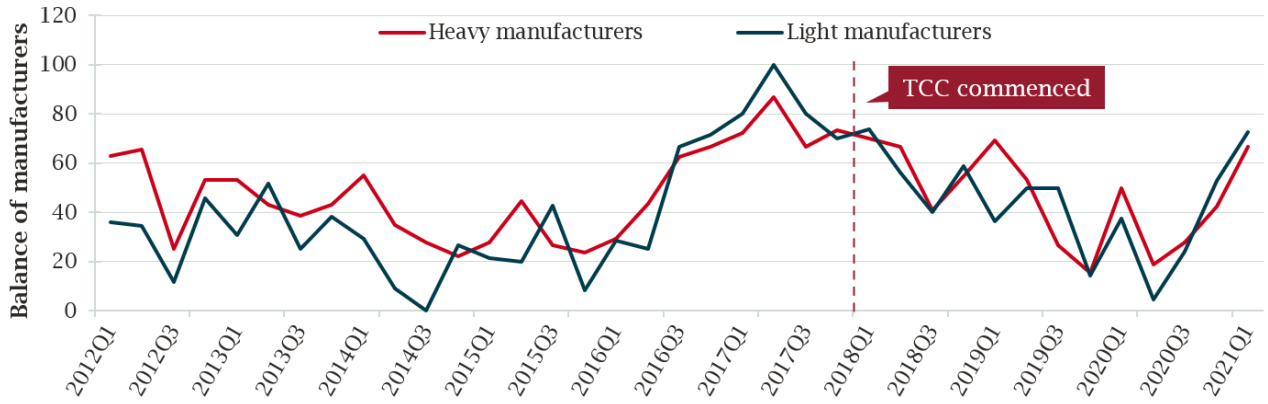
### CPA SURVEY

Figure 48 shows the evolution of the balance of construction manufacturers that reported an increase in actual unit costs relative to the previous quarter. The survey includes between 80 and 150 construction sector manufacturers in each quarter.

Overall, this metric provides limited evidence of reductions in actual unit costs of construction manufacturers from 2018 onwards.

- For all periods since 2012, the majority of manufacturers reported an increase in actual unit costs relative to the prior quarter, for both the heavy and light segments. This is expected given that inflation is not accounted for in the survey.
- The proportion of manufacturers reporting an increase in unit costs increased substantially from 2016 to 2017, and in early 2021. These increases may be in part driven by Brexit, Covid-19 and fluctuations in prices of raw materials.

## FIGURE 48 CPA SURVEY – BALANCE OF CONSTRUCTION MANUFACTURERS WITH INCREASES IN ACTUAL UNIT COSTS RELATIVE TO PREVIOUS QUARTER




*Source: Frontier Economics based on CPA Survey*
*Note: A value above zero means that over half of the manufacturers reported an increase in actual unit costs relative to the previous quarter*

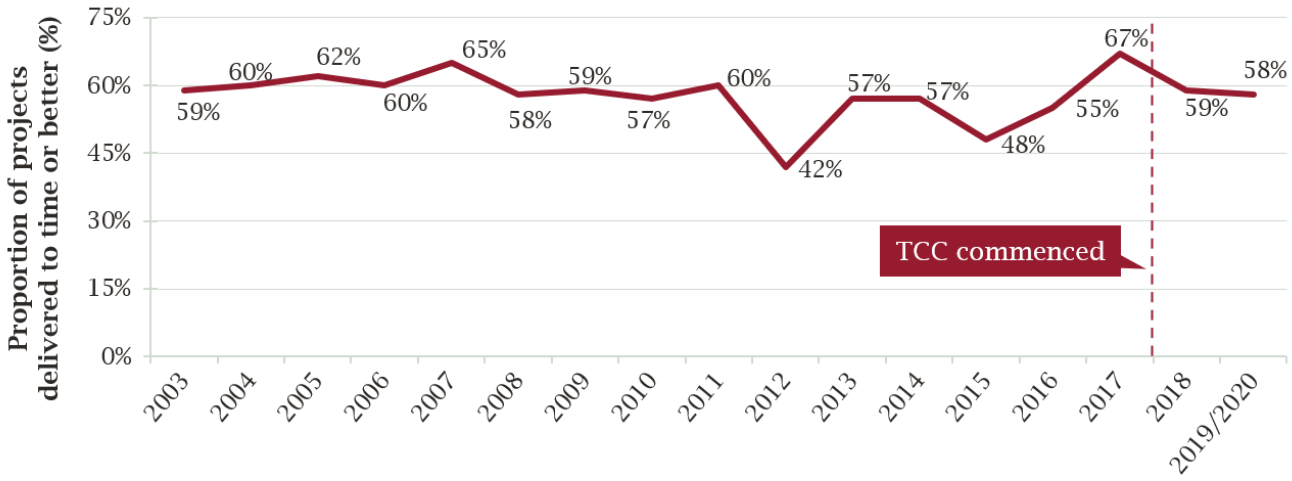
### GLENIGAN

Glenigan data is collected from surveys of construction clients, contractors, sub-contractors and consultants based on projects completed during the preceding year. The sample is based on construction projects that appear in publicly available local planning applications. Figure 49 presents survey responses on the proportion of projects delivered to time or better.

There is no clear evidence that the proportion of projects delivered on time or better increased from 2018 onwards.

- The proportion of projects delivered on time or better remained relatively stable at between 42% and 67% across the full period from 2003 to 2019/2020, without a clear upwards or downwards trend.
- This proportion averaged 58% in the earlier period (2003 to 2017) and 59% in the later period (2018 and 2019/2020).

## FIGURE 49 GLENIGAN – PROPORTION OF PROJECTS IN THE CONSTRUCTION INDUSTRY DELIVERED ON TIME OR BETTER




*Source: Frontier Economics based on Glenigan*

*Note: The coverage of the latest report (relative to 2019/2020) has been extended to cover responses for projects completed over a 2 year period in order to maximise the survey sample size. This is because survey responses have been disrupted by the pandemic.*

### VIEWS OF THE EXPERT PANEL

In the discussions on Theme 6, the experts echoed similar views to those for Theme 5, i.e. that changes to the delivery of built assets in terms of time, quality and whole-life costs is a lagging metric. Therefore, we would not expect to see change in the delivery of built assets at this stage of the TCC's implementation. However, there is optimism about change in the future as a result of the TCC, which is expected to be realised in approximately 5 to 10 years.

# 10 FINDINGS: THEME 7 – IMPROVED ENVIRONMENTAL PERFORMANCE OF BUILT ASSETS

## KEY MESSAGES

- This theme focuses on the wider impacts of incorporating TCC concepts on society. This includes lower carbon emissions through reduced energy consumption buildings and the reduction of waste produced on site.

**Programme outputs provide evidence of expected environmental benefits arising from adoption of TCC concepts**

- The TCC has a target of influencing a total of £3 billion worth of projects that reduce greenhouse gas emissions. In this context, projects 'influenced' by the TCC are those that are linked to the TCC but whose achieved productivity improvements are not necessarily attributable to the TCC's involvement. As of 2021, this target had already been surpassed, with a cumulative committed project value of £22.8 billion.

**Extent to which demonstrators of TCC concepts improve environmental impact of built assets**

- In the primary survey, we find positive evidence for the current (i.e. observed impact) and potential impact of TCC concepts across emissions, energy consumption and waste. Four in five (80%) survey respondents who were already using TCC concepts had observed a positive impact on $CO_2$ emissions. Three-quarters (74%) of those who were already using TCC concepts had observed a positive impact on waste produced on site and, separately, energy consumption on site.
- The case studies find that a number of successful demonstrator projects that result in improvements to environmental performance have been developed as a result of the TCC. These projects show the positive potential of TCC concepts for the environmental impact of built assets. The positive impacts highlighted in the case studies were generally related to reductions in emissions.

**Estimated environmental impact on built assets**

- The case studies highlight how TCC activities are at too early a stage to assess impact, and no interviewees were able to quantify the environmental impact of TCC concepts on built assets. Nonetheless, the case studies highlight clear optimism about the use of TCC concepts for the future.
- Overall, the secondary data analysis conducted suggests that the TCC is operating in an environment with limited changes in the environmental impact of built assets. The secondary data analysis analyses emissions data for domestic properties, domestic properties energy ratings and data on waste removed from construction sites.
- The experts agreed with the evidence that there is potential for the TCC to have a positive impact on the environmental performance of built assets in the future, but this has not been realised yet due to the stage of the programme.
- Wider factors such as government policy and customer choice were highlighted by the experts to be an important driver of changes to the environmental impact of built assets.

This final theme brings together the benefits of TCC for the construction industry and focuses on the wider impacts that the incorporation of TCC concepts may have on society. This includes lower carbon emissions through reduced energy consumption buildings and the reduction of waste produced on site. These objectives are primarily supported by the activities and outputs of ABC.

This section provides the evidence base relating to the evaluation indicators for Theme 6, which are summarised in the table below. The section first outlines the activities undertaken by the TCC relating to this theme and then summarises the evidence for each indicator type below.

### TABLE 29 THEME 7 – SUMMARY OF EVALUATION APPROACH

| INDICATOR TYPE | SUCCESS INDICATOR | DATA SOURCES |
|---|---|---|
| Monitoring | Challenge outputs provide evidence of expected environmental benefits arising from adoption of TCC concepts | Internal benefits data |
| Short-term outcomes | Extent to which demonstrators of TCC concepts improve on environmental impact of built assets | Primary survey<br>Activity case studies<br>Expert review |
| Long-term outcomes and impacts | Estimated environmental impact on built assets | Activity case studies<br>Secondary data analysis<br>Expert review |

*Source: Frontier Economics*

## 10.1 ACTIVITIES UNDERTAKEN BY THE TCC

This theme is primarily supported by the work of the ABC, with smaller contributions from the work of CIH and CR&D. The ABC undertakes research to demonstrate the benefits (both in terms of whole-life costs and energy efficiency), scalability and long-term viability of active buildings. It also provides testing and lab facilities to clients and suppliers to help demonstrate the tangible benefits of active building technologies for new or existing projects.

## 10.2 MONITORING

### 10.2.1 PROGRAMME OUTPUTS PROVIDE EVIDENCE OF EXPECTED ENVIRONMENTAL BENEFITS ARISING FROM ADOPTION OF TCC CONCEPTS

Internal TCC monitoring data provides evidence on the cumulative value of projects with greenhouse gas emission reductions. Figure 50 sets out the cumulative committed (actual) and forecasted value of projects influenced by the TCC. In this context, projects 'influenced' by the TCC are those that are linked to the TCC but whose emission reductions achieved are not necessarily attributable to the TCC's involvement. The TCC has a target of influencing a total of £3 billion worth of projects that reduce greenhouse gas emissions. As of 2021, this target had already been surpassed, with a cumulative committed project value of £22.8 billion.

FIGURE 50 CUMULATIVE VALUE OF PROJECTS WITH GREENHOUSE GAS REDUCTION


*Source: Frontier Economic based on TCC's benefit data*

Activities relating to expected improvements to the environmental performance of built assets as a result of TCC funding and seen in the TCC benefits data presented in Figure 50 include:

- **Active Office:** The activity sought to build a prototype building using cutting-edge off-site manufacturing techniques and incorporating innovative technologies that generate, store and release solar energy.
- **HIPER Pile:** The partners utilised off-site manufacturing to create lighter piles made with an eco-friendly, cement-free material. This method has an 80% lower carbon footprint compared to the production of traditional piles.
- **Cost and carbon calculator:** The calculator assesses the embedded carbon in the building materials being considered and aims to help engineers select the best and most sustainable combination of materials, frameworks and foundations to use.

## 10.3 SHORT-TERM OUTCOMES

### 10.3.1 EXTENT TO WHICH DEMONSTRATORS OF TCC CONCEPTS IMPROVE ENVIRONMENTAL IMPACT OF BUILT ASSETS

#### PRIMARY SURVEY

The primary survey provides evidence for the extent to which TCC concepts improve the environmental impact of built assets for the following metrics:

- **$CO_2$ emissions on site:** expected and observed impact of using TCC concepts on $CO_2$ emissions on site;
- **Energy consumption on site:** expected and observed impact of using TCC concepts on energy consumption on site; and

- **Waste produced on site:** expected and observed impact of using TCC concepts on waste produced on site.

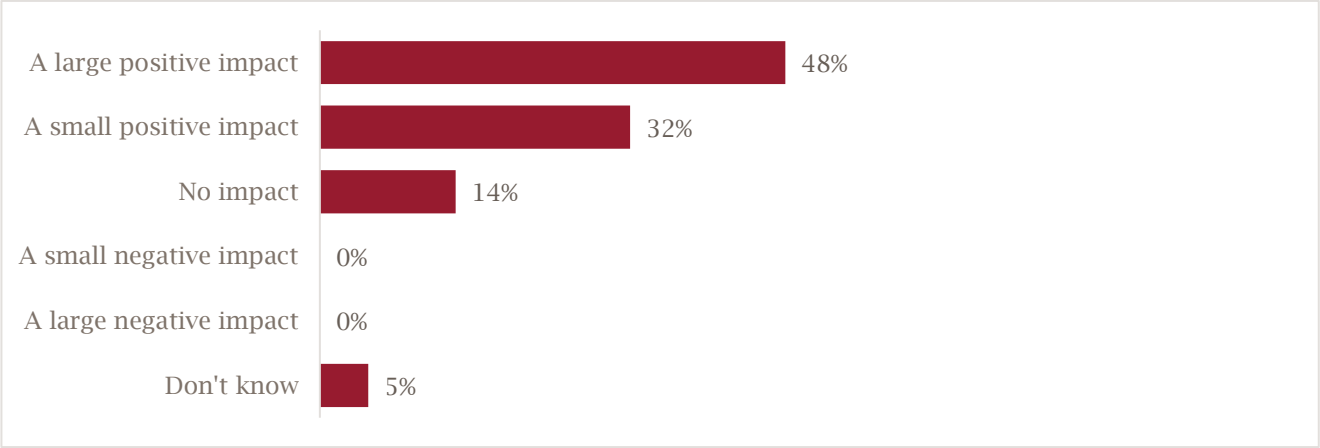
Overall, we find positive evidence for the current (i.e. observed impact) and potential impact of TCC concepts across emissions, energy consumption and waste. A summary of the findings is provided below, with all figures presented in Annex B -

### $CO_2$ EMISSIONS ON SITE

Figure 51 shows the respondents' observed impact of using TCC concepts on $CO_2$ emissions on site for both 'successful' and 'unsuccessful' TCC applicants. We find that TCC concepts did have a positive impact on $CO_2$ emissions on site. Four in five (80%) survey respondents who were already using TCC concepts had observed a positive impact on $CO_2$ emissions produced on site in the construction phase of their projects. This includes 48% who had observed a large positive impact.

Further, these findings are consistent with the expected impact of TCC concepts on $CO_2$ emissions on site. Nearly three-quarters (74%) of survey respondents who were actively considering using TCC concepts expected the use of TCC concepts to have a positive impact on $CO_2$ emissions produced on site in the construction phase of their projects. This includes 45% who expected the use of TCC concepts to have a large positive impact and 29% who expected a small positive impact. None expected it to have a negative impact.

## FIGURE 51 OBSERVED IMPACT OF USING TCC CONCEPTS ON $CO_2$ EMISSIONS PRODUCED ON SITE



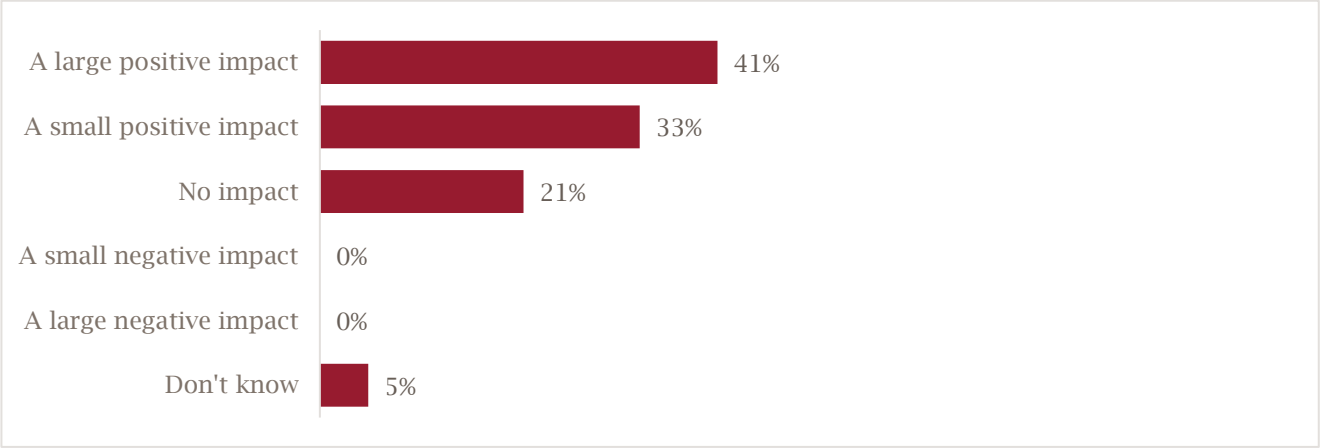

*Source: Beneficiaries survey. Q18C. What impact, if any, do you think using these tools, technologies and concepts have had on the construction phase of your projects in terms of the following indicators? : $CO_2$ emissions on site*
*Note: Base: Impact survey respondents already using TCC concepts (91)*

### ENERGY CONSUMPTION ON SITE

Figure 52 shows the respondents' observed impact of using TCC concepts on energy consumption on site for both 'successful' and 'unsuccessful' TCC applicants. We find that TCC concepts did have a positive impact on energy consumption on site. Three-quarters (74%) of those who were already using TCC concepts had observed a positive impact of TCC concepts on energy consumption on site. This includes 41% who had seen a large positive impact (41%).

This is consistent with the findings on the expected impact of using TCC concepts on energy consumption on site. We find 40% of respondents expected the TCC to have a large positive impact, and a further 31% expected the TCC to have a small positive impact.

## FIGURE 52 OBSERVED IMPACT OF USING TCC CONCEPTS ON ENERGY CONSUMPTION ON SITE



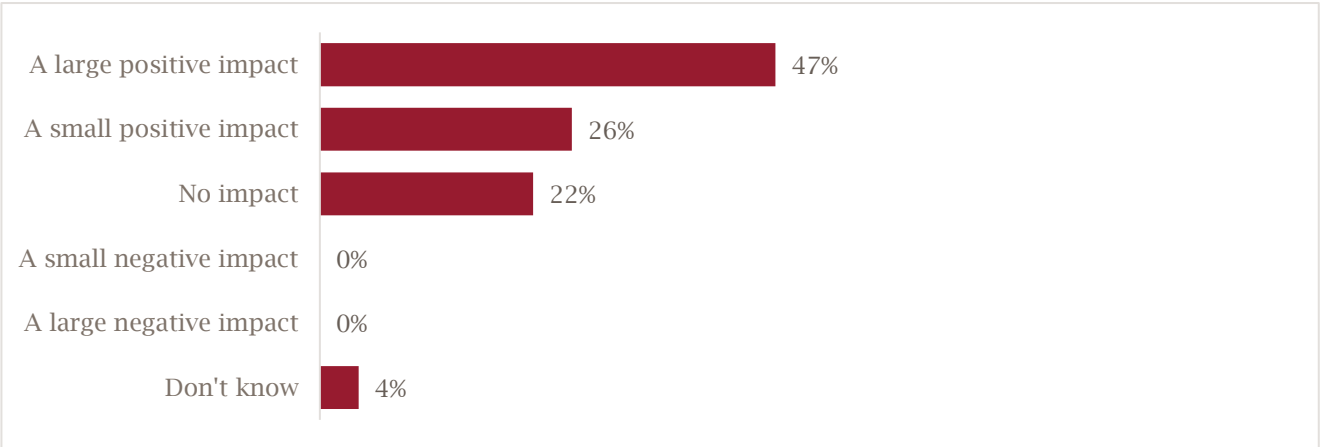

*Source: Beneficiaries survey. Q18C. What impact, if any, do you think using these tools, technologies and concepts has had on the construction phase of your projects in terms of the following indicators? : Energy consumption on site*
*Note: Base: Impact survey respondents already using TCC concepts (91)*

### WASTE PRODUCED ON SITE

Figure 53 shows the respondents' observed impact of using TCC concepts on energy consumption on site for both 'successful' and 'unsuccessful' TCC applicants. We find that TCC concepts did have a positive impact on waste produced on site. Three-quarters (74%) of those who were already using TCC concepts had observed a positive impact on waste produced on site. This includes 47% who had seen a large positive impact.

This is consistent with the findings on the expected impact of using TCC concepts on waste produced on site. We find 50% of respondents expected the TCC to have a large positive impact, and a further 26% expected the TCC to have a small positive impact.

## FIGURE 53 OBSERVED IMPACT OF USING TCC CONCEPTS ON WASTE PRODUCED ON SITE



*Source: Beneficiaries survey. Q18C. What impact, if any, do you think using these tools, technologies and concepts has had on the construction phase of your projects in terms of the following indicators? : Waste produced on site*
*Note: Base: Impact survey respondents already using TCC concepts (91)*

### ACTIVITY CASE STUDIES

A number of successful demonstrator projects which result in improvements to environmental performance have been developed as a result of the TCC. On the whole, these projects mainly relate to the activities of ABC, but there are examples of demonstrator projects developed out of CIH and CR&D. These include, but are not limited to, the following:

- The Active Office, which has demonstrated the use of active buildings and off-site manufacturing to deliver environmentally forward-looking office spaces;
- The Optimised Retrofit Programme, which has successfully measured the impact of retrofitting on the environmental performance of affordable housing; and
- The HIPER Pile activity, which has demonstrated the use of off-site manufacturing to create piles with a lower carbon footprint.

These projects show the potential positive environmental impacts from the use of TCC concepts. The concepts adopted include off-site manufacturing, integrated energy capture and storage systems, and improving the whole-life value of buildings. The positive impacts are generally related to reductions in emissions. The emissions reductions arise from:

- Greater efficiencies in construction methods which reduce the resources required during construction;
- Reduced energy requirements during both the construction phase and the life of the building;
- The use of more sustainable materials; and
- The construction of buildings with improved environmental credentials.

However, many of the case studies remain at an early stage and so the environmental impact has not been established and quantified at this stage of the programme. Further, there were limited mentions of other environmental impacts beyond greenhouse gas emissions. Despite this, the case studies highlight clear optimism about the use of TCC concepts for improving the environmental performance of built assets in the future.

There was an overall view across those interviewed as part of the case studies that the activities would not have been able to go ahead with the same levels of engagement and resource without the collaboration, funding and support that the TCC had provided. As a result, future environmental impacts can be attributed in part to the TCC.

A summary of relevant insights for demonstrators showing environmental improvements for built assets from the activity case studies is presented in the table below. The full write-up of the case studies is provided in Annex D -

### TABLE 30 ACTIVITY CASE STUDY INSIGHTS – DEMONSTRATORS SHOWING ENVIRONMENTAL IMPROVEMENTS

| ACTIVITY | INSIGHTS |
|---|---|
| **West Midland DfMA** | **Activity demonstrated the use of knowledge-based engineering (KBE) for sustainable and affordable homes.** Walsall Housing Group (whg) led this |

| ACTIVITY | INSIGHTS |
|---|---|
| | consortium to improve local neighbourhoods with sustainable and affordable homes. The activity included the design and build of a prototype house that could be easily scaled up. To optimise the installation of the prototype, the consortium developed the KBE tool to estimate where the greatest emissions and costs come from, across both the lifecycle of the build and home once in use, and to adjust the design to minimise carbon footprint. There was a general consensus across interviewees that the KBE developed as part of the activity had been successful and warranted further investment. |
| **Active Office** | **The activity was successful in demonstrating the use of active buildings and off-site manufacturing to deliver environmentally forward-looking office spaces.** The activity sought to build a prototype building using cutting-edge off-site manufacturing techniques and incorporating innovative technologies that generate, store and release solar energy. The building also aimed to provide a constant stream of smart intelligence to ensure that improvements to the efficient running of the building were continually made. The activity was seen to be successful in delivering this building demonstration.<br><br>**The work of the ABC was critical for this activity to go ahead.** All of the parties interviewed agreed that the activity would not have been able to go ahead without the TCC's involvement. The lead partner indicated that any development they might have done would have likely included different concepts as ABC was the driver of the ABC concepts being included in the prototype. Other partners mentioned the lead role that the TCC played in bringing the partners together and how the activity would not have been possible without this involvement. |
| **Behind the Meter Billing and Trent Basin** | **Due to the stage of the project, the impact cannot yet be understood.** The University of Nottingham and SmartKlub set out to demonstrate how flexible, renewable energy systems can reduce energy costs and help to cope with peak demand on the grid in a real-life context. As the activity is still at a set-up stage, the success of the activity cannot yet be fully gauged. |
| **Aquila** | **The activity is expected to have positive spillover effects for the environment which were attributed to the TCC.** The Project focuses on digital technologies that improve plant and equipment utilisation in real time, giving everyone the ability to view plant and equipment in a project by linking live data in a 3D model with time- or schedule-related information. There had been a positive impact on the environmental performance of built assets, and the interviewee thought that the impact would be big in the future too, owing to the research the TCC facilitates. |
| **HIPER Pile** | **The project has demonstrated the use of off-site manufacturing to create piles with a lower carbon footprint.** The partners embraced off-site manufacturing to create lighter piles made with an eco-friendly, cement-free material. This method has an 80% lower carbon footprint compared to the production of traditional piles. The piles are equipped with smart sensors, which monitor strength and durability to give future developers the |

| ACTIVITY | INSIGHTS |
|---|---|
| | confidence that the piles can be re-used, thus making these piles an asset for circular economy aims. The partners have also identified the potential of equipping the void part of the piles with renewable technologies so that emissions can be reduced over the whole lifecycle of the building. All partners considered the activity to be a success, most notably in terms of environmental performance. The HIPER Piles were seen to have a low carbon footprint, the potential to be re-used and the ability to generate and store energy.<br>**The activity would not have happened in the same way without the TCC.** The two parties interviewed expected that it would not have happened at all, while one of the partners believed the activity would have gone ahead in some form, although this may have resulted in longer timings, fewer commercial partners being on board and less academic oversight. |
| **Optimised retrofit programme** | **The activity is expected to be able to measure the impact of retrofitting measures on the environmental performance of affordable housing.** The Active Building Centre Research Programme is using data to help retrofit and decarbonise social homes in Wales. It aims to reduce the carbon footprint of around 2,000 existing homes as part of the Welsh Government's Optimised Retrofit Programme (ORP). By bringing together a range of active energy experts, research hubs, local authorities and social housing providers, ORP aims to create new retrofit standards with the overarching aim of improving affordable warmth in homes, reducing emissions and creating 15,000 new jobs in Wales. The activity aims to evaluate how well the retrofit measures have performed, and this objective is on track to be met. However, the interviewee was aware that the target number of homes to be retrofitted had not been met and had been scaled back. However this will not impact their specific activity objectives. |
| **FASTtrust** | **The activity has evolved with its TCC engagement to spend more time on environmental considerations.** The organisation had spent more time on sustainability than it had originally allocated. For example, organisations involved were creating an early version of an environmental product declaration (EPD) or FASTtruss to see how it compared with competing structural elements. |

*Source: Activity case studies*
*Note: This is a summary of the case study activity included. More detail is provided in the case study-specific annex.*

## 10.4 LONG-TERM OUTCOMES AND IMPACTS

### 10.4.1 ESTIMATED ENVIRONMENTAL IMPACT ON BUILT ASSETS

#### ACTIVITY CASE STUDIES

Those interviewed as part of the case studies suggested that the TCC, at this stage of the programme, had promoted environmental impacts across the industry through increasing general awareness of environmental concerns and how TCC concepts can be used to improve the environmental impact of built assets.

However, as discussed in section 7.1, the projects are at too early a stage to assess impact, and no interviewees were able to quantify the environmental impact of TCC concepts on built assets. Nonetheless, the case studies highlight clear optimism about the use of TCC concepts for the future.

The case studies highlight the need for additional government policy changes and changes in the commercial landscape for the full impact to be released in the future. For example, an interviewee for the Value Toolkit case study stated that the framework would only result in improvements to the environmental impact of built assets if there were wider policy changes that incentivised commissioning around environmental criteria. Separately, a number of private sector interviewees emphasised that it would be difficult for them not to focus predominately on costs unless regulations created incentives to promote wider considerations, such as the environment.

A summary of relevant insights for environmental impacts for built assets from the activity case studies is presented in the table below. The full write-up of the case studies is provided in Annex D -

### TABLE 31 ACTIVITY CASE STUDY INSIGHTS – ENVIRONMENTAL IMPACT ON BUILT ASSETS

| ACTIVITY | INSIGHTS |
|---|---|
| **AIMCH** | **The TCC has helped to increase awareness of environmental concerns.** Interviewees agreed that the Challenge had had a positive impact on the wider construction industry and supply chains, encouraging them to think differently about carbon emissions and whole-life costs. |
| **West Midlands DfMA** | **The project is at too early a stage to assess impact.** There was general consensus across the project that knowledge-based engineering which had been developed as part of the activity had been successful and warranted further investment. However, it was too early for a quantified impact of the activities, but there was an expected positive impact in the future. |
| **Optimised retrofit programme** | **There is limited information available on the expected future impact of the project.** By bringing together a range of active energy experts, research hubs, local authorities and social housing providers, ORP aims to create new retrofit standards with the overarching aim of improving affordable warmth in homes, reducing emissions and creating 15,000 new jobs in Wales. There is limited information to date on any wider impact on stakeholders or how much of an impact is expected in the future. |
| **GenZero** | **For the full impact to be released, changes in government policy and the wider commercial landscape are required.** GenZero has the objective of moving the construction of schools to NetZero. The project was seen to have a lot of potential for the activity to impact the environmental performance of built assets in the future, especially when complemented with the work of the Value Toolkit and Digital Twin. Looking forward, it was expected that the activity would spark a ripple effect in terms of pushing a reduction in emissions. However, the activity alone would not be able to achieve this. It would require inputs that go beyond TCC's remit, such as a change in government policy and the wider commercial landscape. |

| ACTIVITY | INSIGHTS |
|---|---|
| **Value Toolkit** | **The extent to which the environmental impact will be seen in the future will depend on the extent to which organisations are prioritising environmental considerations.**<br>There was seen to be a lot of potential for the Value Toolkit to positively impact the environmental performance of built assets in the future. However, this was very dependent on the aspirations of the organisations using the toolkit. If their aim was to improve environmental performance, then the toolkit would help them to do this and hold them to account but, if that was not their aim and they were instead driven by financial performance or other objectives, it would help them to meet those objectives at the expense of environmental performance. |

*Source: Activity case studies*
*Note: This is a summary of the case study activity included. More detail is provided in the case study-specific annex.*

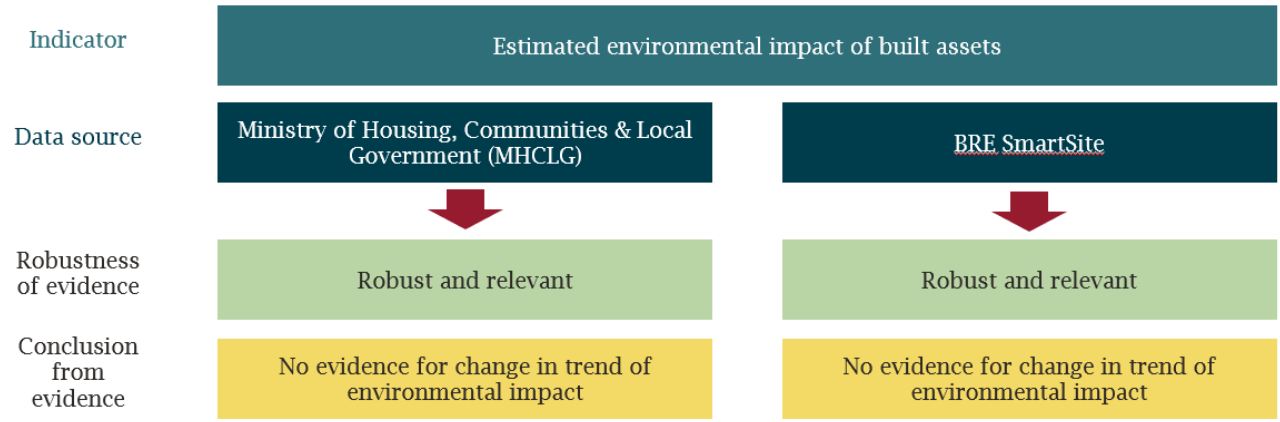
## SECONDARY DATA ANALYSIS

Overall, the secondary data analysis conducted suggests that the TCC is operating in an environment with limited changes in the environmental impact of built assets. Figure 54 summarises the conclusions from the analysis of each of the metrics, as well as their robustness and relevance for the evaluation.

- Ministry of Housing, Communities & Local Government (MHCLG) data shows that $CO_2$ emissions per square metre floor of domestic properties has had a slightly decreasing trend since 2012. This decreasing trend has not accelerated from 2018 onwards.
- MHCLG data on the energy rating of domestic products shows poorer 'energy performance' in the earlier periods, with improvements from 2017 onwards.
- BRE SmartSite data indicates that waste removed on construction sites trended downwards over 2014-2020 (mean decline 30%; median 22%), but there is no clear change in the trend from 2018 onwards. Total emissions generated on site had a stable median over 2014-2020.

Below we present some of the key analysis; a complete set of analysis and assessment of the relevance and robustness of the data is provided in Annex G -

## FIGURE 54 SUMMARY OF RESULTS FROM SECONDARY DATA ANALYSIS



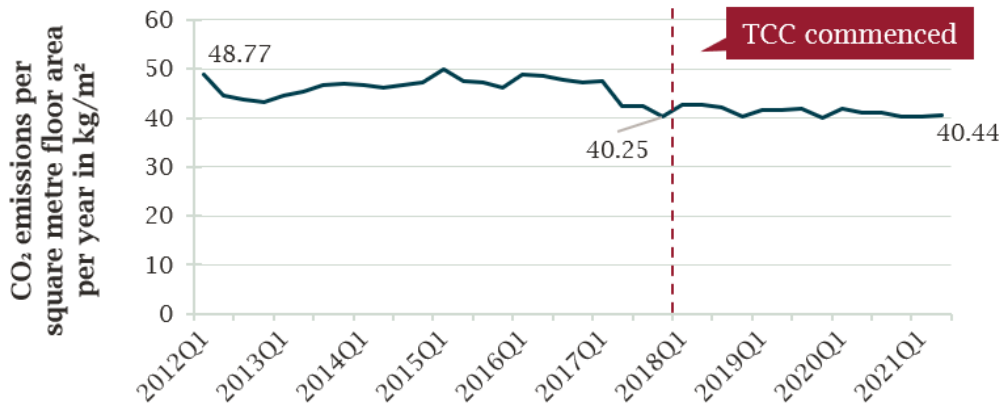

*Source: Frontier Economics*

### MINISTRY OF HOUSING, COMMUNITIES & LOCAL GOVERNMENT

Figure 55 presents the evolution of average $CO_2$ emissions per square metre floor of domestic properties in England and Wales from the Energy Performance of Buildings (EPC) data. The analysis shows that, since 2012, there has been a slightly decreasing trend in $CO_2$ emissions per square metre floor of domestic properties. This decreasing trend has not accelerated from 2018 onwards.

- The CAGR from 2012 Q1 to 2018 Q1 was of -2.2%; and
- The CAGR from 2019 Q1 to 2021 Q1 was of -2.0%.

## FIGURE 55 $CO_2$ EMISSIONS PER SQUARE METRE (DOMESTIC PROPERTIES)




*Source: Frontier Economics based on MHCLG*

Figure 56 presents the distribution of energy performance certificates by environmental impact rating based on $CO_2$ emissions of domestic properties in England and Wales. There is a slightly decreasing trend in the performance index, indicating a subtle improvement in the energy efficiency of domestic properties over time. Focusing on the post-TCC period, there is no clear evidence of an improvement in the distribution of EPC ratings from 2018 onwards, suggesting that the TCC is operating in an environment with a stable improvement in domestic property energy ratings.

- The EPC data indicates that there was a lower average energy performance in the earlier periods (averaging 4.03 between 2012 Q1 and 2017 Q1).
- This value decreased to an average rating of 3.75 for the later part of 2017 (2017 Q2 to 2017 Q4) and remained relatively stable throughout the remaining period (average of 3.74 from 2018 Q21 to 2021 Q2).

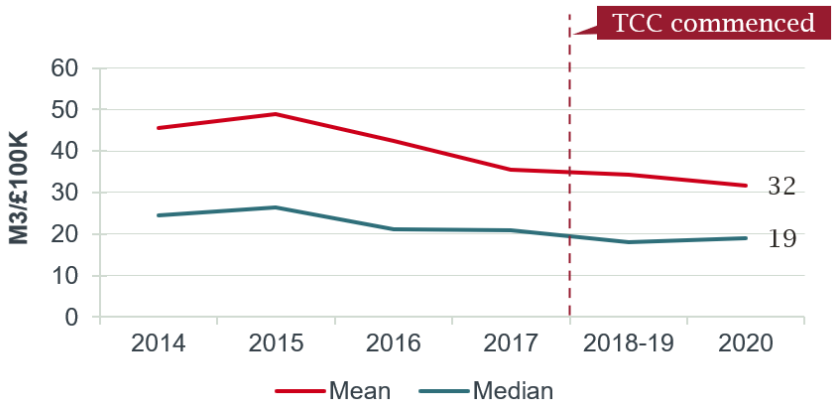
### FIGURE 56 MHCLG – DISTRIBUTION OF ENERGY PERFORMANCE CERTIFICATES BY ENVIRONMENTAL IMPACT RATING (BASED ON $CO_2$ EMISSIONS, DOMESTIC PROPERTIES)


*Source: Frontier Economics based on MHCLG*

## BRE SMARTSITE

Figure 57 presents the evolution of waste arisings for the construction companies that use BRE's productivity measurement tools and are included in the sample of BRE SmartSite. Waste arisings trended downwards over the full period from 2014 to 2020, with a decrease in both the mean (30%) and median (22%). There is no clear change in trend from 2018 onwards.

### FIGURE 57 BRE SMARTSITE – MEAN AND MEDIAN WASTE ARISINGS ON SITE (PER £100K OF CONSTRUCTION PROJECT VALUE)

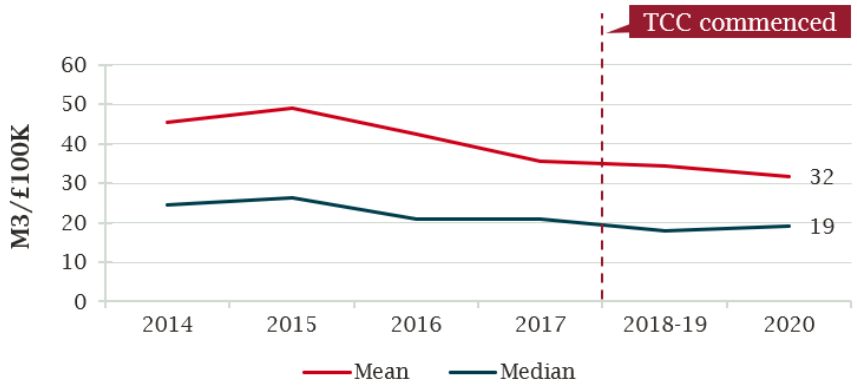



*Source: Frontier Economics based on BRE SmartSite*

Figure 58 presents on-site emissions generated in construction projects resulting from the consumption of energy (i.e. electricity, natural gas and other fuels such as diesel and petrol). There is no evidence that on-

site emissions generated from energy use decreased from 2018 onwards. This suggests that the TCC is operating in an environment with limited improvements to emissions. For the period from 2014 to 2020, total emissions generated have a stable median and a 'U-shaped' pattern for the mean (i.e. a decrease around 2016 and 2017, followed by a surge in the later period).

### FIGURE 58 BRE SMARTSITE – MEAN AND MEDIAN EMISSIONS GENERATED ON SITE FROM ENERGY USE BY CONSTRUCTION PROJECTS (PER £100K OF CONSTRUCTION PROJECT VALUE)




*Source: Frontier Economics based on BRE SmartSite*

### EXPERT REVIEW

Overall, the experts agreed with the evidence that there is optimism that the TCC will have a positive impact on the environmental performance of built assets in the future, but this has not been realised yet due to the stage of the programme.

There were mixed views across the experts on the extent to which change in the environmental performance of built assets should be attributed directly to the TCC. One expert commented that the environmental changes of built assets would be driven largely by the TCC. However, the expert suggested that wider policy changes will be credited with the impact due to a lack of awareness of the activities of the TCC and its strands, particularly the link between the ABC and the TCC. In contrast, another expert suggested that the TCC should be seen as one driver of change among many. They suggested that customer choices as well as policy changes would have a more significant impact than the TCC in the long term.

It should be noted that the time available to discuss Theme 7 in the expert review sessions was limited

# 11 CONTRIBUTION NARRATIVE

The contribution narrative seeks to triangulate across the various sources of evidence and the evaluation metrics to arrive at a set of emerging conclusions on the contributions of the TCC. This includes an understanding of:

- Where the impact of TCC to date appears to be particularly strong or less strong; and
- The extent to which the outputs, outcomes or impacts of the TCC's activities identified from the evidence gathered are additional to what otherwise would have happened had the TCC not been set up.

These emerging conclusions should be considered in the light of the overall positioning of this evaluation. Our expectations based on the evaluation framework were that long-term industry impacts might still be too early to observe, given that the TCC is a relatively new programme. This appears to have been borne out.

Overall, the TCC has been delivering a wide range of activities and outputs, including exceeding its internal targets on projects influenced which achieve productivity improvements as well as reductions to whole-life costs, delivery time and emissions.

The evidence we gathered suggests that those engaged with the TCC have high awareness of TCC concepts and are adopting them. The TCC helped to deepen and improve the understanding and adoption of TCC concepts for those engaged. This is through the TCC's role in strengthening collaboration, 'de-risking' investment and providing proofs of TCC concepts.

Further, there is strong evidence that the use of TCC concepts will have positive impacts for firms and the sector as a whole, and will provide wider benefits (such as to the environment). To the extent that the TCC can successfully promote TCC concepts (and thereby realise the benefits referred to above), these benefits will be partly attributed to the Challenge, although there are clearly wider drivers of change. As yet, there is relatively limited evidence on the wider impact of the Challenge beyond the organisations directly engaged. This is expected, given the stage of delivery and the TCC's current focus on demonstration.

It is clear from the thematic case study on procurement, that the TCC has begun to shape thinking around procurement in the public sector, including through its significant contributions to the Construction Playbook. However, further tangible change, including change across the commercial sector, will take time to deliver.

The remainder of the contribution narrative is structured around each of the seven evaluation themes rather than at the indicator level. We address each theme in turn.

## 11.1 THEME 1 – FIRMS, PUBLIC BODIES AND ACADEMICS ENGAGING IN PROJECTS RELATING TO TCC CONCEPTS

There has been an increase in collaboration related to TCC concepts since the establishment of the TCC. The primary survey finds an increase in collaboration to develop or use new ways of working on construction projects in comparison to the baseline survey (conducted in 2019). Sectors that report the largest increase in collaboration in the primary survey are research and technology organisations (23% prior to TCC, 69% in 2021), and businesses in manufacturing sectors (54% prior to TCC, 81% in 2021). Further, more than half of 'successful' TCC applicants (57%) reported that the TCC had increased

collaboration significantly, while only 5% of 'successful' applicants reported that TCC had either not impacted collaboration or had decreased collaboration. This suggests that increases in collaboration are, to an extent, attributable to the TCC.

The case studies show many examples of interdisciplinary collaboration across academic institutions, consultancy, businesses in the construction and digital sectors, technology specialists and government departments. Those we consulted in the case studies often suggested that the TCC can be credited with improving collaboration across the sector through acting as a facilitator of collaboration, its high-profile nature, and de-risking activities by providing matched funding and resource. However, there was limited evidence in the case studies of collaboration across the wider industry beyond those engaged with the TCC.

Across many of the case studies, engagement with the TCC, and consequently collaboration, was limited to specific activities. There are limited examples of the interviewed parties having other interactions with the Challenge outside of these, such as with different TCC activities or across the TCC strands. Further, we find limited evidence of the TCC impacting collaboration across the wider sector (i.e. beyond organisations that directly engage with the TCC).

The expert panel agreed with the evidence that there has been an increase in collaboration and in the quality of collaboration for organisations that the TCC has engaged with, and that this is at least partly attributable to TCC. Experts agreed with evidence from the case studies that organisations engaged by the Challenge often do not have full visibility of the wider TCC, but there were mixed in views on whether or not this was an issue of concern.

The expert panel suggested the presence of wider factors that have driven collaboration within the construction industry. For instance, there has been an industry-wide movement to improve collaboration that pre-dates the TCC, and Covid-19 has helped foster collaboration across the industry and has accelerated access to digital tools.

## 11.2 THEME 2 – CONSTRUCTION SECTOR CLIENTS ENABLE TCC CONCEPTS TO BE USED IN THE PROCUREMENT PROCESS

Since the implementation of the TCC, there has been a change in the overall strategy within procurement in the public sector to consider a wider range of impacts, such as on people and the environment, rather than just on costs. The procurement case study highlights that this can be in part attributed to the TCC. This impact is linked to the engagement individuals in procurement are having with the TCC, and particularly with the Value Toolkit and the Digital Twin projects. Prior to the TCC, the objectives of projects were mainly focused on the costs and the direct delivery of the project (e.g. number of schools or hospitals built). The TCC has widened the strategic thinking in procurement to consider the 'whole value' of the project, including impacts on people (such as via employment), social impacts, natural impacts (such as those on emissions and biodiversity), and the manufacturing impacts.

Both the expert panel and thematic case studies noted the importance of the Construction Playbook in changing public sector procurement, including via the incorporation of TCC concepts. Although the TCC has been significantly involved in the development of the Construction Playbook, there was a mixed perception among the panel on the extent to which the TCC has been a driving force in integrating TCC concepts in the Construction Playbook.

A number of experts suggested that the TCC has picked up on these concepts, which pre-date the Challenge, and has acted as an accelerator for their consideration in procurement. This is corroborated by

the thematic case study, which suggested that the TCC is an accelerator of change and that there are other wider factors that have impacted the change seen. These wider factors include pressures to decarbonise and movement towards digitisation.

The primary survey does indicate a perception that TCC concepts are more frequently seen in major private infrastructure procurement frameworks since 2018, particularly for integrated energy capture and storage systems, integrated thermal solution and smart controls, and monitoring solutions. Further, there is an expected future increase in the use of TCC concepts for the construction sector, public sector clients and private sector clients.

However, at this stage of the TCC, there is limited evidence of change in the number of TCC concepts included in private and public sector procurement, largely due to the time required (approximately 5 to 10 years according to the stakeholders consulted) to implement change in procurement. The expert panel expressed that changing mindsets within the public sector is challenging and is not an expected output of the TCC at this stage of the programme.

## 11.3 THEME 3 – CONSTRUCTION INDUSTRY AND ASSOCIATED VALUE CHAIN INCREASE INVESTMENT IN R&D RELATED TO TCC CONCEPTS

The TCC has fostered R&D and investment in TCC concepts in the short term through providing matched funding and targets, achieving a cumulative co-investment value of £250 million by 2027. The benefits data suggests that the TCC is on track to meet this target by 2023.

Overall, the secondary data analysis suggests increasing levels of overall investment across the construction sector despite Covid-19 and Brexit. This suggests that the TCC is operating in an environment of increasing construction-related R&D expenditure. ONS BERD data provides evidence of increases in both absolute intramural and extramural R&D spending and the share of R&D relative to total UK R&D spend. Further, HMRC R&D Tax Credits Statistics show that claims of R&D tax credits by firms whose primary activity is construction grew by 47% in the financial year 2017/2018 (compared to 32% in the previous year). The survey and case studies demonstrate some evidence of increased levels of investment in TCC concepts among firms engaged by the Challenge, and that this can be largely attributed to the Challenge. This is mostly a result of the TCC's 'de-risking' role through matched funding.

In contrast, the primary survey finds similar levels of R&D expenditure in 2020/21 compared to the baseline survey. However, the survey suggests that the R&D investments of successful applicants have increased and that these increases are in part driven by the TCC. Fifty-three percent of 'successful' TCC applicants reported that R&D spend had increased significantly as a result of engagement with the TCC, and a further 32% reported that R&D investment had increased slightly as a result of engagement with the TCC.

The activity case studies provide evidence on the mechanisms that enable increases in R&D investment for organisations that engage with the TCC. The TCC has enabled and changed the nature of collaboration for organisations it has engaged with. This has resulted in additional investment in TCC concepts that, without the TCC, is unlikely to have occurred. Further, the additional investment has been enabled through the 'de-risking' role that the TCC has provided. By pooling risk across organisations through matched funding for those engaging with CR&D, the TCC has enabled more investment in 'higher risk' areas that relate to TCC concepts. This was corroborated by the expert review panel.

There is mixed evidence on the extent to which investment in R&D related to TCC concepts is expected to continue in the future. There are examples in the activity case studies of investment continuing after the initial TCC funding has ended, as well as investment in new projects resulting from previous TCC engagement (e.g. the West Midland DfMA project). However, there were limited discussions of follow-on funding in the case studies.

The experts commented that they did not expect the R&D focused on TCC concepts to continue in the long term without further government support; without this, they felt it unlikely that industry would be able to continue the increased level of R&D in TCC concepts seen, as organisations tend to be too focused on 'business as usual' activities. The experts also felt that the TCC's impact on R&D investment has been focused on relatively short-term R&D projects to date.

## 11.4 THEME 4 – CONSTRUCTION SECTOR AND ITS SUPPLY CHAIN ADOPT TCC CONCEPTS

Overall, in the activity case studies we find that organisations that had engaged with the TCC had tended to have high awareness of TCC concepts prior to engagement. This is to be expected given that organisations that had engaged with the CR&D had applied to receive funding for the development of a TCC concept.

However, the activity case studies suggest that the TCC had a role in improving awareness of TCC concepts among those organisations it has engaged with to date. This has occurred through the role the TCC plays in introducing organisations to the concepts, allowing them to better focus their application of TCC concepts and providing a standardisation role. The survey indicated that a high proportion of those engaged with the TCC (whether or not they were successful in receiving funding) were already aware of or using TCC concepts: at least 83% of respondents were using, considering using, or were aware of each TCC concept asked about. Further, there has been an increase in use across the TCC concepts since the baseline survey, particularly for information management frameworks, digital compliance and improving the whole-life value of buildings.

The activity case studies and expert review panel suggest there is limited evidence to date on the extent to which the wider industry is adopting TCC concepts, although this was felt to be consistent with the stage the Challenge has reached. Many of the projects are at a proof-of-concept/demonstrator stage, where a technology is tested within real-world industry settings but is not yet widespread market practice or fully commercialised. Examples of demonstrator projects are provided in section 7.1. As a result, we would not expect the TCC to have an impact on the wider industry adoption at this stage of the programme.

The experts suggested that the adoption of TCC concepts was occurring in a small sub-sector of organisations, but with the majority of the sector was reluctant to implement change in the absence of a clearly articulated business case. There were mixed views across the experts on the uptake of TCC concepts, with uptake suggested to vary across concepts. The experts highlighted the importance of the TCC building a legacy in order to encourage longer-term adoption of TCC concepts and change in the wider industry.

## 11.5 THEME 5 – INCREASED PERFORMANCE OF CONSTRUCTION SECTOR FIRMS AND THEIR SUPPLIERS

The evidence gathered suggests that the impact of TCC support on the economic performance of the sector is expected in the future but has not yet been realised in full.

The TCC has a target of influencing a total of £10 billion of projects which achieve productivity improvements of around 13.5%. As of 2021, internal TCC data shows that the funding target had already been surpassed, with a cumulative committed project value of £29.3 billion.

There is clear recognition of the economic potential for using TCC concepts on business performance. The primary survey shows strong evidence that applying TCC concepts has a positive impact on annual revenue, profit, productivity and speed of delivery. Sixty-one percent of survey respondents who were already using TCC concepts said that their use had had a large positive impact on annual revenue, with 79% survey respondents reporting a positive impact on their organisation's profit. Fifty-one percent of survey respondents who were already using at least one TCC concept reported a large positive impact on their organisation's productivity, with nearly 71% of survey respondents reporting a positive impact on speed of delivery. However, in terms of the impact of TCC support on performance, the evidence is more limited as the survey data gathered focused on the use of TCC concepts rather than the direct impact of engagement with the TCC. However, the strong evidence from organisations on the benefits of using TCC concepts suggests that, to the extent that TCC can increase the use and adoption of TCC concepts, we would expect economic benefits to follow.

The case studies show a number of examples of projects with potential to improve the performance of the construction sector through the integration of TCC concepts. However, many of the TCC activities remain at demonstration/proof-of-concept stages. Examples of demonstrator projects are provided in section 7.1. As such, it is not possible to demonstrate a direct impact of the TCC on the performance of construction sector firms and their suppliers at this stage. Nonetheless, the adoption of TCC concepts is expected to be transformative for performance in the future.

The activity case studies and panel review also support the idea that a longer timeframe will be needed to see the impact of the TCC on the performance of the construction sector firms and their suppliers. The experts suggested that changes to the performance of the construction sector is a lagging metric, particularly when compared to collaboration and R&D investment. As a result, the experts did not expect to see a clear impact of the TCC at this stage, both for beneficiary firms and the wider industry. The experts reflected the optimism in the case studies in indicating that the TCC will be a critical driver of future change in the performance of the construction sector as a result of incorporating TCC concepts. The experts suggested that change is likely to be realised in the next 5 to 10 years.

## 11.6 THEME 6 – IMPROVED DELIVERY OF BUILT ASSETS (TIME, QUALITY AND WHOLE-LIFE COSTS)

As with the economic impact (Theme 5), we also find some early evidence of a potential future positive impact of the use of TCC concepts on the improved delivery of built assets in terms of quality, whole-life costs and speed of delivery. The case studies show a number of examples of projects with potential to improve the delivery of built assets through the integration of TCC concepts; for example, the Advanced Industrialised Methods for the Construction of Homes Initiative (AIMCH) aims to provide comparative cost data on new manufacturing approaches compared to traditional methods. The concepts have helped cut costs and delivery times, resulting in higher expected future profits. This provides an indication of future impact through the TCC's role of disseminating TCC concepts. Internal TCC monitoring data shows that the TCC is significantly surpassing targets for the value of projects related to reducing whole-life costs and delivery times.

However, many of the TCC activities remain at demonstration/proof-of-concept stages. Examples of demonstrator projects are provided in section 7.1. As such, it is not possible to demonstrate a direct

impact of the TCC on the delivery of built assets at this stage. This was suggested across the activity case studies, primary survey and expert review panel.

The experts agreed that changes to the delivery of built assets in terms of time, quality and whole-life costs is a lagging metric, and therefore we would not expect to see an impact of the TCC at this stage of its implementation. However, there is optimism about change in the future as a result of the TCC, which is expected to be realised in approximately 5 to 10 years.

## 11.7 THEME 7 – IMPROVED ENVIRONMENTAL PERFORMANCE OF BUILT ASSETS

There is clear optimism about the role of TCC concepts in improving the environmental performance of built assets. However, the evidence does not suggest that the TCC is currently having a significant impact on the environmental performance of built assets across the sector. Similarly to Themes 5 and 6, this is expected given the stage of the programme. To the extent that TCC will drive wider adoption of relevant concepts, some of the environmental benefits would be attributable to the Challenge, though stakeholders also stressed the critical role of wider factors including net zero commitments and consumer preferences in driving change.

Internal TCC monitoring data shows that the TCC has a target of influencing a total of £3 billion of projects that reduce greenhouse gas emissions. As of 2021, this target had already been surpassed, with a cumulative committed project value of £22.8 billion. In the primary survey, we find positive evidence for the current (i.e. observed impact) and potential impact of TCC concepts across emissions, energy consumption and waste. Four in five (80%) survey respondents who were already using TCC concepts had observed a positive impact on $CO_2$ emissions. Three-quarters (74%) of those who were already using TCC concepts had observed a positive impact on waste produced on site and, separately, energy consumption on site. The case studies find that a number of successful demonstrator projects which result in improvements to environmental performance have been developed as a result of the TCC. These projects show the positive potential of TCC concepts for the environmental impact of built assets; for example, the Active Office programme sought to build a prototype building using cutting-edge off-site manufacturing techniques and incorporating innovative technologies that generate, store and release solar energy. The experts agreed with the evidence that there is optimism that the TCC will have a positive impact on the environmental performance of built assets in the future.

Nonetheless, the evidence does not suggest a current impact of the TCC on the environmental performance of built assets at this stage of the programme. Many of the case studies remain at an early stage and so the environmental impact has not been established and quantified at this stage of the programme. Further, wider factors such as government policy and customer choices were highlighted by the expert review panel to be an important driving factor for changes to the environmental impact of built assets, alongside the TCC.

## 11.8 REFLECTING THE IMPACT EVALUATION FINDINGS AGAINST THE TCC BUSINESS CASE OBJECTIVES

This evaluation of the TCC is structured around themes identified from the evaluation framework. A key input into that framework was the business case for the TCC, which contained a number of objectives for the Challenge. While the evaluation has not explicitly sought to test those objectives, given the wider inputs used to develop the overall framework, it is nevertheless useful to reflect back those objectives given the evidence collected for this evaluation.

Table 32 summarises this. We find evidence supporting each TCC business case objective from across the evaluation themes. For instance, there are numerous examples of successful R&D demonstrator activities that can be attributed to the TCC, the TCC has surpassed its matched funding targets and there is clear optimism of the role of TCC concepts in improving sector performance and environmental impact. However, many of the TCC activities remain at a demonstration/proof-of-concept stage. As such, it is too early to fully understand the impact of the TCC on the wider sector.

## TABLE 32 REFLECTING THE IMPACT EVALUATION FINDINGS AGAINST THE TCC BUSINESS CASE OBJECTIVES

| | TCC BUSINESS CASE OBJECTIVE | IMPACT EVALUATION EVIDENCE |
|---|---|---|
| 1 | **Objective**: Establish the facilities for integration, demonstration and R&D to enable faster commercialisation of a digital manufacturing approach to construction and inclusion of active components.<br>**Target**: Increased adoption of programme technologies and methods in government programmes and by the construction sector. Hubs established with full R&D programmes and sharing knowledge/training to help sector develop different skill base. | ▪ **Theme 2:** Since the implementation of the TCC, there has been a change in the overall strategy within procurement in the public sector to consider a wider range of impacts, such as on people and the environment, rather than just on costs. The procurement case study highlights that this can be in part attributed to the TCC. This impact is linked to the engagement that individuals in procurement are having with the TCC, and particularly with the Value Toolkit and the Digital Twin projects. The TCC has widened the strategic thinking in procurement to consider the 'whole value' of the project, including impacts on people (such as via employment), social impacts, natural impacts (such as those on emissions and biodiversity), and the manufacturing impacts. Both the expert panel and thematic case studies noted the importance of the Construction Playbook which the TCC was significantly involved in developing in changing public sector procurement, including via the incorporation of TCC concepts.<br>▪ **Theme 4:** The TCC has successfully established CIH and ABC, whose activities involves the development of demonstrator programmes, some of which were evaluated as part of the activity case studies. All the 19 activity case studies included as part of the evaluation can be seen as successful R&D or demonstrator activities. However, the activity case studies and expert review panel suggest there is limited evidence to date on the extent to which the wider industry is adopting TCC concepts, although this was felt to be consistent with the stage the Challenge has reached given that many of the projects are at a proof-of-concept/demonstrator stage. |
| 2 | **Objective:** Deliver an R&D programme match funded by industry, leading to increased productivity in construction methods.<br>**Target:** All programme projects demonstrate a scalable >15% increase in productivity compared with current methods. | ▪ **Theme 3:** The TCC has delivered an R&D programme that is expected to reach its 2027 matched funding target of £250 million by 2023. The primary survey and case studies demonstrate some evidence of increased level of investment in TCC concepts among firms engaged by the Challenge and that this can be largely attributed to the Challenge. We find that 53% of 'successful' applicants reported that R&D spend had increased significantly as a result of engagement with the TCC. The cases studies suggest this is mostly as a result of the TCC's 'de-risking' role through matched funding. By pooling risk across organisations through matched funding for those engaging with CR&D, the TCC has enabled more investment in 'higher risk' areas that relate to TCC concepts. |

| | TCC BUSINESS CASE OBJECTIVE | IMPACT EVALUATION EVIDENCE |
|---|---|---|
| | | ■ **Theme 5:** There is clear recognition of the economic potential for using TCC concepts on business performance. The primary survey shows strong evidence that applying TCC concepts has had a positive impact on annual revenue, profit, productivity and speed of delivery. However, across the evaluation evidence we find that a longer timeframe will be needed to see the impact of the TCC on the performance of the construction sector firms and their suppliers. The case studies show a number of examples of projects with potential to improve the performance of the construction sector through the integration of TCC concepts. However, many of the TCC activities remain at demonstration/proof-of-concept stages. As such, it is not possible to demonstrate a direct impact of the TCC on the performance of construction sector firms and their suppliers at this stage. |
| 3 | **Objective:** Establish the test facilities, methodologies and R&D programmes to better design buildings for increased lifetime performance and value of buildings and infrastructure.<br>**Target:** Scalable 50% reduction in carbon emissions compared to current methods. Develop science to support design for enhanced whole-life value. | ■ **Theme 7:** There was clear optimism for the role of TCC concepts in improving the environmental performance of built assets. In the primary survey, we find positive evidence for the current (i.e. observed impact) and potential impact of TCC concepts across emissions, energy consumption and waste. The case studies find that a number of successful demonstrator projects, which result in improvements to environmental performance, have been developed as a result of the TCC. These projects show the positive potential of TCC concepts for the environmental impact of built assets. However, the evidence does not suggest that the TCC is currently having a significant impact on the environmental performance of built assets across the sector. As for Themes 5 and 6, this is expected given the stage of the programme. To the extent that TCC will drive wider adoption of relevant concepts, some of the environmental benefits would be attributable to the Challenge, though stakeholders also stressed the critical role of wider factors including net zero commitments and consumer preferences in driving change. |
| 4 | **Objective:** Develop and demonstrate new building designs that drive faster delivery at lower cost.<br>**Target:** Target for programme projects to demonstrate scalable reduction in cost (>33%) and speed of delivery (>50%) compared to current methods. | ■ **Theme 6:** We find early evidence of a potential future positive impact of the use of TCC concepts on the improved delivery of built assets in terms of quality, whole-life costs and speed of delivery. The case studies show a number of examples of projects with potential to improve the delivery of built assets through the integration of TCC concepts; for example, the Advanced Industrialised Methods for the Construction of Homes Initiative (AIMCH) aims to provide comparative cost data on new manufacturing approaches compared to traditional methods. The concepts have helped cut costs and delivery times, resulting in higher expected future profits. This provides an indication of future impact through TCC's role of disseminating TCC concepts. However, many of the TCC activities remain at demonstration/proof-of-concept stages. As such, it is not possible to demonstrate a direct impact of the TCC on the delivery of |

| TCC BUSINESS CASE OBJECTIVE | IMPACT EVALUATION EVIDENCE |
|---|---|
| | built assets at this stage. This is suggested across the activity case studies, primary survey and expert review panel. |
| 5 **Objective:** Reduction in trade gap between total exports and total imports of construction products and materials.<br>**Target:** Target to showcase demonstrator projects internationally. | ■ The evaluation did not focus on trade performance given the stage of the intervention. Initial secondary data analysed for Theme 5 provides some evidence for an increase in the value of exports of construction products and (particularly relevant for TCC) services following the introduction of the TCC, although attribution to TCC is difficult to evidence at this stage and in our view the aggregate trade data should be seen to reflect wider industry trends.<br>■ We understand that there are activities within the TCC that driven new policy in other countries to adopt TCC concepts in order to create new markets for UK firms. This was not considered directly within this evaluation. |

*Source: Impact evaluation evidence*

# 12 LEARNINGS AND LESSONS FOR FUTURE EVALUATION

This report represents final output of the evaluation of the TCC. This section provides some learnings and recommendations for future evaluation, recognising that some of the potential longer-term benefits may only be realised in the future.

## 12.1 PRIMARY SURVEY

While the quality of survey responses for the impact evaluation allowed for detailed consideration of the impact of the TCC on respondents, the number of contact details provided and responses received was lower than hoped for across a number of strands, limiting the extent to which analysis could be conducted at the strand level. Specific recommendations to increase the achieved sample size in order to provide greater robustness and ability to break down results for future evaluation include:

- **Combining the primary survey questions with project completion reports**. Theintention would be for the impact survey data to be collected at a similar point for each project, and the response rate would likely be higher as it would be administered alongside a mandatory requirement. Further, this would increase the richness of data collected as it would be possible to link the two data sources.
- **TCC adopts a consistent method, across all strands, for gathering and storing project contact details**. Currently, each strand maintains its own system for gathering and storing project contact details, which resulted in variation in terms of accessibility and timeliness
- **The primary survey was also limited to those who had engaged with TCC and so did not allow data to be gathered about the wider constructionindustry. Any future TCC evaluations should consider whether industry-wide surveys would be of value.** Any such surveys would need to cover the breadth of the construction industry, including contractors, sub-contractors, suppliers of raw materials, consultancies and professional services. It will be important to balance the costs of such surveys with the depth of data they are likely to provide. It will also be important to consider how response rates to such surveys could be boosted to limit the risk of self-selection bias so that the data collected is as representative of the industry as possible. It may be possible to utilise existing industry surveys to collect data on a small number of measures.

## 12.2 CASE STUDIES

### 12.2.1 ACTIVITY CASE STUDIES

By conducting qualitative research on specific activities, the activity case studies provided a rich understanding of the nature and method of the impact of the TCC 'on the ground'. A number of activity case studies took place with a single interview due to the limited availability of contact details (as referred to above). In order to provide a deeper and more robust understanding of the impact of the TCC on specific activities, we recommend that future evaluations conduct multiple interviews for all case studies, with relevant contact information and permissions gathered at the start of activities to enable this.

Due to the early stages of the activities supported by the TCC, many of these remain at a proof-of-concept/ demonstration phase. As a result, we recommend that some case studies could be re-visited in a future evaluation of TCC or a successor to understand the quantifiable longer-term impacts of the TCC, the extent of dissemination of TCC concepts across industry and whether hoped-for or expected benefits are realised in practice.

### 12.2.2 THEMATIC CASE STUDY

As a targeted approach, the thematic case study allowed for detailed consideration of the impact of the TCC in an area which was not touched upon to as great as an extent by the other methods of the evaluation. However, due to the limited availability of contact details in private sector procurement, the thematic case study focused on procurement in the public sector. Based on the case study findings, we recommend that any future evaluation expands the scope of the thematic case study to also consider the impact of the TCC on private sector procurement as our findings indicated that the private and public sectors were at different stages in terms of reflecting TCC concepts in thinking and practice.

### 12.2.3 SECONDARY DATA ANALYSIS

The secondary data analysis allowed for a rich understanding of sector-level and sub-sector-level trends in the construction sector. However, at this stage of the programme it was not possible to demonstrate a direct impact of the TCC on these broader aggregates. In addition, a substantial portion of the evaluation period was impacted by Covid-19, which further prevented the ability to make reasonable inferences from data trends. As a result, the secondary data analysis should be re-visited as part of any further evaluation. This could include consideration of micro-econometric analysis of firm-level impacts, comparing changes in the performance of organisations supported by TCC to a 'control group' of unsupported firms either in the construction or related sectors. This would draw on firm-level administrative data collected through e.g. the Business Structure Database and Annual Business Survey, linked with TCC-held data on organisations engaged and the nature of this engagement. This approach was considered, but ruled out, for this evaluation largely because too limited time had elapsed since the TCC was introduced to expect firm-level impacts to be observable, particularly given lags in data availability.[23]

### 12.2.4 EXPERT REVIEW

The stakeholder engagement was an effective way of cross-checking emerging insights with industry experts in order to help validate our early conclusions and provide wider contextual viewpoints on the contribution of the TCC to date. We therefore recommend that any future evaluation also contains an expert review process.

[23] We note that econometric analysis of the wider ISCF is to be undertaken in the next 3-4 years as part of the fund-level evaluation being delivered by RAND Europe and Frontier Economics.

## Annex A - PRIMARY SURVEY – RESPONDENT SAMPLE STATISTICS

The survey sought to gather the experiences and opinions of businesses and academics who have engaged with the TCC in a meaningful way. Contact details for the survey sample were collected from each of the TCC strands: CR&D, CIH, ABC, Network +, and Research Leaders. Each TCC strand was asked to provide a full list of businesses and academics that had engaged with it since the beginning of the Challenge. In some cases, permission to share contact details for the purpose of evaluation had already been sought, for example via the UKRI terms and conditions associated with the CR&D competitions. Where this permission had not previously been sought, the strands undertook an 'opt-out' process to give their contacts the opportunity to not be included in the survey sample.

Once the lists of contacts were received from the strands, they were combined into one file and a de-duplication process applied so that any contacts who had engaged with more than one strand were only represented once. All contacts received that had valid contact details were invited to complete the survey.

A total of 162 respondents completed the survey. The following table shows the response rates against the different strands.

### TABLE 33 RESPONSE RATE BY MAIN STRAND ENGAGED WITH

| STRAND | NUMBER OF CONTACTS | COMPLETE | RESPONSE RATE |
|---|---|---|---|
| ABC | 32 | 7 | 22% |
| CIH | 33 | 11 | 33% |
| Network+ | 17 | 5 | 29% |
| CR&D | 773 | 138 | 18% |
| Research Leaders | 4 | 1 | 25% |

*Source: Primary survey*

CR&D contacts can be grouped into 'successful' (CR&D funding was awarded), 'unsuccessful' (CR&D funding was not awarded), and 'ineligible/withdrawn' (the application was either deemed to not meet the necessary criteria for consideration or the applicants withdrew it) based on the status of their application for TCC funding. The table below shows the response rate for CR&D contacts by these groupings.

### TABLE 34 RESPONSE RATE BY CR&D FUNDING APPLICATION OUTCOME

| GROUP | NUMBER OF CONTACTS | COMPLETE | RESPONSE RATE |
|---|---|---|---|
| Successful | 189 | 76 | 40% |
| Unsuccessful | 500 | 52 | 10% |
| Ineligible/withdrawn | 84 | 12 | 14% |

*Source: Primary survey*

The table below provides a breakdown of the respondents by project role type.

## TABLE 35 RESPONDENTS BY PROJECT ROLE

| PROJECT ROLE | NUMBER IN SURVEY |
|---|---|
| Project lead | 48 (30%) |
| Collaborator | 64 (40%) |
| Researcher | 10 (6%) |
| Supporter/influencer/stakeholder – Civil Service or policy maker | 2 (1%) |
| Supporter/influencer/stakeholder – trade body or industry organisation | 12 (7%) |
| Supporter/influencer/stakeholder – academic | 7 (4%) |
| Client-side/product end user | 3 (2%) |
| Other | 12 (7%) |
| Prefer not to say | 2 (1%) |

*Source: Primary survey*

The following table provides a breakdown of the respondents by organisation/employer type.

## TABLE 36 RESPONDENTS BY ORGANISATION/EMPLOYER TYPE

| ORGANISATION/EMPLOYER TYPE | ORGANISATION/EMPLOYER TYPE |
|---|---|
| Academic/research institution | 37 (23%) |
| Main/lead contractor | 22 (14%) |
| Sub-contractor – services | 15 (9%) |
| Sub-contractor – materials | 4 (2%) |
| Public procurement of construction services | 1 (1%) |
| Private procurement of construction services | 1 (1%) |
| Business supplier of raw materials for construction sector | 3 (2%) |
| Consultancy and professional services | 52 (32%) |
| Client-side/product end user | 3 (2%) |
| Other | 23 (14%) |
| Prefer not to say | 1 (1%) |

*Source: Primary survey*

# Annex B - PRIMARY SURVEY – FULL WRITE-UP

The results for the primary survey are presented by evaluation theme. This contains the full results for all survey questions included.

## B.1 - FINDINGS: THEME 1– FIRMS, PUBLIC BODIES AND ACADEMICS ENGAGING IN PROJECTS RELATING TO TCC CONCEPTS

### B.1.1 - SHORT-TERM OUTCOMES

#### B.1.1.1 - CHANGE IN NUMBER AND TYPE OF COLLABORATION ENGAGED IN BY TCC BENEFICIARIES SHORTLY AFTER PARTICIPATION

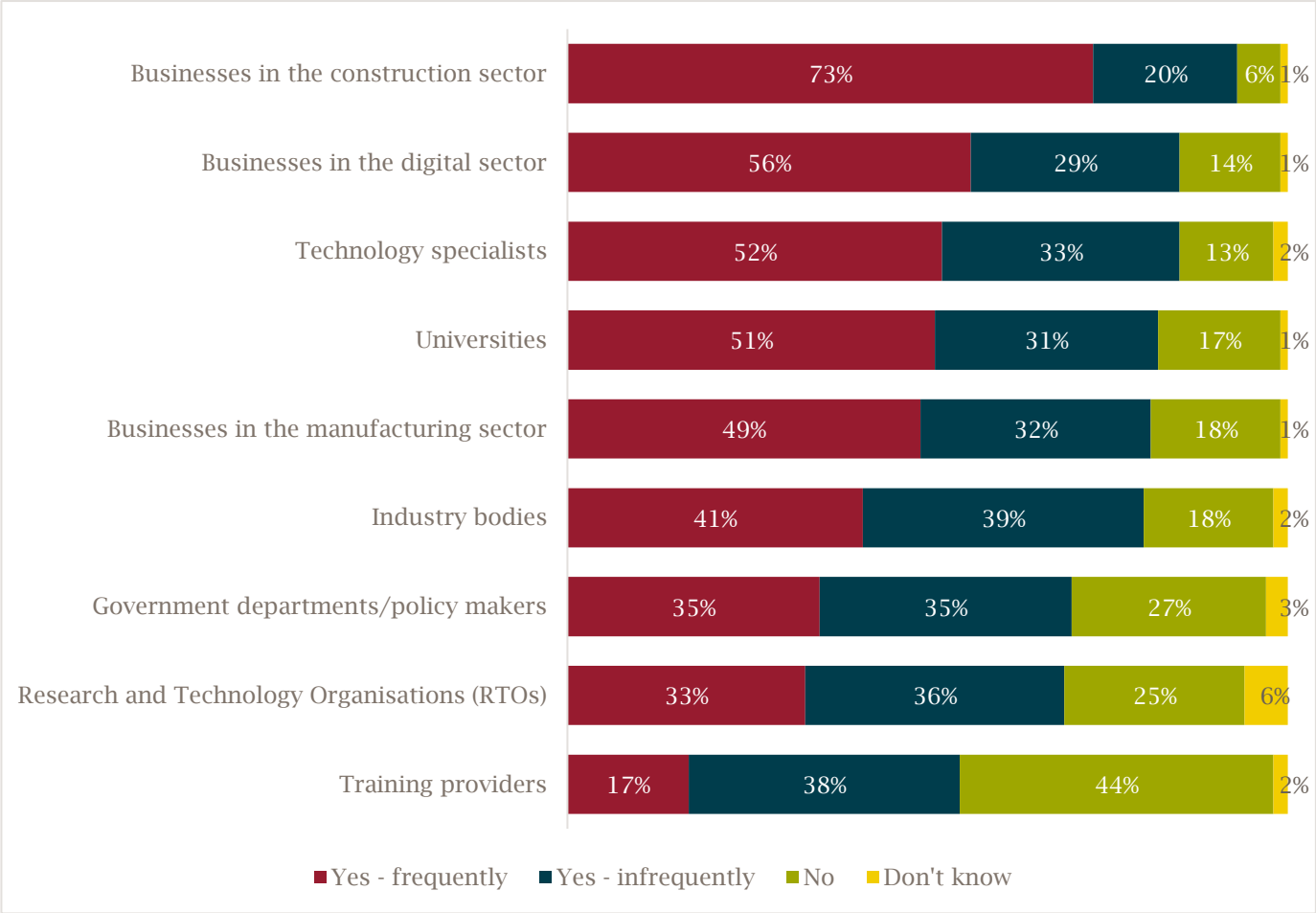
Collaboration to develop or use new ways of working on construction projects was common. Ninety-eight percent of survey respondents were collaborating with at least one type of organisation. This compares to 93% of baseline survey respondents who had collaborated with at least one type of organisation in the year prior to TCC engagement.

The most common organisation type survey respondents were collaborating with is businesses in the construction sector (93% were collaborating with this group), followed by businesses in the technology sector, and technology specialists (both 85%). Around four in five were collaborating with universities (83%), businesses in the manufacturing sector (81%) and industry bodies (80%). Collaboration with government departments/policy makers (70%), research and technology organisations (RTOs) (69%) and training providers (54%) were less common but were still undertaken by the majority of survey respondents.

Survey respondents who had been 'successful' in their application for TCC funding were more likely to be collaborating with businesses in the digital sector (96% were collaborating with this type), than those who had been 'unsuccessful' in their TCC funding application (73% were collaborating with this type). Successful applicants were also more likely to be collaborating with RTOs (78% were doing so, compared to 60% of unsuccessful applicants).

Perhaps unsurprisingly, academics were more likely to be collaborating with universities (95% were collaborating with this type) and RTOs (84% were collaborating with this type).

## FIGURE 59 TYPES OF UK ORGANISATIONS BENEFICIARIES WERE COLLABORATING WITH ON NEW WAYS OF WORKING ON CONSTRUCTION PROJECTS

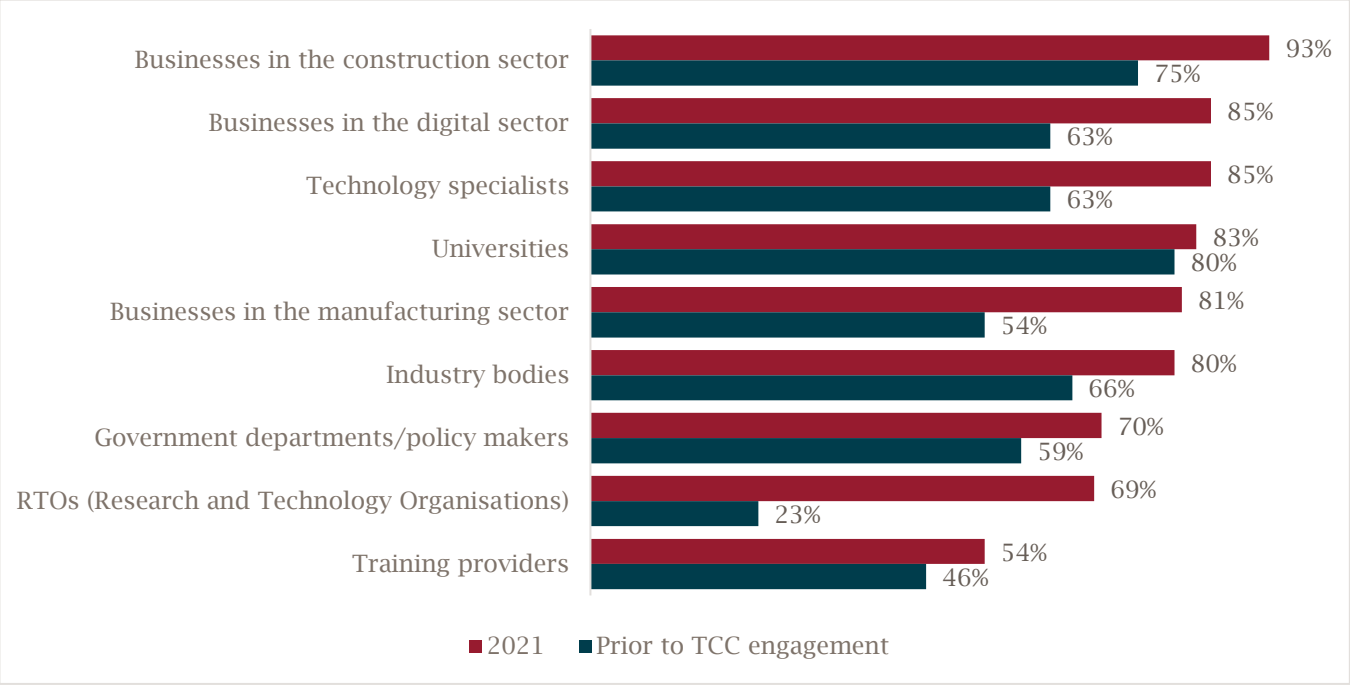



*Source: Beneficiaries survey. C21. Has your organisation/Have you collaborated with any of the following in the UK to develop or use new ways of working on construction projects?*

*Note: Base: all impact survey respondents (162)*

The proportion of TCC beneficiaries surveyed who were involved in collaborations increased compared to the baseline for each group measured. The group where the biggest increase in collaboration can be seen is RTOs: 23% were collaborating with this group a year prior their TCC engagement, compared to 69% in 2021. Other groups where substantial increases in the proportion collaborating can be seen include businesses in the manufacturing sector (54% prior to TCC engagement, compared to 81% in 2021), businesses in the digital sector (63% prior to TCC engagement, compared to 85% in 2021) and technology specialists (63% prior to TCC engagement, compared to 85% in 2021).

## FIGURE 60 TYPES OF UK ORGANISATION BENEFICIARIES WERE COLLABORATING WITH ON NEW WAYS OF WORKING ON CONSTRUCTION PROJECTS COMPARED TO BASELINE

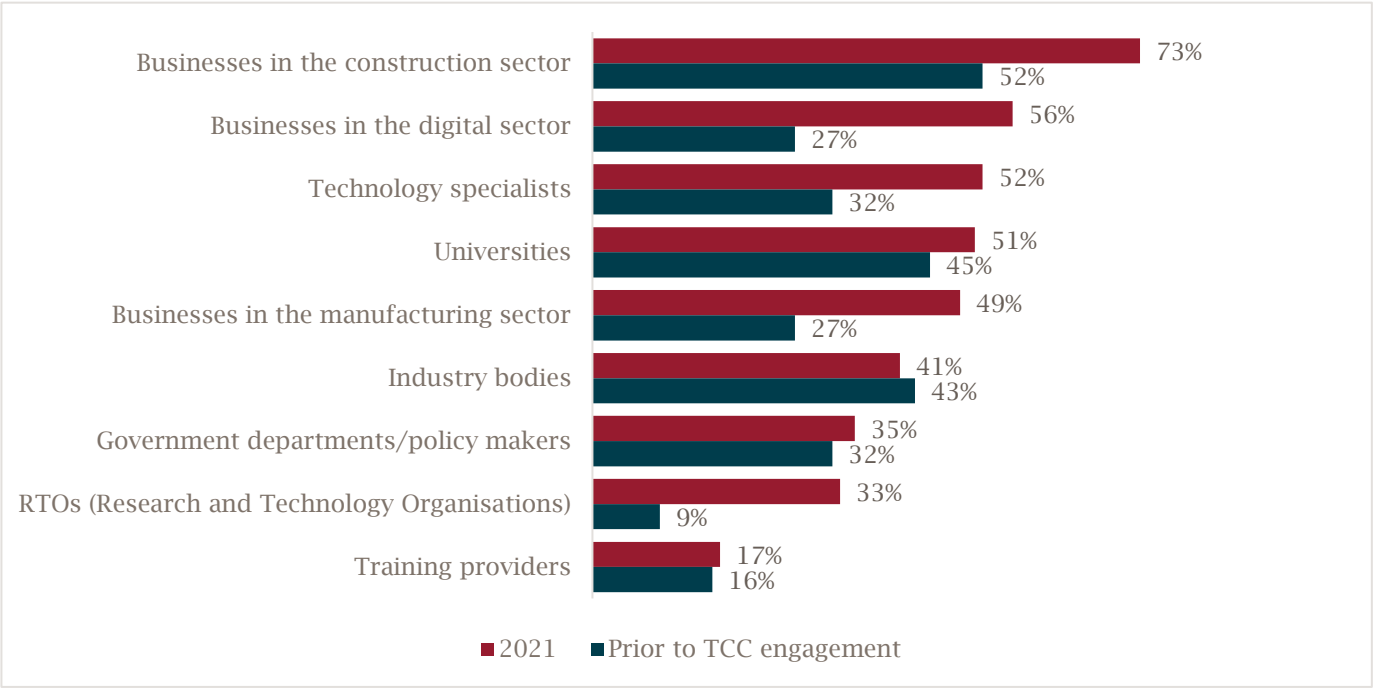



*Source: Beneficiaries surveys. Q10. In the year prior to your TCC engagement had your organisation/you collaborated with any of the following in the UK to develop or use new ways of working on construction projects? C21. Has your organisation/Have you collaborated with any of the following in the UK to develop or use new ways of working on construction projects?*

*Note: Base: All baseline survey respondents (56) all impact survey respondents (162)*

The frequency of collaboration with these types of organisations also increased. Nearly three-quarters (73%) of survey respondents were now collaborating 'frequently' with businesses in the construction sector, compared to just over half (52%) in the year prior to their engagement with TCC. Other notable increases in the proportion who were collaborating 'frequently' can be seen for businesses in the digital sector (56%, compared to 27% prior to TCC engagement), technology specialists (52%, compared to 32% prior to TCC engagement), businesses in the manufacturing sector (49%, compared to 27% prior to TCC engagement), and RTOs (33%, compared to 9% prior to TCC engagement).

FIGURE 61 TYPES OF UK ORGANISATIONS BENEFICIARIES WERE COLLABORATING WITH FREQUENTLY ON NEW WAYS OF WORKING ON CONSTRUCTION PROJECTS COMPARED TO BASELINE




*Source: Beneficiaries surveys. Q10. In the year prior to your TCC engagement had your organisation/you collaborated with any of the following in the UK to develop or use new ways of working on construction projects? C21. Has your organisation/Have you collaborated with any of the following in the UK to develop or use new ways of working on construction projects?*

*Note: Base: All baseline survey respondents (56) all impact survey respondents (162)*

## B.1.2 - LONG-TERM OUTCOMES AND IMPACTS

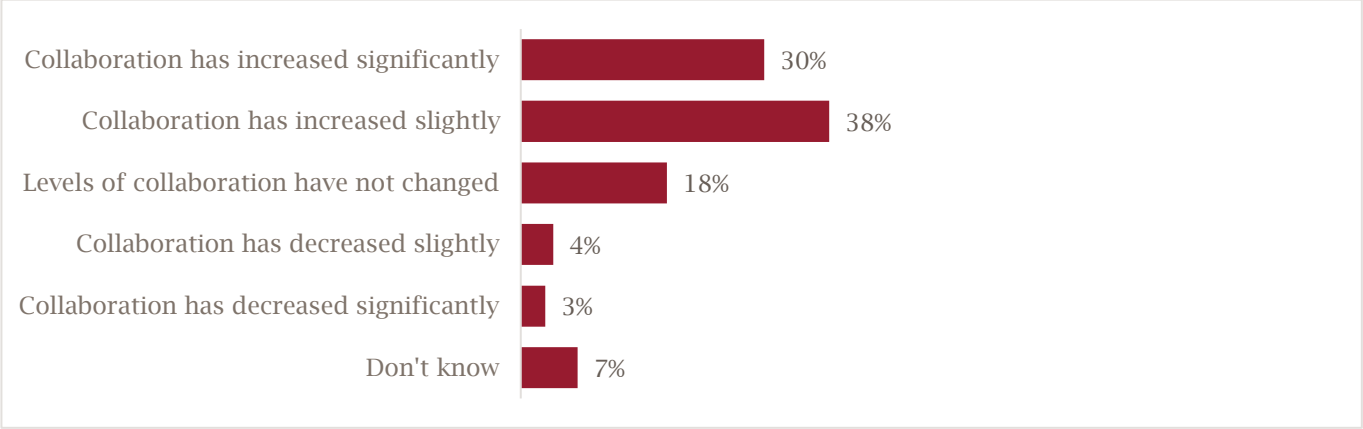
### B.1.2.1 - CHANGE IN NUMBER AND TYPE OF COLLABORATIONS BETWEEN EX-TCC BENEFICIARIES IN THE LONGER TERM

Survey respondents were also asked to give an overall estimation of how much they perceived collaboration in general on construction projects or grants had changed since 2018 (i.e. before TCC). Over two-thirds (68%) felt that collaboration had increased, including 30% who felt it had increased significantly. Seven percent felt that it had decreased, including 3% who felt it had decreased significantly.

Academics were more likely to feel that collaboration had decreased (16%), while contractors and sub-contractors were more likely to feel it had increased (80%).

The 'successful' TCC applicants surveyed were more likely to feel that collaboration had increased since 2018 (79%), compared to the 'unsuccessful' TCC applicants surveyed (54%).

## FIGURE 62 CHANGE IN COLLABORATION ON PROJECTS OR GRANTS CONCERNING CONSTRUCTION SINCE 2018



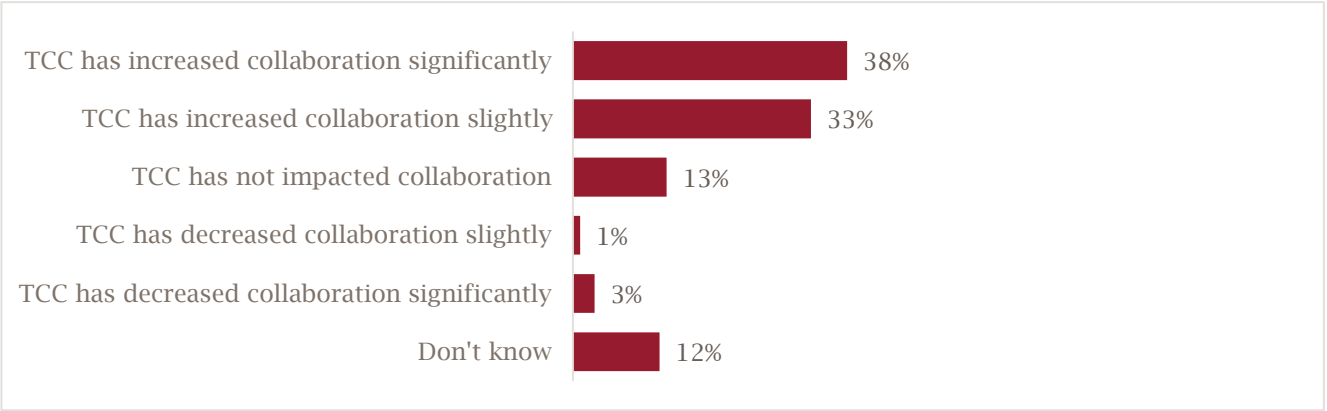

*Source: Beneficiaries survey. C22. How do you think collaboration in general on projects or grants concerning construction has changed since 2018?*
*Note: Base: All impact survey respondents (162)*

Survey respondents were also asked to state the impact that they felt the TCC had had on collaboration on projects or grants aimed at lowering costs, speeding up delivery, lowering emissions or improving exports.

Close to three-quarters (71%) thought that the TCC had increased collaborations, including 38% who thought the TCC had increased collaboration significantly. Only 4% thought that the TCC had caused a decrease in collaboration. Just over one in ten (13%) thought that the TCC had not had any impact on collaboration.

The 'successful' TCC applicants surveyed were more likely to feel that the TCC had increased collaboration (88%) compared to 'unsuccessful' applicants (54%). In fact, over half of 'successful' applicants surveyed (57%) thought that the TCC had significantly increased collaboration.

## FIGURE 63 PERCEIVED IMPACT OF TCC ON COLLABORATIONS




*Source: Beneficiaries survey. C23. How much to do you think the Transforming Construction Challenge has impacted collaboration in general on projects or grants aimed at any of the following: lowering costs, speeding up delivery, lowering emissions or improving exports?*
*Note: Base: All impact survey respondents (162)*

## B.2 - FINDINGS: THEME 2– CONSTRUCTION SECTOR CLIENTS ENABLE TCC CONCEPTS TO BE USED IN THE PROCUREMENT PROCESS

## B.2.1 - SHORT-TERM OUTCOMES

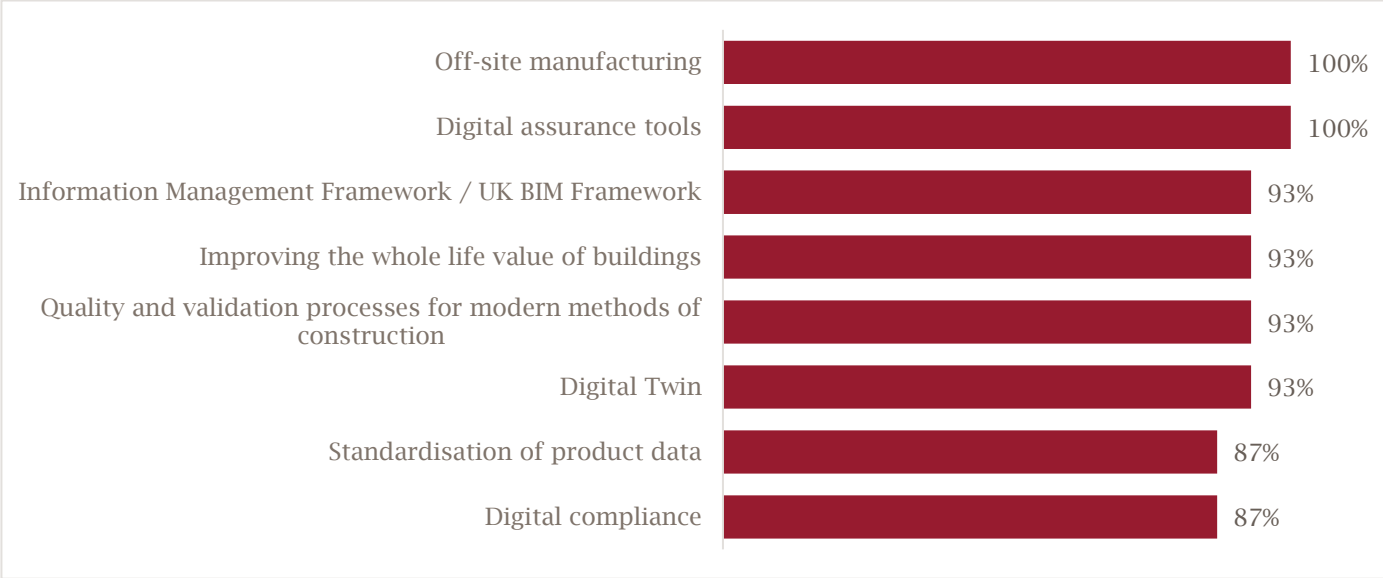
### B.2.1.1 - CHANGE IN CONSTRUCTION SECTOR CLIENTS' INTENTION TO ADOPT TCC CONCEPTS IN THEIR PROCUREMENT PROCESSES

Survey respondents were asked to what extent they were aware of and using TCC concepts. The concepts shown to each respondent varied depending on the main TCC strand they had engaged with. For the purpose of this theme, we analysed the awareness of TCC concepts for the companies with the largest turnover (£25 million or more). This can be viewed as a short-term indicator of intention to adopt the concepts.

It is worth noting that only 15 businesses with a turnover of £25 million or more, who had mainly engaged with CR&D, N+ or RL, responded to the survey. Therefore, these figures should be treated as indicative only.

The majority of these businesses were aware of all of the concepts measured. All were aware of off-site manufacturing and digital assurance tools. The concepts with the lowest levels of awareness were standardisation of product data and digital compliance. However, these were still known by the vast majority of the large businesses surveyed.

**FIGURE 64 AWARENESS OF TCC CONCEPTS BY LARGE-SCALE CONSTRUCTION BUSINESSES**




*Source: Beneficiaries survey. Q18. Please describe your familiarity with the following tools, technologies and concepts.*
*Note: Base: Impact survey respondents whose main engagement was with CR&D, CIH, N+ or RL with turnover of at least £25 million (15)*

## B.2.2 - LONG-TERM OUTCOMES AND IMPACTS

### B.2.2.1 - CHANGE IN NUMBER/VALUE OF MAJOR PRIVATE INFRASTRUCTURE CLIENTS' PROCUREMENT FRAMEWORKS WHICH INCORPORATE TCC CONCEPTS

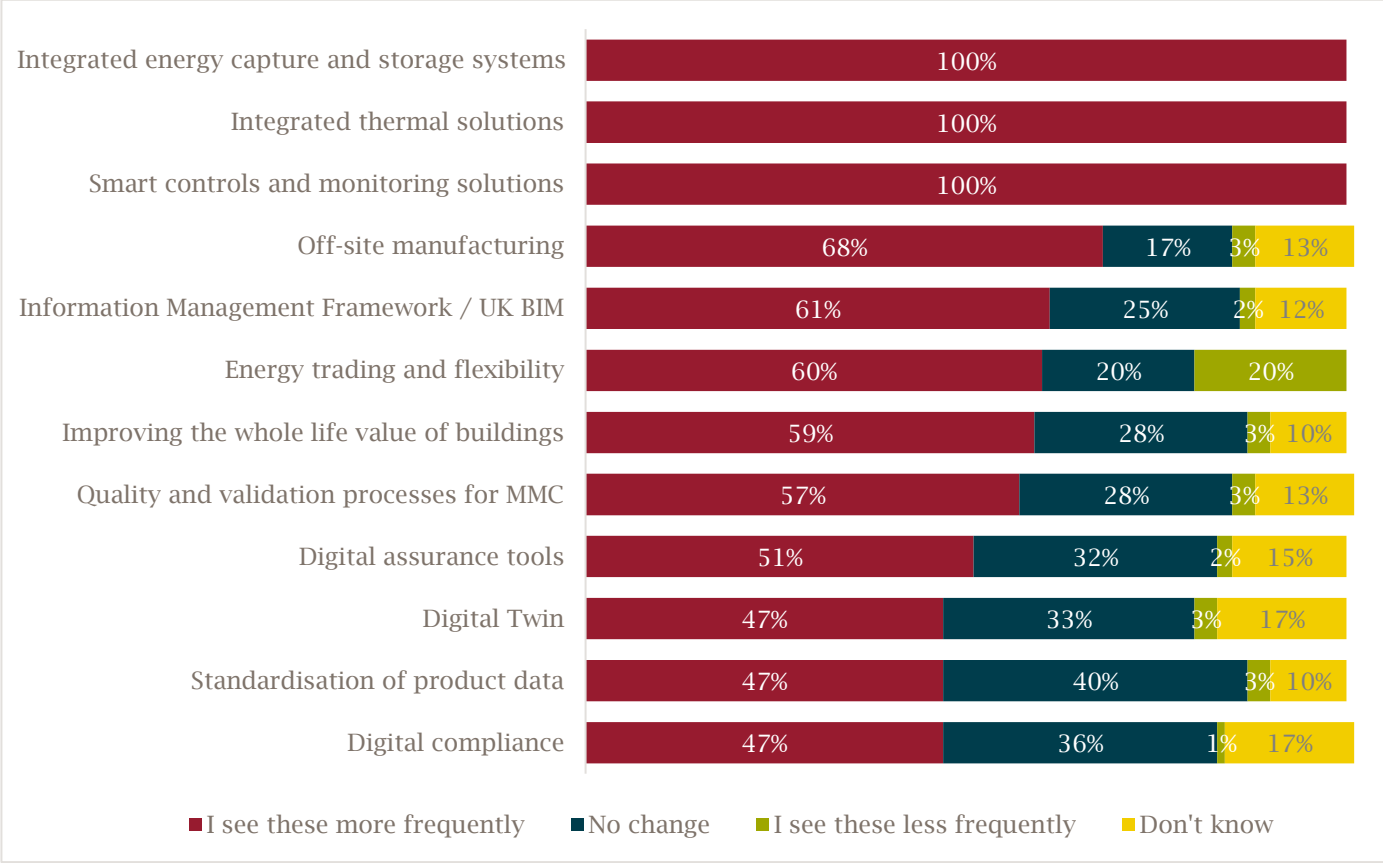
Survey respondents who worked for businesses were asked if they had noticed a change in the presence of TCC concepts in major private infrastructure clients' procurement frameworks compared to 2018. The

concepts they were asked about depended on the TCC strand they had had the most engagement with.[24] Over two-thirds (68%) of survey respondents who were businesses that had mainly engaged with CR&D, CIH, N+ or RL reported seeing off-site manufacturing in major private infrastructure clients' procurement frameworks more frequently than in 2018. Other concepts where the majority had seen the concept more frequently included Information Management Framework/UK BIM (61%), improving the whole-life value of buildings (59%), quality and validation processed for MMC (57%), and digital assurance tools (51%). Just under half (47%) said they had seen an increase in the other concepts measured: Digital Twin, standardisation of product data and digital compliance.

The 'successful' TCC funding applicants surveyed wer more likely to have seen digital assurance tools (63%), Digital Twin (59%) and digital compliance (58%) more frequently.

Interestingly, those who classed themselves as a 'project lead' in terms of their involvement with TCC were less likely to say they had seen digital assurance tools (37%), UK BIM (46%) and digital compliance (34%) more frequently. They were also more likely to say they had seen improving the whole-life value of buildings, standardisation of product data and off-site manufacturing less frequently (7%, 7% and 6% respectively).

## FIGURE 65 PERCEPTIONS OF CHANGE IN THE PRESENCE OF CONCEPTS IN MAJOR PRIVATE INFRASTRUCTURE PROCUREMENT FRAMEWORKS SINCE 2018




*Source: Beneficiaries survey. Q20A. Have you noticed any changes at all in the presence of the following tools, technologies, and concepts in major private infrastructure clients' procurement frameworks since 2018?*

[24] Only five businesses stated that their main engagement was with ABC. As such, there is not enough evidence from the surveys to comment on perceptions of the change in the presence of ABC concepts in major private infrastructure procurement frameworks.

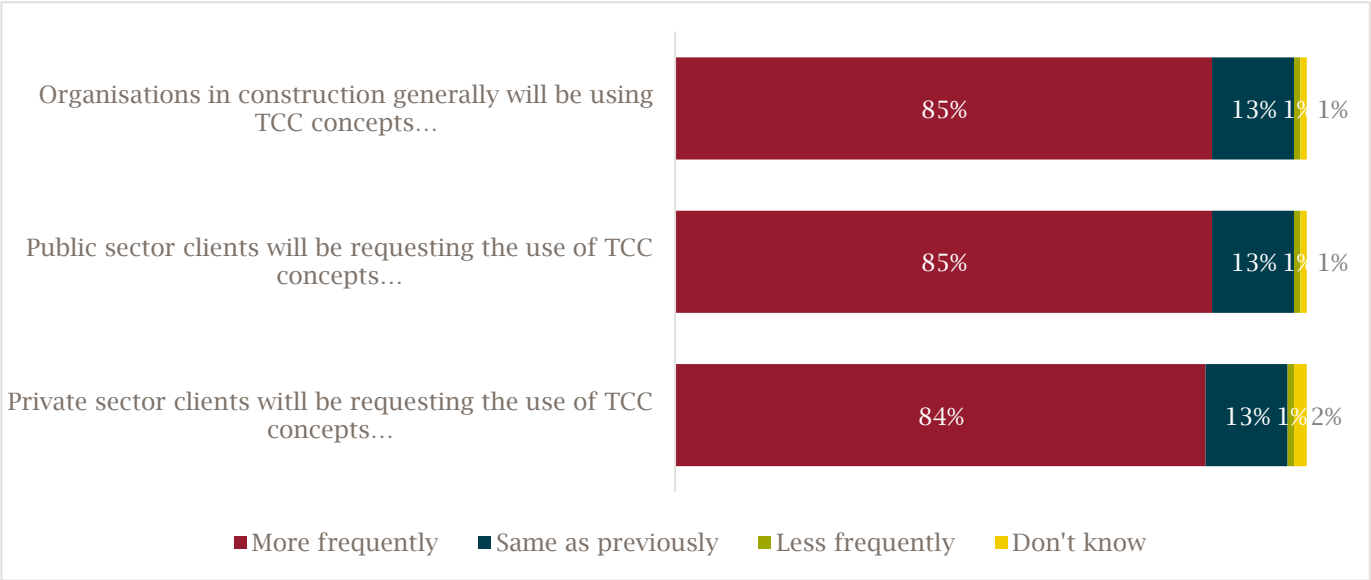
*Note: Base: Impact survey business respondents whose main engagement was with CR&D, CIH, N+ or RL (115)*

Businesses surveyed who were aware of at least one of the TCC concepts measured were asked whether they expected public sector and private clients to be requesting the use of TCC concepts more frequently, based on their knowledge of TCC and its activities.

Overall, 85% expected construction organisations to be generally using TCC concepts more frequently. The same proportion (85%) expected public sector clients to be requesting the use of TCC concepts more frequently and a similar proportion (84%) expected private sector clients to be requesting their use more frequently.

Those whose organisations were typically involved with cladding were more likely to expect both public and private sector clients to be requesting the use of TCC concepts more frequently (97% for both), as were those whose organisations were typically involved with superstructure (95% for public and 93% for private clients).

## FIGURE 66 EXPECTATIONS OF USE OF TCC CONCEPTS




*Source: Beneficiaries survey. Q20. Based on your knowledge and experience of the Transforming Construction Challenge, do you expect as a result of its activities to see the following things more frequently, less frequently, or same as previously?*
*Note: Base: Impact survey business respondents aware of at least one TCC concept measured (158)*

## B.3 - FINDINGS: THEME 3 – CONSTRUCTION INDUSTRY AND ASSOCIATED VALUE CHAIN INCREASE INVESTMENT IN R&D RELATED TO TCC CONCEPTS

### B.3.1 - SHORT-TERM OUTCOMES

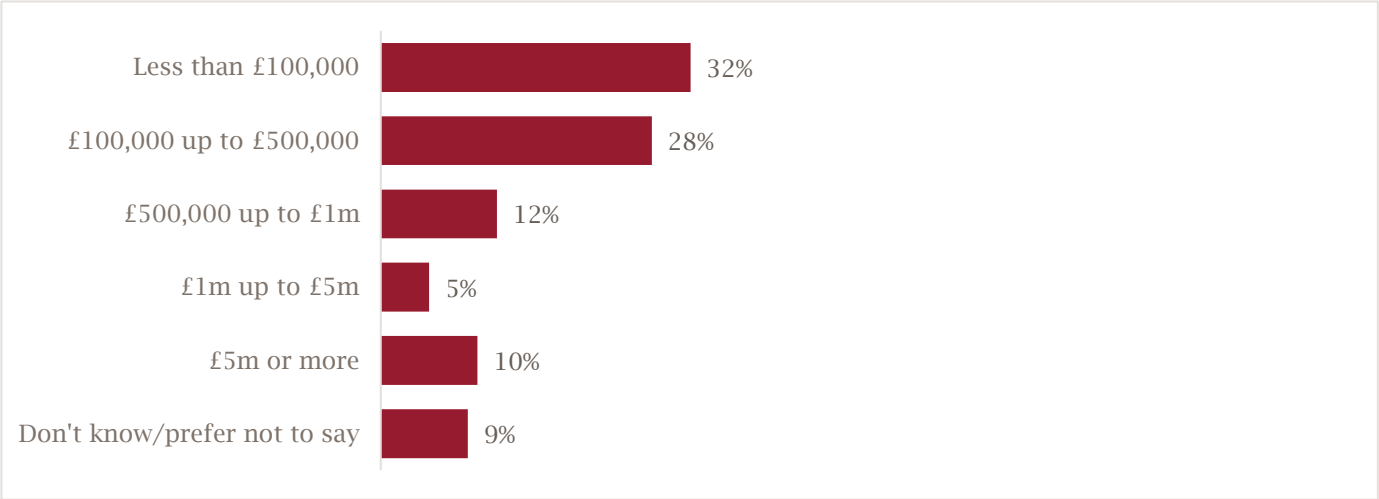
#### B.3.1.1 - CHANGE IN VALUE OF R&D LINKED TO TCC CONCEPTS

Survey respondents who were businesses were asked about their organisations level of investment in R&D in the previous financial year. For most of the businesses surveyed this previous financial year will have included at least some of the Covid-19 pandemic as this began in early 2020. Ten percent of those surveyed had invested £5 million or more in R&D in the previous financial year. Nearly a third (32%) had

invested less than £100,000, and over a quarter (28%) had invested between £100,000 and £500,000. As the profile of businesses surveyed differs noticeably from those surveyed in the baseline in terms of turnover, a direct comparison to R&D spend before TCC is not possible. However, later we provide a comparison of R&D spend as a proportion of turnover that can be compared to the baseline.

The mean amount invested for 'successful' TCC applicants was more than double that for the 'unsuccessful' applicants surveyed. Those businesses surveyed that were successful in their application had invested an average of £2.2 million, while those that were unsuccessful had invested an average of £1 million. However, it should be noted that the successful applicants interviewed tended to have greater turnover in the previous financial year than the unsuccessful applicants interviewed, which is likely to have impacted their R&D investment.

## FIGURE 67 CURRENT INVESTMENT IN R&D

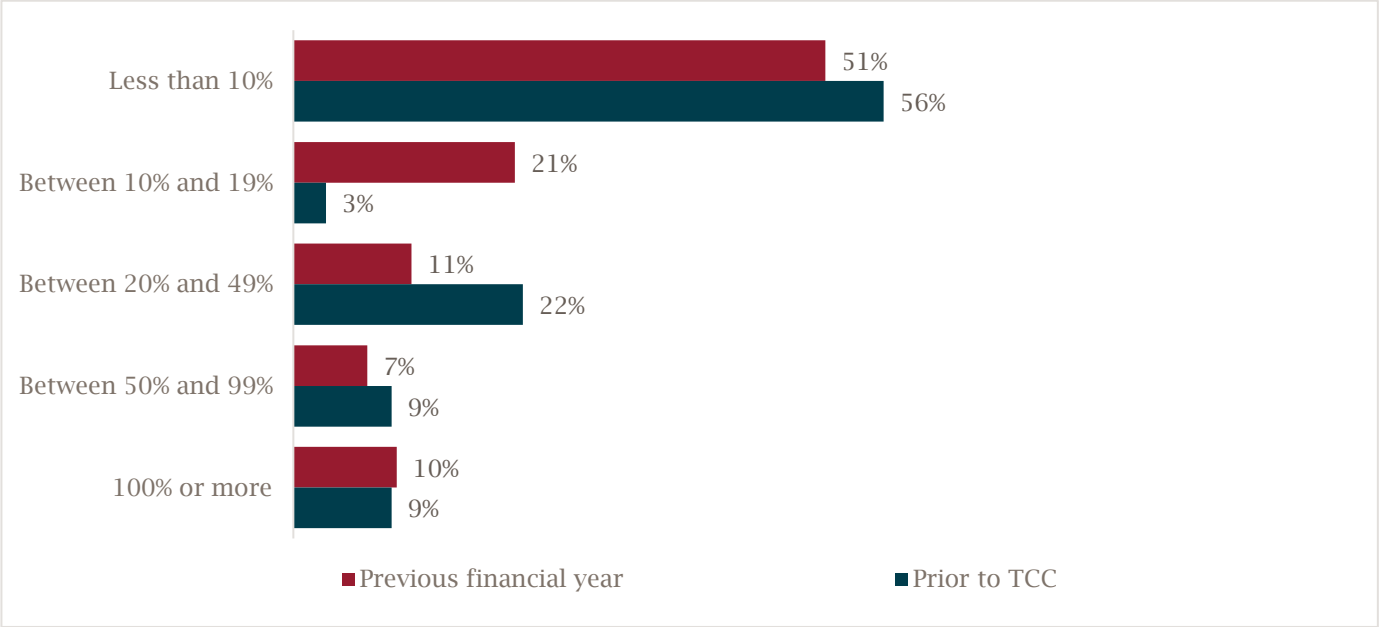



*Source: Beneficiaries survey. Q2Di. What was your organisation's level of investment in research and development in the previous financial year?*
*Note: Base: Impact survey business respondents (82)*

As mentioned above, by presenting R&D spend as a proportion of turnover we can compare R&D spend in the previous financial year to before engagement with the TCC. This comparison takes account of the differing turnovers of businesses that took part in the baseline survey and those that took part in the impact survey.

The average R&D spend as a proportion of turnover was 30% for the previous financial year. This is very similar to the average of 29% seen in the year prior to TCC engagement. The majority of businesses continued to spend less than 10% of their turnover on R&D (51% for the previous financial year, and 56% for the year prior to engagement with TCC). Around one in ten continued to spend 100% or more of their turnover on R&D (10% in the previous financial year and 9% in the year prior to engagement with TCC).

## FIGURE 68 CURRENT INVESTMENT IN R&D AS A PROPORTION OF TURNOVER COMPARED TO BASELINE



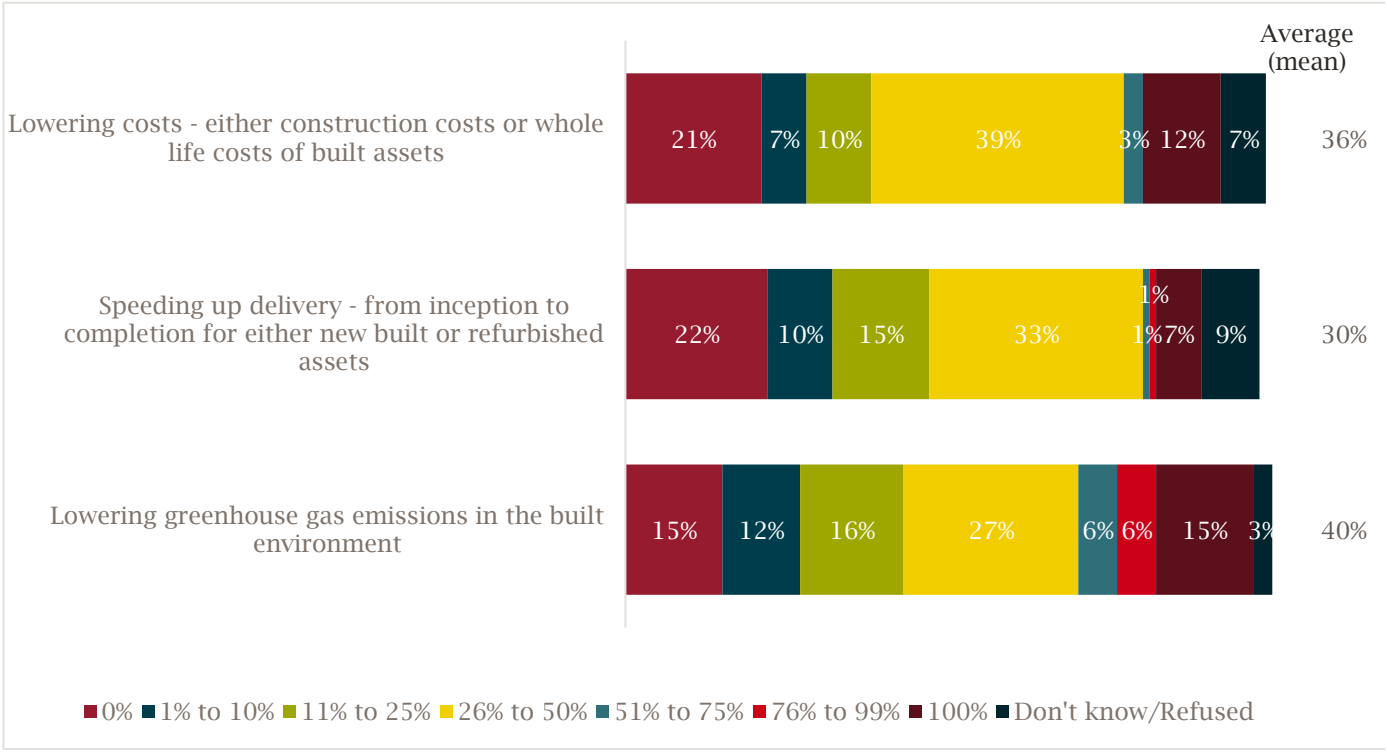

*Source: Beneficiaries survey. Q2Di. What was your organisation's level of investment in research and development in the previous financial year?*
*Note: Base: Impact survey business respondents (82)*

Survey respondents were also asked to estimate the proportion of their organisation's R&D spend that was related to the areas of TCC focus. The area with the highest average proportion of R&D spend (40%) was lowering greenhouse gas emissions in the built environment. Fifteen percent of respondents said all of their R&D spend was related to this, while 15% said none of their R&D spend was related to this.

The average proportion of R&D allocated to lowering costs – either construction costs or whole-life costs of built assets – was just over a third (36%). Twelve percent said all of their R&D was allocated to this, while 21% had no R&D in this area.

The average proportion of R&D allocated to speeding up delivery was 30%. Seven percent of those surveyed had allocated all of their R&D spend to this, while 22% had allocated none of their R&D spend.

## FIGURE 69 PROPORTIONS OF SPEND RELATED TO TCC AREAS OF FOCUS



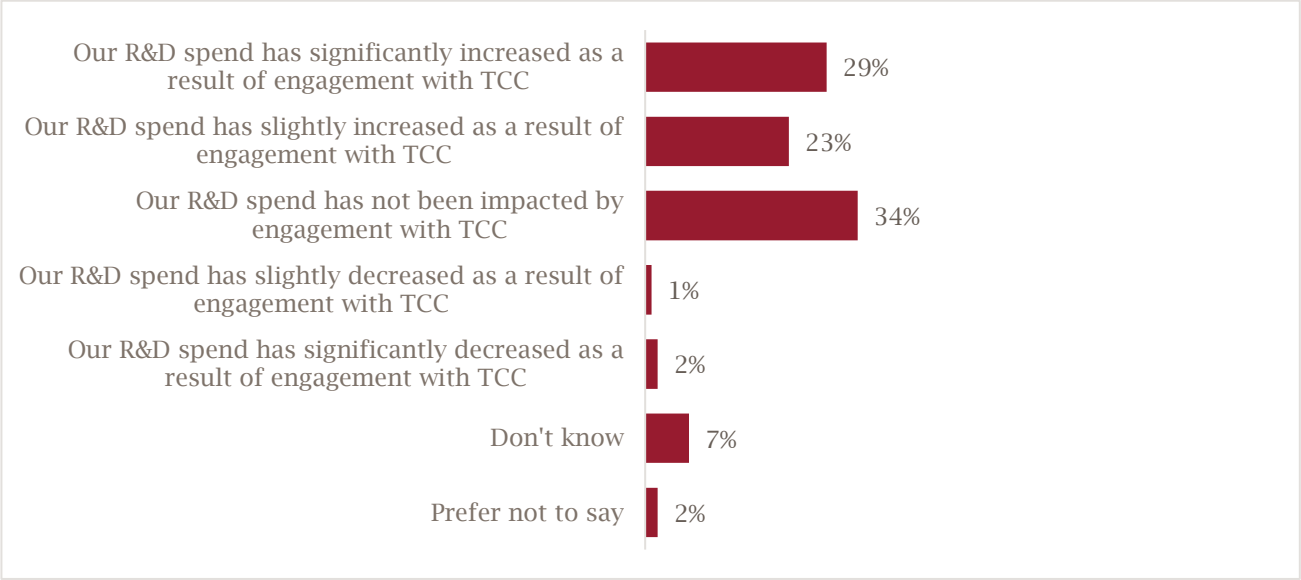

*Source: Beneficiaries survey. C18. And what proportion of this spend was related to each of the following*
*Note: Base: Impact survey business respondents with R&D spend (67)*

Over half (52%) of the beneficiaries surveyed that were businesses stated that their R&D spend had increased as a result of their engagement with TCC. This includes 29% who stated their R&D had increased significantly as a result of their TCC engagement. Four percent stated that their R&D spend had decreased as a result of their TCC engagement.

Those who had been successful in their application for TCC funding were much more likely to say their R&D spending had increased as a result of their TCC engagement (85%). This includes over half (53%) who stated that the TCC had significantly impacted their R&D spend. However, even a quarter (25%) of those who had not been successful in their TCC application stated that their R&D spend hade increased as a result of their engagement with TCC.

Those who focused on programming and project management, off-site manufacture and active building technology were more likely to state that their R&D spend had increased considerably as a result of their engagement with TCC (45%, 43% and 43% respectively).

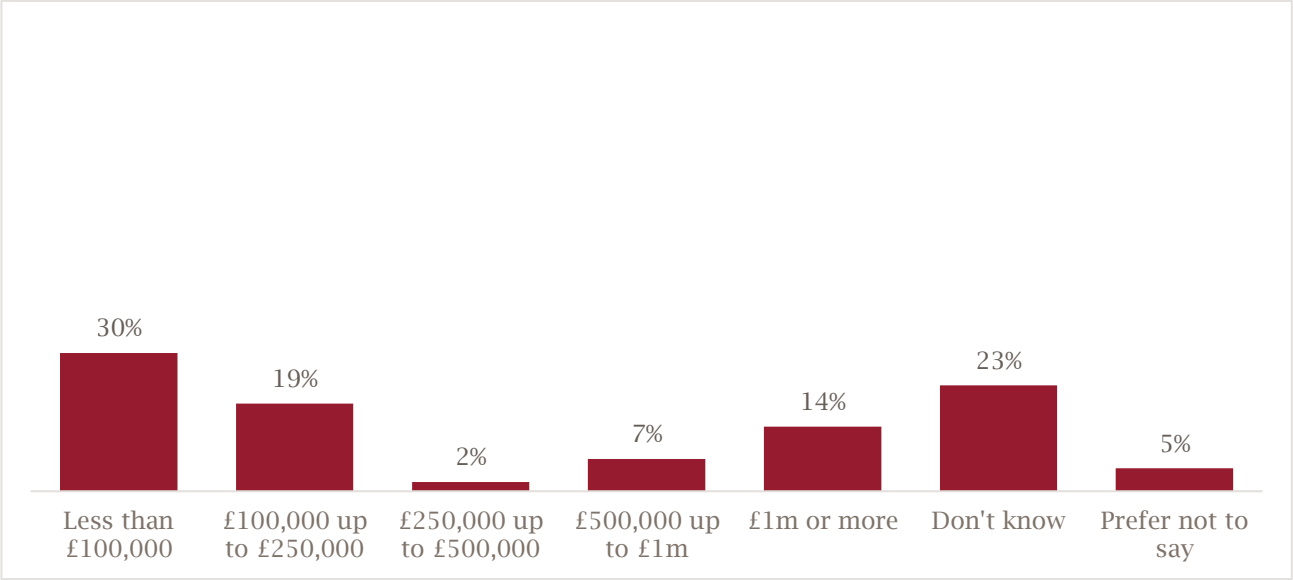
## FIGURE 70 PERCEIVED IMPACT OF TCC ON R&D SPEND




*Source: Beneficiaries survey. Q2F. Which of the following best describes how your engagement with TCC has impacted your organisation's R&D spend?*
*Note: Base: Impact survey business respondents (82)*

Those who reported an increase in R&D spend as a result of their TCC engagement (52%) were asked to quantify this increase. The most common increase was less than £100,000 (30%), followed by between £100,000 and £250,000 (19%). Fourteen percent had increased their R&D by £1 million or more as a result of their TCC engagement. Nearly a quarter (23%) could not quantify this increase.

## FIGURE 71 AMOUNT R&D SPEND HAS INCREASED AS A RESULT OF TCC ENGAGEMENT

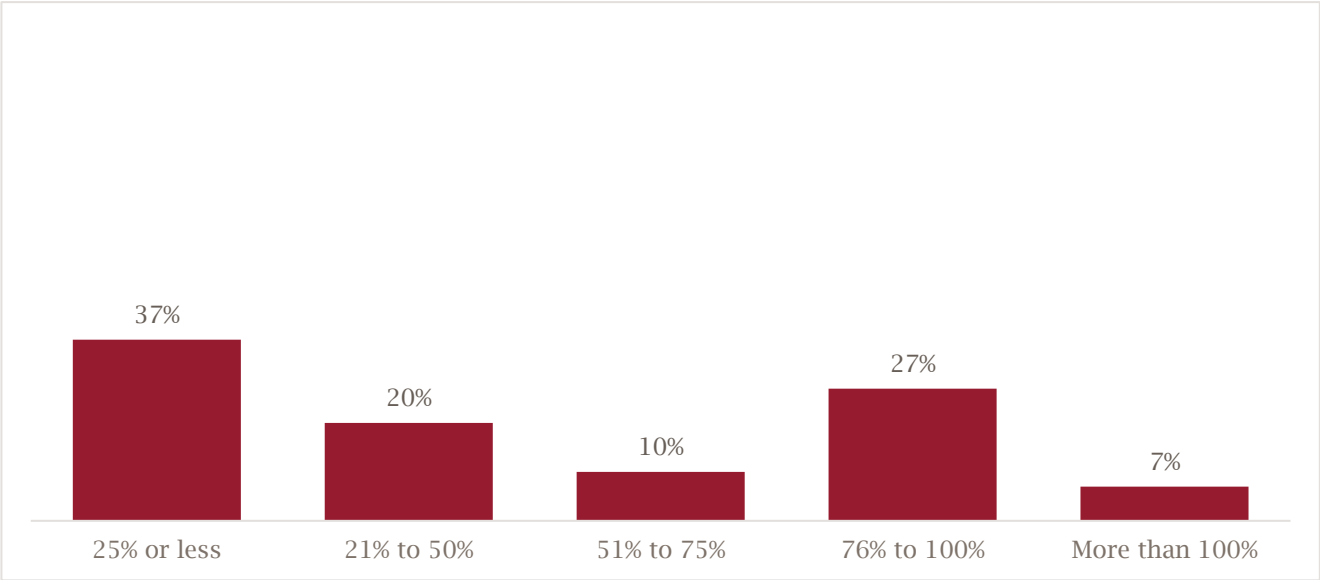



*Source: Beneficiaries survey. Q2G. How much has your organisation's R&D spend increased as a result of your engagement with TCC?*
*Note: Base: Impact survey business respondents with increased R&D spend (43)*

Where these businesses were able to quantify both their increase in R&D spend as a result of TCC engagement and their current investment in R&D, we are able to analyse this increase as a proportion of R&D spend. This analysis was possible for 30 of the businesses surveyed.

The average increase for these businesses, as a proportion of total R&D spend, is 60%. Over a third of these businesses (37%) reported an increase in R&D spend as a result of their engagement with TCC that was 25% or less of their total R&D spend. Twenty percent reported an increase of between 21% and 50% or their R&D spend. Ten percent reported an increase of between 51% and 75%, 27% reported an increase of between 76% and 100%, and the remaining 7% reported an increase of more than 100%, i.e. greater than their total R&D spend in the previous year.

### FIGURE 72 AMOUNT R&D SPEND INCREASED AS A RESULT OF TCC ENGAGEMENT AS A PROPORTION OF TOTAL R&D SPEND




*Source: Beneficiaries survey. Q2G. How much has your organisation's R&D spend increased as a result of your engagement with TCC? Q2Di. What was your organisation's level of investment in research and development in the previous financial year?*
*Note: Base: Impact survey business respondents with increased R&D spend who provided amounts for total R&D and increase in R&D as a result of TCC engagement (30)*

## B.4 - FINDINGS: THEME 4–CONSTRUCTION SECTOR AND ITS SUPPLY CHAIN ADOPT TCC CONCEPTS

### B.4.1 - SHORT-TERM OUTCOMES

#### B.4.1.1 - CHANGE IN USE OF TCC CONCEPTS BY PROGRAMME BENEFICIARIES POST PROGRAMME

Survey respondents were asked to what extent they were aware of and using TCC concepts. The concepts shown to each respondent varied depending on the main TCC strand they had engaged with.

Those who had engaged with ABC were asked about their use of integrated energy capture and storage systems, integrated thermal solutions, smart controls and monitoring solutions, and energy trading and flexibility. As only a small number of survey respondents gave responses about the ABC concepts (6), the results for these concepts are not displayed in graphical form. Four out of the six ABC respondents were already using or considering using integrated energy capture and storage, integrated thermal solution and

smart controls and monitoring solutions. The remaining two were aware of these concepts, but not using them. For energy trading and flexibility, two were actively considering using the concept and four were aware of the concept.

Survey respondents who had primarily engaged with CR&D, CIH, RL or N+ were asked about a different list of concepts. The most common TCC concepts currently in use by these survey respondents were information management framework (48% were currently using) and off-site manufacturing (47% were currently using). The least commonly used concept was Digital Twin where a little under a third (31%) were currently using it. However, a further 19% were actively considering using this concept and only 14% of these survey respondents were not familiar with the concept.

Respondents who had been successful in their TCC application for funding were more likely to be currently using digital assurance tools (50%, compared to 27% of unsuccessful applicants) and digital compliance (42%, compared to 21% of unsuccessful applicants).

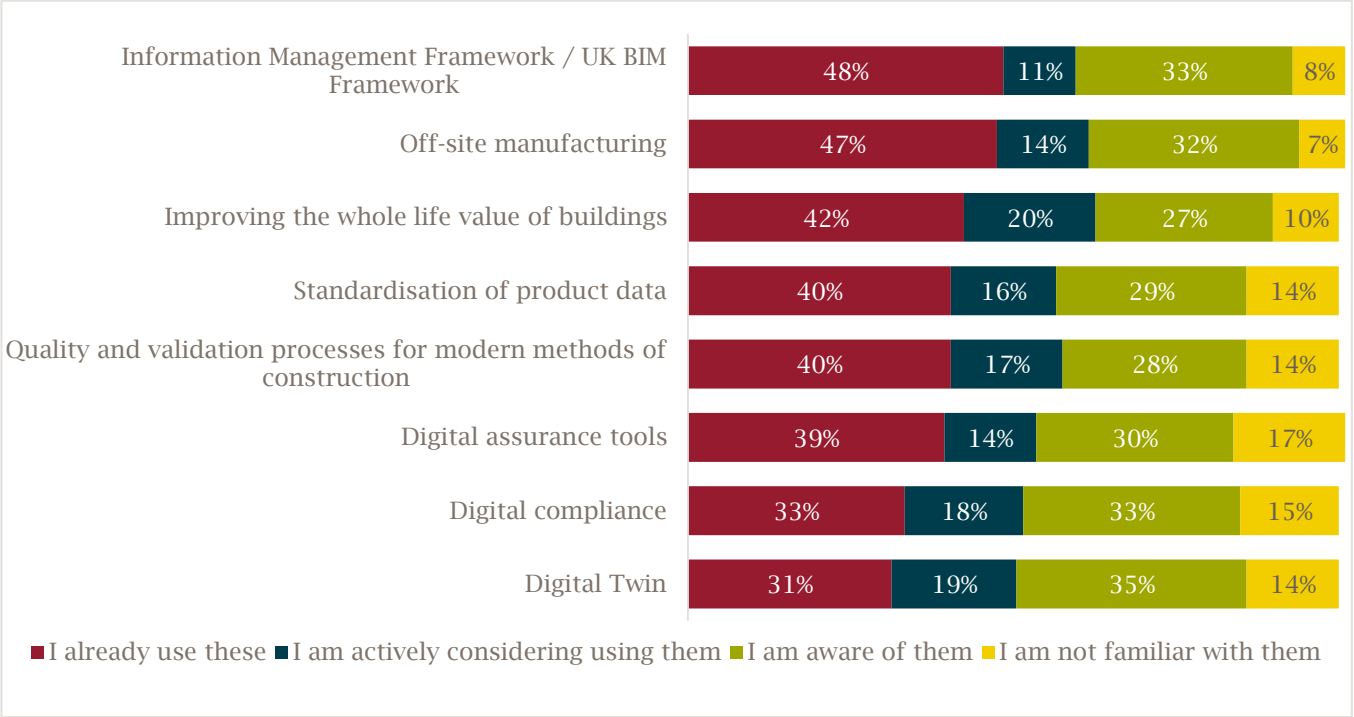
Respondents who were involved with Ministry of Defence building functions were more likely to be currently using off-site manufacturing (74%), improving the whole-life value of buildings (59%), standardisation of product data (56%), quality and validation processes for MMC (62%), digital assurance tools (62%) and digital compliance (47%).

Respondents who were involved with Ministry of Justice building functions were more likely to be currently using Information Management Framework/UK BIM (71%), off-site manufacturing (65%), improving the whole-life value of buildings (58%), digital assurance tools (65%) and digital compliance (48%).

Respondents who were involved with industrial building functions were more likely to be currently using off-site manufacturing (58%) and digital assurance tools (55%).

Respondents who were involved with retail building functions were more likely to be currently using Information Management Framework/UK BIM (60%) and digital assurance tools (60%).

## FIGURE 73 AWARENESS OF AND USE OF TCC CONCEPTS




*Source: Beneficiaries survey. Q18. Please describe your familiarity with the following tools, technologies and concepts.*
*Note: Base: Impact survey respondents whose main engagement was with CR&D, CIH, N+ or RL (155)*

Awareness and usage of some of these concepts was also measured in the baseline survey. However, in the baseline survey only respondents who had primarily engaged with CIH were asked about them. It is worth noting that this only comprised 20 respondents in the baseline survey.

The proportions who were currently using each concept had increased compared to the baseline for all of the concepts. In particular, the increases were notably large for Information Management Framework (48% currently using, compared to 25% in the baseline), improving the whole-life value of buildings (42% currently using, compared to 20% in the baseline) and digital compliance (33% currently using, compared to 5% in the baseline).

## TABLE 37 CHANGE IN TCC CONCEPT AWARENESS AND USAGE

| | BASELINE | | 2021 | |
|---|---|---|---|---|
| CONCEPT | % CURRENTLY USING | %ACTIVELY USING | %CURRENTLY USING | %ACTIVELY USING |
| Information Management Framework/UK BIM* | 25% | 15% | 48% | 11% |
| Off-site manufacturing | 35% | 15% | 47% | 14% |

| | BASELINE | | 2021 | |
|---|---|---|---|---|
| CONCEPT | % CURRENTLY USING | %ACTIVELY USING | %CURRENTLY USING | %ACTIVELY USING |
| Improving the whole-life value of buildings | 20% | 25% | 42% | 20% |
| Quality and validation processes for MMC | 15% | 35% | 40% | 17% |
| Digital assurance tools | 25% | 15% | 39% | 14% |
| Digital compliance | 5% | 20% | 33% | 18% |
| Digital Twin | 25% | 15% | 31% | 19% |

*Source: Beneficiaries survey. Q18. Please describe your familiarity with the following tools, technologies and concepts.*

*Note: Base: Impact survey respondents whose main engagement was with CR&D, CIH, N+ or RL (155). Baseline survey respondents whose main engagement was with CIH (20). *Text shown to respondents in the baseline survey was 'Information Management Framework'*

### B.4.2 - LONG-TERM OUTCOMES AND IMPACTS

#### B.4.2.1 - NUMBER AND PROPORTION OF FIRMS IN RELEVANT SECTORS ADOPTING CIH AND ABC CONCEPTS

Survey respondents that were currently using TCC concepts were asked to estimate the number of contracts using each concept and the value of these contracts.

Typically, organisations were using the concepts on a large number of contracts. The highest average number of contracts per organisation was for Information Management Framework/UK BIM where, on average, each organisation using this concept was using it on 70 contracts. The average value of these contracts is £170 million.

Where organisations used digital assurance tools, they were also typically used on a large number of contracts: the average is 63. The average value of these contracts is £437 million.

Even for off-site manufacturing and Digital Twin, the concepts with the lowest average number of contracts, where they were being used by respondent organisations, they were typically used on more than 20 contracts.

For quality and validation processes for MMC, even though the average number of contracts this concept was being used on by each organisation was relatively low (22), the average value of these contracts is noticeably high at £2.1 billion.

## TABLE 38 AVERAGE NUMBER AND VALUE OF CONTRACTS USING TCC CONCEPTS

| CONCEPT | NUMBER CURRENTLY USING | MEAN NUMBER OF CONTRACTS | MEAN VALUE OF CONTRACTS |
|---|---|---|---|
| Information Management Framework/UK BIM* | 52 | 70 | £170 million |
| Off-site manufacturing | 56 | 21 | £90 million |
| Improving the whole-life value of buildings | 51 | 53 | £835 million |
| Standardisation of product data | 50 | 54 | £101 million |
| Quality and validation processes for MMC | 47 | 22 | £2.1 billion |
| Digital assurance tools | 48 | 63 | £437 million |
| Digital Compliance | 41 | 57 | £889 million |
| Digital Twin | 32 | 20 | £92 million |

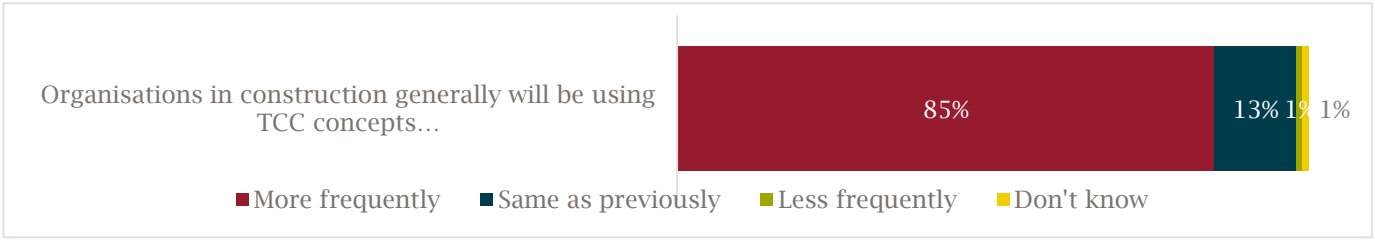
*Source: Beneficiaries survey. Q18A. You said that you/your organisation is already using some of these tools, technologies and concepts. Can you please indicate how many of your contracts use these and what the overall values of the contracts are?*

*Note: Base: Impact survey business respondents whose main engagement was with CR&D, CIH, N+ or RL and are currently using TCC concepts (base sizes shown in table)*

As mentioned under Theme 2, the majority expected that organisations in construction would generally be using TCC concepts more frequently (85%). Those that had been successful in their TCC application for

funding were more likely to expect to see the concepts used more frequently (93%), compared to those that had been unsuccessful in their application (75%).

### FIGURE 74 EXPECTATIONS OF USE OF TCC CONCEPTS




*Source: Beneficiaries survey. Q20. Based on your knowledge and experience of the Transforming Construction Challenge, do you expect as a result of its activities to see the following things more frequently, less frequently, or same as previously?*
*Note: Base: Impact survey business respondents aware of at least one TCC concept measured (158)*

## B.5 - FINDINGS: THEME 5–INCREASED PERFORMANCE OF CONSTRUCTION SECTOR FIRMS AND THEIR SUPPLIERS

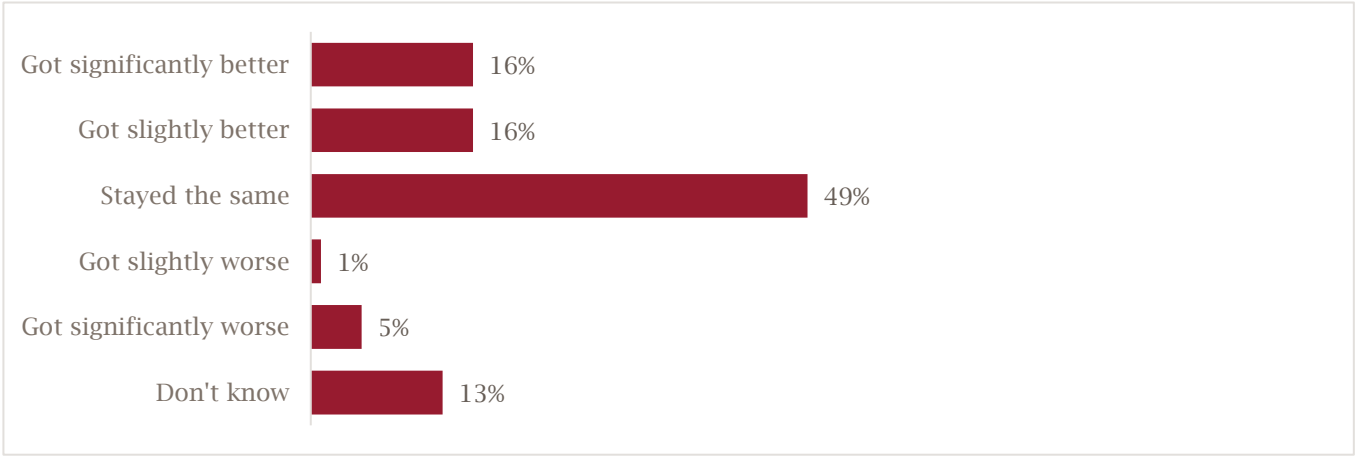
### B.5.1 - SHORT-TERM OUTCOMES

#### B.5.1.1 - CHANGE IN PERFORMANCE OF TCC BENEFICIARY FIRMS POST PARTICIPATION

Nearly half (49%) of the businesses surveyed reported no change in their annual revenue since their engagement with TCC. Nearly a third (32%) reported an increase in annual revenue, with 16% reporting that it had got 'significantly better'. Six percent reported that their annual revenue hade got worse since their engagement with TCC.

Half of successful applicants for TCC funding reported that their annual revenue had got better (50%, compared to 22% of those whose application for funding had been unsuccessful). This includes 21% who reported it had got significantly better and 29% who reported it had got slightly better. Six percent of successful applicants reported it had got 'significantly worse' and none reported it had got 'slightly worse'.

### FIGURE 75 CHANGE IN ANNUAL REVENUE SINCE ENGAGEMENT WITH TCC

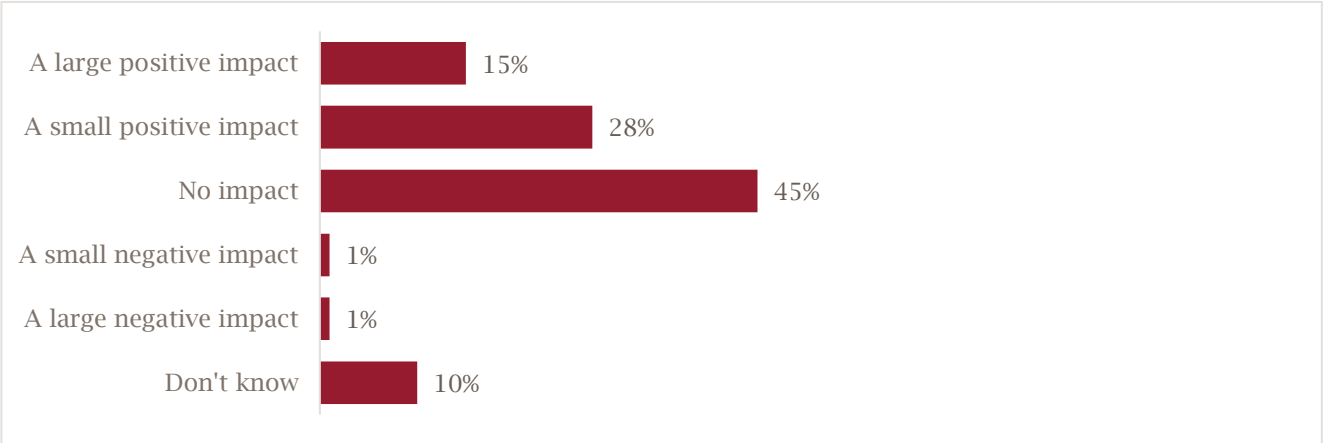



*Source: Beneficiaries survey. Q21. How, if at all, have the following changed for your organisation since your engagement with TCC?: Annual revenue*
*Note: Base: Impact survey business respondents (82)*

Over two in five (43%) of the businesses surveyed reported that TCC had had a positive impact on their annual revenue, including 15% that reported that the TCC had had a large positive impact. Forty-five percent reported that the TCC had had no impact on their annual revenue, and 2% reported that the TCC had had a negative impact.

Over three-quarters (76%) of businesses surveyed that had been successful in their TCC application for funding reported that the TCC had had a positive impact on their annual revenue, including 29% that reported that the TCC had had a large positive impact. Just under one in five (19%) of 'unsuccessful' businesses reported that the TCC had positively impacted their annual revenue.

## FIGURE 76 IMPACT OF TCC ON ANNUAL REVENUE

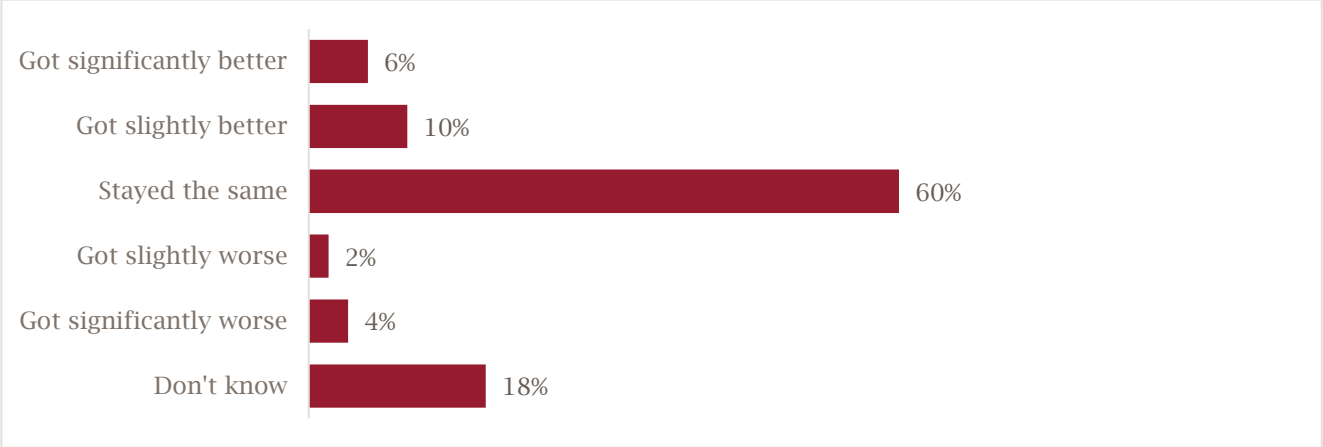



*Source: Beneficiaries survey. Q22. And what impact do you think TCC has had on these?: Annual revenue*
*Note: Base: Impact survey business respondents (82)*

The majority (60%) of businesses surveyed reported no change in the proportion of construction projects delivered on time or in advance since their engagement with TCC. Sixteen percent reported that this has got better, including 6% that reported it had got 'significantly better'. Six percent reported that it had got worse, including 4% that reported that it had got significantly worse.

Businesses whose application for TCC funding was successful were more likely to say the proportion of projects delivered on time or in advance had got better since their engagement with TCC: 9% reported it had got significantly better and 18% reported it has got slightly better. None of these businesses reported that it had got worse.

## FIGURE 77 CHANGE IN THE PROPORTION OF CONSTRUCTION PROJECTS DELIVERED ON TIME OR IN ADVANCE SINCE ENGAGEMENT WITH TCC

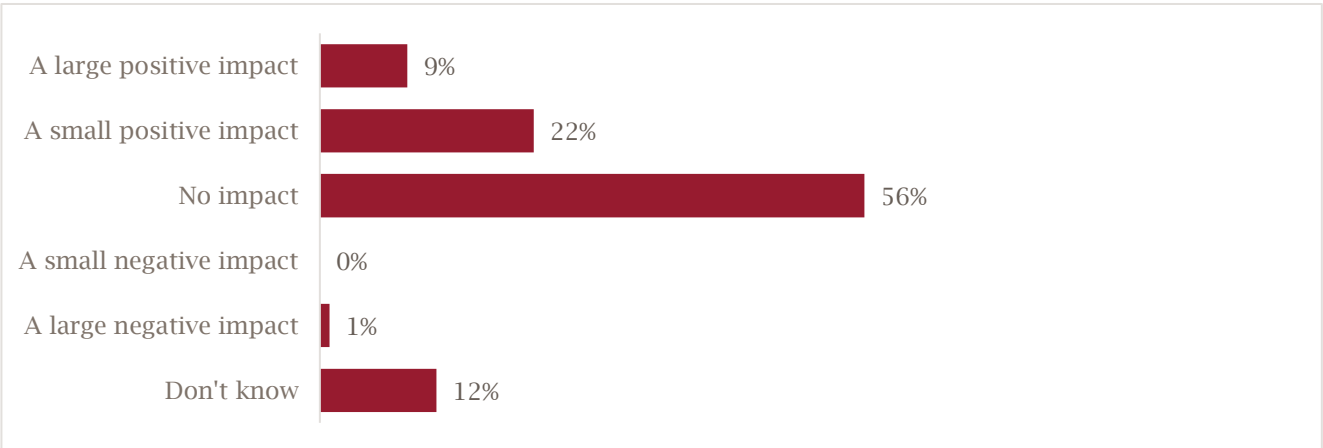



*Source: Beneficiaries survey. Q21. How, if at all, have the following changed for your organisation since your engagement with TCC?: The proportion of construction projects delivered on time or in advance*
*Note: Base: Impact survey business respondents (82)*

Close to a third (30%) of the businesses surveyed reported that the TCC had had a positive impact on the proportion of construction projects delivered on time or in advance. A little over half (56%) reported that the TCC had had no impact and 1% reported that the TCC had had a negative impact.

Over half (59%) of businesses whose application for TCC funding had been successful reported TCC as having a positive impact on the proportion of projects delivered on time or in advance. This includes 15% who reported that the TCC had had a large positive impact and 44% that reported the TCC had had a small positive impact. None of these businesses reported the TCC had had a negative impact on delivery.

## FIGURE 78 IMPACT OF TCC ON THE PROPORTION OF CONSTRUCTION PROJECTS DELIVERED ON TIME OR IN ADVANCE



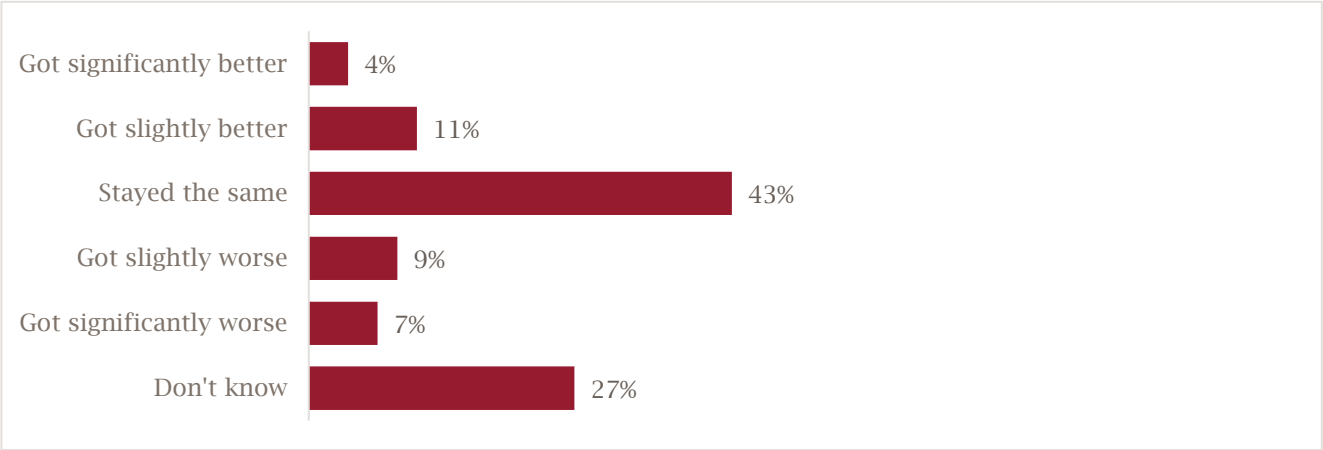

*Source: Beneficiaries survey. Q22. And what impact do you think TCC has had on these?: The proportion of construction projects delivered on time or in advance*
*Note: Base: Impact survey business respondents (82)*

Over two in five (43%) of businesses surveyed reported that construction costs per $m^2$ had stayed the same since their engagement with TCC. Fifteen percent reported that they had got better, while 16% reported

that they had got worse. It is worth noting that over a quarter (27%) did not know the answer to this question.

Businesses that had been successful in their application for TCC funding were more likely to report that their construction costs per m² had got better (26%) than those that had been unsuccessful (9%).

## FIGURE 79 CHANGE IN CONSTRUCTION COSTS PER M² SINCE ENGAGEMENT WITH TCC

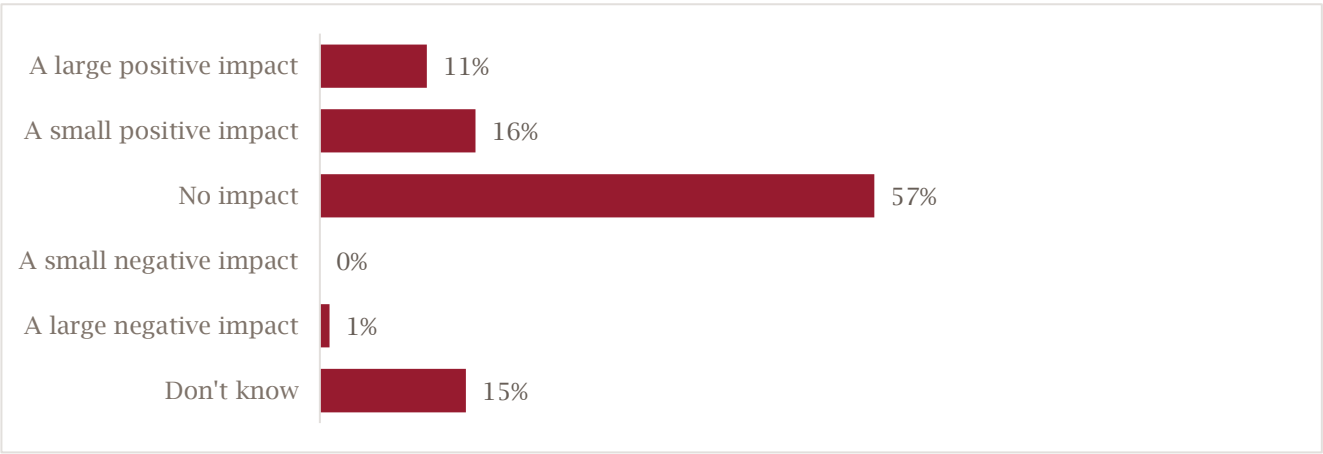



*Source: Beneficiaries survey. Q21. How, if at all, have the following changed for your organisation since your engagement with TCC?: Construction costs per m²*
*Note: Base: Impact survey business respondents (82)*

The majority (57%) reported that the TCC had not impacted their construction costs per m². Just over a quarter (27%) reported that the TCC had had a positive impact and only 1% report that the TCC had had a negative impact.

Half (50%) of surveyed businesses that had been successful in their TCC application for funding reported that the TCC had had a positive impact on constructions costs, including 21% that reported that the TCC had had a large positive impact. None of these respondents reported that the TCC had had a negative impact on construction costs.

## FIGURE 80 IMPACT OF TCC ON CONSTRUCTION COSTS PER M²

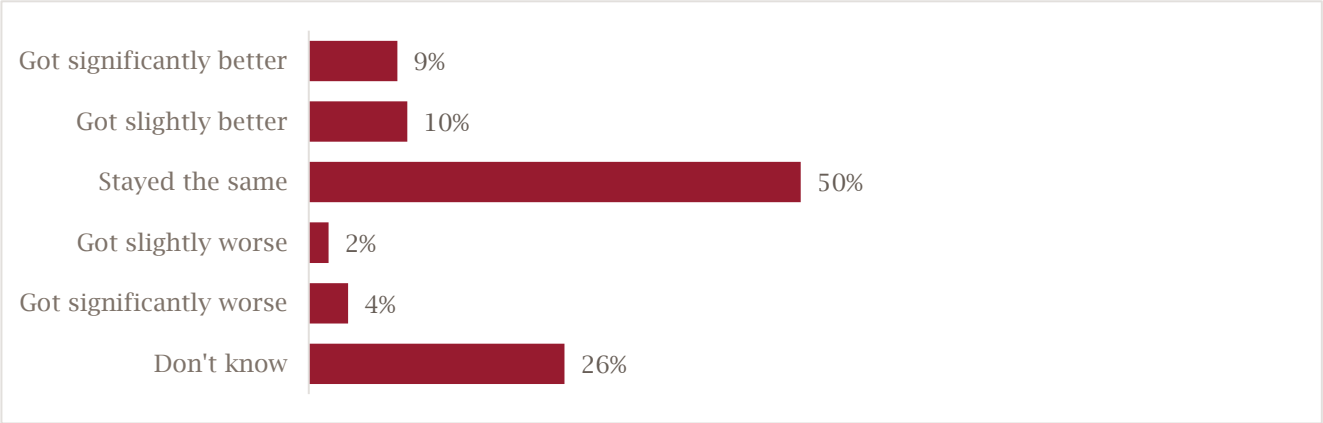



*Source: Beneficiaries survey. Q22. And what impact do you think TCC has had on these?: Construction costs per m²*
*Note: Base: Impact survey business respondents (82)*

Half (50%) of businesses surveyed reported no change in the labour hours spent on site per $m^2$ of interior floor space since their engagement with the TCC. Just under one in five (18%) reported that this had got better and 6% reported it had got worse. It is worth noting that over a quarter (26%) did not know how this had changed since their engagement with the TCC.

Businesses that had been successful with their application for TCC funding were more likely to say this had got better (29%, compared to 16% for those that had been unsuccessful with their application).

## FIGURE 81 CHANGE IN LABOUR HOURS SPENT ON SITE PER M² OF INTERIOR FLOOR SPACE SINCE ENGAGEMENT WITH TCC

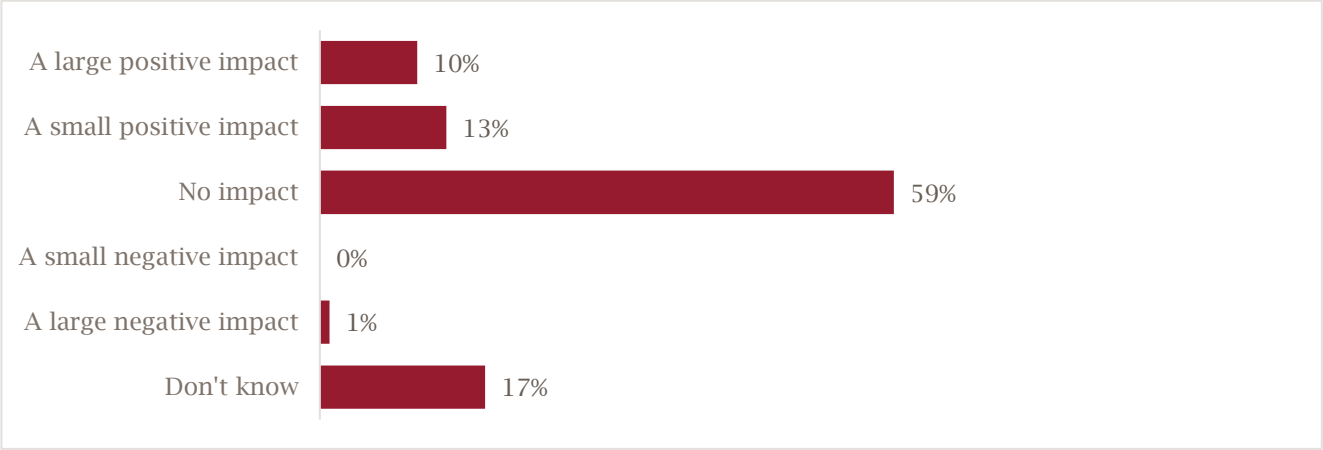



*Source: Beneficiaries survey. Q21. How, if at all, have the following changed for your organisation since your engagement with TCC?: Labour hours spend on site per $m^2$ of interior floor space*
*Note: Base: Impact survey business respondents (82)*

The majority (59%) reported that the TCC had not impacted their labour hours spent on site. Nearly a quarter (23%) reported that TCC had had a positive impact, including 10% that reported that the TCC had had a large positive impact. Only 1% reported that TCC had had a negative impact on labour hours.

Over two in five (44%) surveyed businesses that had been successful in their TCC application reported the TCC as positively impacting labour hours, including 18% that felt the TCC had had a large positive impact. None of these 'successful' businesses surveyed reported the TCC as having a negative impact on labour hours.

FIGURE 82 IMPACT OF TCC ON LABOUR HOURS SPENT ON SITE PER M² OF INTERIOR FLOOR SPACE




*Source: Beneficiaries survey. Q22. And what impact do you think TCC has had on these?: Labour hours spend on site per m² of interior floor space*
*Note: Base: Impact survey business respondents (82)*

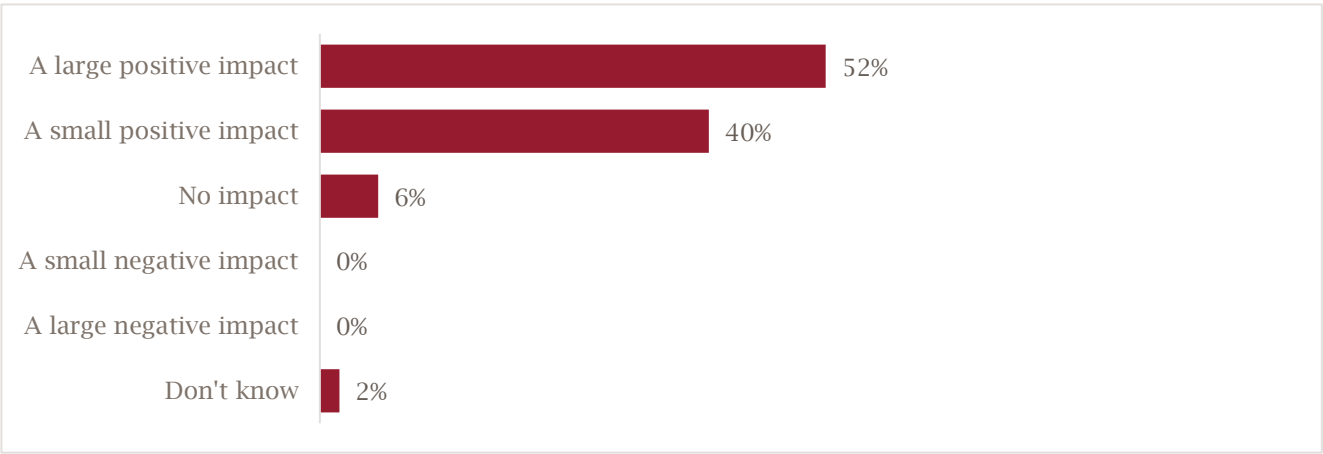
## B.6 - FINDINGS: THEME 6 – IMPROVED DELIVERY OF BUILT ASSETS (TIME, QUALITY AND WHOLE-LIFE COSTS)

### B.6.1 - SHORT-TERM OUTCOMES

#### B.6.1.1 - DEMONSTRATORS OF TCC CONCEPTS IMPROVE ON CONSTRUCTION COSTS AND DELIVERY TIMES

Over half (52%) of survey respondents that were actively considering using at least one of the TCC concepts expected the use of TCC concepts to have a large positive impact on their organisation's annual revenue. A further 40% expected the use of TCC concepts to have a small positive impact. None of those who were actively considering using at least one of the TCC concepts expected their use to have a negative impact.

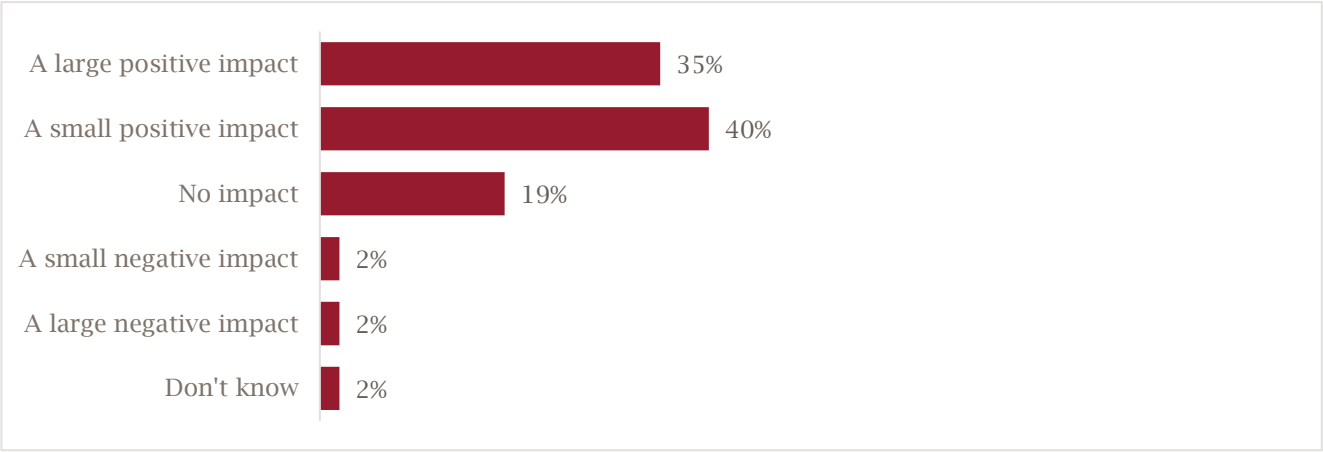
FIGURE 83 EXPECTED IMPACT OF USING TCC CONCEPTS ON ANNUAL REVENUE




*Source: Beneficiaries survey. Q18B. What impact, if any, do you think using these tools, technologies and concepts will have on your organisation's performance in the following areas?: Your organisation's annual revenue*
*Note: Base: Impact survey respondents considering using TCC concepts (62)*

Just over a third (35%) of survey respondents who were actively considering using at least one TCC concept expected the use of TCC concepts to have a large positive impact on their organisation's profit. A further 40% expected the use of TCC concepts to have a small positive impact. Four percent expected the use of TCC concepts to have a negative impact on profit: 2% expect a large negative impact and 2% expect a small negative impact.

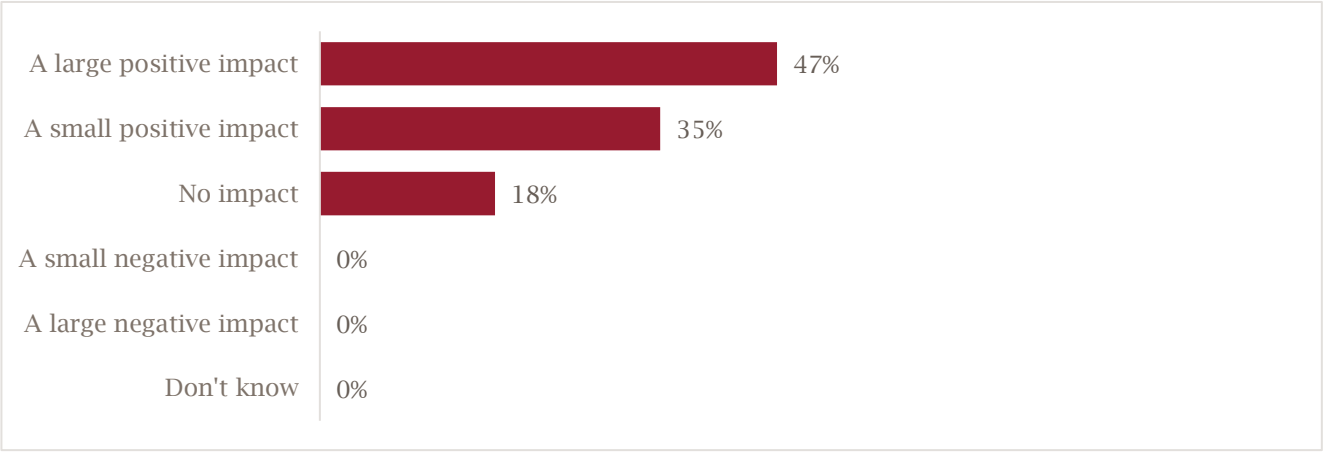
## FIGURE 84 EXPECTED IMPACT OF USING TCC CONCEPTS ON PROFIT




*Source: Beneficiaries survey. Q18B. What impact, if any, do you think using these tools, technologies and concepts will have on your organisation's performance in the following areas?: Your organisation's profit*
*Note: Base: Impact survey respondents considering using TCC concepts (62)*

Over four in five (82%) of survey respondents who were actively considering using at least one TCC concept expected the use of TCC concepts to have a positive impact on their organisation's productivity. This includes nearly half (47%) who expected the use of TCC concepts to have a large positive impact on productivity. None of those who were actively considering using at least one TCC concept expected their use to have a negative impact on productivity.

## FIGURE 85 EXPECTED IMPACT OF USING TCC CONCEPTS ON PRODUCTIVITY

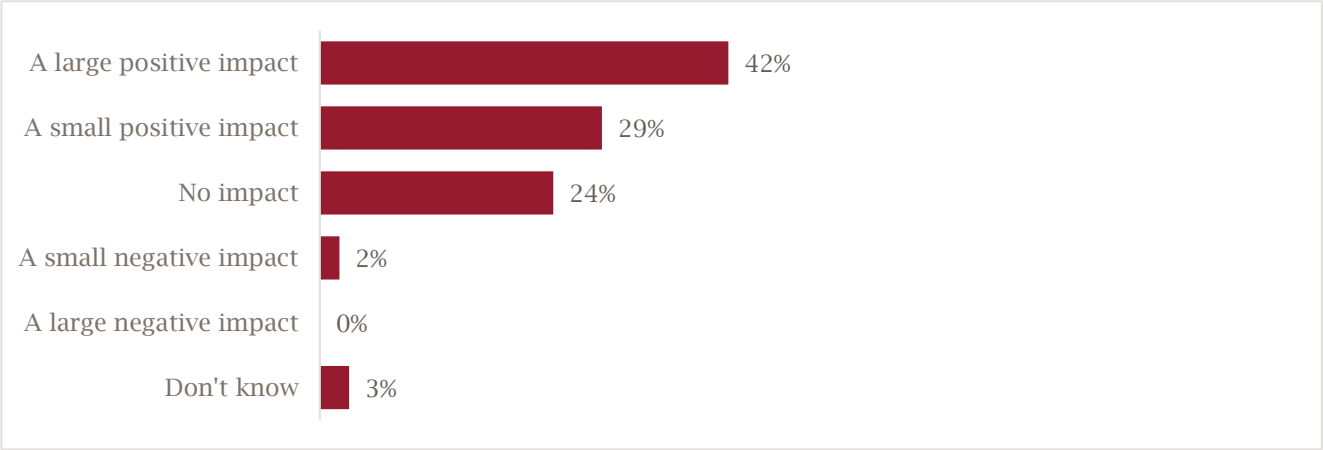



*Source: Beneficiaries survey. Q18B. What impact, if any, do you think using these tools, technologies and concepts will have on your organisation's performance in the following areas?: Your organisation's productivity*
*Note: Base: Impact survey respondents considering using TCC concepts (62)*

Nearly three-quarters (71%) of survey respondents who were actively considering using at least one TCC concept expected the use of TCC concepts to have a positive impact on their organisation's speed of

delivery. This includes 42% who expected the use of TCC concepts to have a large positive impact. Two percent expected the use of TCC concepts to have a small negative impact on speed of delivery.

### FIGURE 86 EXPECTED IMPACT OF USING TCC CONCEPTS ON SPEED OF DELIVERY



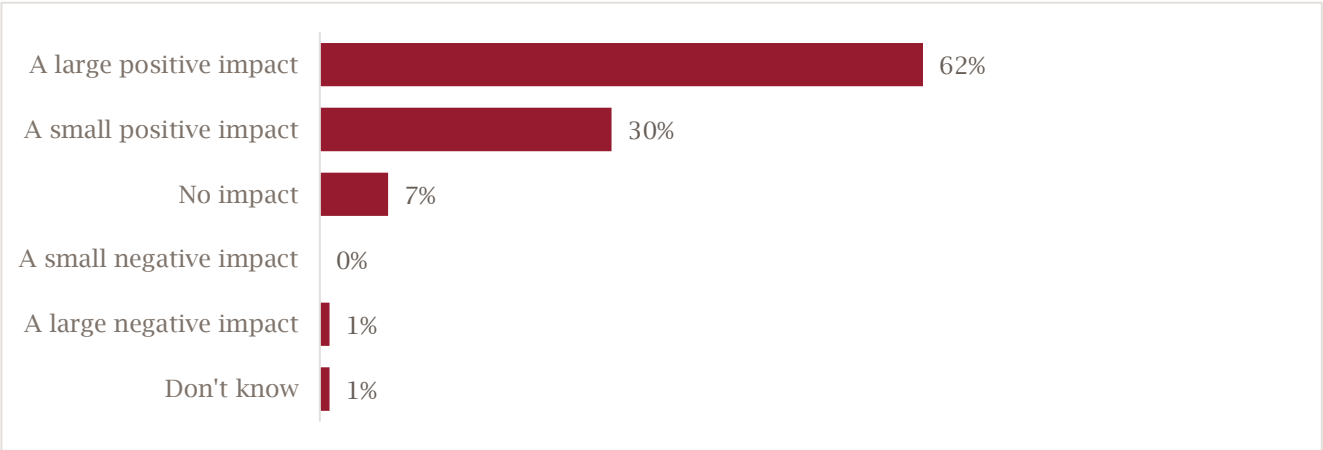

*Source: Beneficiaries survey. Q18B. What impact, if any, do you think using these tools, technologies and concepts will have on your organisation's performance in the following areas?: Your organisation's speed of delivery – from inception to completion for either new built or refurbished assets*
*Note: Base: Impact survey respondents considering using TCC concepts (62)*

### B.6.1.2 - DEMONSTRATORS OF TCC CONCEPTS IMPROVE ON CONSTRUCTION COSTS AND DELIVERY TIMES

Over three in five (61%) survey respondents who were already using TCC concepts said that their use had had a large positive impact on annual revenue. This is 10 percentage points higher than those who were actively considering using TCC concepts, suggesting that the observed impact may be greater than expected when businesses are actively considering their use.

A further 30% of those who were using at least one TCC concept had observed a small positive impact on their annual revenue. Only 1% had observed a large negative impact.

### FIGURE 87 OBSERVED IMPACT OF USING TCC CONCEPTS ON ANNUAL REVENUE

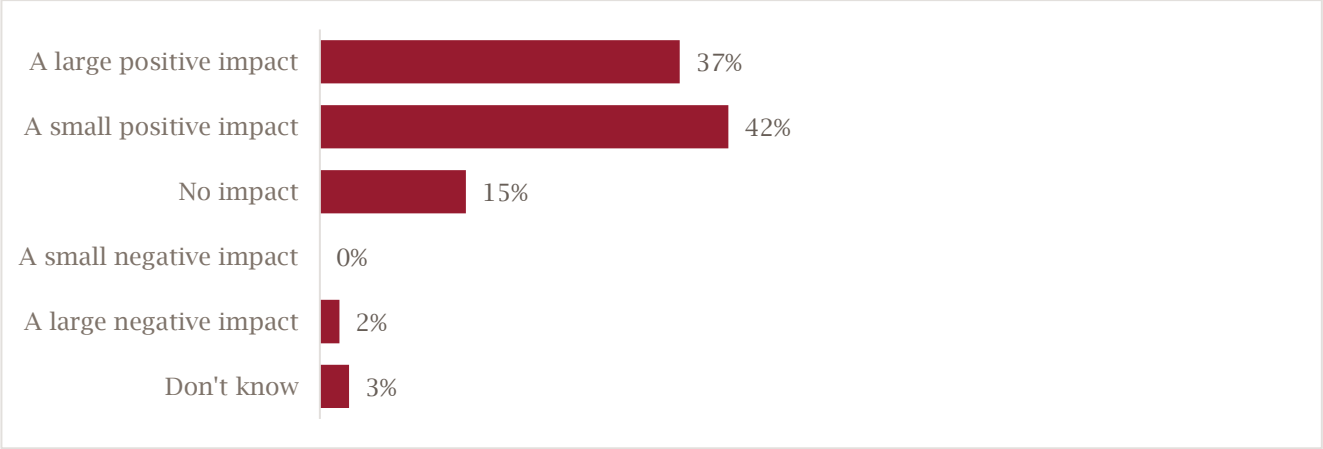



*Source: Beneficiaries survey. Q18B. What impact, if any, do you think using these tools, technologies and concepts has had on your organisation's performance in the following areas?: Your organisation's annual revenue*
*Note: Base: Impact survey respondents already using TCC concepts (91)*

Nearly four in five (79%) survey respondents who were already using at least one TCC concept reported a positive impact on their organisation's profit. This is a similar proportion to those who were considering using TCC concepts and expected to see a positive impact (76%).

Over a third (37%) said this positive impact had been large. Two percent said the use of TCC concepts had had a large negative impact on profit.

## FIGURE 88 OBSERVED IMPACT OF USING TCC CONCEPTS ON PROFIT

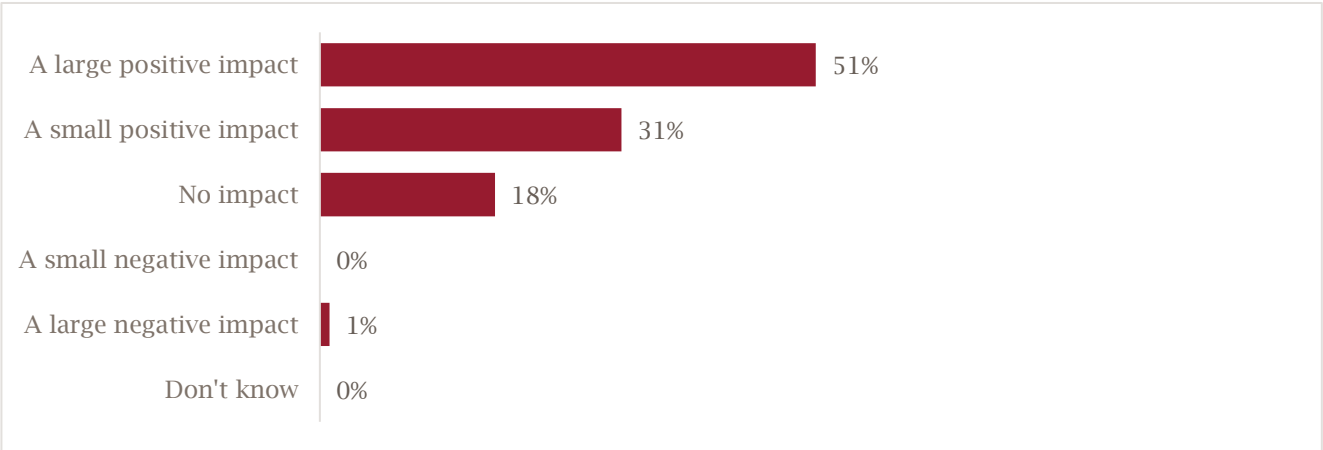



*Source: Beneficiaries survey. Q18B. What impact, if any, do you think using these tools, technologies and concepts has had on your organisation's performance in the following areas?: Your organisation's profit*
*Note: Base: Impact survey respondents already using TCC concepts (91)*

Over half (51%) of survey respondents who were already using at least one TCC concept reported a large positive impact on their organisation's productivity. A further 31% reported a small positive impact. These proportions are similar to those who were actively considering using TCC concepts and expected a positive impact on productivity.

Only 1% had observed a large negative impact on productivity as a result of using TCC concepts.

## FIGURE 89 OBSERVED IMPACT OF USING TCC CONCEPTS ON PRODUCTIVITY

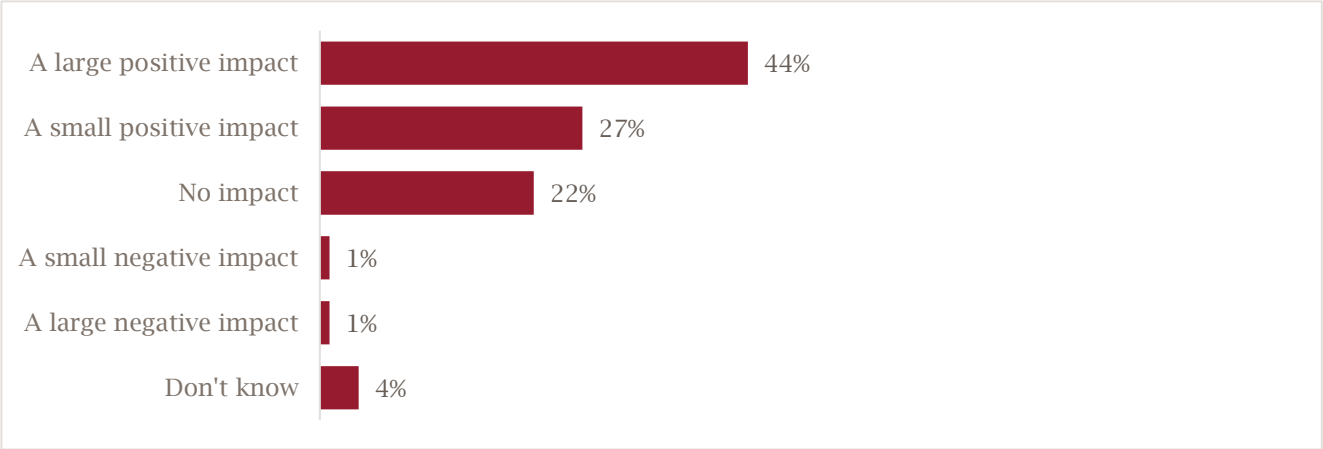



*Source: Beneficiaries survey. Q18B. What impact, if any, do you think using these tools, technologies and concepts has had on your organisation's performance in the following areas?: Your organisation's productivity*
*Note: Base: Impact survey respondents already using TCC concepts (91)*

Nearly three-quarters (71%) of survey respondents who were already using at least one TCC concept reported a positive impact in speed of delivery. This includes 44% who reported a large positive impact. These proportions are similar to those who were actively considering using TCC concepts and expected a positive impact on speed of delivery.

Two percent had observed a negative impact on speed of delivery. This includes 1% who had observed a large negative impact and 1% who had observed a small negative impact.

### FIGURE 90 OBSERVED IMPACT OF USING TCC CONCEPTS ON SPEED OF DELIVERY




*Source: Beneficiaries survey. Q18B. What impact, if any, do you think using these tools, technologies and concepts has had on your organisation's performance in the following areas?: Your organisation's speed of delivery – from inception to completion for either new built or refurbished assets*
*Note: Base: Impact survey respondents already using TCC concepts (91)*

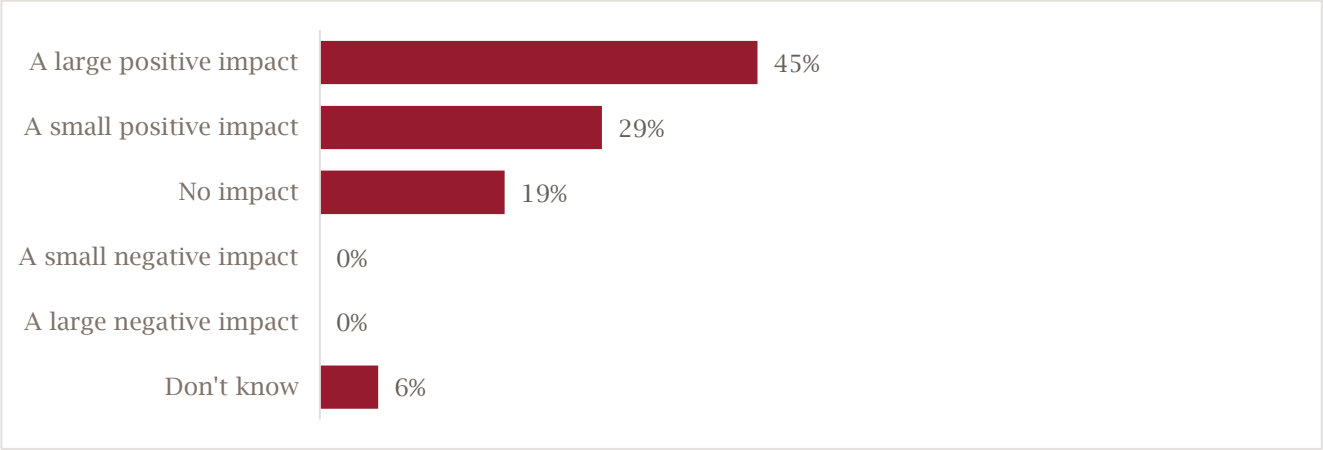
## B.7 - FINDINGS: THEME 7 – IMPROVED ENVIRONMENTAL PERFORMANCE OF BUILT ASSETS

### B.7.1 - SHORT-TERM OUTCOMES

#### B.7.1.1 - EXTENT TO WHICH DEMONSTRATORS OF TCC CONCEPTS IMPROVE ENVIRONMENTAL IMPACT OF BUILT ASSETS

Nearly three-quarters (74%) of survey respondents who were actively considering using TCC concepts expected the use of TCC concepts to have a positive impact on $CO_2$ emissions produced on site in the construction phase of their projects. This includes 45% who expected the use of TCC concepts to have a large positive impact and 29% who expected a small positive impact. None expected it to have a negative impact.

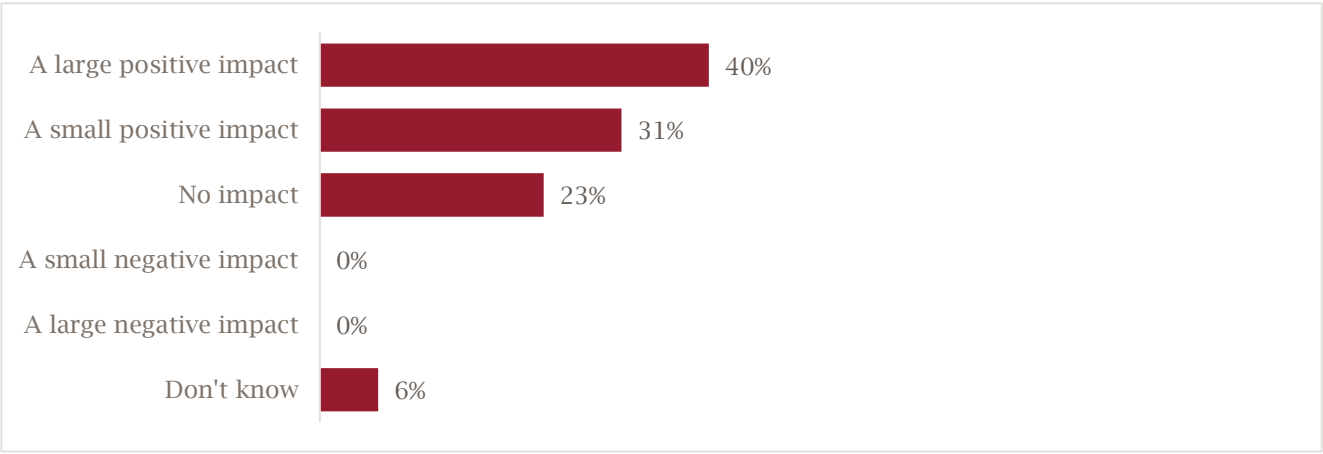
## FIGURE 91 EXPECTED IMPACT OF USING TCC CONCEPTS ON $CO_2$ EMISSIONS PRODUCED ON SITE




*Source: Beneficiaries survey. Q18C. What impact, if any, do you think using these tools, technologies and concepts will have on the construction phase of your projects in terms of the following indicators? : $CO_2$ emissions on site*
*Note: Base: Impact survey respondents considering using TCC concepts (62)*

Around seven in ten (71%) survey respondents who were actively considering using TCC concepts expected the use of TCC concepts to have a positive impact on energy consumption on site for the construction phase of their projects. This includes 40% who expected a large positive impact and 31% who expected a small positive impact. None expected a negative impact.

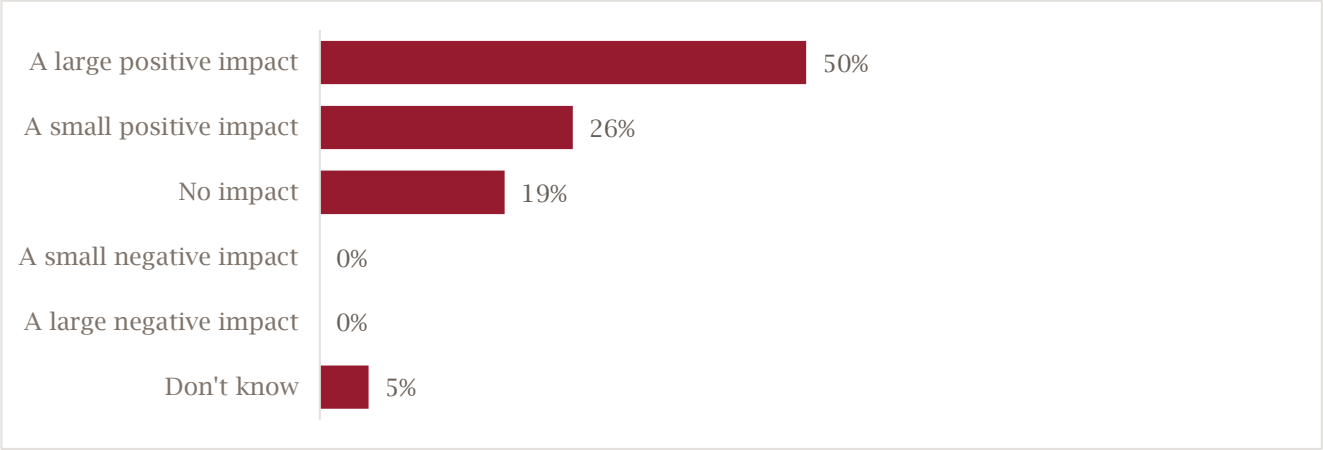
## FIGURE 92 EXPECTED IMPACT OF USING TCC CONCEPTS ON ENERGY CONSUMPTION ON SITE




*Source: Beneficiaries survey. Q18C. What impact, if any, do you think using these tools, technologies and concepts will have on the construction phase of your projects in terms of the following indicators? : Energy consumption on site*
*Note: Base: Impact survey respondents considering using TCC concepts (62)*

Half (50%) of survey respondents who were actively considering using TCC concepts expected the use of TCC concepts to have a large positive impact on waste produced on site for the construction phase of their projects. A further 26% expected a small positive impact. None expected a negative impact.

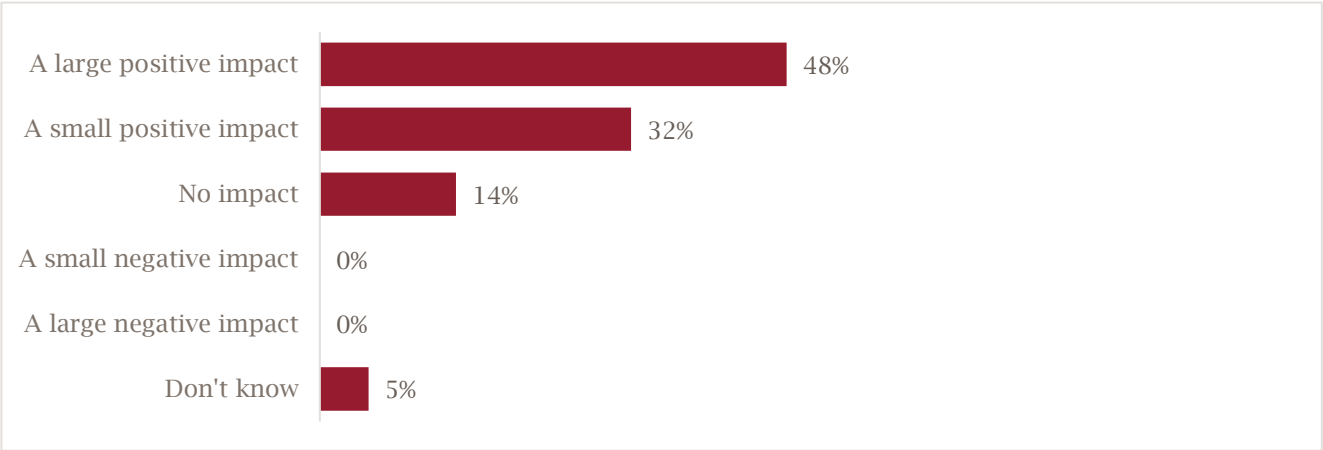
## FIGURE 93 EXPECTED IMPACT OF USING TCC CONCEPTS ON WASTE PRODUCED ON SITE




*Source: Beneficiaries survey. Q18C. What impact, if any, do you think using these tools, technologies and concepts will have on the construction phase of your projects in terms of the following indicators? : Waste produced on site*
*Note: Base: Impact survey respondents considering using TCC concepts (62)*

Four in five (80%) survey respondents who were already using TCC concepts had observed a positive impact on $CO_2$ emissions produced on site in the construction phase of their projects. This includes 48% who had observed a large positive impact. This is slightly higher than the proportion who were actively considering using TCC concepts and expected a positive impact (74%), suggesting that the observed impact may be greater than expected when considering using TCC concepts. None had observed a negative impact.

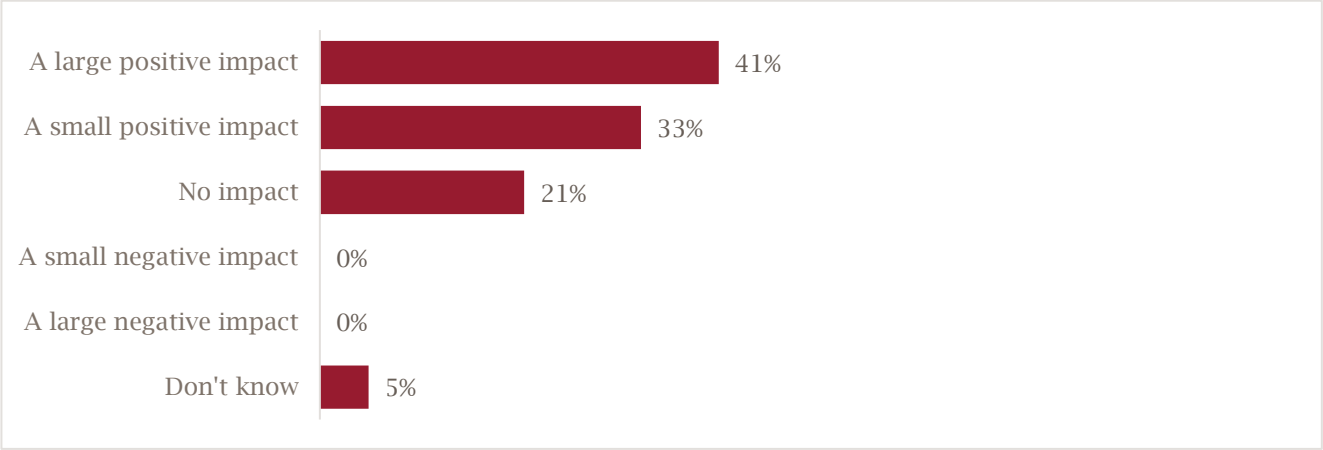
## FIGURE 94 OBSERVED IMPACT OF USING TCC CONCEPTS ON $CO_2$ EMISSIONS PRODUCED ON SITE




*Source: Beneficiaries survey. Q18C. What impact, if any, do you think using these tools, technologies and concepts have had on the construction phase of your projects in terms of the following indicators? : $CO_2$ emissions on site*
*Note: Base: Impact survey respondents already using TCC concepts (91)*

Just under three-quarters (74%) of those who were already using TCC concepts had observed a positive impact of TCC concepts on energy consumption on site. This includes 41% who had seen a large positive impact (41%). These proportions are similar to the expectations of those who were actively considering using TCC concepts.

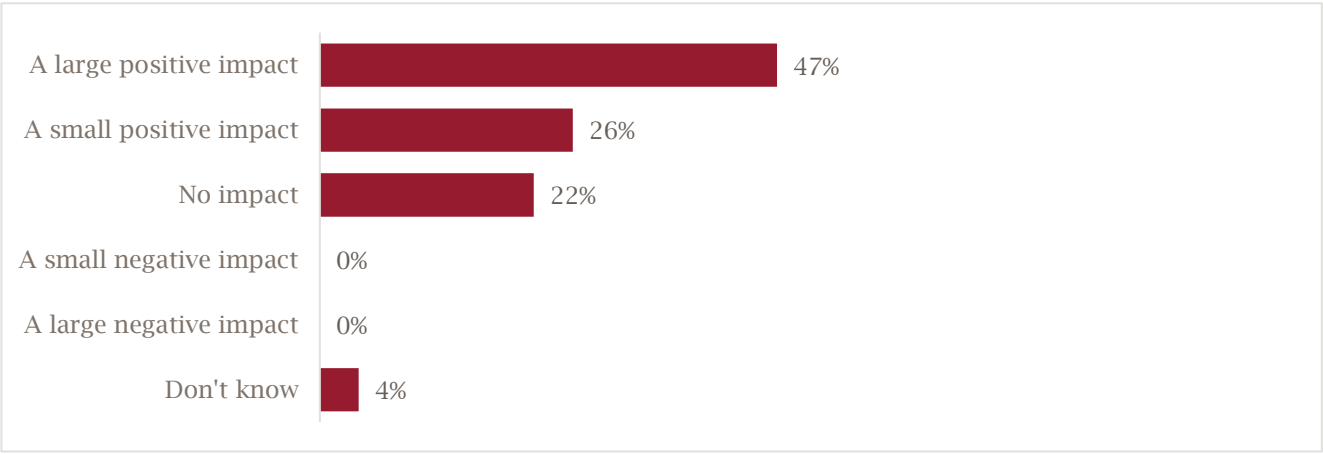
## FIGURE 95 OBSERVED IMPACT OF USING TCC CONCEPTS ON ENERGY CONSUMPTION ON SITE




*Source: Beneficiaries survey. Q18C. What impact, if any, do you think using these tools, technologies and concepts has had on the construction phase of your projects in terms of the following indicators? : Energy consumption on site*
*Note: Base: Impact survey respondents already using TCC concepts (91)*

Nearly three-quarters (74%) of those who were already using TCC concepts had observed a positive impact on waste produced on site. This includes 47% who had seen a large positive impact. None had seen a negative impact. These proportions are similar to the expectations of those who were actively considering using TCC concepts.

## FIGURE 96 OBSERVED IMPACT OF USING TCC CONCEPTS ON WASTE PRODUCED ON SITE




*Source: Beneficiaries survey. Q18C. What impact, if any, do you think using these tools, technologies and concepts has had on the construction phase of your projects in terms of the following indicators? : Waste produced on site*
*Note: Base: Impact survey respondents already using TCC concepts (91)*

# Annex C - ACTIVITY CASE STUDY TOPIC GUIDE

## C.1 - ORGANISATION PROFILE (3 MINS)

- Ask respondents to introduce themselves and their organisation:
  - Type of organisation (academic, main contractor, sub-contractor, public procurement, private procurement, business supplier or raw materials, consultancy and professional services, other)
  - Nature of construction activity (where they sit in the supply or design chain), technologies that they focus on, design and construction, MMC system (modern methods of construction)
  - Number of employees [only for businesses]
  - Turnover [only for businesses]
  - How long they have been established [only for businesses]
  - How long they have been working in construction-related activities or with partners in the construction industry
  - Where in the UK they are located and work?

## C.2 - ENGAGEMENT WITH THE CHALLENGE (5 MINS)

- When did your organisation's engagement with the TCC begin?
- How has your organisation engaged with the TCC?
- Which strand(s) have you engaged with? If more than one, probe for main one (Active Building Centre, Construction Innovation Hub, Network Plus, Collaborative & Development Grants (incl Research Leaders)).
- Did you receive funding from TCC? If so, was it through a competition/competitions? How much funding was received?
- What projects are the organisation working on in relation to the Challenge?
- What stage are these projects at?
- What are the objectives of the projects?
- Have these objectives been met or are they on track to be met? If not, why not?
- What other interaction has the organisation had with the Challenge? If not mentioned probe for:
  - Webinars
  - Events
  - Newsletters
  - Networking events
  - Anything else

## C.3 - OUTPUTS, OUTCOMES AND IMPACTS (15 MINS)

## TCC CONCEPTS

- How familiar are you with the TCC concepts?
- IF NECESSARY, PROMPT WITH CONCEPTS:
  - Integrated energy capture and storage systems (ABC)
  - Integrated thermal solutions (ABC)
  - Smart controls and monitoring solutions (ABC)
  - Energy trading and flexibility (ABC)
  - Off-site manufacturing
  - Digital assurance tools
  - Digital Twin
  - Information Management Framework/UK BIM Framework
  - Standardisation of product data
  - Digital compliance
  - Improving the whole-life value of buildings
  - Quality and validation processes for modern methods of construction
- How many of these concepts has your organisation used or incorporated into their business?
- Why have these concepts been used?
- [IF CONTRACTOR OR CONSTRUCTION SUPPLY CHAIN] What impact have these concepts had on your organisation?
- Probe for:
  - Impact on construction costs
  - Impact on delivery times
  - Impact on emissions [net 0 challenge]
  - Impact on exports
- How has TCC affected your understanding of these concepts?
- Do you think your organisation would be using these concepts if the TCC didn't exist? Probe into how they would expect it to be different.
- Does your organisation intend to adopt any of these concepts in the future? Why is that? Why have they not already been adopted? Probe for any Covid or Brexit barriers.
- Are TCC concepts being adopted by other organisations in the construction industry? If so, what impact are they having? How important do you think TCC has been to this?
- Probe for:
  - Impact on construction costs – fundamental impact, big impact
  - Impact on delivery times – new more homes, fundamental impact
  - Impact on emissions – fundamental impact and real benefit
  - Impact on exports
- Are TCC concepts being used in procurement processes? If so, what impact is this having?
- How important are the TCC concepts to your business and its future success?

## COLLABORATIONS

- How many collaborations has your organisation been involved with that relate to TCC concepts?
- What type of other organisations are involved in these collaborations?
- How valuable are these collaborations to your organisation? Do they allow your organisation to do things that they would otherwise not be able to?
- What role, if any, has TCC played in these collaborations? Would they have been possible without the Challenge? If so, would they have been any different if the Challenge did not exist?
- Have there been any changes in the number or nature of collaborations since your engagement with TCC? Have the quality or effectiveness of collaborations changed at all? If so, how?

## FUNDING (3 MINS)

- What co-investment did your organisation provide for the projects related to TCC? If not mentioned probe for:
- Staff, access to knowledge
    - Whether co-investment was for a project they received direct TCC funding for, or for TCC-related concepts where they didn't receive direct funding from TCC
    - Financial co-investment
    - Other forms of co-investment such as time, commitments etc.
- Did you receive any funding or in-kind support from other organisations? Would this funding have been possible without TCC funding?
- Did you receive any follow-on funding?
- If so, what was the nature of this follow-on funding? Would the follow-on funding have been possible without the TCC?
- Were there any funding conditions? If so, how did these impact the project(s)?

## WIDER AND UNINTENDED CONSEQUENCES (3 MINS)

- Were there any unintended consequences from the project(s)?
- What have been the impacts of these? Probe for both positive and negative.

## THE NATURE AND SCALE OF THE CHALLENGE'S ADDITIONALITY (10 MINS)

- Would the project(s) have gone ahead without the Challenge?
- How would they have been different? If not mentioned, probe for:
    - Timescales
    - Scale
    - Objectives
- Overall, how do you think your organisation's engagement with the TCC has impacted your organisation? Note: respondents may find it difficult to separate the impact of TCC, Brexit and Covid. If not mentioned, probe for:
    - Revenue [BUSINESSES ONLY]
    - Profitability [BUSINESSES ONLY]

  - Productivity [BUSINESSES ONLY]
  - Resilience
  - Future proofing
  - Access to finance/investment -
  - Any other impacts?
- How, if at all, does this differ from the impact you expected from working with TCC?
- How much do you think the impact of TCC has been affected by Covid-19? In what ways do you think the Challenge has been impacted by Covid-19?
- How much do you think the impact of TCC has been affected by Brexit? In what ways do you think the Challenge has been impacted by Brexit?
- **What impact, if any, do you think the Challenge has had on the environmental performance of built assets? Why is that?** *If not mentioned, probe for:*
  - $CO_2$ emissions
  - Building energy ratings
  - Waste
  - Other environmental factors
- What impact, if any, do you think TCC will have on the environmental performance of built assets in the future? Why is that?
- What impact, if any, do you think the Challenge has had on the wider construction industry and its supply chains? Why is that?

## LESSONS LEARNED (5 MINS)

- What went well with your engagement with the Challenge?
- What didn't go so well?
- Is there anything that could be improved in terms of how the Challenge engaged with you?
- Is there anything else that could be improved in terms of the Challenge?
- Is there anything else that you would like to add about the Challenge that we haven't discussed today?

# Annex D - ACTIVITY CASE STUDY - FULL WRITE-UPS

## D.1 - WEST MIDLANDS DFMA

| | | | |
|---|---|---|---|
| Activity name | West Midlands DfMA | Activity status | Complete, with some follow-on activity |
| Strand | CR&D | Funding awarded | £727,923 |
| Objectives | • Provide proof of concept for using MMC for small site residential homes<br>• Reduce life costs of residential social housing stock<br>• Reduce emissions of residential social housing stock | | |

### SUMMARY OF ACTIVITY

Walsall Housing Group (whg) led this consortium to improve local neighbourhoods with sustainable and affordable homes. The partners applied Design for Manufacture and Assembly (DfMA) to a proof-of-concept project. The consortium involved Hadley Group, Birmingham City University, Energy Systems Catapult and Northmill Associates.

The activity included the design and build of a prototype house that could be easily scaled up. To optimise the installation of the prototype, the consortium developed a knowledge-based engineering (KBE) tool that would estimate where the greatest emissions and costs come from across both the lifecycle of the build and home once in use and that would adjust the design to minimise investment and carbon footprint.

### ENGAGEMENT WITH TCC

This was the main activity that the consortium engaged with TCC on. However, a follow-on project has been commissioned to further develop the KBE and so two of the parties have also engaged with TCC on this follow-on project.

In general, the engagement was limited to CR&D and communications specifically about the activity. Some non-lead partners commented that they had very little awareness of other TCC activities or strands. None of the parties interviewed had any engagement with other TCC strands. Two of the partners had attended some forums and webinars but could not confidently attribute these to TCC.

### PERCEIVED SUCCESS OF ACTIVITY

The perceived success of the project against its objectives differed by partner. This is due to each partner having their own objectives from the activity. In general, the concept was seen to be a success and a viable option for future projects, but as the prototype houses had not been built as originally planned some of the parties saw this as not achieving all of the objectives. From their point of the view the objectives had not been to just design, manufacture and build a prototype house but also to complete the manufacture

and building of the subsequent 200 residential buildings that were planned on whg sites. None of these buildings will now be going ahead.

All parties interviewed perceived that they had gained from the activity, even if not in the way originally envisaged at the beginning of the project, and all interviewed had taken the concept forward in some respect. There was a general consensus that the KBE developed as part of the activity has been successful and warranted further investment.

### USE OF TCC CONCEPTS

The activity incorporated a number of TCC concepts, including UK BIM Framework, off-site manufacturing, digital assurance, digital compliance, integrated thermal solutions, smart controls and monitoring solutions, standardisation of product data and improving the whole-life value of buildings.

Awareness of the concepts among the activity partners was high when prompted, but some were not aware of which concepts the TCC is focusing on outside of the ones that were involved in the activity. This aligns with the limited engagement the partners had had with the wider Challenge. Generally, this awareness of the concepts was not attributed to the TCC, but was something that the parties already had.

The concepts involved in the activity were generally seen to be vital for keeping up with the industry and were aligned to current growth. All of the parties interviewed expected to be using the concepts in the future, but they differed in terms of whether they considered themselves to be early adopters or not. One of the parties had embraced the concept fully, saw lots of opportunities in the near future and expected 50% of their business in the next three years to be accounted for by projects involving the TCC concepts that were incorporated into the activity.

> *"This part of the market is exciting and it's growing. The opportunity to keep using this type of tech is definitely there."*

Others mentioned being constrained by their organisation's level of resources and so, while they recognised the benefits of the concepts, they admitted that they would not be the first adopters, even though it would help their organisation to reach their goals. They saw that role being played by larger, more commercial companies in the industry.

Interestingly, for some of the parties interviewed, while the 'UK Government' was seen to be driving increased uptake of TCC concepts, this was attributed to Homes England rather than the TCC.

> *"The market is genuinely changing to embrace them [TCC concepts]. The primary driver is UK Government, not that I want to give huge marks out of 10, but what Homes England has driven is genuinely starting to revolutionise the market."*

### COLLABORATION

Certain elements of the collaboration for the specific activity were seen the be successful. Generally, the collaboration with the academic partner was seen to have been successful, and the resulting KBE tool was expected to have a positive impact on the partners. However, the collaboration between whg and the Hadley Group was not seen to be as successful, predominantly because the planned prototype houses had not been commissioned by whg as planned. This commission was first delayed by Covid-19, and the whg reassessed its needs in light of Covid-19 and decided that the planned specification did not offer the

flexibility needed in a house design when occupants were expected to spend a greater amount of time at home, including greater home working.

Views on how integral TCC were to the formation of the consortium varied. Some of the parties felt that the consortium would have worked together at some stage without TCC involvement or engagement, although maybe this would have been less likely with the more industrial partners. However, others felt that they would not have engaged in the consortium without TCC's involvement and credited TCC with bringing the consortium together.

Overall, the parties interviewed were open to future collaborations and expected to continue to work with at least some of the other parties in some capacity in the future.

### FUNDING

All parties contributed in terms of co-investment. Some of this involved additional time beyond what had been budgeted for, while others contributed financially as well. Follow-on funding had been received by some of the parties to carry out further activity linked to the KBE tool. One of the parties had also made considerable investment off the back of the activity, linked to the full objectives not being met in terms of the building of the prototype houses. They had also furthered the designs used in the activity and were currently developing new solutions for their business incorporating those designs.

### ADDITIONALITY

Perceptions of whether the activity would have gone ahead without TCC input varied. Two parties interviewed expected that it would have gone ahead in some form, although this might have resulted in longer timings. The other party interviewed f that it would not have gone ahead as they were not aware of any other funding sources that could have been used for the activity. All agreed that if TCC investment had not existed they would have needed to seek investment from another source as the initial cost was too much for the partners to commit themselves.

Some of the parties interviewed also acknowledged the impact of the conditions attached to the TCC funding in driving the project forward at a pace that might not have been possible otherwise.

> *"The acceleration that TCC gave us made it happen really quickly and focused."*

As the activity sought to produce a proof of concept, it was hard for some of the activity partners to quantify the impact of the activity on their organisation. It was considered too early to tell. However, all of the parties interviewed expected a positive impact in the future from their involvement in the activity.

One objective of the activity is reducing the whole-life costs of residential buildings. Due to the timescales involved, it is too early to evaluate this objective. However, all of the parties interviewed agreed that they expected the whole-life costs to be reduced.

### SPILLOVERS

One of the partners has taken the concept and early prototypes from the activity and adapted it so that it can be used as part of a new project for the organisation. This new project involves the off-site manufacture of houses, very similar to the original design for the West Midlands DfMA activity, but on a platform that is designed to rise and fall in line with predictions of flooding levels. This would allow residential housing to be built on sites that have a risk of flooding and so would expand the possible sites

for residential buildings. They are currently at the stage of building a proof of concept. This has been fully funded by the activity partner and they consider it an evolution of the original activity.

## D.2 - ACTIVE OFFICE

| | | | |
|---|---|---|---|
| Activity name | Active Office | Activity status | Complete |
| Strand | ABC | Funding awarded | £800,000 |
| Objectives | • Test and prove the 'Active Buildings' concept with a range of building uses<br>• Build a prototype to showcase the benefits of MMC and integrated technologies<br>• Deliver a building that can optimise operation and make energy use as efficient as possible | | |

### SUMMARY OF ACTIVITY

SPECIFIC Innovation & Knowledge Centre, based at Swansea University, led this full-scale demonstration programme. The activity sought to build a prototype building using cutting-edge off-site manufacturing techniques and incorporating innovative technologies that generate, store and release solar energy. The other partners involved were Wernick, BIPVco, Naked Energy, NSG, AKZO Nobel and Dulas. The project is sponsored by Tata Steel and Cisco, who have both provided products that form different elements of the building.

The demonstration building was constructed on Swansea University's campus and sits alongside another demonstration programme, Active Classroom. It incorporates more thermally efficient materials and aims to actively respond to the environment around the building to minimise energy usage. It also incorporates the generation of its own energy via solar. The building also aims to provide a constant stream of smart intelligence to ensure that improvements to the efficient running of the building are continually made.

### ENGAGEMENT WITH TCC

The activity started in 2018 and for most of the partners this was the beginning of their engagement with TCC.

Levels of engagement with TCC varied among the activity partners. The activity lead, SPECIFIC, were also involved with two other ABC activities and a CIH activity. They had had fairly extensive engagement with TCC to publicise the Active Office activity and had delivered Engage With webinars as well as participating in webinars about other activities. Other partners were less involved and had only engaged with TCC on the Active Office activity. In fact, one interviewee stated that they had had no interaction with TCC at all since the project had completed in December 2018.

### PERCEIVED SUCCESS OF ACTIVITY

The activity was seen to have been successful and to have achieved its aims. The activity completed in December 2018 and since its completion it has received a lot of publicity through both TCC and non-TCC activities.

The activity was completed before Covid-19, so was not delayed at all by the pandemic. However, one partner discussed the impact of the pandemic on attitudes towards offices and remote working. Their concern was that office working is now less attractive and so, commercially, Active Office is now less feasible than it was before the pandemic.

A commercial partner also mentioned that they were struggling to take full advantage of the activity and roll out the concept to lots of other clients due to the current structure of the energy grid and the conservativeness of the construction industry.

> *"I just wish there was further momentum beyond this project. From our perspective it doesn't look like there was commercial tracking beyond this project because unless we can reduce pressure on the grid we're still going to have a problem. The construction industry is very conservative."*

### USE OF TCC CONCEPTS

Familiarity with TCC concepts varied by the activity partners. The lead organisation had already been familiar with the concepts being used in Active Office: integrated energy capture and storage systems, integrated thermal solutions, smart controls and monitoring solutions, and energy trading and flexibility. These concepts had previously been used in earlier prototype active buildings (Active Pod and Active Classroom), particularly smart controls and monitoring solutions. Their work had already focused on these concepts and would have continued to do so without engagement with TCC.

For other partners, awareness of TCC concepts was lower. One of the interviewees indicated they had learned about them through TCC and had not had much knowledge prior to their involvement with TCC. They also indicated that, as they were specialists in solar energy, they did not have any particular plans to adopt TCC concepts going forward.

For the activity partners that were in the construction industry, the concepts were seen to be 'massively important'. However, there were perceived to be barriers to adoption due to them not being demanded by current regulations and the current cost focus of procurement.

> *"Those who work in the construction industry are so driven by what their clients want that they find it difficult to use these concepts unless one of them is funded."*

> *"The whole procurement process is very cost driven, so the cost of using these concepts is the main barrier at the procurement stage."*

### COLLABORATION

All of the partners interviewed mentioned a number of collaborations with a variety of types of organisations, including universities, local authorities, architects and engineers. The Active Office collaboration was seen as valuable to the lead partner in particular as it helped them to obtain more data evidence and focus their work in the future. The other partner interviewed felt that the collaboration was useful for Active Office but would not benefit them much outside of the activity.

The TCC was seen to be instrumental in the collaboration for Active Office. The TCC had put the parties in touch with other so that they could bid for funding and, by awarding the funding, had provided the means for the partners to work together. However, they did not perceive the number or effectiveness of collaboration to have changed since their involvement with the TCC.

### FUNDING

The lead partner had received the funding from ABC, while the other partners interviewed had been paid market price for the products that they had provided as part of the prototype. In this respect, some of the non-lead partners considered that they had not had any funding and had not provided any form of co-investment. Although Cisco and Tata Steel are listed as project sponsors, it is not clear whether they provided any kind of funding or in-kind support.

No follow-on funding has been received and none is expected in the future.

### ADDITIONALITY

All of the parties interviewed agreed that the activity would not have been able to go ahead without TCC's involvement. The lead partner indicated that any development they may have done would have likely included different concepts as ABC was the driver of the ABC concepts being included in the prototype. Other partners mentioned the lead role that TCC had taken in bringing the partners together and how the activity would not have been possible without this involvement.

The high-profile nature of Active Office had positively benefited the partners, with some of the commercial partners attributing increases in revenue directly to their involvement in the activity. This had also led to an increase in staff to allow them to deliver this additional work.

> *"As a springboard it's been fantastic."*

Active Office was seen to be a good example of how the TCC can have a positive impact on the environmental performance of built assets as it is connected to the grid and is energy positive. However, the slow pace of change in the construction industry was seen to be a barrier to wider adoption.

### SPILLOVERS

No spillovers were identified, and none were expected.

## D.3 - AQUILA

| | | | |
|---|---|---|---|
| Activity name | Aquila | Activity status | Completed |
| Strand | CR&D | Funding awarded | £492,919 |
| Objectives | • Develop a tool that allows emissions on construction sites to be accurately measured | | |

| | |
|---|---|
| | • Reduce emissions on construction sites |

### SUMMARY OF ACTIVITY

Site plant equipment, particularly heavy earthmoving equipment, represents a major cost element in construction projects, with utilisation rates as low as 30%. Site equipment acts as a major contributor to on- and off-site congestion and air pollution.

BIM Academy, a consultancy developing digital solutions for construction, saw an opportunity to use BIM project planning to improve the productivity of site plant and equipment. It led a team to develop a digital platform that could better plan the use of plant equipment. The result is Aquila, which improves plant and equipment utilisation in real time, enabling everyone to view plant and equipment in a project by linking live data in a 3D model with time- or schedule-related information.

Using artificial intelligence, the information is processed to synchronise activity and create a sequence for what equipment is needed and when. The result is more streamlined projects and safer, cleaner and more productive sites.

### ENGAGEMENT WITH TCC

There was some confusion among the activity partner interviewed about which strand they had engaged with on the activity. They had previously been involved in other TCC-funded activities, including a precursor to Aquila towards the beginning of the Challenge. This earlier stage had been a feasibility study on how live data is linked to 3D models of sites and was completed in December 2019.

The interviewee mentioned they had primarily engaged with the CIH strand and had received 70% funding through this, but they had also interacted with N+ and were actively looking for further funding opportunities across multiple strands.

> *"We've tried to keep our finger on the pulse with most of the funding opportunities, because we'd like to secure more funding going forward."*

One thing the interviewee felt could be done better was after-care support; there had been very little engagement in how to leverage the work of the project. They felt it would be beneficial for TCC to be more involved in terms of providing support with commercialisation, connecting partners, identified funding opportunities or pipelines.

> *"The one thing they could do better is the after support and care, getting to the next stage of funding or commercialising things – that's the bit they don't do well at."*

### PERCEIVED SUCCESS OF ACTIVITY

When the tender for the second round of the TCC came out, the organisations applied and were successful. Aquila commenced in April 2020, at the start of the outbreak of Covid-19. As of September 2021, the project had been built, and some functionality had been demonstrated, but the interviewee felt there needed to be more funding to make it a viable commercial solution in the industry and build it on to pilot projects.

The activity aimed to develop a demonstrable product that can be used within the industry, and this objective has been met. The interviewee felt they had not got as far as they would have liked to in terms of commercialising the product, as it was not robust enough to start selling on a monthly basis or via a subscription service. That being said, it was acknowledged that this was not where the funding had been meant to get them to; the funding had been intended to demonstrate the functionality of the product, which it had done successfully.

Looking forward, they would like to secure more private or research funding to build the product as a solution to sell to construction companies and clients to manage plant equipment on site and would continue to look at ways to commercialise.

### USE OF TCC CONCEPTS

The interviewee was not very familiar with all of the concepts but used the BIM Framework on a daily basis. The organisation was doing a little bit of work on integrating smart controls and sensors into building models to get better insights into what was happening on site:

> *"We're not doing anything major in these spaces, they are more conversations at the moment."*

Additionally, there was a PhD student within the organisation who was looking at Digital Twin for asset information and how to manage assets moving forward, predominantly in the infrastructure space. They were also looking at compliance quite heavily in terms of fire and building safety:

> *"This [compliance] is definitely on our radar at the moment."*

Although not directly involved, there was awareness of the whole-life value concept. The nature of what the organisation does, i.e. making sure information is robust, does mean they touched on this concept, but it was something they supported with rather than consulting on.

Additionally, the organisation was acutely aware of the climate crisis and the need to seek opportunities to support businesses on the digital side of work.

### COLLABORATION

The organisation had worked in a consortium with Build Stream and Northumbria University and previously Walters Group. The interviewee felt the collaboration between BIM Academy and other partners worked well, and they had a close relationship with Northumbria University in particular; for example, some of the university academics were on their board. However, this collaboration had started long before TCC, hence the Challenge had been less impactful in harnessing these collaborations.

It was unclear whether there had been any changes in the number or nature of collaborations since engaging with TCC.

### FUNDING

The funding was awarded to the consortium as a whole, and each organisation then received a proportion of this based on resource needs. There were funding conditions, such as submitting completed timesheets and quarterly reports.

The partner organisation interviewed had not provided any co-investment for the activity, nor had it receives any funding or support from other organisations. They thought further funding would be necessary to move forward to the commercial stage. They were actively looking at follow-on funding to continue to develop the product, potentially using machine learning to improve functionality and begin to commercialise.

### ADDITIONALITY

The project would not have been able to go ahead without funding from the Challenge. The interviewee felt that the Challenge had positioned the organisation as an 'innovative partner', making it attractive to other companies, and had fostered new relationships and partnerships with different organisations and customers.

> *"Brilliantly, the thing about what Innovate do is that they allow you to fund riskier projects. It's not what we do day to day, but is an interest of ours, and we wanted to develop a platform. We wouldn't have brought in a team of two developers to support that without the funding."*

The impacts of working with TCC had been as expected. As the organisation had worked previously on projects with UKRI, they knew what to expect to some degree.

There had been a positive impact on the environmental performance of built assets, and the interviewee thought the impact would be big in the future too, owing to the research the TCC facilitates:

> *"I think it's fantastic in terms of the level of funded support they give you to develop and support innovative research."*

### SPILLOVERS

The interviewee commented that without the TCC, the project would not have got to the stage it had, and that it had gone beyond what they initially expected, which was having a project ready to be commercialised.

## D.4 - BEHIND THE METER BILLING AND TRENT BASIN

| | | | |
|---|---|---|---|
| Activity name | Behind the Meter Billing and Trent Basin | Activity status | Ongoing, set-up stage |
| Strand | ABC | Funding awarded | £484,936 |
| Objectives | • Understand the impact of real-time energy supply and cost data on behaviour change in terms of energy usage at home<br>• Blend on-site renewables and grid energy to improve energy trading and flexibility, and reduce costs of utility bills for residents | | |

| | |
|---|---|
| | • Reduce emissions of residential homes by generating, storing and using renewable energy in the local community |

### SUMMARY OF ACTIVITY

The University of Nottingham and SmartKlub set out to demonstrate how flexible, renewable energy systems can reduce energy costs and help cope with peak demand on the grid in a real-life context. The partners were successful in obtaining a derogation from Ofgem to set themselves up as an energy provider in an existing active building housing development in Trent Basin. The Behind the Meter experiment allows partners to test different scenarios in terms of energy supply and billing: from the standard set-up of households only being supplied by the grid and charged using flat rate or variable time-of-use tariffs to being billed for a mix of renewable in-house and grid energy supply, right through to the occupant being supplied entirely by community energy and essentially off-grid and being billed by a half-hourly tariff fully broken down by energy source.

The partners set out to identify whether real-time energy supply and price data could drive residents' behaviour in terms of adapting their energy usage according to this information. At-home meters will be used to provide this data. At the time of fieldwork, partners said that they were in the process of installing the meters, with a view of the activity commencing by the end of 2021.

The precursor of this activity is the Energy Research Accelerator and Innovate UK-funded Project SCENe (Sustainable Community Energy Networks).

### ENGAGEMENT WITH TCC

The Behind the Meter experiment was the main activity that the consortium had engaged with TCC on. One of the partners was also involved in a separate activity with the Active Building Centre. Engagement was therefore limited to the Active Building Centre. None of the parties interviewed had had any engagement with other TCC strands. Only one of the interviewed partners said that they had also had a look at the website dedicated to the Challenge as well as a number of blog posts.

### PERCEIVED SUCCESS OF ACTIVITY

As the activity was still at a set-up stage, the success its success could not yet be fully gauged . Nonetheless, there was agreement that the activity was on track to meet its objectives. One of the partners stated that the consortium had asked for an extension to carry out the Behind the Meter experiment due to Covid-19 related delays; however, this had not affected their confidence with regard to the consortium's ability to deliver the activity:

> *"The timings have changed but we are confident we'll get there."*

In general, the proof of concept was seen to be a success and a commercially viable option for tackling climate change:

> *"Overall, I think it's been very good. It's given us a perfect opportunity to prove what we said in theory is possible and creating that in practice with a business model that will suit market. And already other developers are phoning us and saying 'we want to do what you're doing at Trent Basin, we want to do it for our development as well'. So we're becoming known for doing this, which*

*is obviously really beneficial to us as a company and hopefully that means we can turn the funding into something that's commercially attractive and also combat climate change."*

From the point of view of the interviewed academic partners, the activity's impact was also regarded as positive, most notably because it had led to research publications and had enabled knowledge exchange with the commercial partners.

### USE OF TCC CONCEPTS

The activity incorporated a number of TCC concepts centred around energy, including energy trading and flexibility, smart control and monitoring solutions, and integrated energy capture and storage systems.

Awareness of the concepts among the activity partners was high when prompted, but partners were not aware of the rest of the concepts TCC was focusing on outside of the ones that were involved in the activity. This aligns with the limited engagement the partners had had with the wider Challenge. Generally, this awareness of the concepts was not attributed to the TCC, but there was agreement that the Challenge had helped enhance partners' knowledge of these concepts:

*"I was familiar with them before but it's certainly helped. People in the Active Building Centre have contributed to the project and were very helpful."*

The concepts involved in the activity were generally seen to be vital for keeping up with industry developments in order to meet the government's emission targets:

*"The only way we can reach the net zero target is by having more [energy] generation and storage in the built environment."*

All of the parties interviewed expected to be using the concepts in the future, whether in a commercial or research capacity. One of the parties operated by solely using these concepts when offering solutions to customers. As mentioned in the previous sub-section, they were already receiving enquiries from developers who wished to adopt the Behind the Meter approach to their housing developments.

### COLLABORATION

The collaboration for this specific activity was seen to be successful. This was attributed to good coordination between academic partners to avoid duplication of work, as well as being generally supported by ABC and having a platform to successfully exchange views among stakeholders.

Another positively viewed aspect of this collaboration was the TCC's flexibility to adapt to the 'disruption' caused by Covid-19, which had resulted in the activity being extended.

The TCC was seen as being an integral part of bringing the consortium together, not only in terms of providing funding to enable companies to take the risk of embarking on this activity but also in terms of providing the credibility and backing that the partners needed for obtaining the derogation from Ofgem:

*"The fact that you're a participant in such a programme also gives you credibility [„„] It helps open doors."*

The parties felt that it would have been unlikely for the consortium to have worked together without TCC involvement or engagement. It would have been hard for the academic partners to convince commercial

organisations to take the risk involved in proving a concept without external funding. Similarly, it would have been difficult for commercial partners to develop this concept by themselves.

### FUNDING

All the parties had contributed in terms of co-investment. Apart from staff time in kind, co-investment had also included a financial contribution of £50,000 as well as a funded PhD position offered as part of the programme. No follow-on funding had as yet been received for this activity but one of the partners was currently looking for sources that could provide this.

### ADDITIONALITY

There was agreement by all the parties interviewed that the activity would not have gone ahead without TCC's involvement. This was mainly due to the funding needed for this type of programme:

> *"The Transforming Construction Challenge took the risk out of the innovation we really wanted to do."*

One of the parties stated that, prior to TCC coming along, they had tried to get funding from BEIS for this activity but that the funding had fallen through. None of the partners were aware of other possible sources of funding for this project.

As the activity sought to produce a proof of concept, it was hard for some of the activity partners to quantify the impact of the activity on their organisation. It was considered to be too early to tell. Nonetheless, the interviewed commercial partner was already seeing interest in the concept from developers and expected this to positively impact the company's revenue in the future.

Most partners foresaw that the Behind the Meter experiment would have a positive impact on emissions, given the potential of using renewables in residential developments. However, since Behind the Meter is at a proof-of-concept stage, partners believed that it would take approximately five years for the concept to be brought to market and for these benefits to materialise.

### SPILLOVERS

As the activity is at a set-up stage, there have been no spillovers as yet.

## D.5 - GENZERO

| | | | |
|---|---|---|---|
| Activity name | GenZero | Activity status | Completed |
| Strand | CIH | Funding awarded | £4 million |
| Objectives | • Create new and improved design standards for school buildings that will facilitate a shift towards modern methods of construction and whole-life value | | |

| | |
|---|---|
| | • Support the move to net zero emissions for schools |

### SUMMARY OF ACTIVITY

The Department of Education (DfE) has partnered with construction innovators to collectively invest £4 million in GenZero – a project with ambitions to create new and improved design standards for school buildings. The work is supported by the Infrastructure & Projects Authority and aims to support the use of modern methods of construction (MMC) to help meet net zero targets through the buildings it procures.

The collaboration set out to explore and define new design and build standards to inform the next generation of school procurement. The new design guide will be used for all DfE-procured schools and will set a standard for the construction industry to deliver new schools that are net zero emissions.

The activity aims to forward the thinking and design of secondary schools and associated social infrastructure by developing a digital platform approach that can easily be replicated. At the time of interview, the activity had finished and a small classroom prototype was in development.

### ENGAGEMENT WITH TCC

The organisation had engaged with the TCC through the CIH strand for the most part. However, the interviewee had also worked with Digital Twin, the IPA and Construction Playbook, and was a stakeholder for the Value Toolkit facilitated by CIH. There was no mention by the interviewee of any additional engagement with TCC.

### PERCEIVED SUCCESS OF ACTIVITY

The interviewee felt the activity had been a huge success. Although there had been some delays due to Covid-19, these delays had not had a detrimental impact on the success of the activity.

There was seen to be a lot of potential for the activity to impact the environmental performance of built assets in the future, which was a core objective of GenZero. Furthermore, the Value Toolkit and Digital Twin were cited favourably as complementary means to assess $CO_2$ emissions:

> *"It helps to focus the mind of the client on achieving better environmental outcomes."*

Looking forward, it was thought that the activity, and the TCC, would spark a ripple effect in terms of pushing a reduction in emissions. However, the activity alone would not be able to achieve this. It would require inputs that go beyond TCC's remit, such as a change in government policy:

> *"The environmental performance of buildings in 10 years will be better than now, that's the direction of travel, and I think the work of the Challenge and the hub [CIH] will be part of that, but it's a bigger picture, it is government policy, the wider commercial landscape, and the stick and carrot of policy to push us that way."*

### USE OF TCC CONCEPTS

Prompted awareness of TCC concepts was high and these were deemed important for innovation and progression:

> *"The policy and direction of travel for the UK central government and associated orgs is MMC and off-site, digitisation, standardisation, automation […] if I'm not a leader in that space I'd be overtaken quite quickly by competitors."*

There was prompted familiarity with some concepts, such as MMC and off-site manufacturing, owing to the nature of the interviewee's work. Awareness of other concepts, which were less familiar, for example Digital Twin and digitisation, had increased since involvement with the TCC. It was acknowledged that these concepts were important to remain competitive and would likely have been used regardless of TCC's involvement. At the time of interview, the organisation incorporated MMC and off-site manufacturing into its business. Going forward, it intended to adopt the Digital Twin concept in future work for the NHS, although it should be noted that the interviewee had worked on projects involving this before.

TCC concepts were expected to be adopted by other organisations within the industry, albeit with a more gradual uptake, and this was attributed by the interviewee to the TCC bringing together different organisations with similar but competing aims:

> *"Some organisations will experience a more difficult leap to some of these concepts than others, and therefore may experience some early negatives in the process e.g. for a developer to go from traditional methods of construction to MMC might mean that in the early stages, cost, time and re-strategising the processes of their company might incur early-stage costs, but the wider benefits to their organisation I think will be very positive – people talk about 30-50% savings in costs and time by moving to standardisation and MMC."*

> *"I think the uptake, like with anything, will be slow to start with and I can see the acceleration of that uptake across the industry happening now. If you look at residential construction, there's a real push for standardisation and digitisation there [...] there's a real push to it from all corners of the market."*

Overall, the concepts were seen to be key to remaining competitive and keeping up with government policy, and were important for the future success and progression of the industry.

### COLLABORATION

Collaborations with other stakeholders such as academics, government departments, construction companies, CIH and design consultants had proved very valuable for business networking and development.

The TCC was deemed instrumental in these collaborations, not only in providing funding but in providing a hub for like-minded organisations to get together, as opposed to a decentralised network of collaborations. While the frequency of such collaborations had not changed, the interviewee credited the TCC for better quality collaborations.

### FUNDING

The organisation had provided two members of staff for the TCC-related projects, and no additional funding had been provided by other organisations in the consortium or by the TCC. Follow-on funding had been provided by CIH to build a prototype of a classroom, and matched funding had been given by DfE and from the supply chain which was building the prototype. However, the interviewee's organisation was not

involved in this. It was thought that this follow-on funding would have been possible without TCC because of funding from DfE and other companies.

### ADDITIONALITY

The Challenge was critical to the project implementation, with it being seen as being almost impossible to implement without it. As the interviewee expected, it was felt that engagement with the TCC had future-proofed the organisation in terms of collaborations and consulting services offered around MMC and off-site construction:

> *"I can't see a way it would have gone ahead without the Challenge funds. It may not have been impossible, but I can't see where those funds would have come from and how that would have been set up to deliver."*

### SPILLOVERS

There had been one spin-off project from GenZero, which was a classroom prototype, and the interviewee felt it would have been beneficial to look at what other projects could have followed suit, but there were no channels to do this easily. Better engagement could be fostered through having a forum within CIH which would address this.

## D.6 - HIPER PILE

| | | | |
|---|---|---|---|
| Activity name | HIPER Pile | Activity status | Complete |
| Strand | CR&D | Funding awarded | £614,357 |
| Objectives | • Develop lighter cement-free concrete piles that have the same bearing capacity, in order to reduce carbon emissions by up to 80%<br>• Embrace off-site manufacturing in building foundations to increase safety and speed up delivery<br>• Create wireless sensors that can measure the properties of the piles in terms of strength and durability so that piles can be re-used for new buildings in the future, thus reducing waste<br>• Incorporate renewable technologies into the void of the piles so that the piles are able to produce, manage and store energy as part of an active building | | |

### SUMMARY OF ACTIVITY

Keltbray Piling led this consortium to improve the environmental performance of building foundations. The consortium involved Keltbray Piling, Converge, DB Group and Arup, as well as an academic partner from City, University of London.

The partners embraced off-site manufacturing to create lighter piles made with an eco-friendly, cement-free material, which has an 80% lower carbon footprint compared to the production of traditional piles. The piles were equipped with smart sensors which monitor strength and durability to give future developers the confidence that the piles can be re-used, thus making these piles an asset for circular economy aims. The partners have also identified the potential for equipping the void part of the piles with renewable technologies so that emissions can be reduced over the whole lifecycle of the building.

### ENGAGEMENT WITH TCC

HIPER Pile was the main activity that the consortium had engaged with TCC on. However, one of the partners had not engaged with TCC directly as their involvement in the project had been mediated by a commercial partner.

In general, the engagement had been limited to CR&D and communications specifically about the activity, including dissemination of findings at an event organised by UKRI. None of the parties interviewed had had any engagement with other TCC strands or activities. One of the partners had attended an online event about potential opportunities for further funding but could not confidently attribute this to TCC.

### PERCEIVED SUCCESS OF ACTIVITY

All partners considered the activity to be a success, most notably in terms of environmental performance. The HIPER Piles were seen to have a low carbon footprint, the potential to be re-used and the ability to generate and store energy:

> *"We were using a special cement-free concrete which effectively lowers considerably the embodied carbon of the material components of it to 80% lower carbon and […] the hope [is] that one day when a new building is constructed these piles are left in the ground for further use."*

> *"Reducing emissions by generating energy from the foundations of buildings."*

Two of the three partners interviewed also emphasised that taking the manufacture of piles off site reduces safety risks for operatives and saves time, as opposed to creating the piles on site.

All partners perceived that they had gained from the activity and felt that all parties had achieved what they had set themselves, in spite of the project being delayed due to Covid-19:

> *"It has been a fantastic opportunity for the company to be involved in."*

> *"Everyone was able to achieve the goal they initially set themselves."*

There was a general consensus that the HIPER Piles that were developed as part of the activity had been successful and warranted further investment. In this regard, some partners would have liked more information on follow-on funding from TCC and more flexibility to adapt the project activities to interim findings:

> *"Access to more funding could be made easier, especially for projects that have been proven to be successful and provide good value for money."*

### USE OF TCC CONCEPTS

The activity had incorporated a number of TCC concepts, including off-site manufacturing, smart controls and monitoring solutions, integrated thermal solutions, improving the whole-life value of buildings, digital assurance, and quality and validation processes for modern methods of construction.

Awareness of the concepts among the activity partners was high when prompted, but some were not aware of which concepts TCC was focusing on outside of the ones that were involved in the activity. This aligns with the limited engagement the partners had had with the wider Challenge. Generally, this awareness of the concepts was not attributed to TCC, but the partners agreed that they had all gained a deeper understanding of these concepts through their involvement in this activity.

The concepts involved in the activity were generally seen to be essential for keeping up with the industry and meeting the government's net zero targets. All of the commercial parties interviewed expected to be using the concepts in the future, albeit to different degrees depending on the type of company they were and how they operated. One of the parties had embraced the concepts that were relevant to their area of expertise, while the other commercial partner was currently in the process of having internal conversations to adopt these concepts.

### COLLABORATION

Certain elements of the collaboration for the specific activity were seen to be successful. Generally, communication between academic and commercial partners was considered a success.

> *"The regular meetings structure, the quarterly meeting catch-ups with the monitoring officers […] the whole structure is well done to ensure compliance between parties."*

Views on how integral the TCC had been to the formation of the consortium varied. The commercial partners felt that the consortium would have worked together at some stage without TCC involvement or engagement, although in a less structured way and at a slower pace. Nonetheless, all partners credited the TCC with bringing the consortium together and facilitating the collaboration:

> *"We would still be having these conversations anyway but I don't want to diminish the value of the grant. We were engaging with each member of this consortium anyway but the fact that each member had the opportunity to trial innovations on a part-funded basis reduced the barriers to doing so because a lot of contractors don't have the funds or appetite to sit there and play expensive experiments to get an understanding of things. The grant facilitated to a great extent those developments […] and put them higher up on the road map."*

The academic partner, in contrast, felt that their involvement in the activity would not have been possible at all without the TCC funding and stated that it would have been 'unusual' to get such good industry-academia collaboration without TCC enabling this as it would have been difficult to get the commercial partners on board without the funding. One of the commercial partners, which was not a construction company, echoed this lack of 'appetite' from companies to get involved in these types of activity without funding:

> *"There's a different culture and mentality in terms of failure and learnings […] Understandably so, there's lower risk for us trying a switchboard 1,000 times and failing at each iteration, compared to taking on a multi-million-pound safety critical asset and making mistakes there. […] It's also a very*

*low margin industry for a lot of the contractors involved, which doesn't leave them a huge amount of money for R&D activities necessarily."*

### FUNDING

All the parties had contributed in terms of co-investment. Most commonly, this took the form of in-kind staff time, while one of the partners had also contributed financially by providing 30% of the value of the grant themselves (this amounted to approximately £100,000-£120,000). No follow-on funding had been received yet by any of the parties to carry out further activity linked to the HIPER Pile. However, the academic partner was planning to apply for follow-on funding from Innovate UK in the near future.

### ADDITIONALITY

Perceptions of whether the activity would have gone ahead without TCC input varied. Two parties interviewed expected that it would not have happened at all, while one of the partners believed the activity would have gone ahead in some form, although this might have resulted in longer timings, fewer commercial partners being on board and less academic oversight. In the absence of the TCC, funding was seen as the main barrier to bring this activity to fruition.

One of the parties interviewed also acknowledged the impact of the conditions attached to the TCC funding in driving the project forward to an extent that may not have been possible otherwise:

*"I'm sure it's improved with the requirements, the reporting, regular meetings. It introduced a strong collaborative environment, which is good."*

As the HIPER Pile is not yet commercially available, it was too early for some of the activity partners to quantify the impact of the activity on their organisation. However, all of the parties interviewed expected a positive impact in the future from their involvement in the activity in terms of revenue and the possibility of conducting further R&D activities.

The core objective of the project centred around reducing emissions from creating building foundations, all the way from production to whole-life energy performance and re-usability. Although it was too early to tell whether these potential benefits would materialise, all partners were confident that this would be the case. This also applied to expected benefits around cost reduction (as the piles will require a lower amount of material) and increased construction safety (by taking the production of piles off site).

### SPILLOVERS

There had been no spillovers yet. Two of the partners expected adoption of the HIPER Pile across the industry more widely to take at least two years because one of the commercial partners had a licence/patent of this product at the time which was due to expire in two years' time.

## D.7 - IDEMA PANEL HOUSE

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|---|---|---|---|
| Activity name | IDEMA Panel House | Activity status | Complete |

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|---|---|---|---|
| Strand | CR&D | Funding awarded | £211,123 |
| Objectives | • Provide a proof of concept of easy to assemble, pre-manufactured homes that are well insulated so as to improve productivity and reduce costs<br>• Produce affordable net zero homes that can generate energy to meet its own energy requirements and charge an electric vehicle<br>• Speed up the delivery times of construction projects by adopting an off-site manufacturing approach | | |

### SUMMARY OF ACTIVITY

Mills Power Architecture led a consortium to deliver faster, cheaper, net zero carbon homes. The partners set out to achieve this by adopting a pre-manufactured approach that uses repetitive structures while still giving designers the autonomy to select a design that matches their needs and budget.

The consortium brought together partners with expertise in a wide variety of fields including architecture, robotics, energy, sensor networking and thermal insulation. The consortium consisted of Mills Power Architecture, i3D robotics, L&B Services, DG Cities, Price & Myers, University of Greenwich and University of Bath. The partners developed an Intelligent Design for Manufacture and Assembly (IDEMA) Panel House, which builds on manufacturing, robotics and sensor technology to create efficient 'click-and-assemble' homes. By adopting this approach and using carbon-neutral materials, a 15% improvement in productivity can be achieved, as well as a 30% reduction in costs. From an environmental perspective, there is a reduction in emissions by using carbon-neutral materials and producing homes that can generate even more energy than they need, thus providing whole-life value.

### ENGAGEMENT WITH TCC

The partners interviewed had been involved with the TCC since the start of its existence. However, their engagement had been generally limited to the IDEMA Panel House activity. One of the partners had visited the Active Building Centre but no collaboration or further engagement had emerged from that visit.

While one of the interviewees was also involved with another TCC activity, they were not sure what strand the activity sat in.

There was no recognition of receiving more general communications from TCC and low awareness of what other activities TCC is supporting.

### PERCEIVED SUCCESS OF ACTIVITY

Although the activity was generally regarded as a success, one of the partners believed it was too early to know whether the activity had been successful as they had not yet used the IDEMA Panel House concept commercially. Nonetheless, the activity was now at a proof-of-concept stage and one of the partners intended to get planning permission to start a construction project using the IDEMA concept for a private client.

There was seen to be a lot of potential for the IDEMA Panel House activity, particularly when it comes to delivering environmentally friendly and affordable buildings, as well as tackling housing shortages.

> *"If people adopt the IDEMA concept then you'll be able to move to zero carbon homes which are manufactured more cheaply."*

The perceived success of the activity had also given partners, most of whom are SMEs, a confidence boost:

> *"It's made us more confident. Because the project was a success, we're more confident in our own abilities and how we market."*

In addition to this, while one of the partners said they were yet to see financial benefits from this activity, the other interviewed partner stated that the IDEMA Panel House activity had helped them 'win additional contracts'.

In general, partners agreed that the activity had improved their knowledge base and their thinking for delivering projects.

### USE OF TCC CONCEPTS

Off-site manufacturing was the core concept that the activity focused on. However, other concepts were also incorporated into the activity, including improving the whole-life value of buildings, quality and validation processes for modern methods of construction, energy trading and flexibility, and smart control and monitoring solutions.

Awareness of the various TCC concepts measured was mixed. None of the partners that took part in the interviews were aware of these concepts unprompted. One of the partners was familiar with most of the concepts when prompted while the other partner was not familiar even when prompted. This was because these concepts had not yet been adopted by this partner because they considered that a certification process would be required in order to do this and they provided a very individualised service to their clients.

One of the partners did not attribute their knowledge of the concepts to TCC and believed that these concepts would be being used anyway, even without TCC's involvement. The other partner was not familiar with most concepts and was not using them but attributed their knowledge of quality and validation for modern methods of construction to TCC. There was a general lack of knowledge about whether these concepts were being adopted by the construction industry more widely. However, one of the partners felt that the industry was adopting off-site manufacturing in particular.

These concepts were seen as generally important for the industry, most notably to enable the creation of low carbon, energy efficient buildings that are affordable.

### COLLABORATION

Although the TCC was seen to have played a role in bringing together all the partner organisations to work on the IDEMA Panel House activity, the interviewed partners believed that this collaboration would have happened anyway, even if TCC had not existed. This was because most of the commercial partners were small organisations and had many collaborations outside of IDEMA Panel House. As small companies, these collaborations were considered essential not only to be able to afford R&D and but also to reach the expertise that their companies did not have.

The collaboration between commercial partners and local authorities for this activity was seen to have been successful:

> *"Everyone did what they were tasked to do in a timely way and were keen to work together."*

However, one of the partners stated that the collaboration with academic partners had not worked so well and, as a result of this experience, they would be less inclined to work with this type of organisation in the future. They felt that the academic partners had not achieved what they set out to (but they did not wish to provide more detail about this).

### FUNDING

All parties had contributed in terms of co-investment. Most commonly, co-investment involved in-kind staff time, with one of the interviewed partners contributing financially as well (30% of the value of the grant they had been awarded, which amounted to £50,000 of financial co-investment). Follow-on funding had been received from a private client by one of the parties to carry out a project using the activity concepts.

### ADDITIONALITY

There was agreement that the IDEMA Panel House activity would not have been possible without the involvement of TCC. This was mainly due to the funding needed to undertake R&D:

> *"It would not have gone ahead, because we would not have been able to meet the costs of this project."*

This activity was seen to have the potential to have positive environmental impacts in the future, not only in terms of emissions but also in regards to energy and waste:

> *"Energy would come from solar or hydrogen and it won't generate any emissions. […] A report came out recently saying 13% of what's produced on site is wasted. If you use IDEMA, you only ship what you need so that's 13% less waste."*

Despite this, one of the partners stated that the wider impact of the TCC on the environmental performance of built assets was not necessarily positive, at least at the moment:

> *"A negative impact, because of large companies that have received funding and not changed the ways in which they build houses. [They keep building houses] without taking into account any consideration for environmental issues."*

### SPILLOVERS

As the activity had been completed recently, partners were still engaging with the industry to bring this concept to market.

One of the partners also mentioned the Stronger Stories article that TCC wrote about this activity and stated that the learnings from IDEMA were now being used by other sectors:

> *"A number of lessons learned from that programme are now being used in other sectors, including robotics, looking at road assets and welding."*

## D.8 - OPTIMISED RETROFIT PROGRAMME

| | | | |
|---|---|---|---|
| Activity name | Optimised Retrofit Programme (ORP) | Activity status | Ongoing. Funding until September 2022 (extended by 6 months due to Covid-19) |
| Strand | ABC | Funding awarded | **[TBC]**. |
| Objectives | • Evaluate how well new retrofit measures have performed | | |

### SUMMARY OF ACTIVITY

Legislated in the 2015 Wellbeing of Future Generations Act, the government in Wales is pioneering using innovative ways to decarbonise the environment for future generations. It committed £19.5 million in 2020/21 alone to kickstart the initiative. To deliver on this new legislation, the Welsh government has enlisted support from the Active Building Centre Research Programme, based at Swansea University, which was already working to improve the data generated from newly built properties.

The Active Building Centre Research Programme is using data to help retrofit and decarbonise social homes in Wales. It aims to reduce the carbon footprint of around 2,000 existing homes as part of the Welsh Government's Optimised Retrofit Programme (ORP). By bringing together a range of active energy experts, research hubs, local authorities and social housing providers, ORP aims to create new retrofit standards with the overarching aim of improving affordable warmth in homes, reducing emissions, and creating 15,000 new jobs in Wales.

### ENGAGEMENT WITH TCC

The activity is engaged with the ABC strand of the TCC, and funding was received through competition. Swansea University received the full £36 million of funding, which was then split out between the consortium partners, with Swansea retaining around £15 million of this. The project was due to finish in March 2022, but it is anticipated this will now finish in September 2022 due to delays caused by Covid-19. The most notable impact of Covid-19 on this activity is this delay. Covid-19 also meant that activity meetings had to move online but this did not cause problems for the interviewed parties.

Aside from the activity, there was some additional interaction with the Challenge at a Future Build event which took place just before the outbreak of Covid-19. The TCC had a stand, and the entire TCC portfolio attended the event. Swansea University also joined, presenting and giving talks with consortium partners. The interviewee mentioned that there was occasional interaction with CIH and engagement with other TCC partners.

### PERCEIVED SUCCESS OF ACTIVITY

The activity aims to evaluate how well the retrofit measures have performed, and this objective is on track to be met. However, the interviewee was aware that the target number of homes to be retrofitted has not been met and has been scaled back. However, this will not impact their specific activity objectives.

There was limited information on any wider impact on stakeholders, or how much of an impact was expected in the future.

### USE OF TCC CONCEPTS

Prompted awareness of the TCC concepts was relatively high, particularly those relevant to this activity, and those concepts with a research focus – for example, integrated energy capture and storage systems, integrated thermal solutions and smart controls and monitoring solutions – had been incorporated into their business.

Knowledge and use of such concepts were largely attributed to the TCC, as well as engagement with other stakeholders working in the field, such as energy networks and the Welsh government, through involvement in the activity. The interviewee pointed to the research facilitated under TCC and the projects they had been working on as part of the Challenge for increasing knowledge of the concepts.

> *"My understanding has grown a lot during my time at TCC in these fields."*

There was acknowledgement that TCC concepts were being adopted by other organisations in the construction industry, although it was perceived that these were mostly in the early stages. The TCC had been valuable in providing standardisation, and the concepts were crucial to the construction industry overall, particularly in relation to energy, and were empirical in achieving the UK's decarbonisation ambitions:

> *"It's something I know is becoming more prevalent in all areas of the construction industry. It's the need to provide smart energy systems and smart energy response mechanisms for the electrical grid."*

> *"A lot of these small companies have not appeared because of TCC – a key value of TCC is not that it has created anything new [technology], but it's about standardisation because a lot of it is still in its infancy, which should help to speed up growth."*

> *"It feels like early days but there's a lot of activity in the industry. Over the last five years there have been a lot of companies providing this, particularly in the residential market e.g., electrification of heat, but ultimately, it's a very, very small percentage. It's still very much in its infancy but it's happening in the real world, and it's slowly gathering momentum."*

### COLLABORATION

Collaboration with other partners was seen as pivotal, and the university had been involved in 5-6 large collaborations with around 20 partners, including other universities, local authorities, energy service providers and technology suppliers.

ABC had brought together 10 universities under a single research programme, which had been their largest collaboration to date, and was funded and facilitated by TCC. This collaboration had been hugely beneficial and had brought together various expertise across the different universities. Something of this scale had not been done before, and this wider consortium had meant there was a greater offering for industry partners:

> *"The University doesn't have all of the expertise, so we wouldn't be able to do 90% of our workload without the other academic partners."*

### FUNDING

The University had provided 20% of the funding, and no additional funding or income from other organisations had been received.

At present, no follow-on funding had been received but funding directly from The Engineering and Physical Sciences Research Council (EPSRC) was being looked into at the time of interview.

### ADDITIONALITY

The project would have gone ahead regardless of the Challenge as the Welsh government has already been investing in retrofits for social housing and low energy homes for a number of years. However, the TCC had funded the evaluation to provide data on the impact of retrofit, which was otherwise lacking:

> *"We've hopefully improved the quality [via TCC project] by writing specifications around monitoring and control of energy and we've increased the knowledge share – rather than saying we've retrofitted 10,000 homes we'll be able to tell them how much of a performance increase they've got i.e., numerical evidence. It will help the rest of the industry as there's next to no data on the impact of retrofit out there."*

There was limited knowledge on how the engagement with TCC had impacted the university as a whole, which is understandable given that the interviewee had been brought in especially for this activity.

### SPILLOVERS

No specific spillovers were mentioned above and beyond the expected impact on retrofitting for other actors in the industry. It was expected that the lessons learned from the activity would be taken on by others in the industry taking on retrofitting programmes. One of the key lessons was how to 'sell' retrofitting to tenants:

> *"It has been difficult getting residents (who are social tenants) to sign up [to retrofit], as it'd be several weeks of having builders in your house and if they're happy with the energy bills they're paying then they have no particular motivation to have their house turned upside down for six weeks."*

> *"One of the challenges is that it's a lot of work for not much immediate payback."*

## D.9 - VALUE TOOLKIT

| | | | |
|---|---|---|---|
| Activity name | Value Toolkit | Activity status | Ongoing – being tested in the market |
| Strand | CIH | Funding awarded | Unknown **[TBC]** |
| Objectives | • Provide the sector with a tool to help embed value-based decision making | | |

| | |
|---|---|
| | • Provide a consistent, consensus-based process for defining value<br>• Support a shift towards smarter, better decision making which ensures that buildings are delivering whole-life value |

### SUMMARY OF ACTIVITY

The Value Toolkit has been developed by over 120 different construction clients, companies, professional bodies and membership organisations, led by the Construction Innovation Hub. The activity aims to further the work of 'Procuring for Value', led by the Construction Leadership Council, by developing a suite of tools and processes to embed value-based decision making throughout the construction investment lifecycle. It is predominantly focused on large-scale public sector procurement but is also applicable to the private sector.

The activity involved work to agree a consensus definition of value, and then an approach to the measurement of value. In the Toolkit, value is measured under four 'capitals'; natural, social, human and manufactured. The activity organisations then worked together to design indices for value and to develop measurement tools for each of these capitals. At the time of interview, the toolkit was being tested on live projects by clients and practitioners. This testing was due to finish at the end of October 2021.

### ENGAGEMENT WITH TCC

As this activity has involved so many organisations the levels of engagement with the TCC understandably varied considerably. A number of the organisations interviewed had been engaging with the TCC since the very start of its existence. Equally, some of the key organisations involved in Value Toolkit had also previously been involved with the CLC's Procuring for Value activity and saw Value Toolkit very much as a continuation of this work., albeit with a renewed focus and objectives.

For all of the organisations interviewed, Value Toolkit was the main way that they had engaged with the TCC, with some of them having had indirect contact only as they had been sub-contracted by other organisations. While some of the interviewees were also involved with some of the other TCC strands or activities, for the most part engagement did not go beyond this specific activity. There was limited recognition of receiving more general communications from the TCC and low awareness of what other activities the TCC was supporting.

### PERCEIVED SUCCESS OF ACTIVITY

The Toolkit was currently at testing stage. Although success could not yet be measured, there was optimism that the Toolkit had the potential to significantly disrupt public procurement in particular.

Some perceived the activity to be a bigger undertaking than anticipated and that the implementation had been tougher than they had expected. They had underestimated the challenge of the engagement and training that was needed for Value Toolkit to be adopted by public sector organisations:

> *"I hadn't realised just how much engagement and training and cajoling and reminding and all these things would be needed."*

> *"It does demand a huge amount of client engagement as well. It doesn't matter how much a consultant or a contractor says we think is a really good way of doing something, if the clients aren't*

> *wholly engaged it starts to get diluted very quickly. What we are experiencing with clients is that the very top where the engagement is happening, so at Director level, for example in the Department for Education, people are nodding in all the right places. But actually we work on loads of DfE schemes, nothing to do with Value Toolkit, so when I talk to my colleagues who work at DfE they say they've heard about it from me, but not from anyone else, so it's not filtering down."*

Others suggested that there might be an element of 'new initiative fatigue' or too many competing priorities for construction companies for uptake to be quick and widespread:

> *"It's a very difficult market in regard to availability of resources, so getting clients' attention to things like the Value Toolkit is hard because there really is a viability and affordability challenge because there's not a lot of head room to talk about long term value."*

There was seen to be a lot of potential for the Value Toolkit, and therefore the TCC, to positively impact the environmental performance of built assets in the future. However, it was very dependent on what the aspirations were of the organisations using the Toolkit. If their aim was to improve environmental performance then the Toolkit would help them to do this and hold them to account, but if that was not their aim and they were instead driven by financial performance or other objectives it would help them to meet those objectives at the expense of environmental performance:

> *"The Toolkit has the facility to have enormous impact, because what the Toolkit gives you is a way of actually converting aspirations into measurable outcomes."*

### USE OF TCC CONCEPTS

Awareness of the various TCC concepts measured was high among the participants involved with this activity. However, due to the nature of the organisations involved (including professional bodies, membership organisations and consultancies) most were not actively using TCC concepts themselves. However, their members and clients were. This was what had driven their awareness of the concepts. For some, there was little knowledge that TCC was focusing on these concepts and as such they did not consider them to be 'TCC' concepts. They also did not attribute their knowledge of the concepts to the TCC.

There was a general consensus that these concepts would have been being used anyway without the TCC's involvement. However, some felt that the TCC had increased the speed of take-up of these concepts and had helped them to be more standardised. There was also a general agreement that use of the concepts in the industry would continue to grow and were important to the future of the industry.

### COLLABORATION

There was agreement that CIH had played a pivotal role in bringing all of these organisations together to work on Value Toolkit, and that this would not have been possible without it being led by someone like CIH. Some even mentioned that the levels of collaboration might not have been possible without Covid-19. The activity had been easily able to progress while other construction work had been limited and the use of remote collaboration tools had worked really well for the activity.

However, collaboration was not as applicable to this activity as it was to some of the other TCC activities. Although an incredibly large volume of organisations had been involved in the development of the Value Toolkit, most of the interviewees stated that they had no other collaboration outside of Value Toolkit. In

fact, some of the Value Toolkit participants were working through another organisation and had very limited direct engagement with CIH. As such, they did not feel that they had fully collaborated on the Value Toolkit, more that they had just performed their role.

### FUNDING

The general model for involvement with Value Toolkit is that the participants will be remunerated for half of the time they actually spend on Value Toolkit activities. However, most of those interviewed for this case study indicated they had in fact spent more time than originally planned and so that remuneration accounted for a lower proportion of their time spent. In some instances, their participation had begun in a voluntary capacity and was only partly remunerated at later stages of the Toolkit's development.

In general, this funding arrangement was seen to be fair and the participants interviewed recognised the long-term potential impact of the Value Toolkit. They felt their participation was beneficial to them and their organisation even if they were not remunerated fully.

None of the organisations interviewed were receiving follow-on funding, although the funding for the involvement in Value Toolkit was still ongoing at the time of interview. One interviewee commented on what they perceived to be a 'short-sightedness' through there being no current plans to fund keeping the Value Toolkit up to date in the future:

> *"It puts a bit of risk into the actual life of the tool."*

### ADDITIONALITY

There was agreement that Value Toolkit would not have been possible without the involvement of the TCC, and CIH in particular. Although there was some ambition to further the thinking in this area, it needed an organisation with authority and funding to bring all of the activity participants together and to fund the pieces of work that needed to take place. Some small pieces of work might have been undertaken by individual organisations if the TCC had not been involved, but the learnings from that work would not have been shared across the industry and would have stayed within the organisation that had commissioned the work:

> *"It has certainly, for our organisation, made us think about the way we approach particularly large public sector commissions. We work in the private sector as well and it's probably had less impact on that. It's probably had less impact on small commissions. But on large public sector commissions it has really made us think hard about how we approach clients, the skill sets our staff need, some of our enhanced IT facilities that we've invested in now. I can plot you a direct link between what we've done on Value Toolkit and the changes we've made in the business."*

As awareness of other TCC activities was fairly low among those interviewed, most felt they could not comment on the impact of TCC more generally.

### SPILLOVERS

As the activity had not yet concluded there had not yet been any spillovers. However, Value Toolkit had been directly referenced in the procurement playbook and so was expected to start to have an impact on large-scale public sector procurement. There was a general feeling that it has the potential to significantly change public sector procurement if it is adopted fully by public sector organisations:

> *"I think there's a huge opportunity over the next 2 or 3 years because we have these very large funded programmes, so there's now the opportunity to align the work of the centre with these large private sector programmes. That's how for example the new hospitals programme is being organised."*

However, it does require some in-depth understanding to use Value Toolkit and what they were finding was that not all relevant staff had the time to learn how to use it. There was a worry that it would end up being 'watered down' when it fully launched or that it would get stuck with the original team that had been involved with its development and not be taken up by others in their organisations or in the industry.

Some mentioned the challenge of encouraging adoption among public sector bodies and clients:

> *"In my naivety back in 2018 I honestly thought that if government sponsored it, which they have because it is in the construction playbook, I thought that would be implementation."*

> *"I hadn't realised just how much engagement and training and cajoling and reminding and all these things would be needed."*

Another challenge with the Value Toolkit being used widely for public sector procurement is the funding cycles that public bodies are tied into. One of the interviewees gave the example of the Department for Education, where they had seen some push back to adopting the Value Toolkit as they were committed to projects and the way things were done in the current funding cycle and could not even contemplate introducing it until the next funding cycle. Timing was seen to be a major barrier as currently DfE construction projects had to work to incredibly tight timeframes that did not allow for a differing whole-life value approach.

The TCC's involvement in Value Toolkit  meant that it had focused on large-scale public procurement, whereas its precursor, Procuring for Value, was more directed towards the private sector. They were now expecting the public sector to lead on Value Toolkit and for the private sector to follow.

## D.10 - ACTIVE BUILDING RESEARCH CENTRE

| | | | |
|---|---|---|---|
| Activity name | Active Building Research Centre (ABRC) | Activity status | Ongoing |
| Strand | ABC | Funding awarded | N/A |
| Objectives | • Provide research facilities to allow active building solutions to be tested in combination with other parts of an active building solution | | |

### SUMMARY OF ACTIVITY

The Active Building Research Centre (ABRC) is one of the key activities of the Active Building Centre. The Active Building Centre site was established in Gloucestershire and aims to provide the research facilities needed to allow pioneering in active building solutions to test their technology in combination with other

parts of an active building solution. The site includes demonstrator warehouses, laboratories and offices. A second site is also planned in Swansea.

Each of the buildings at the Research Centre has been built to a different specification so that they can showcase how renewable generation and storage technologies can be either retrofitted into past generations of housing stock or incorporated into modern-day new builds. The Research Centre also allows for the capturing of data on the impact of active technology under variable conditions in real-world settings. The lab and live environments can model a number of variables and scenarios and capture a huge volume of data during the rapid cycles of development, testing and refinement. It also allows for live test situations to be created as digital twins, so refinements and improvements back at the lab can be almost immediate and ongoing.

For the purpose of this case study, organisations that had interacted with the Active Building Research Centre were interviewed. This included an academic institution and a public sector organisation.

### ENGAGEMENT WITH TCC

The purpose of engagement with ABRC differed considerably for the organisations interviewed.

The academic institution was the owner of the science park where the ABRC was located and was essentially the ABRC's landlord. It also engaged with ABC to better understand the construction skills that will be needed in the future, with the aim of aligning the training they provide to their learners to these needs.

The other had been approached by ABC with an offer to retrofit an upgraded air conditioning system to their building.

Engagement with TCC had mostly been limited to these activities. One of the interviewees reported no contact beyond their specific activity, while the other reported some limited engagement in the form of occasional meetings to learn which other projects the ABRC was supporting. Neither reported engagement with any of the other TCC strands.

### PERCEIVED SUCCESS OF ACTIVITY

As each interviewee's engagement with the ABRC had been for a specific purpose, neither of them felt able to comment on the overall success of the ABRC as they did not have sight of this. However, both perceived the specific interaction to have been a success and to have delivered what they had hoped to get out of the interaction.

### USE OF TCC CONCEPTS

Awareness of the TCC concepts varied among those interviewed. One had no awareness at all, while the other was aware of most, but had only really engaged with the ones focused on energy, including integrated energy capture and storage systems, integrated thermal solutions, smart controls and monitoring, and energy trading and flexibility.

For both of the interviewees, the engagement with the ABRC had improved their knowledge of the concepts. For the public sector organisation, where there was no awareness to begin with, it had helped it to understand that there were possibilities to help them improve the efficiency of its building using retrofitted technologies. For the academic institution, where there was some awareness already, the

engagement had deepened its knowledge and allowed it to develop more relevant course content based on this deeper knowledge:

> *"Massively, as a college we wouldn't know which way technologies are going."*

Neither planned to use the concepts in construction projects in the future due to the nature of their organisations, but the academic institution was actively developing course content around the concepts to help ensure their learners have the necessary skills in this area.

One of the interviewees perceived that some companies would be using the TCC concepts anyway, but it would only be a small number, i.e. those who were most engaged. They saw the TCC's impact to be around increasing the number of organisations adopting TCC concepts, and that was where they saw the TCC making a difference.

### COLLABORATION

For the public sector organisation, its only collaboration in this area was the one associated with the ABRC. It did not plan to collaborate with any other organisations in the construction sector.

The academic institution considered its collaboration with ABC to be 'very valuable' and noted that it allowed it to do things, such as planning courses that did not currently exist that they would otherwise not be able to do. Its collaboration with ABC helped it to attract companies to the institution and increase its collaborations with other organisations. The interviewee described the ABC as 'crossing the divide' between it as an academic organisation and companies that were able to bring forward technologies.

### FUNDING

No funding had been received in relation to the Active Building Research Centre but, as mentioned earlier, ABC had invested in the research facilities at the academic institution. The interviewee was not sure of the level of this investment.

The research facility was seeking to investigate active building technologies and how they could be implemented, as well as the effectiveness of different technologies and how they could be used together. The academic institution had provided co-investment in the form of the infrastructure at the site and staff time.

Although the public sector body considered itself not to have received funding from the TCC, it did admit that ABC had funded the sub-contractor that had installed its retrofitted AC system. However, the interviewee did not know the value of this investment.

### ADDITIONALITY

In the case of the public sector body, the activity would not have been possible without TCC. It did not have the funds or the knowledge to implement the retrofit programmes itself.

In the case of the academic institution, the TCC was seen to be '100% essential' to the research facilities on its site. Without the TCC investment it would not have been possible at all. The presence of the ABRC on its site allowed it to prepare courses covering practical skills that will be needed to implement the new technologies being researched.

### SPILLOVERS

The academic institution had had an increase in enquiries from companies about investing in its science and technology site as a result of the ABRC facility being there. This was something that it had not foreseen and had been a positive unintended impact. It was also planning to implement learnings from the ABRC into the other buildings on its science park and in its portfolio.

## D.11 - AEC DELTA MOBILITY

| | | | |
|---|---|---|---|
| Activity name | AEC Delta Mobility | Activity status | Completed |
| Strand | CR&D | Funding awarded | £722,103 |
| Objectives | • Create a data exchange standard for the industry that allows design teams to exchange data with greater efficiency and assurance | | |

### SUMMARY OF ACTIVITY

Most architecture, engineering and construction firms spend large amounts of resourcing trying to tackle data exchange and interoperability of Building Information Modelling (BIM). Many tools emerge out of necessity and are independent of one another but with similar functions. These fragmented systems of information sharing have delayed many projects in the sector.

Buro Happold, 3D Repo, UCL and a consortium of industry collaborators have tried to overcome the biggest barrier to the adoption of BIM – the ability to share data safely and securely. AEC Delta Mobility is an open-source solution that is flexible for teams to use and will improve knowledge sharing and programme management across the sector, dramatically improving workflow.

### ENGAGEMENT WITH TCC

Both of the interviewed organisations – an engineering consultancy and software company – had received £200,000 and £263,000 of funding respectively through competition from the TCC. Both were engaged with the TCC via the CR&D strand for the AEC Delta Mobility project, but they were also working on other projects in relation to the Challenge. Both organisations were working on the AEC Production Control Room and the engineering consultancy was also working on Rebar 4.0, which are still ongoing. Both of these were CR&D activities.

Furthermore, the engineering consultancy had taken an active role in the digital stream of the CIH following calls for industry involvement, and the software company was part of an ICF advisory group.

The engineering consultancy felt that the Challenge had "*created a movement*", and giving that movement a voice and a brand had mobilised academics and tech companies and had brought in venture capital and talent. They said that it was "*exciting*" to be involved in construction when tech companies could easily work in other industries.

### PERCEIVED SUCCESS OF ACTIVITY

Both organisations felt that the objectives of the project had been met. The interviewee from the engineering consultancy mentioned there had been a published reference of implementations for AEC Delta Mobility, with some universities starting to look at using it.

### USE OF TCC CONCEPTS

The interviewee from the engineering consultancy had prompted awareness of TCC concepts, although was familiar with this through engagement with CIH and the associated documentation rather than through any other engagement with TCC. The software company interviewee was familiar with all of the concepts.

The software company was using Digital Twin and the Information Management Framework. The engineering consultancy was familiar with off-site manufacturing but referred to it as *"industrialised construction"* and said it was *"very much central to how we now approach the market".* Similarly, the Information Management Framework and UK BIM Framework was *"very much engrained"* in its company, and it had 12 experts working on it specifically.

The engineering consultancy said that using such concepts paved way for a better business. The interviewee felt it was more efficient and was a requirement of the types of buildings they worked on – *"all of the buildings we create historically have a requirement to have very robust information management".*

Similarly, the software company said that it implemented the concepts *"to make ourselves more competitive in the market and offer value to our customers".*

Both organisations had some familiarity with the concepts prior to the TCC, with the engineering consultancy stating that the TCC had helped to provide a standardised language for the concepts. When asked about Information Management, the interviewee said, *"we invented it, and we wrote the standards"* and would have used this regardless of TCC.

Conversely, for the software company, the interviewee felt they were exposed to concepts they would not normally be exposed to because they provided software as opposed to physical products, but the interviewee could not comment on whether they would implement the concepts in the future:

> *"It's irrelevant for my business and my day-to-day job, because that's not what we do."*

When asked about the wider take-up of concepts within the construction industry, both interviewees agreed that this was not happening enough as yet. The software company said, *"it's going to take years until you see genuine tangible benefits*". However, the interviewee also commented that the TCC was raising awareness of concepts, whether companies were adopting them or not, and this was seen as a positive:

> *"At least they're talking about it which I see as a positive…the early signs are there."*

Both interviewees agreed there was some use of TCC concepts in procurement processes but had different opinions on the impact they were having. Optimistically, the engineering consultancy said:

> *"They are having a very positive impact. The value is in the quality of the information exchanged; it allows change in one data point as opposed to all data points in IC files."*

The software company on the other hand stated, "*it takes a lot of time and effort to transform a very conservative industry…introducing changes increases risks*".

Perhaps unsurprisingly, owing to the nature of their work, the engineering consultancy felt the concepts were important to its business and future success, whereas there was some ambiguity on importance for the software company.

### COLLABORATION

Both organisations had been involved in multiple collaborations. The engineering company had been involved in 8-10 with a range of other partners, such as academics, SME tech firms, and construction companies. Similarly, the software company had been involved in around 24 with commercial partners and academics. There was agreement that such collaborations were very valuable to their organisation:

> "*They bring challenges, they bring projects, they bring engagement, marketing and PR, and obviously paying for the work.*"
>
> *"They're very valuable as a vector for progress."*

Both interviewees agreed that the collaborations would not have happened without the TCC, especially not to the scale they had, and they thought the number had increased as a result of the Challenge:

> *"It gives people the opportunity to try new things under the banner of research – it's a good excuse for companies that otherwise would be competing with each other to join forces and do something for the common good."*

### FUNDING

The engineering consultancy had provided staff time to the project, and the software company had provided £104,000 of financial investment, plus staff time. Neither had received any additional funding from other organisations, but acknowledged that other organisations were also providing staff time and their organisational knowledge.

No follow-on funding had been obtained and none mentioned any plans to seek follow-on funding.

### ADDITIONALITY

Both interviewees agreed that the projects would not have gone ahead without the Challenge. Speaking of the impact of its engagement with the Challenge, the engineering consultancy felt it had provided an external validation which had increased the confidence of the business to invest in technology. The software company felt it had raised its profile within the sector, but was more sceptical about future proofing as this largely depends on demand.

COVID-19 was cited as the single biggest factor in accelerating technology adoption by the engineering consultancy, as the number of people allowed on site was very limited. For the software company, the impacts of the pandemic were limited to meetings being moved online.

Thinking about the impact on the environmental performance of built assets, the engineering consultancy referenced the Information Management System and Value Toolkit, which allowed it to measure embodied

carbon in a design which it could then share with customers. The software company did not know whether the Challenge had had an impact here or not.

### SPILLOVERS

There were no spillovers reported.

## D.12 - AIMCH

| | | | |
|---|---|---|---|
| Activity name | AIMCH | Activity status | Ongoing |
| Strand | CR&D | Funding awarded | Approx. £1.4 million to consortium |
| Objectives | • Scale up and make modern methods of construction a viable approach to building houses for the same price as traditional building costs | | |

### SUMMARY OF ACTIVITY

The construction industry is not building enough high-quality, high-performing affordable housing at scale to meet government goals and customer needs. This is owing to a multitude of factors such as an ageing workforce, with limited new skilled workers entering, poor supply chain efficiency and high building costs. Without change, the target number of homes to be built simply cannot be met.

Led by Stuart Milne, and together with SME Forster Roofing, Barratt Homes and L&Q, the collaborative set out to gather data on MMC at scale on real housing sites. The Advanced Industrialised Methods for the Construction of Homes Initiative (AIMCH) aims to provide comparative cost data on new manufacturing approaches compared to traditional methods.

By embracing improved digital systems, efficient scheduling and standardised supply chain processes throughout the build, more houses can be built in half the time, using the same skilled workforce, making construction more productive at scale, safer for workers and ultimately better quality and more affordable for the end user.

### ENGAGEMENT WITH TCC

Engagement with the TCC had been fairly similar for both organisations interviewed – these were a large developer which builds houses and a house-building business which focuses on both the design and supply chain construction of houses. Both had engaged with TCC via the CR&D strand.

The house-building business was the industry lead for the AIMCH project. The project had commenced two years earlier and was due to last for three years. However, timelines had been extended by one-quarter due to Covid-19.

The consortium had received around £1.4 million of funding in total from TCC, which had been split amongst the partners. The developer could not recall exactly how much it had received, but thought it had been a grant of around £700,000, and the house-building company had received a grant of £770,000.

The house-building company regularly attended the Innovate UK events and had frequent meetings with its stakeholders. It had given 12 presentations to sector-wide bodies, including academics and other industry members.

The developer mentioned that it had worked with Innovate UK for many years and so would regularly keep abreast of upcoming Challenges and had heard about this one via its marketing.

### PERCEIVED SUCCESS OF ACTIVITY

Both organisations interviewed felt they wer on track to meet the objectives of the project.

### USE OF TCC CONCEPTS

There was a good level of awareness of the TCC concepts amongst both interviewees. They were particularly familiar with MMC and off-site manufacturing. The developer also had good unprompted awareness of UK BIM, and the building company knew about integrated energy capture and storage systems and digital interfaces, as they were working on these concepts.

Both interviewees were favourable about the concepts owing to the impact they were having on their businesses, with the developer adding that it had helped to future proof the organisation. The concepts had helped to cut construction costs and delivery times, which in turn created higher profits.

The TCC had helped to expedite the take-up of these concepts. When asked if their organisation would be using these concepts if the TCC had not existed, one interviewee said, *"not as quickly – R&D would have taken longer", w*ith the other commenting that the TCC had helped to *"de-risk the delivery of these innovations".*

There was a perception that the TCC had already had an impact on the wider construction industry in terms of the take-up of TCC concepts:

*"The TCC has had a fundamental impact on construction costs, levels of emission, and delivery times. Thanks to the TCC, commercial barriers have been broken to help these concepts become a considered option in the sector."*

However, the developer did not think these concepts were yet being used enough by the industry:

*"These organisations will have to adopt them in the future though because of regulations on emissions and a reduction of skilled labour."*

Both interviewees agreed that implementation of the concepts would be important to their organisations going forward, and that the TCC had been fundamental in helping to accelerate the use of these concepts:

*" [Of TCC concepts] They're critical, we've got major drivers – regulatory, skills – there are lots of big changes happening in our sector that require change. MMC, BIM, zero carbon and others will play a critical component of future proofing our business."*

### COLLABORATION

Both interviewees cited the AIMHC as the only collaboration they had been involved in within the TCC. Other organisations within the collaboration had included the government, housing associations, sub-contractors and academics:

*"Collaboration is critical because it's the way we get to learn about other companies' drivers and they get to learn about ours, and we work together to come up with solutions so it's very important."*

Similarly, both organisations felt the TCC had played a crucial role in these collaborations, with the developer mentioning that the funding from the Challenge had enabled the partners to be brought together and that they would not have been able to progress at the speed they had without such collaborations.

The developer said there was a good dynamic between consortium partners, but some had little experience of this type of project so they spent a lot of time explaining what was needed. Going forward, they would recommend that Innovate UK provide clarity to new entrants on what they were expected to do and could provide templates to support.

The TCC had increased the number of collaborations for both parties and had linked them to other bidders, which had increased the scope to form other types of partnership in the future.

### FUNDING

The developer had provided financial investment to the project but was unclear on the exact amount. The building company had invested 50% of costs associated with the project, while the TCC had provided the other half. It had also provided staff time and commitment for the projects. Neither of the interviewed organisations had received any funding or additional support from other organisations, nor had they received any follow-on funding.

The house builder added that the Challenge could be improved by making the grants more accessible to smaller companies.

### ADDITIONALITY

Both interviewees agreed that the project would not have gone ahead without the TCC. The developer interviewed mentioned that engagement with the TCC had enabled higher risk R&D, introduced it to other commercial partners, improved the relationship with the partners it already knew, and had increased its awareness of what other innovations were happening, through Innovate UK.

The house builder interviewed had seen an improvement in revenue, profitability and productivity associated with TCC concepts. Involvement with the TCC had given it access to finance, which had been used to invest in the usage of these concepts, and as such it felt its expectations of working with the TCC had been exceeded.

In terms of the environmental impact of the Challenge, the views were positive:

*"The TCC had a fundamental positive impact because it helped to increase the usage of renewable material across the industry."*

Similarly, both interviewees thought the Challenge had had a positive impact on the wider construction industry and supply chains, encouraging them to think differently about carbon emissions and whole-life costs:

*"These aspects will be critical to the way we measure performance in the future so they'll have to get on board."*

### SPILLOVERS

The house builder commented that, positively, there had been other organisations which had wanted to replicate their work. There were no spillovers to note from the developer.

## D.13 - CHALLENGING SPACE FRONTIERS IN HOSPITALS

| | | | |
|---|---|---|---|
| Activity name | Challenging Space Frontiers in Hospitals | Activity status | Completed |
| Strand | CR&D and N+ | Funding awarded | £98,400 |
| Objectives | • Challenge the way hospitals are built by looking at how modern methods of construction could be applied in hospital operation theatres. | | |

### SUMMARY OF ACTIVITY

Procurement and construction systems need to better support the complex and varied clinical needs that hospital buildings have and are calling out for more innovatve solutions that draw on learnings from other industries.

A research collaboration between UCL, Loughborough University and Cranfield University has investigated the parallels between space-shuttle engineering and modern methods of construction (MMC) with an aspiration to develop an advanced platform for the design, manufacture and assembly of surgical spaces. This academic partnership has brought together respective expertise in health infrastructure, MMC, and astronautics and space engineering, and aims to improve the procurement of construction methods and processes currently being used to design and build clinical spaces.

### ENGAGEMENT WITH TCC

Engagement with the TCC began in November/December 2019, through the CR&D and the N+ strands. The N+ project was the first to begin, and the interviewee was engaged in writing an innovation leader proposal.

The organisation had been involved with 4/5 projects in total, but the interviewee had directly worked on two projects and a demonstrator for MACE (AC production control room). One of these projects fell under the CR&D strand, and the Challenge Space Frontiers in Hospitals activity was part of the N+. The project had been completed and the work had been disseminated via a conference and an academic paper, and was now moving into its propagation phase.

The organisation had engaged with the Challenge in various other ways, such as networking events, N+ conferences and presenting at the European Healthcare Design Conference. It had also taken part in workshops with Manufacturing Technology Centre (MTC) clients and contractors, and had had 5/6 steering group meetings with contractors, clients, manufacturers, designers and engineers, which had harnessed anywhere between 10 and 30 attendees.

### PERCEIVED SUCCESS OF ACTIVITY

The interviewee felt that the objectives had been met; in practical terms, it had worked with MTC to change the business models and innovate the supply chain, and had engaged with 40-50 contractors and suppliers to deliver an operating theatre. Additionally, it had recently run two sandpit events and engaged 200-300 integrators and supplier to look at how that might be done and the business models to do so.

It was also in the process of delivering the work of three PhD students who have been looking at integrated project delivery, MMC and the delivery of Digital Twin, focusing on the complex setting of a hospital.

### USE OF TCC CONCEPTS

There was a good level of awareness of TCC concepts, particularly ABC concepts, and quality and validation processes for MMC. The rationale for using these concepts spoke to the objectives of the activity, which was to deliver MMC within operating theatres, to increase their sustainability and increase the capacity of service delivery.

The interviewee commented that their understanding of the design process to build an operating theatre and other academical aspects associated with this had not changed very much as a result of TCC. However, the level of understanding of the business model that had enabled innovation in the supply chain, and the economics behind this innovation drive, had improved significantly.

Looking forward, the organisation planned to continue working with clients that aim to focus on building and integrating TCC concepts. It was continuing to work with contractors, innovators and specialist suppliers, as well as the MTC, which has its own number of organisations involved. The interviewee believed the concepts were incredibly important to their organisation and the wider industry, and promisingly, both MACE and MTC had taken up the project and were using it. The interviewee was involved with a demonstrator of an operating theatre, and this was supported by a number of parties engaged in the new hospitals programme.

The interviewee felt the concepts were incredibly important in the construction industry, but there was a long way to go in their implementation. The concepts in their activity were only at the demonstrator phase and the interviewee perceived that this was the stage other concepts were at as well.

### COLLABORATION

The organisation had been involved with around 50-60 collaborations that related to TCC concepts, with clients such as hospitals, manufacturing and supply chain organisations. The interviewee felt the collaborations had been vital to the organisation, with the TCC playing a pivotal role:

*"The TCC provided funding which succeeded the pipeline for innovation. It has also provided motivation and incentive to engage with academic research and institutions, and has re-defined the level of engagement and relationship between the industry and academia in a positive way. It's helped with re-shaping the way the*

*industry looks at the way it goes about research, design and innovation. It has also provided a means to showcase the work that academics do, and N+ were particularly good at allowing them to engage with the parties leading the TCC."*

The TCC had expedited the number of collaborations and changed the narrative of discussion, creating a collaborative environment for people engaged in research related to the concepts.

### FUNDING

The organisation had provided staff time and commitment to the activity, as well as its own data and intellectual property. During the course of the project, the interviewee felt it had been delivering above and beyond what it had been funded for because it saw value in this. Since the delivery of the project, it had been teaching the concepts at the university, directly translating the work into student research projects, and had continued its engagement with other partners that were involved in the project, which had been unfunded.

It had also received funding from XYZ and was exploring other collaborations that would be funded with MTC. It was keen to win funding from other research calls with NHS partners. This funding would have been possible without the TCC funding but might have been less likely.

The organisation had also received follow-on funding from MACE for a demonstrator project, which was partially attributable to the TCC, but it was not in the healthcare sector. This had been to the value of £500,000 for an AC production control room across a number of different projects.

### ADDITIONALITY

The project would not have gone ahead without the Challenge, as it had provided access to finances that had enabled advancements in innovation. The interviewee felt that Covid-19 had made the impact of the Challenge more influential because of the strain the virus had placed on the NHS, forcing it to think differently about how it procured operating theatres. Since then, the organisation had continued to have conversations about how MMC concepts could be applied in pandemic-like situations.

The Challenge had helped to increase awareness and drive innovation for the concepts, but the interviewee could not comment on any impacts at present. The Challenge will have greater impacts in the future, providing there is funding available.

### SPILLOVERS

An unexpected positive outcome was that the work with the TCC had highlighted the importance of research into areas that had previously not been thought to be really important. They were now focusing more on mechanical, electrical and plumbing solutions down the supply chains.

## D.14 - CONSTRUCTION QUALITY PLANNING TOOL

| | | | |
|---|---|---|---|
| Activity name | Construction Quality Planning (CPQ) Tool | Activity status | Complete, with some follow-on activity |

| | | | |
|---|---|---|---|
| Strand | CIH | Funding awarded | Unknown **[TBC]** |
| Objectives | • Shift construction to off-site manufacturing methods to improve industry productivity and quality of built assets<br>• Create a quality assurance tool that moves from defect checking once the building is complete to a defect-prevention approach<br>• Reduce remediation costs and waste by preventing defects<br>• Promote whole-life value by incorporating quality, safety, durability, servicing and sustainability factors at the design stage | | |

## SUMMARY OF ACTIVITY

The Construction Innovation Hub led this consortium to prevent the realisation of defects in buildings made, using an off-site manufacturing approach. The partners created a tool to shift the construction industry from a defect remediation approach once buildings are completed to a quality assurance prevention approach from the outset. Ultimately, the objective is to increase the confidence in the quality of built assets made, using modern methods of construction (MMC). The consortium involved industry collaborators such as Project Etopia and Ilke Homes, both of whom focus on MMC.

The Construction Quality Planning Tool aims at reducing costs and waste by preventing defects. It ensures that quality, safety, durability and sustainability requirements are embedded at the planning stage so that the resulting built asset provides whole-life value.

## ENGAGEMENT WITH TCC

Levels of engagement with the TCC varied across the consortium. One of the interviewed partners had started to get involved with the Challenge from the beginning of its existence and, apart from the Construction Quality Planning Tool, had engaged with another activity relating to CR&D. The other interviewed party, however, had only engaged with the Construction Quality Planning Tool activity, not to design the tool but rather in a follow-on capacity to incorporate the Construction Quality Planning approach into their business.

Engagement was limited to specific activities, none of the interviewed parties had had any other interactions with the Challenge outside of these.

## PERCEIVED SUCCESS OF ACTIVITY

The perceived success of the project against its objectives differed by partner. This was due to each partner having its own levels of interaction with the activity. The partner that was involved in designing the tool believed that the objectives of the project had been met. However, for the party that had engaged with the activity to implement the tool into its business, it was too early to say whether this had been successful as this had not happened yet. Nonetheless, this partner was confident that the Construction Quality Planning Tool 'has the potential' to meet its objectives once it was incorporated into the business.

In general, the concept was seen to be a success for ensuring the quality of manufactured buildings from the outset.

### USE OF TCC CONCEPTS

The activity centred around the following TCC concepts: quality and validation processes for modern methods of construction, off-site manufacturing, digital assurance tools and improving the whole-life value of buildings.

Awareness of the concepts relating to the Construction Quality Planning Tool among the activity partners was high when prompted, but there was low awareness of the concepts the TCC is focusing on outside of the ones that were involved in the activity. Generally, this awareness of the concepts was not attributed to TCC, as parties had already been aware of these before the TCC had come along. However, one of the partners attributed its increased understanding of some of these concepts to TCC through itsinvolvement in this activity:

> *"Without [the funding] we wouldn't know nowhere near what we know right now."*

The partners felt that the industry was adopting the concepts involved in the activity, albeit slowly with still some way to go:

> *"Modern Methods of Construction account for less than 10% of UK construction."*

Nonetheless, these concepts were generally seen to be central to keeping up with the industry and meeting the government's house-building targets.

### COLLABORATION

The collaboration for this specific activity was seen to be successful, mainly due to the partners being clear on their objectives and the regular meetings and catch-ups that the consortium held.

The funding provided by the TCC was seen as integral in bringing the consortium together. The parties felt that the consortium would have worked together at some stage without TCC involvement or engagement, although this would have taken longer and would have been seen as a lower priority:

> *"[TCC] has helped because each company is bringing in their specialities which otherwise would have been difficult and expensive to procure without the government funding that work, because it's high-risk work, so in the business it would have been lower priority. It would have been done but very slowly."*

> *"That shared learning has been important and that coordinated effort, and it's saved us as an industry a long time in figuring these things out."*

Overall, the parties interviewed were open to future collaborations and expected to work with at least some of the other partners in some capacity in the future.

### FUNDING

All parties had contributed in terms of co-investment. Most commonly, this had involved in-kind staff time, but one of the partners had contributed financially as well (around 50% of the value of the project).

No follow-on funding had been received by any of the parties interviewed to carry out further activity linked to the Construction Quality Planning Tool. However, one of the parties was working closely with CIH to implement the tool in its business.

### ADDITIONALITY

Perceptions of whether the activity would have gone ahead without TCC input varied. One of the parties interviewed expected that it would have gone ahead in some form, as this was something they had already been considering before TCC had come about. However, the other party firmly believed that the activity would not have happened at all given the general low appetite of companies when it comes to getting involved in 'high-risk' activities, such as the CQP Tool, without external funding.

As the tool had not yet been implemented as a framework in the partners' businesses, it was hard for the activity partners to quantify the impact of the activity on their organisations. It was seen to be too early to tell. However, all of the parties interviewed expect a positive impact in the future from their involvement in the activity. One of the partners mentioned that it expected positive outcomes in terms of revenue and future proofing once it started using the tool. The CQP framework was also seen to have potential for improving the environmental performance of built assets as the tool allowed for environmental and sustainability factors to be built in from the outset. However, whether these factors are included depended on whether these were important considerations for the individual or business commissioning the building. Partners expected that these would be important considerations going forward:

> *"It will be important for customers because as a society we're becoming more aware of climate change and issues that affect our environment."*

Despite the tool's ability to ensure quality and other important standards such as durability, sustainability and whole-life value in general, one of the interviewed parties expected some reluctance from the industry when it comes to incorporating the CQP framework into organisations:

> *"Companies would have to invest quite a lot of time at the front end of construction projects so it has to be clear to them what the benefits will be to justify this. Everybody is very busy and asking someone to take something additional on is a difficult sell."*

### SPILLOVERS

In summer 2020, an industry consultation on the Construction Quality Planning Tool was held. The consultation showed that the tool aligns with other industry quality frameworks such as RIBA Building in Quality initiative and Tracker, CIOB Code for Quality Management and the Get It Right Initiative (GIRI).

A number of pilot case studies were also being conducted, with the aforementioned implementation that one of the partners interviewed was working on being an example of this.

## D.15 - DATA CAPTURE FOR WHOLE LIFECYCLE COMPLIANCE CHECKING

| | | | |
|---|---|---|---|
| Activity name | Data Capture for Whole Lifecycle Compliance Checking | Activity status | Ongoing, due to finish in June 2022 |

| | | | |
|---|---|---|---|
| Strand | CIH and N+ | Funding awarded | £71,337 |
| Objectives | • Reduce time and cost of compliance checking by digitising data capture processes where possible<br>• Increase confidence on accuracy of compliance data<br>• Enable continuous inspections to track compliance of a building throughout its lifecycle to ensure remediation happens as errors occur rather than at completion or not at all | | |

## SUMMARY OF ACTIVITY

Cardiff University and the Construction Innovation Hub (CIH) teamed up to digitise regulatory compliance in the construction industry. The partners carried out research with industry experts to identify the areas seen as most important to automate. Following on from this, they developed digital prototypes to automate compliance across three areas: warning signs and fire doors by using AI; escape routes by using a scanner and an app that run geometric checks; and thermal state/energy leakages via a prototype that uses a thermal camera and continuous infrared sensor technology.

The aim of these prototypes is to enable regulatory compliance checks to be carried out in a time and cost-effective way while maintaining confidence in the accuracy of the data collected. These automated and continuous checks should ultimately make buildings safer and more environmentally sustainable.

This activity follows on from The Digital Compliance (D-COM) research network (set up through the Centre for Digital Built Britain), which revealed an interest in automation of compliance processes among the industry.

## ENGAGEMENT WITH TCC

Apart from engagement in this activity via CIH, the interviewed partner had had interactions with Network Plus (N+) through attendance at a series of events organised by the latter, as well as by taking part in an additional N+ activity. Therefore, the level of engagement with TCC was high and went beyond the activity around Data Capture for Whole Lifecycle Compliance Checking.

## PERCEIVED SUCCESS OF ACTIVITY

Although the activity was still ongoing, it was already seen as a success by the party interviewed, particularly for automating compliance processes and ensuring that buildings are safe. However, even though the activity was meeting its objectives, it was not being used by the industry yet as it had still not been finalised. Therefore, it was too early to tell with certainty what the impact on the wider construction industry will be.

Nonetheless, the activity is predicted to lead to cost savings:

> "*I expect a reduction in wasted time which translates into money, for example from people submitting things that are incorrect and having to re-submit.*"

The partner interviewed perceived that they had gained from the activity and was open to working on projects related to this activity in the future if this was deemed viable once the activity was completed:

> *"It's had a positive impact on my own career. It's increased my profile I think and the funding I won. It's given me a strong track record to go on and win more funding."*

### USE OF TCC CONCEPTS

The activity centred around the following TCC concepts: digital assurance tools, digital compliance, smart control and monitoring solutions, and improving the whole-life value of buildings.

Awareness of the concepts among the activity partners was high when prompted, with the partner interviewed also having awareness of some of the concepts TCC was focusing on outside of the ones that were involved in the activity. This aligned with the wider engagement the partner had had with the Challenge. Generally, this awareness of the concepts was not attributed to TCC, but was something that the party already had expertise in through their professional career.

The UK Government and construction contractors were seen to be driving increased uptake of TCC concepts related to this activity, with the Grenfell Tower disaster being a decisive turning point:

> *"Certainly, the catalyst for this was Grenfell Tower and the government wanting to know how many buildings have this dangerous cladding on. Local authorities would have had to go through filling cabinets so they wouldn't have been able to answer easily. And there's also a desire from construction companies to make the process more transparent and give people the ability to pre-check."*

TCC concepts were generally seen to be vital for keeping up with the industry. The interviewed party expected to be focusing on the concepts in the future. There was a perception that the industry was getting more interested in these concepts, which would lead to wider adoption. The TCC was seen as accelerating this adoption:

> *"I think companies would have adopted BIM anyway, but the Challenge has probably accelerated it."*

### COLLABORATION

Generally, the collaboration between partners was seen to have been successful, and the resulting prototypes were expected to have a positive impact on the industry.

The TCC was regarded as an integral player in bringing the consortium together to work on this activity:

> *"There's nothing like funding to bring a collaboration together. [Collaborations] might have been possible [without the Challenge] but they wouldn't have been as fruitful or as easy. It would have taken more time and effort to convince partners to come on board."*

The TCC was also credited with enabling networking between industry and academic partners, which will facilitate future collaborations:

> *"When you see an interesting idea, you've got people that you've got established relationships with. Sometimes you have to write a bid for a project but you may need industry partners to pull the*

*actual project off. Usually, you have 4 weeks to write a bid and if you have to approach a company that you don't know and sell the idea in that time, that's virtually impossible."*

### FUNDING

In-kind staff time had been provided by partners. Follow-on funding had not been received as the activity was ongoing but the party interviewed was open to looking into this option in due course.

### ADDITIONALITY

The partner interviewed firmly believed that the activity would not have gone ahead without TCC involvement. The TCC was credited with providing the necessary funding and a platform to bring the consortium together:

*"To deliver stuff on compliance there needs to be an open bit in the middle, something that is there to tie the thing together, and that is very difficult to produce without funding because companies are not necessarily willing to put their own resources into something that is not going to imminently directly benefit their products. From the university's point of view, if it's something that involves development activities, I need funding to employ staff to do them."*

The TCC was also considered as a key driver of innovation in the construction industry by allowing partners to take risks and providing funding that is specific to the industry:

*"We didn't know whether the project was going to work when we started and [TCC was] OK with that. This is quite rare."*

*"Having a whole series of projects and partners involved allows us to bring the industry together and gives the whole wide industry the opportunity to commit. If you go for general UK open calls, you're up against people developing new scanners for medicine, space rockets… so it's sometimes very difficult to make the case for construction there because it's less cool and attractive sometimes. But also, even when you had the odd one in a few years construction specific call, you might fund 2-3 projects every 5 years and that's not really enough to build a community working towards it."*

In terms of this specific activity, apart from the aforementioned benefits in terms of safety as well as cost and time savings, the compliance checking approach developed in this activity was also expected to have a positive impact on the environmental performance of built assets. The prototypes developed will allow users to monitor the thermal temperature of buildings and any energy leakages, which should lead to a reduction on unnecessary energy usage and associated carbon emissions.

### SPILLOVERS

As the activity was still ongoing, there had been no spillovers yet but the party interviewed was looking into engaging with the industry in relation to this activity to promote adoption of the regulatory compliance process developed as part of this activity. However, the Covid-19 context was seen as a difficulty in bringing about this engagement:

*"I think there's a lot of apathy to do stuff online at the moment and doing face to face is still quite tricky."*

## D.16 - DIGITAL ACCELERATOR

| | | | |
|---|---|---|---|
| Activity name | Digital Accelerator | Activity status | Completed – cohorts are now using the programme |
| Strand | CIH | Funding awarded | c.£400,000 |
| Objectives | • Understand the need for an accelerator programme for construction start-ups focused on digital technology<br>• Design an accelerator programme to train deep technology start-ups to have a higher degree of success when they grow | | |

### SUMMARY OF ACTIVITY

The Digital Accelerator activity focused on the design of a new development programme aimed at deep technology start-ups. The programme is being run by Deeptech Labs, who are a post-seed accelerator. Deep technology typically refers to start-up companies that have the express objective of providing technology solutions based on substantial or scientific engineering challenges.

The TCC's investment was at the concept stage of the Accelerator programme. The funding was used to explore the need for an Accelerator programme involving construction companies and to understand how construction start-up companies could best be helped. This early-stage exploration showed that post-seed was the stage when additional support was most needed as this is when most UK construction start-ups failed. The learnings from this exploration stage were also used to develop the content of the Accelerator programme.

Each of the start-ups in the Accelerator programme will receive financing and a structured three-month development programme. The programme also aims to foster strong relationships and collaboration by giving the start-ups access to a community of deep technology leaders to act as advisers and mentors.

### ENGAGEMENT WITH TCC

Generally, engagement with TCC had been limited to the specific activity. One of the interviewees was also involved in another CIH activity through her role as an academic.

Knowledge of other TCC activities was limited and none of the interviewees reported engagement through webinars, newsletters or other communications from TCC.

### PERCEIVED SUCCESS OF ACTIVITY

The funding from CIH had been specifically for the development of the programme. In this respect the objectives of the programme had been successfully met as the programme was up and running with the first cohort. There were two construction companies in the first cohort.

One of the interviewees mentioned that the programme was not specific to construction and could have benefited from having mentors who were more construction focused as this would have provided better networking opportunities for the construction-focused members of the cohort. They also commented on the theory-driven nature of the programme and how it could have benefited by having more practical interactions with the construction industry.

### USE OF TCC CONCEPTS

Levels of awareness of the TCC concepts varied among those interviewed for this activity case study. Some had a good understanding of the concepts, particularly those relating to digitisation of the construction process. Others had very little knowledge at all due to their role in the activity. The activity involved supporting start-ups and some of the start-ups involved were using TCC concepts. In particular, the construction companies in their cohort were using digital twinning and digital compliance. These concepts were the focus of the start-up's businesses.

Those that were aware of the concepts creddit their interaction with TCC with deepening their knowledge. The concepts were seen to be a 'hot topic' in the industry, but the rate of adoption varied a lot. It was perceived that it was too early to see any tangible impact of the concepts across the industry as they were at such an early stage.

However, Covid-19 was seen to be a possible accelerant to the adoption of digital processes in construction:

> *"From what I've heard companies seem to be a lot more open to digitisation now. My perception previously is it was a 'nice to have', but companies were busy. Now they're really starting to see the value in it."*

### COLLABORATION

Two forms of collaboration were relevant to this activity: the collaboration of Deeptech Labs with TCC and the construction sector, and the resulting collaboration that they can facilitate with the cohort of the Accelerator programme.

From Deeptech Labs' point of view, CIH had helped to put them in contact with relevant construction companies they can invest in and there were ongoing conversations about possible investment. CIH was seen to be important to these introductions.

From the point of view of the construction start-ups in the Accelerator programme cohort, collaborations continued to be important, particularly with academics. CIH funding had provided the opportunities for new collaborations to be formed that might otherwise have been constrained by lack of finance. It was thought that most of these collaborations with academics would have happened without TCC's input as they were a result of existing personal connections, but for some it was easier to form them using the TCC.

### FUNDING

The funding from CIH had been for the development of the Accelerator programme. As part of the programme, Deeptech Labs invests £350,000 in each of the start-ups in the cohort. As there are two construction-related start-ups in the current (and first) cohort, this has amounted to £700,000 of

investment in construction companies. It was expected that one of the construction companies involved in the cohort would soon achieve a further £1.5 million in investment.

### ADDITIONALITY

Although Deeptech Labs had already been at the concept stages, it would not have focused on the construction industry for its Accelerator programme if it had not been for the involvement of CIH. It would have focused on other sectors to invest in.

For the construction companies that were part of the first cohort on the Accelerator programme, it was likely that the scale of their company would have been smaller and their timelines longer if it had not been for the Accelerator programme. The interviewees cited a positive impact on access to future investment, commercial viability, future proofing, profitability, productivity and revenue.

There was potential for the TCC to have a great impact on the environmental performance of built assets. The Accelerator company was specifically looking to invest in sectors and start-ups that had a green focus. One of the construction companies in the Accelerator programme cohort focused on digital twinning, which had the potential to get rid of some of the mistakes in the construction programme and therefore reduce waste. It also had the potential to reduce the number of site inspections and the emissions associated with those.

The TCC was perceived to be impacting the wider construction industry, but because the activities it is investing in are innovative it was not clear when these concepts could become a part of the wider industry.

> *"For things like digital twinning and the BIM work it seems like the UK are at the forefront of that and I think that's been led by the TCC."*

### SPILLOVERS

No spillovers were reported.

## D.17 - FABRICATION AUTOMATION FOR STEEL LATTICE TRUSSES (FASTTRUSS)

| | | | |
|---|---|---|---|
| Activity name | Fabrication Automation for Steel Lattice Trusses (FASTtruss) | Activity status | Ongoing, but near completion |
| Strand | CR&D | Funding awarded | £500,000 to consortium |
| Objectives | • Produce a robotically welded demonstrator that can automate the design and manufacture of steel lattice trusses<br>• Transform the way superstructures are constructed | | |

## SUMMARY OF ACTIVITY

The manufacture of steel trusses used in construction has involved extensive manual labour which is time consuming and rarely cost-effective. Tata Steel UK is working with Bryden Wood and the Advanced Manufacturing Research Centre (part of University of Sheffield) to produce a robotically welded demonstrator called FASTtruss, that can automate the design and manufacture of steel lattice trusses.

The FASTtruss project was expected to finish in December 2021. It is a proof of concept and a full-scale trial was rolled out in October 2021. The final stage of the activity was proving the economic viability of the concept.

## ENGAGEMENT WITH TCC

Engagement with the TCC was via CR&D and was mostly limited to the specific activity. Colleagues in other parts of the lead partner organisation were working with CIH, but the interviewee was not part of this engagement.

Besides FASTtruss, the interviewee mentioned they had bid for two other projects as part of the Challenge, but had been unsuccessful. Another part of the organisation was currently involved with Seismic 2 as part of TCC.

## PERCEIVED SUCCESS OF ACTIVITY

The objectives had largely been met as the proof of concept had been proven. However, the full-scale trial had not yet begun at the time of interview. This stage will make FASTtruss ready to be marketed. The economic viability was unknown, as this will take more time to understand.

## USE OF TCC CONCEPTS

The interviewee had a good awareness of the concepts, notably Digital Twin, off-site manufacturing, and digital assurance tools.

The interviewee felt that around 80% of the organisation's knowledge of TCC concepts could be attributed to itself, i.e., it was familiar prior to the Challenge and 20% had resulted from the TCC. The interviewee specifically mentioned their understanding of Digital Twin had been enhanced by TCC, and they had adopted most of these concepts.

> *"[TCC] is giving us the last bits of knowledge, the little bits of the jigsaw that we were missing."*

The organisation considered itself to be an innovator in whole-life value. It was the only steel company that independently reviewed environmental product declarations (EPDs). It was looking at creating traceability systems to track products from raw steel through the whole life of a product, including deconstruction, reconstruction or re-use phases. This would include digital and physical tracing and would allow it to calculate the whole carbon content of its products.

The interviewee said that the concepts were integral to the organisation in terms of lowering carbon emissions, and while there was hope they were being adopted by other organisations, the interviewee was unsure if this was the case.

### COLLABORATION

The consortium partners were already known to each other and had worked with the lead partner prior to FASTtruss. The TCC did not play a role in the forming of the consortium. The consortium had put an earlier unsuccessful bid in for FASTtruss and the utilisation of FASTtruss in a demonstrator building, with the same partners and the addition of a developer.

The collaborations had been fruitful, particularly with Bryden Wood, which had brought additional expertise in digital twinning.

### FUNDING

The lead partner had received £500,000 via a CR&D competition. This had been distributed unequally between the partners, but the interviewee could not give exact details of how much each organisation had received. Match funding had been a requirement of the bid for funding and each of the organisations had contributed, although the contribution from the lead organisation (Tata Steel) had been the largest. The interviewee could not give an exact amount for the matched funding. The interviewee also did not know if their organisation had received any follow-on funding.

The lead partner organisation had been successful in bidding for other UKRI funding, but this was usually done through its R&D department and the interviewee was not able to detail specific amounts or projects.

### ADDITIONALITY

The project would not have gone ahead to the extent it had without the funding and would have been a more theoretical model if done internally. The TCC had enabled them to reach the physical demonstration stage.

> *"It probably wouldn't have got as far as it has if we tried to fund it internally. We would probably have done it more on theoretical models and I'm not sure we would have carried it through as an organisation."*

The interviewee felt that the TCC demonstrated how the sector was moving in the correct direction, but that change was slow.

### SPILLOVERS

The interviewee mentioned there were no specific elements in the bid to UKRI that looked at sustainability, and therefore the green element of the project was unintended. The organisation had spent more time on sustainability than they had originally put in the bid, and were now focusing on this a lot more, for example creating an early version of an EPD or FASTtruss to see how it compared with competing structural elements.

## D.18 - GOVERNMENT SOFT LANDINGS

| | | | |
|---|---|---|---|
| Activity name | Government Soft Landings (GSL) | Activity status | Ongoing |
| Strand | CIH | Funding awarded | Unknown **[TBC]** |
| Objectives | • Provide a modern method of procurement and project management to enable clients to get the maximum value from their investments | | |

### SUMMARY OF ACTIVITY

Government Soft Landings (GSL) is an open-source framework that aims to smooth the transition between the design and construction of a building to its operation and use and helps to ensure a building is easy to operate and maintain. GSL makes sure user needs are weaved into the design and construction of buildings, supporting a smooth transition ('soft landing') between design and construction teams and the people running new public buildings such as schools and hospitals.

Adoption of the framework has been slow, so NHS Scotland and the Department for Education (DfE) set out to prove its effectiveness, with the aim of increasing adoption.

The framework helps to manage procurement activities for any construction or maintenance related work, such as managing frameworks or long-term contracts, looking at supply chains, client requirements and the vast range of new initiatives, laws or advice coming from the government or other bodies.

TCC funding, via CIH, was used to align existing DfE projects and contract management processes with GSL, and also with the latest UK BIM Framework guidance. TCC funding was also used to clarify user needs and expectations from GSL and to create an interactive GSL process map. The activity essentially acted as a proof of concept of the GSL approach.

One interview was conducted for this case study. The individual interviewed worked for a county council and was responsible for putting in place procurement arrangements for all of the council's construction categories and anything to do with buildings. The interviewee was also heavily involved in regional frameworks and the National Association of Construction Frameworks (NACF). In terms of this specific activity, the individual had been trialling applying CIH tools, including GSL, in their daily procurement activities.

### ENGAGEMENT WITH TCC

As part of their work with the National Association of Construction Frameworks (NACF), the interviewee had been involved with the CIH for a while on various aspects of their work. Part of this engagement focused on how the Building Information Modelling (BIM) framework was applied to local government, and through this the interviewee had become aware of the GSL through a presentation by DfE and NHS Scotland on their TCC activity. The interviewee had seen an opportunity for GSL within local government

and had approached DfE and NHS Scotland to develop a roadmap for applying GSL to local government, which had been presented to the NACF.

Engagement with DfE and NHS Scotland on GSL began in 2020. The interviewee had also been quite heavily involved with CIH and sat on a number of the digital groups and the procurement group within CIH. They had also been involved in Value Toolkit through CIH, running trials and being trained as a facilitator.

The interviewee had been involved with CIH through several face-to-face meetings, as part of their procurement or BIM groups, and had taken part in the Value Toolkit training. The key relationship had been regular contact through the working groups that had been established, although the interviewee also thought it was likely they were receiving newsletters.

Overall, the interviewee was positive about their engagement with the Challenge, and felt it was a good opportunity to generate new ideas and ways of looking at things, while expanding their network.

### PERCEIVED SUCCESS OF ACTIVITY

The interviewee had only become aware of the activity towards its end. The original aim had been to prove the effectiveness of the framework and increase adoption. As part of the activities to raise awareness and increase adoption the interviewee had become aware of GSL. The adaption of GSL to work in local government had not been planned as part of the original activity funded by TCC. As such, the original activity could be considered a success as adoption had increased, and in areas that had not originally been planned.

In terms of the impact of GSL on the interviewee's organisation, they had compared key performance indicators of the projects that were using various TCC frameworks to industry norms, and encouragingly all were exceeding those norms, particularly for cost and time predictability.

### USE OF TCC CONCEPTS

The interviewee was very familiar with the Information Management Framework and the BIM Framework concepts, and was also familiar with Digital Twin, Standardisation of Product Data, Government Soft Landings and Value Toolkit through the work the organisation was doing.

The interviewee acknowledged that some concepts had already been familiar prior to the Challenge but that CIH had helped to develop, refine and consolidate their thinking, bringing a focus on where the company's work should be going:

> *"CIH has brought a focus, an emphasis, and a refinement to where we are going."*

There was limited awareness of how much these concepts were being used in the wider construction industry. However, the interviewee mentioned that any local authorities which were involved with the NACF had adopted many of the concepts provided by CIH, such as BIM, GSL, and value management. Some of these were also being further developed.

It was difficult to attribute improvements on any one initiative; it was about putting all of the practices together:

> *"You couldn't say, for example, this project has saved money because of BIM."*

The interviewee felt the concepts were important to the industry, but they always had been. However, it would be interesting to see how these developed over the next few years:

> *"The concepts aren't a revolution, but they are evolution of concepts that have always been around. They have never manifested themselves because no-one has shaken it up, put it into a pipeline and invest in it."*

### COLLABORATION

The main collaborations were directly within the BIM, Government Soft Landing, Digital Twin and other procurement activities, and included consultant organisations, those who worked with CIH, and people from other local authorities. The interviewee was not able to recall the exact number of collaborations owing to the fact that a number of colleagues had been working on the projects or using a framework that related to TCC concepts.

The interviewee felt the collaborations were extremely valuable because they provided an opportunity for organisations to develop their knowledge, keep up to date with what was being offered in the industry, and helped organisations to understand which toolkits were available to support them. Without the collaboration, people would be working in a silo. While the collaborations would have happened without TCC, it had helped to bring focus and dedication to them.

Covid-19 had impacted on the quality of these collaborations to some degree, as all meetings were now online, so the value you got from face-to-face meetings was missing.

### FUNDING

The organisation had made co-investments through staff time and commitment to the Challenge, but no other form of funding, nor had it receives any funding from other organisations.

### ADDITIONALITY

It was acknowledged that the frameworks would still have been applied without the TCC, but the TCC had accelerated the focus and uptake of the concepts which had been circulating in the industry for a long time. Due to Covid-19, the training of the toolkits and the teaching of the concepts had been moved online and this had made things more difficult to implement.

The interviewee felt it was too early to say whether the Challenge had impacted the environmental performance of built assets but was optimistic it would make a big difference going forward, although the could not say exactly what impact they expected. The Challenge had had a positive impact on the wider construction industry, with the interviewee noting that more people in the supply chain were aware of TCC concepts.

### SPILLOVERS

No spillovers were identified.

## D.19 - PLASMA

| | | | |
|---|---|---|---|
| Activity name | PLASMA | Activity status | Completed |
| Strand | CR&D | Funding awarded | £590,540 |
| Objectives | • Provide a technology platform to improve supply chain management and productivity in construction projects | | |

## SUMMARY OF ACTIVITY

PLASMA is a digital platform that has the potential to transform the productivity of construction. Vinci and Skanska set out to improve supply chain processes through greater collection, sharing and access to historic and live site data, allowing teams to plan better and learn from how projects performed and where improvements could be made. The consortium for the activity was made up of five members; Vinci (lead partner), Skanska, The Building Research Establishment (BRE), nPlan (software specialists) and Assentian Limited (cyber security and blockchain specialists).

PLASMA lifts data from site sensors and project management systems to give a holistic picture of the supply chain flow, which allows project planning teams to map programmes, test project delivery scenarios and identify supply chain pinch points.

## ENGAGEMENT WITH TCC

The consortium consisted of five partners in total, and two of these organisations were interviewed – a technology company and a global construction company.

The technology company had been invited to take part in the bid and had received funding through the CR&D competition, but the interviewee could not recall how much this was.

The interviewee from the construction company was also unaware of when their engagement had begun because they had joined the project after the funding had been won. They had also received funding via competition for 50%, which equated to £57,781, and had received the lowest amount of funding within the consortium.

Further engagement had included a networking event which they had attended and at which they had presented their innovation to other competition winners. They had not been approached about other calls and were unaware of what other competitions were available, stating their work was very much PLASMA driven.

## PERCEIVED SUCCESS OF ACTIVITY

The aim of the toolkit was to make silos within the construction industry more interoperable with each other. The lead partner in the activity perceived that most of the objectives had been achieved and noted that the consortium partner that owned the IP (Assentian) now had a product that could be taken to market which improved efficiency and productivity and would bring the supply chain closer together with contractors.

The interviewee from the technology company felt it was too early to say if the objectives had been met and that it would not be clear for another 10 years.

### USE OF TCC CONCEPTS

There was some level of awareness of TCC concepts within the technology company. The interviewee was familiar with off-site manufacturing, Digital Twin, digital compliance, standardisation of product data and digital assurance tools. However, the interviewee said their organisation had not implemented any of the concepts since and had little awareness of how these concepts were being used in the wider sector.

The interviewee from the construction company was not familiar with any of the concepts.

### COLLABORATION

BRE was the driver of the forming of the consortium and was responsible for bringing the consortium members together. The consortium had originally bid for TCC funding as a consortium of four organisations, but upon TCC recommendation had included a fifth member in the consortium (nPlan) to strengthen their bid. The TCC had suggested who this fifth member could be, and so had played a fairly large role in facilitating their collaboration on PLASMA.

Including PLASMA, the lead partner company had been involved in three collaborations – with one research and technology organisation and two Tier 1 construction contractors. The interviewee felt they had been valuable to the organisation because they were looking at ways to turn what they had developed into a product, and these connections could be helpful for this. The interviewee was unsure what role the TCC had played in these collaborations but recognised that they had not been involved with any other construction companies prior to the Challenge.

### FUNDING

The interviewee from the construction company had a limited awareness of the funding structure within the consortium. It was unclear whether they had received any additional or follow-on funding.

The technology company had made a financial investment, but could not recall how much, and had also provided staff time. It had not received any additional funding from other organisations or any follow-on funding.

### ADDITIONALITY

The interviewee from the technology company had very little awareness of the impact the TCC had had. They were unsure whether the project would have gone ahead without the Challenge, and felt it was too early to say whether engagement with the TCC had impacted their organisation, because it would take a number of years to make the project into something tangible that could be introduced into the market.

Looking forward, the interviewee could see some benefits for the wider construction industry:

> *"The industry would have learned from this how to do things better, at least the construction contractors that took part, and can create processes that are replicable and consistent rather than ad-hoc."*

Conversely, the construction company felt the project had only gone ahead because of the TCC, and while this was largely owing to funding, the Challenge had also improved access to partners and had brought people together. The interviewee spoke very positively about the impact of PLASMA and hoped other competition winners saw similar levels of impact:

> *"Our project has had a pretty big and impressive impact and has got the potential to be industry changing."*

Additionally, the interviewee felt positive about the impacts on the wider construction industry:

> *"The construction industry has small pockets of individual brilliance, but needs something like the TCC to get some traction."*

> *"TCC gives the industry the ability to learn, fail, improve and then be successful."*

### SPILLOVERS

The interviewee from the construction company felt the TCC had helped them to better understand the construction process beyond the activity and to better document it and capture data within their organisation. Their involvement with PLASMA had impacted their operations across their business, including in areas not related to PLASMA. Their learnings had helped them to manage data flows within their organisation more effectively.

# Annex E - THEMATIC CASE STUDY – FULL WRITE-UP

## E.1 - CASE STUDY BACKGROUND

A specific thematic case study on procurement was undertaken as part of the evaluation. This case study provides the main evidence for Theme 2 – 'Construction sector clients enable TCC concepts to be used in the procurement process'.

This theme relates to the long-term objective to integrate TCC solutions throughout public procurement processes and regulatory frameworks. This outcome is supported by outputs from the CIH and ABC strands, which aim to increase adoption of TCC technologies and methods in government programmes and across the construction sector.

Theme 2 captures outputs that are necessary to enable the adoption of TCC concepts among construction companies, their clients as well as wider industry. The adoption of new concepts is likely to be costly to firms, and incentives will initially need to be driven by the demand side, i.e. through the implementation of TCC concepts in procurement frameworks.

The procurement thematic case study involved four semi-structured interviews, with the following bodies:

- Two interviews with central government representatives from the Department for Business, Energy and Industrial Strategy (BEIS) and the Infrastructure and Projects Authority (IPA); and
- Two interviews with representatives from devolved and central government departments. Both representatives had roles linked to procurement within their respective department.

We supplemented the targeted evidence collected as part of this thematic case study with evidence from interviews supporting the activity-level case studies where relevant to the procurement theme, including an individual from a large commercial sector client.

## E.2 - ENGAGEMENT WITH AND AWARENESS OF THE TCC

The interviewees highlighted a wide number of TCC programmes and TCC organisations that they were actively aware of and had engaged with, showing clear knowledge of and engagement with the Challenge. These programmes included the Value Tool Kit (CIH), Digital Twin (CIH), Government Soft Landings (GSL), AutoBIM, and the Active Building Research Centre (ABC), which are described below.[25]

- **Value Toolkit:** "The industry has come together to (…) introduce a new approach that is focused on whole-life value. More than 120 organisations, led by the Construction Innovation Hub, have developed the Value Toolkit – a suite of tools and processes that will embed value-based decision making throughout the investment lifecycle. The Value Toolkit takes clients through four modules that cover how to define value; how to index and measure value; how to create a business case and shape a commercial strategy; and how it can inform a value-based procurement process and subsequent delivery."
- **Digital Twin:** "Digital twins use live data to create a virtual model of a building. In complicated projects, they give supply chain confidence that they are all working from the same information

[25] Descriptions are sourced from the TCC's Stronger Stories: https://tc-catalogue.strongerstories.org/

and can help make predictions about how a building will perform in the real world. But digital twins aren't used consistently in construction. Professor Sergio de Cesare at University of Westminster interviewed leading construction firms and SMEs to understand why. One of the barriers he uncovered is that the flow of data is interrupted when it comes from different sources or systems – essentially the data isn't consistent or speaking the same language. His team has developed a methodology that can help organisations apply a common foundation to their data at the very start of a project to improve consistency and make it easier to integrate digital twins."

- **Government Soft Landings:** "The Government Soft Landings (GSL) is a strategic open-source framework that helps the smooth transition from design and construction to operation and use of a building. Just like when we buy a car and have a list of requirements – is it big enough? does it have low emissions? – so GSL makes sure the same questions are asked of the end user to ensure design and construction teams build with the final occupants in mind."
- **AutoBIM:** "Inputting information into BIM can be a laborious process and a blocker to its wider use, particularly as data comes from many different sources in different formats. AutoBIM is a plug-in software solution that supports easier use and adoption of BIM for construction professionals. It automates task delivery plans; it provides an embodied carbon calculation tool; it has a health check tool to validate the quality of design data and spot gaps; and it has a risk alert tagging tool to share lessons learned. The software will support organisational BIM adoption, industry compliance and collaboration."
- **Active Building Research Centre:** "Active Buildings incorporate various renewable energy technologies so they are able to generate, store and use power and heat intelligently. How these various technologies work together is key to maximising performance for the shortest payback time. The Active Building Centre has research centres so developers of renewable energy solutions for buildings can test them as part of an integrated system using a plug-and-play approach in both lab and live environments. The facility can create different scenarios, replicate conditions and standards of existing buildings, and create digital twins of buildings – so ideas can be quickly remodelled and refined in the lab and re-tested in real life."

Further, interviewees' engagement with the TCC had not been isolated to specific projects or activities. A number of interviewees spoke highly of the TCC and respective organisations they had engaged with. They suggested that the TCC was seen as a focal point of innovation within the sector and a body they would seek to work with when pursuing innovation within procurement:

> *"There was little sense of industry-wide innovation with the objective of improving the industry (e.g. making the industry more stable). TCC has changed that, creating something that people gravitate towards (…) TCC has had a significant impact on raising awareness and encouraging innovation."*

Interviewees highlighted that the demonstrator elements of TCC engagement were working particularly well. It was suggested that there was often an element of doubt or uncertainty when incorporating a new concept into procurement and interviewees suggested that demonstrators were a critical mechanism to reduce these barriers, showing how TCC concepts can work in practice:

> *"When we can demonstrate things, e.g. walk through a building and show what works, it makes it easier to shift people's mindsets."*

## E.3 - AWARENESS OF TCC CONCEPTS

The interviewees all showed a clear understanding of TCC concepts (the Value Toolkit and modern methods of construction were particularly mentioned), and the benefits that they have versus traditional construction methods. Interviewees illustrated a wide range of views on the extent to which the TCC had increased their understanding of TCC concepts. By and large, this varied depending on the individual's role and previous level of knowledge of TCC concepts prior to engagement with the TCC. All interviewees suggested that the nature of their role meant they had had a high level of awareness of TCC concepts prior to the TCC's introduction. This was particularly the case for the interviewee from the commercial sector. However, government representatives expressed that the TCC had helped increase their knowledge of specific concepts and their potential and had also opened their eyes to other concepts. In particular, this was linked to innovations in relation to the environmental sustainability of buildings and information management, which interviewees suggested were often theoretical but the TCC had made more digestible.

Interviewees also offered views on the overall awareness of TCC concepts in wider government procuring bodies. It was suggested that the more experienced individuals with influence over procurement had a high awareness and understanding of the TCC and its concepts. This was the case in central government departments and private sector bodies. However, it was noted by an interviewee that government procurement was broad and included a wide range of departments and arm's length bodies. The interviewee questioned the extent to which there was widespread awareness of the TCC and TCC concepts across government and arm's length bodies. Nonetheless, it was suggested that the focus that the TCC currently had on influencing senior procurement stakeholders in government bodies was appropriate:

> *"Where procurers are sufficiently involved and senior enough in order to influence things, there is usually quite good awareness and understanding of TCC and TCC concepts. However, people are less aware of TCC lower down the chain."*

The individuals we interviewed in government had been particularly aware and had engaged with the TCC. We approached other potential interviewees in government who declined to participate as they felt they had insufficient knowledge or familiarity of the TCC, perhaps supporting the view that there is still a gap in widespread awareness of the Challenge and TCC concepts across government.

## E.4 - CHANGE TO PROCUREMENT AND ATTRIBUTION TO THE TCC

Overall, interviewees offered a number of areas where there had been changes to public procurement processes and regulatory frameworks, including the concepts which were being procured. However, at this stage of the implementation of the TCC, the level of impact was suggested to be at a strategic level than a direct impact on individual procurement decisions. That is, the TCC's impact broadened procurement strategy to consider wider outcomes rather than simply the inputs (i.e. costs). The interviewees noted that this was to be expected given the timeframe required to influence the concepts used in public procurement processes and regulatory frameworks. This is explored in more detail in this sub-section, focusing first on the current impact of the TCC and the potential future impact.

- **Government interviewees highlighted that the TCC was having a clear, strategic impact on procurement.** This impact was linked to the overall engagement individuals in procurement were having with the TCC, and particularly with the Value Toolkit and the Digital Twin project. Interviewees highlighted the role of the TCC in changing the overall approach to procurement to consider wider factors. Prior to the TCC, the objectives of projects had been mainly focused on the costs and the direct delivery of the project (e.g. number of schools or hospitals built). The TCC had widened the strategic thinking in procurement to consider the 'whole value' of the project,

including impacts on people (such as via employment), social impacts, natural impacts (such as those on emissions and biodiversity), and the manufacturing impacts. As a result, a number of interviewees cited the TCC as critical in changing the current strategy within procurement processes:

> *"Overall, we are seeing a big cultural change which is guided towards outcomes rather than inputs, so we are expecting a very positive impact from it."*

- **The TCC is having a clear influence on government thinking. This has the potential to result in additional spillovers to the sector.** A number of interviewees suggested that the TCC was influencing wider government thinking, as can be seen in the latest Construction Playbook with its emphasis on digitalisation and decarbonisation. These areas have been key features of the TCC. As a result, it was expected that TCC concepts will have an impact on large-scale public sector procurement.

- **The interviewees suggested that the TCC had helped accelerate change, but that there were wider factors contributing to the changes seen.** Interviewees suggested that the TCC had begun to change culture and influence government thinking, although the extent to which that change could be attributed to the TCC was not clear. Interviewees suggested that there were a wider range of factors that were driving the changes, such as concerns about global warming and the pressure to decarbonise. Overall, interviewees agreed that the TCC had been an important factor in contributing to the change seen in government culture due to its role in bringing industry and government together, which had accelerated the pace of change:

> *"A whole load of things are driving cultural change (e.g. worries about global warming), but TCC is an important element of it and without TCC we wouldn't see progress in quite the same way. TCC is good at bringing the industry and government together."*

- **Overall, interviewees across the commercial, government procurement and central government groups agreed that there had been a limited impact on the number of TCC concepts incorporated in procurement processes and regulatory frameworks to date.** Interviewees suggested that this was as expected given the short time frame since implementation of the TCC. Nonetheless, interviewees noted that they expected future impact, both due to the TCC and the wider pressures linked to decarbonisation and digitisation strategies:

> *"In terms of TCC concepts being included in the procurement process, I don't think that has been the case yet. However, it is to be expected in the future."*

- **Interviewees suggested they expected to see a change to the number of TCC concepts incorporated in procurement processes and regulatory frames in the next five years.** This time frame was suggested for both the incorporation of TCC concepts in government and commercial procurement. These changes were expected to include the changed strategy for procurement; procurement objectives moving beyond cost; digitalisation; MMC; waste minimisation and decarbonisation. The interviewees suggested that the TCC was a critical enabler of the adoption of these concepts in the future.

## E.5 - BARRIERS TO IMPACT

Across the interviews, a number of potential learnings were suggested for the TCC to have a larger impact. Further, a combination of construction sector-wide and procurement-related barriers were suggested as having an inhibitive impact on the adoption of TCC concepts. These are discussed below.

### E.5.1 - TCC LEARNINGS

- **An interviewee suggested that the TCC could have greater influence with government procurement through greater alignment to procurement processes within the specific department and government timetables.** Often, government funding was specific for a financial year, and therefore the input of the TCC was required to be timely within that financial year in order to have the greatest impact. Further, an interviewee suggested that the some of the suggestions made by the TCC would not have been compatible with the government procuring guidelines for the specific department, and therefore needed to be adjusted.
- **More shared learnings across the TCC.** An interviewee suggested that engagements with the Challenge had been project and activity focused, and more could be done to ensure shared learnings across projects.

### E.5.2 - SECTOR-WIDE BARRIERS

A number of sector-wide and procurement-related barriers were identified by the interviewees as limiting the impact that the TCC had been having and would continue to have in incorporating TCC concepts in procurement processes and frameworks.

- **The frequent separation between innovation and procurement within organisations.** A number of interviewees flagged difficulties in integrating innovation concepts due to the general separation between innovation and procurement activities. This was suggested to be a common problem within a range of organisations and prevented the adoption of innovative concepts in procurement or, at a minimum, created significant time delays. This was flagged, in particular, by government procuring bodies. It was suggested by one interviewee that the TCC acted as an effective link between innovation and procurement, but there was still an existing gap to close:

  > *"The problem, which is common to most organisations, is that the people responsible for R&D/innovation and the people responsible for procurement are not the same, and are not connected."*

- **Skills shortages in the industry.** Interviewees suggested that skills shortage were a critical barrier that would likely delay the adoption of TCC concepts in procurement processes and regulatory frameworks. There was uncertainty about whether the industry had the skills and capabilities to adopt many of these technologies linked to TCC concepts in a short timeframe. Therefore, although the TCC was creating incentives to improve the supply of the TCC concepts in the construction industry through increasing demand, the gap in skills in the supply side was likely to cause delays in the wider adoption of TCC concepts and, thereby, the ability of organisations to include TCC concepts in procurement processes.

- **In general, Covid-19 was *not* suggested by interviewees to have limited the adoption of TCC concepts in procurement processes and regulatory frameworks.** On the contrary, a number of interviewees cited Covid-19 as motivating change across the industry through, for example, placing more emphasis on off-site construction.

# Annex F - DETAILED DESCRIPTION OF THE SECONDARY DATA ANALYSIS APPROACHES

## F.1 - DIFFERENCE-IN-DIFFERENCE

The difference-in-difference analysis was conducted via a weakly defined difference-in-difference approach. This was used to estimate the changes for each metric for specific sub-sectors that the Challenge is engaged with.

The difference-in-difference analysis was used to understand any change in the following metrics and datasets that showed early signs of TCC impact:

- Intramural and extramural R&D expenditure in ONS BERD data;
- Net capital expenditure in ONS ABS data;
- Turnover per employee in ONS BSD data; and
- Gross value added in ONS ABS data.

Under a difference-in-difference approach, the change in an outcome of the treatment group (e.g. a beneficiary) is compared over time to the change in that same outcome observed in another otherwise comparable control group. Any change in the treatment group more than that observed in the control group is then attributed to the intervention.

It is assumed that, in the absence of the Challenge intervention, changes in outcomes of the beneficiary group would have been the same as those changes observed in the control/benchmark group. A critical element of the difference-in-difference approach is therefore the identification of the treatment and the control group.

In the context of the evaluation, we implemented a **weakly defined difference-in-difference approach:**

- Many of the data sources on which the evaluation relies did not enable us to isolate groups of firms that received treatment from those that did not. For some of the metrics, the best available control group was only loosely characteristically similar to the treatment group. As a result, we considered that it was more appropriate to refer to the weakly identified control groups as 'benchmark groups'.
- We **identified the benchmark and treatment groups for the difference-in-difference analysis based on SIC codes**. These treatment and control groups were discussed with the TCC. For the treatment group, we identified a list of 5-digit SIC codes covering sub-sectors that the TCC aims to impact. This was done for three separate areas: (1) core construction, (2) construction products and (3) construction services.
- We then derived the three benchmark groups below for each of the three treatment areas listed above:
    1. **SIC codes in the same sector** (here a set of 5-digit SIC codes) but which were not included in the treatment group as these are areas the TCC does not aim to impact.
    2. **SIC codes in similar sectors** (here a set of 2-digit SIC codes such as 24: manufacturing of basic metals).
    3. A whole-economy group.

The exact SIC codes included in the benchmark and treatment groups are shown in the sub-section below.

Our analysis compared the trends across the treatment and benchmark groups to make inferences on the impact of the TCC on the relevant metrics. This analysis is presented in full in Annex G -

### F.1.1 - CORE CONSTRUCTION: TREATMENT AND CONTROL GROUPS

### TABLE 39 CORE CONSTRUCTION TREATMENT AND CONTROL

| TREATMENT/CONTROL | SIC CODES | |
|---|---|---|
| **Treatment group defined at 5-digit SIC code level** | 41100 | Development of building projects |
| | 41201 | Construction of commercial buildings |
| | 41202 | Construction of domestic buildings |
| | 42110 | Construction of roads and motorways |
| | 42120 | Construction of railways and underground railways |
| | 42130 | Construction of bridges and tunnels |
| | 42990 | Construction of other civil engineering projects n.e.c. |
| | 43120 | Site preparation |
| | 43130 | Test drilling and boring |
| | 43910 | Roofing activities |
| **Control group – digit level (5-digit SIC code)** i.e. in core construction SIC code but not identified in treatment group | 42210 | Construction of utility projects for fluids |
| | 42220 | Construction of utility projects for electricity and telecommunications |
| | 42910 | Construction of water projects |
| | 43110 | Demolition |
| | 43210 | Electrical installation |
| | 43220 | Plumbing, heat and air-conditioning installation |
| | 43290 | Other construction installation |
| | 43310 | Plastering |
| | 43320 | Joinery installation |
| | 43330 | Floor and wall covering |
| | 43341 | Painting |
| | 43342 | Glazing |
| | 43390 | Other building completion and finishing |
| | 43991 | Scaffold erection |

| | | |
|---|---|---|
| | 43999 | Other specialised construction activities n.e.c. |
| **Control group – division level (2-digit SIC code)**<br>i.e. in comparable sector, here manufacturing | 19 | Manufacture of coke and refined petroleum products |
| | 20 | Manufacture of chemicals and chemical products |
| | 21 | Manufacture of basic pharmaceutical products and pharmaceutical preparations |
| | 22 | Manufacture of rubber and plastic products |
| | 24 | Manufacture of basic metals |
| | 25 | Manufacture of fabricated metal products, except machinery and equipment |
| | 26 | Manufacture of computer, electronic and optical products |
| | 27 | Manufacture of electrical equipment |
| | 28 | Manufacture of machinery and equipment n.e.c. |
| | 29 | Manufacture of motor vehicles, trailers and semi-trailers |
| | 30 | Manufacture of other transport equipment |
| | 31 | Manufacture of furniture |
| | 32 | Other manufacturing |

*Source: Frontier Economics*

## F.1.2 - CONSTRUCTION PRODUCTS MANUFACTURERS: TREATMENT AND CONTROL GROUPS

### TABLE 40 CONSTRUCTION PRODUCTS MANUFACTURERS TREATMENT AND CONTROL

| TREATMENT/CONTROL | SIC CODES | |
|---|---|---|
| **Treatment group defined at 5-digit SIC code level** | 23120 | Shaping and processing of flat glass |
| | 23320 | Manufacture of bricks, tiles and construction products, in baked clay |
| | 23510 | Manufacture of cement |
| | 23520 | Manufacture of lime and plaster |
| | 23610 | Manufacture of concrete products for construction purposes |
| | 23620 | Manufacture of plaster products for construction purposes |
| | 23630 | Manufacture of ready-mixed concrete |
| | 23640 | Manufacture of mortars |

| TREATMENT/CONTROL | SIC CODES | |
|---|---|---|
| | 23650 | Manufacture of fibre cement |
| | 23690 | Manufacture of other articles of concrete, plaster and cement |
| **Control group – digit level (5-digit SIC code)** i.e. in construction product manufactures SIC codes but not identified in treatment group | 23110 | Manufacture of flat glass |
| | 23130 | Manufacture of hollow glass |
| | 23140 | Manufacture of glass fibres |
| | 23190 | Manufacture and processing of other glass, including technical glassware |
| | 23200 | Manufacture of refractory products |
| | 23310 | Manufacture of ceramic tiles and flags |
| | 23410 | Manufacture of ceramic household and ornamental articles |
| | 23420 | Manufacture of ceramic sanitary fixtures |
| | 23430 | Manufacture of ceramic insulators and insulating fittings |
| | 23440 | Manufacture of other technical ceramic products |
| | 23490 | Manufacture of other ceramic products n.e.c. |
| | 23700 | Cutting, shaping and finishing of stone |
| | 23910 | Production of abrasive products |
| | 23990 | Manufacture of other non-metallic mineral products n.e.c. |
| **Control group - division level (2-digit SIC code)** i.e. in comparable sector, here manufacturing | 19 | Manufacture of coke and refined petroleum products |
| | 20 | Manufacture of chemicals and chemical products |
| | 21 | Manufacture of basic pharmaceutical products and pharmaceutical preparations |
| | 22 | Manufacture of rubber and plastic products |
| | 24 | Manufacture of basic metals |
| | 25 | Manufacture of fabricated metal products, except machinery and equipment |
| | 26 | Manufacture of computer, electronic and optical products |
| | 27 | Manufacture of electrical equipment |
| | 28 | Manufacture of machinery and equipment n.e.c. |
| | 29 | Manufacture of motor vehicles, trailers and semi-trailers |
| | 30 | Manufacture of other transport equipment |

| TREATMENT/CONTROL | SIC CODES | |
|---|---|---|
| | 31 | Manufacture of furniture |
| | 32 | Other manufacturing |

*Source: Frontier Economics*

## F.1.3 - PROFESSIONAL SERVICES FOR THE CONSTRUCTION INDUSTRY: TREATMENT AND CONTROL GROUPS

Please note that there is not a digit level control group as all the relevant digit SIC codes are part of the treatment group.

### TABLE 41 PROFESSIONAL SERVICES TREATMENT AND CONTROL

| TREATMENT/ CONTROL | SIC CODES | |
|---|---|---|
| **Treatment group defined at 5-digit SIC code level** | 71111 | Architectural activities |
| | 71112 | Urban planning and landscape architectural activities |
| | 71121 | Engineering design activities for industrial process and production |
| | 71122 | Engineering related scientific and technical consulting activities |
| | 71129 | Other engineering activities |
| | 71200 | Technical testing and analysis |
| **Control group – division level (2-digit SIC code)** i.e. in comparable sector, here professional services | 69 | Legal and accounting activities |
| | 70 | Activities of head offices; management consultancies activities |
| | 72 | Scientific research and development |
| | 73 | Advertising and market research |
| | 74 | Other professional, scientific and technical activities |

*Source: Frontier Economics*

# Annex G - ADDITIONAL SECONDARY DATA ANALYSIS CONDUCTED

This annex complements the evidence presented on the secondary data analysis in the main body of the report. In order, it contains the following:

1 An analysis on the robustness and relevance of the datasets considered as part of the secondary data analysis; and

2 The outstanding analyses conducted as part of the secondary data analysis which were not included in the main body of the report. These analyses were considered to be less robust or relevant for the purposes of the evaluation, and therefore weighted less in the evaluation.

## G.1 - ROBUSTNESS AND RELEVANCE OF DATASETS

### ONS BERD

- ONS Business Enterprise Research and Development Survey (BERD) is a statutory survey that collects information about employment and expenditure on research and development (R&D) performed within UK businesses on an annual basis.
- We consider this data source to be **robust** and **relevant**, although there are some stakeholder concerns over firm-level data validity. In particular:
    - R&D definitions follow internationally agreed standards defined by the OECD; however
    - The data does not support an analysis of alignment of firms R&D expenditure with TCC principles.

### HMRC TAX CREDITS

- We consider this data source to be **robust**: it is based on a census of all R&D tax credit claims, is comparable over time and of high quality, being reconciled with claims data by claims handling units within HMRC.
- It is **relevant**, as the value of R&D expenditure associated with a tax credit claim is an informative statistic for the total value of R&D expenditure. However, not all expenditure on R&D in the UK is used to claim the tax credit, so these statistics are not a comprehensive account of all R&D activity in the UK. Further, we understand from stakeholders that few construction firms claim R&D tax credits in full. **Therefore, we expect that the trends shown in the data represent a conservative measure.**
- The data enables measurement of construction sector firms. However, claims are grouped by the primary activity of the business rather than the nature of the R&D activity itself. As such, investment by non-construction sector firms in R&D in construction sector activities will not be captured.

### CPA SURVEY

- The survey sample size varied between 120 and 150 firms (with the exception of 2020 Q2 when it fell to 80 firms), including firms that we expect to be directly and/or indirectly impacted by the TCC programme. However, the CPA Survey does not capture engineering consultancy firms, which is a key group that the TCC programme expects to impact.
- Due to anti-trust law, the CPA is only able to ask respondents to report percentage increases in variables (rather than the underlying cash values). This impacts the trends shown in the data, as it does not enable calculation of aggregate absolute changes in variables.

- Overall, we consider this data source to be **relevant** and **broadly robust** for purposes of the evaluation, although it does not perfectly capture the success indicator.

### ONS ABS

- The ONS Annual Business Survey (ABS) is the main structural business survey conducted by ONS and crosses most business sectors.
- We consider this data source to be **relevant** and **robust**.
- Annual net capital expenditure reported by ONS ABS captures acquisitions or disposals of land and buildings, vehicles, plant, machinery and similar equipment.
- The data is able to capture, isolate and measure specific firms and activities that are relevant for TCC programme evaluation, including those outside of the construction industry (as defined by the ONS).
- However, the data is based on a stratified sample and therefore will not capture all firms of interest to the evaluation.

### OBS BUSINESS INVESTMENT BY INDUSTRY AND ASSET

- The data is of high quality: sector-level statistics are weighted using combined ratio estimation and outliers are treated by an established outlier methodology; robustness is assessed through revisions made in accordance with national accounts revisions policy.
- The data captures investment in ICT, machinery and equipment and intellectual property products (which includes R&D). It is sector-level data and may capture investment that is unrelated to TCC evaluation and exclude relevant ones (e.g. construction product manufacturers).
- Overall, we consider this data source to be **robust** and **broadly relevant**.

### ONS BSD

- The ONS Business Structure Database (BSD) is part of the collection of microdata that is held by the ONS accessibly in a secure setting. Using HMRC and PAYE data, the BSD reports data on the number of employees for most UK firms.
- We consider this data to be **robust** and **relevant**.
- It is estimated that 99% of economic activity is captured in the BSD. The chief benefits of using BSD as a long-term outcome and impact metric is in its ability to capture and identify (close to) all of the Challenge's beneficiary firms.
- The survey respondents represent the most comprehensive sample of engineering consulting firms in the UK. This sub-group is typically difficult to target in ONS and other public data sources due to the way firms are grouped and classified into industry categories.

### GLENIGAN

- Glenigan data is collected from surveys of construction clients, contractors, sub-contractors and consultants based on projects completed during the preceding year. The sample is based on construction projects that appear in publicly available local planning applications. As such, the types of firms represented each year will change with the types of projects.
- We understand that between 150 and 200 contractors, consultants and clients report productivity data to Glenigan each year.
- Glenigan reports that its Construction Key Performance Indicators were endorsed by Department of Business Innovation & Skills.

- Overall, we consider this data source to be **relevant** and **broadly robust**.

### ACE SURVEY

- We consider this data to be **less robust** for the purposes of the evaluation as the survey has a relatively low sample size (covering 15 and 14 large UK firms in 2017 and 2019, respectively).
- We consider this data to be **relevant**. In particular:
    - GVA per worker for construction consultancy and engineering firms is an informative statistic for productivity at the firm-level.
    - The survey respondents represent the most comprehensive sample of engineering consulting firms in the UK. This sub-group is typically difficult to target in ONS and other public data sources due to the way firms are grouped and classified into industry categories.

### ONS LABOUR PRODUCTIVITY BY INDUSTRY DIVISION

- The ONS publishes experimental labour productivity estimates of labour productivity at the 2-digit SIC industry level for the UK economy.
- Labour productivity is calculated based on estimates of gross value added (GVA) and of labour input.
- The GVA figures are taken directly from the UK National Accounts; and labour input is calculated by estimating the number of jobs in a given industry and multiplying these by estimates of average hours worked per job in that same industry.
- Overall, we consider this data source to be **robust** and **relevant.**

### HMRC OST

- HMRC Overseas Trade Statistics (OST) are compiled monthly from trade declarations using 8-digit commodity codes. Valuation of exports is on a Free on Board (FOB) delivery terms basis (i.e. the cost of goods to the purchaser abroad).
- The data is a representative snapshot of trade in a defined commodity. Businesses whose annual value of dispatches exceeds £250,000 are required to report monthly declarations, covering roughly 97% of trade for dispatches.
- The exported value of defined commodities relevant to the TCC programme is an informative statistic for reporting on the industry trade gap. It enables a focus on commodities which are relevant to TCC. However, TCC aims to have a larger impact on exports of services rather than commodities.
- Overall, we consider this data source to be **robust** and **broadly relevant**.

### BEIS

- The Building Materials and Components statistics data is of high quality: it is census data of all identified producers of construction commodities and is used for national statistics and as part of analyses for policy development.
- It can capture, isolate and measure specific construction products. However, the data does not cover exports of services, which is the key export area where the TCC aims to have an impact. Therefore, we do not consider this data source to be relevant for the purposes of the evaluation.
- Overall we consider this data source to be **robust** and of **limited relevance.**

#### ONS PINK BOOK

- The Pink Book time series are annual publications of statistics from the UK Balance of Payments (BoP), compiled by the ONS. The BoP is one of the UK's main economic statistical series, measuring economic transactions between entities in the UK and the rest of the world.
- It includes detailed annual statistics on trade in services. We note that the TCC aims to have an impact on the export of construction services. Therefore, this dataset is particularly relevant for analysis on exports and more relevant than the analysis on the exports of products (e.g. the BEIS Building Materials and Components analysis).
- Overall, we consider this data source to be **robust** and **relevant**.

#### MINISTRY OF HOUSING, COMMUNITIES & LOCAL GOVERNMENT

- The data is a representative sample of newly built domestic properties in England and Wales. It is drawn from 18,470,000 Environmental Impact Ratings (EPCs) issued since 2008. Domestic properties account for 96% of the total buildings constructed, and therefore the data presents a good proxy of overall industry trends.
- Since 2012, the data has been subject to quality assurance audit. However, the data is an experimental official statistic series.
- Overall, we consider this data source to be **relevant** and **robust.**

#### BRE SMARTSITE

- The data is representative of the UK construction sector. However, the construction companies captured by BRE's data self-select themselves into the sample. Users of these tools are likely to experience improvements over time irrespective of TCC concepts, simply by virtue of them selecting BRE's on-site productivity tools and using these insights to improve performance.
- We understand that median waste removed from site is an informative statistic for environmental impact of construction projects and the change in on-site energy use is an informative statistic for the environmental impact of construction projects.
- Overall, we therefore consider this data source to be **robust** and **relevant.**

## G.2 - ADDITIONAL EVIDENCE FROM THE SECONDARY DATA ANALYSIS

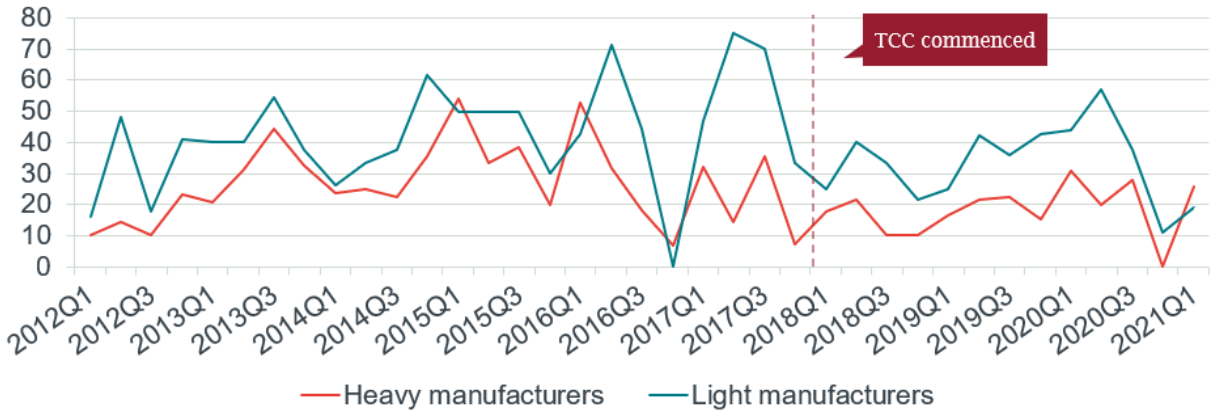
This section contains the additional analyses conducted as part of the secondary data analysis which were not included in the main body of the report. These analyses were considered to be less robust or relevant for the purposes of the evaluation, and therefore weighted less in the evaluation.

### G.2.1 - THEME 3 - ADDITIONAL AGGREGATE R&D SPENDING IN THE CONSTRUCTION SECTOR AND KEY SUPPLIERS

#### CPA

Figure 97 shows the evolution of the balance of construction manufacturers that reported an increase in R&D expenditure relative to the previous year. The survey includes between 80 and 150 construction sector manufacturers in each quarter.

## FIGURE 97 CPA SURVEY




*Source: Frontier Economics based on CPA Survey*
*Note: A value above zero means that over half of the manufacturers reported an increase in R&D relative to the previous year.*

There is **no evidence** that manufacturers increased R&D expenditure following the start of TCC:

- Throughout the whole period, from 2021 Q1 to 2021 Q2, the majority of manufacturers (light and heavy) reported increases in R&D expenditure relative to the prior year (with the exception of 2016 Q4 for light manufacturers where the number of manufacturers reporting an increase was the same as those reporting a decrease).
- Heavy and light manufacturers follow similar trends in increases and decreases in R&D expenditure, but with light manufacturers tending to have a more positive balance.
- The deceleration in 2016 to 2017 and early 2021 is likely to be in part driven by a response to Brexit and Covid-19.

### ONS BERD – INTRAMURAL AND EXTRAMURAL R&D EXPENDITURE

The table below presents the summary results from the ONS BERD sub-sector-level analysis on intramural and extramural R&D expenditure. It is followed by the individual analyses for each treatment group.

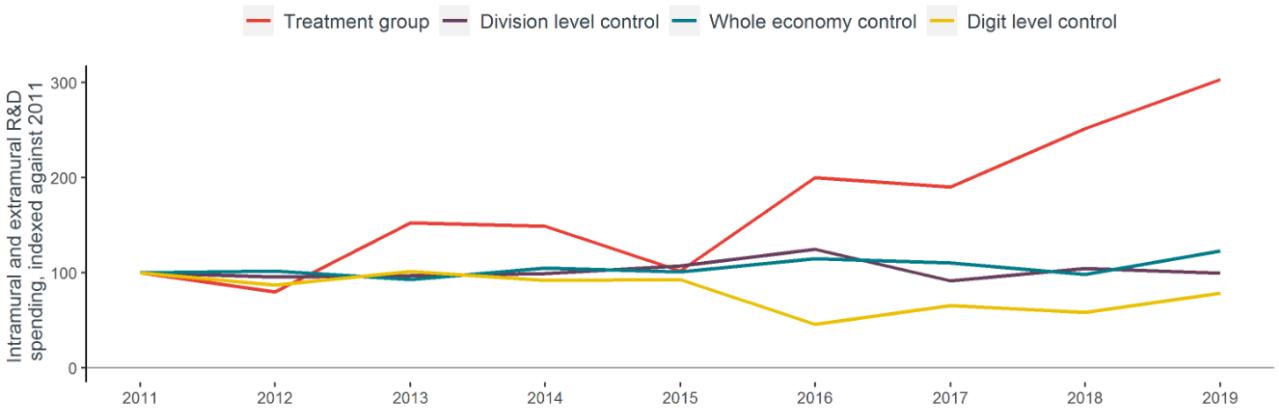
## TABLE 42 ONS BERD SUB-SECTOR ANALYSIS

| TREATMENT GROUP | CHANGE IN INTRAMURAL AND EXTRAMURAL EXPENDITURE |
|---|---|
| Core construction | There is evidence of increases in the total of intramural and extramural R&D expenditure for the core construction treatment group post 2018, with larger increases in comparison to the sub-sector and sector benchmark groups. |
| Construction product manufacturers | Extramural and intramural R&D expenditure for the construction product manufacturers treatment group has followed a similar trend to the sub-sector benchmark and has not followed the increased trend seen in the sector and whole-economy benchmarks. |

| TREATMENT GROUP | CHANGE IN INTRAMURAL AND EXTRAMURAL EXPENDITURE |
|---|---|
| Professional services for the construction industry | There is evidence of increases in R&D expenditure for the professional services treatment group post 2018, with larger increases in comparison to the sector and whole-economy benchmark groups.[26] |

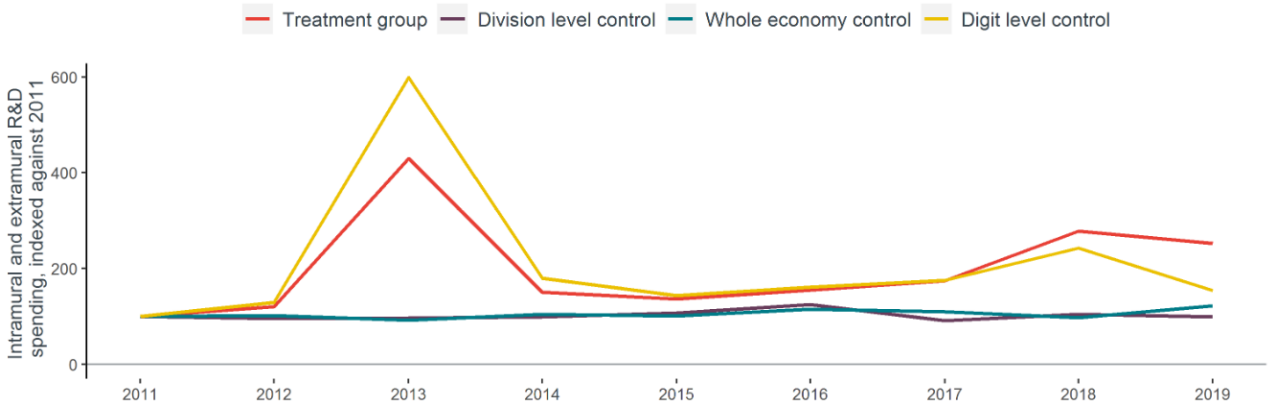
*Source: Frontier Economics based on ONS BERD data*

## FIGURE 98 INTRAMURAL AND EXTRAMURAL EXPENDITURE (CORE CONSTRUCTION, INDEX=2011)




*Source: Frontier Economics based on ONS BERD*

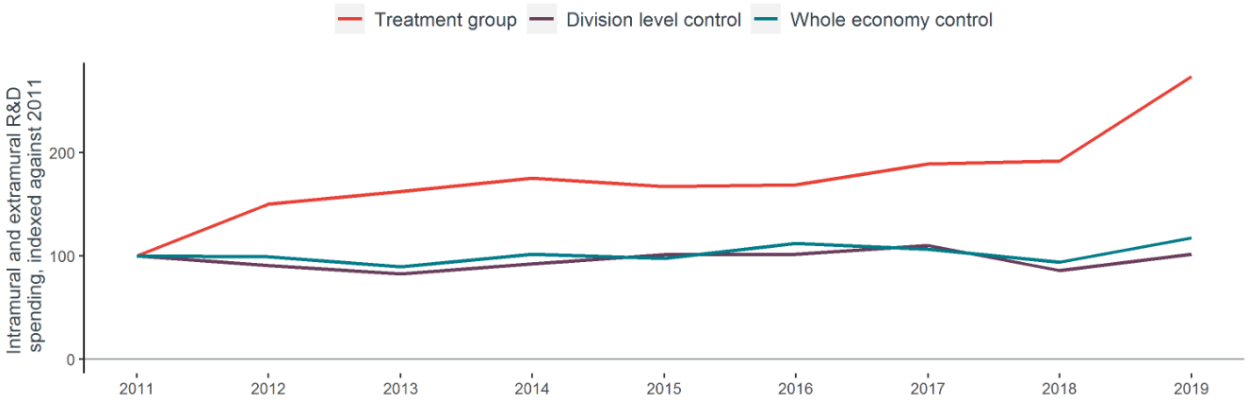
## FIGURE 99 INTRAMURAL AND EXTRAMURAL EXPENDITURE (CONSTRUCTION PRODUCT MANUFACTURERS, INDEX=2011)




*Source: Frontier Economics based on ONS BERD*

[26] There is no sub-sector level control available for the treatment group relative to professional services for the construction industry as all the relevant digit SIC codes are part of the treatment group. More detail on how the treatment and control groups are defined is provided in Annex D.

## FIGURE 100 INTRAMURAL AND EXTRAMURAL EXPENDITURE (PROFESSIONAL SERVICES FOR THE CONSTRUCTION INDUSTRY, INDEX=2011)




*Source: Frontier Economics based on ONS BERD*

### ONS SRS ABS – NET CAPITAL EXPENDITURE

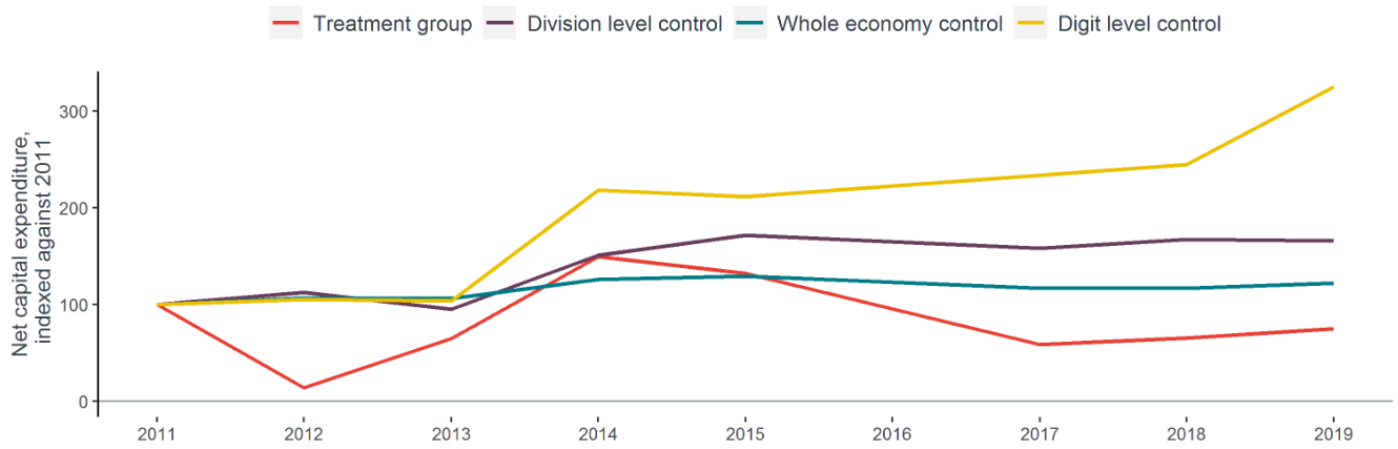
The table below presents the summary results from the ONS SRS ABS sub-sector-level analysis on net capital expenditure. It is followed by the individual analyses for each treatment group.

## TABLE 43 ONS SRS ABS SUB-SECTOR ANALYSIS

| TREATMENT GROUP | CHANGE IN NET CAPITAL EXPENDITURE |
|---|---|
| Core construction | Net capital expenditure fell for the core construction treatment group relative to all benchmarks in 2017 and has since followed a similar overall increasing trend to the benchmark groups. |
| Construction product manufacturers | Net capital expenditure increased significantly between 2013 and 2015 for the construction product manufacturers treatment group. Since 2016/17 the treatment group has followed similar groups to the sector and whole-economy benchmark. |
| Professional services for the construction industry | Net capital expenditure has followed similar trends to the sector and whole-economy benchmarks. |

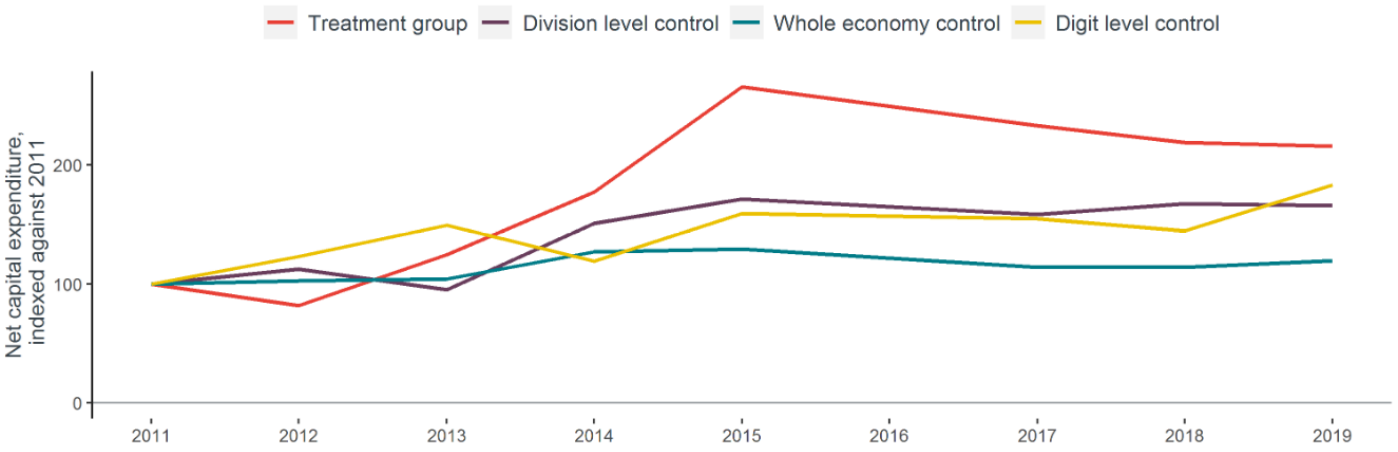
*Source: Frontier Economics based on ONS SRS ABS data*

## FIGURE 101 NET CAPITAL EXPENDITURE (CORE CONSTRUCTION, INDEX=2011)



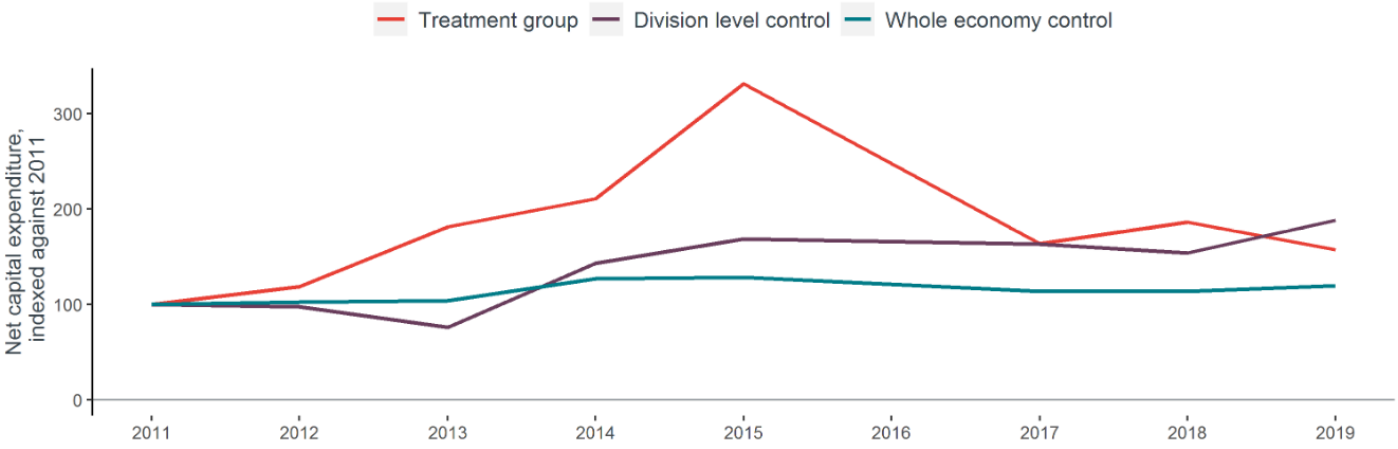

*Source: Frontier Economics based on ONS SRS ABS data*

## FIGURE 102 NET CAPITAL EXPENDITURE (CONSTRUCTION PRODUCT MANUFACTURERS, INDEX=2011)




*Source: Frontier Economics based on ONS SRS ABS data*

## FIGURE 103 NET CAPITAL EXPENDITURE (PROFESSIONAL SERVICES FOR THE CONSTRUCTION INDUSTRY, INDEX=2011)



*Source: Frontier Economics based on ONS SRS ABS data*

## G.2.2 - THEME 5 – YEAR-ON-YEAR CHANGE IN SECTOR (AND RELEVANT SUPPLY CHAIN) PRODUCTIVITY PERFORMANCE

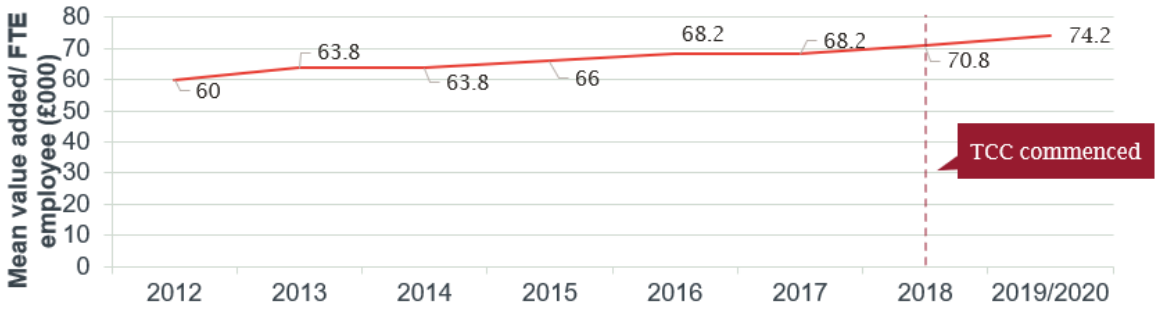
### GLENIGAN

Glenigan data is collected from surveys of construction clients, contractors, sub-contractors and consultants based on projects completed during the preceding year. The sample is based on construction projects that appear in publicly available local planning applications. Figure 104 presents the evolution of the mean value added per employee for survey respondents.

There is evidence of a **slight acceleration** in the trend of mean value added per employee following the introduction of TCC:

- Over the full period from 2012 to 2020, there is an increasing trend in the mean value added per employee.
- This trend slightly accelerated in recent years:
  - From 2012 to 2017, the CAGR was 2.6%;
  - From 2017 to 2020, CAGR was 2.9%. Note that this estimation is conservative as it assumes that all observations included in the period 2019/2020 relate solely to 2020, thus decreasing the CAGR relative to its real value.

### FIGURE 104 GLENIGAN - MEAN VALUE ADDED PER EMPLOYEE




*Source: Frontier Economics based on Glenigan*

*Note: The coverage of the latest report (relative to 2019/2020) has been extended to cover responses for projects completed over a 2 year period in order to maximise the survey sample size. This is because survey responses have been disrupted by the pandemic.*

### ACE

The Association for Consultancy and Engineering (ACE) survey gathers data from its members relative to their operations and business. Figure 105 presents average net revenue figures from respondents to the survey.

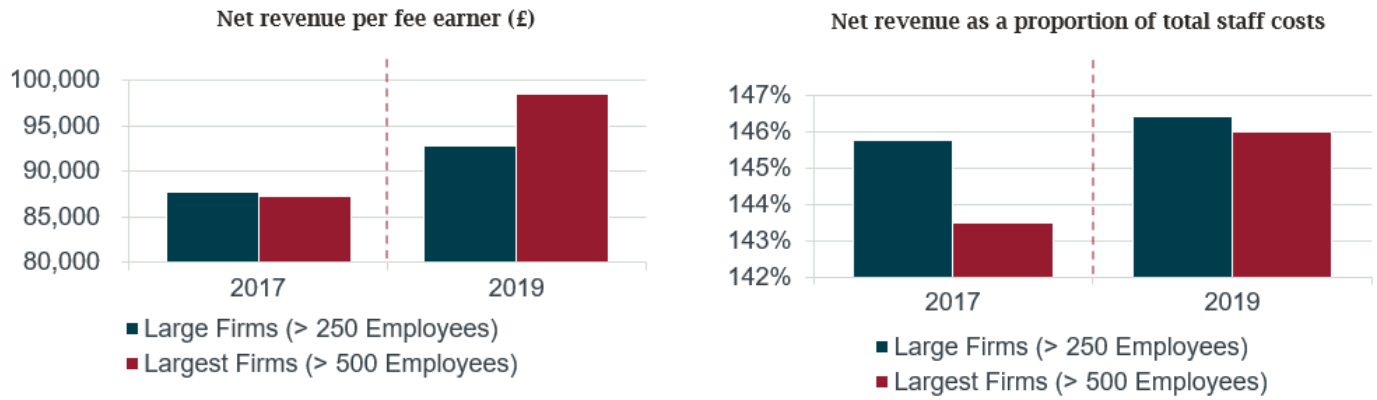
The analysis shows that GVA per worker of large UK engineering consulting firms has increased following TCC's start:

- From 2017 to 2019, net revenue per fee earner increased by 5.8% and 12.7% for 'large' and 'largest' firms, respectively.

- From 2017 to 2019, net revenue as a proportion of staff costs increased by 0.4% and 1.8% for 'large' and 'largest' firms.

However, the ACE survey has a small sample size, covering 15 and 14 large UK firms in 2017 and 2019, respectively. As such, results should be interpreted with caution.

### FIGURE 105 ACE SURVEY – AVERAGE NET REVENUE (PER FEE EARNER/AS A PROPORTION OF TOTAL STAFF COSTS)




*Source: Frontier Economics based on ACE Survey*

### ONS ABS – IN GVA PER £ OF EMPLOYMENT COSTS

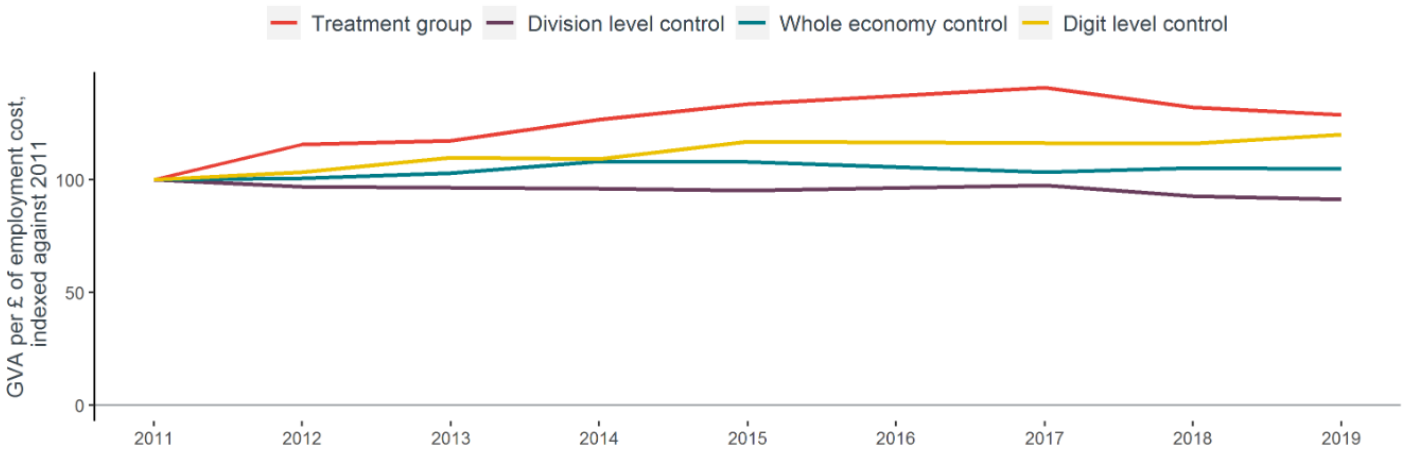
The table below presents the summary results from the ONS ABS sub-sector-level analysis on GVA per pound of employment costs. It is followed by the individual analyses for each treatment group.

### TABLE 44 ONS ABS SUB-SECTOR ANALYSIS

| TREATMENT GROUP | CHANGE IN GVA PER £ OF EMPLOYMENT COSTS |
|---|---|
| Core construction | GVA per £ of employment costs for the core construction treatment group has followed a similar trend to all benchmark groups post 2018. |
| Construction product manufactures | There has been a slight decrease in GVA per £ of employment costs post 2018, while this metric has remained mostly stable for the benchmark groups. |
| Professional services for the construction industry | There is no evidence of differences in the evolution of GVA per £ of employment costs post 2018 for the treatment and benchmark groups. |

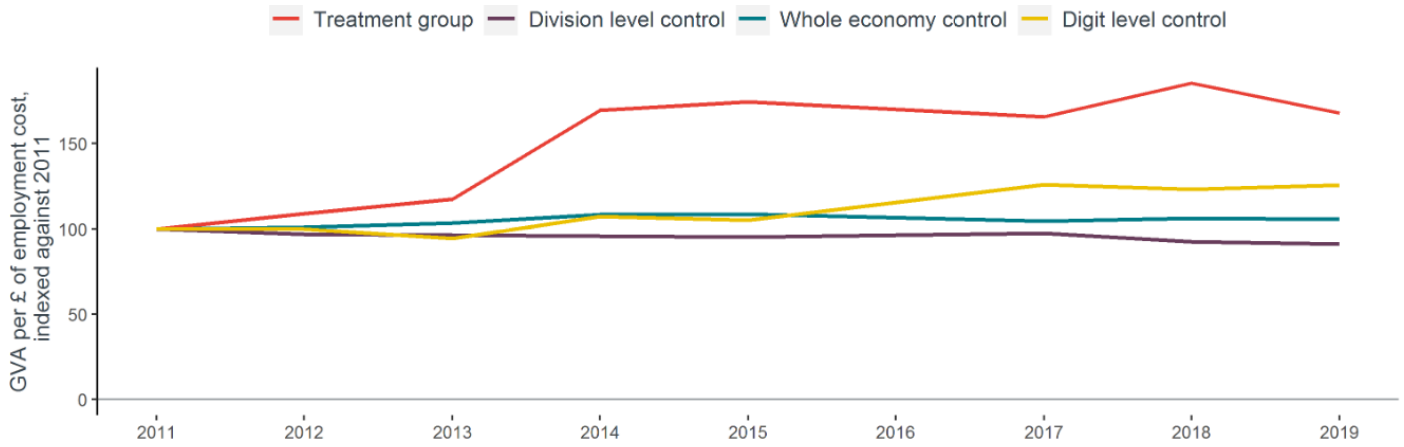
*Source: Frontier Economics based on ONS ABS data*

## FIGURE 106 GVA PER £ OF EMPLOYMENT COSTS (CORE CONSTRUCTION, INDEX=2011)



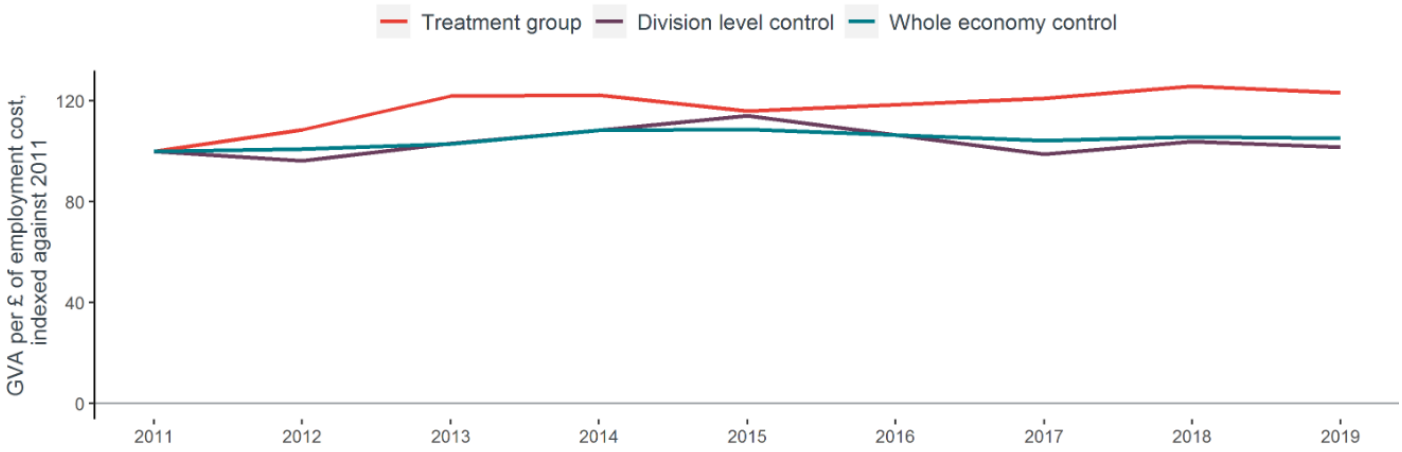

*Source: Frontier Economics based on ONS ABS data*

## FIGURE 107 GVA PER £ OF EMPLOYMENT COSTS (CONSTRUCTION PRODUCT MANUFACTURERS, INDEX=2011)




*Source: Frontier Economics based on ONS ABS data*

## FIGURE 108 GVA PER £ OF EMPLOYMENT COSTS (PROFESSIONAL SERVICES FOR THE CONSTRUCTION INDUSTRY, INDEX=2011)




*Source: Frontier Economics based on ONS ABS data*

### ONS BSD – TURNOVER PER EMPLOYEE

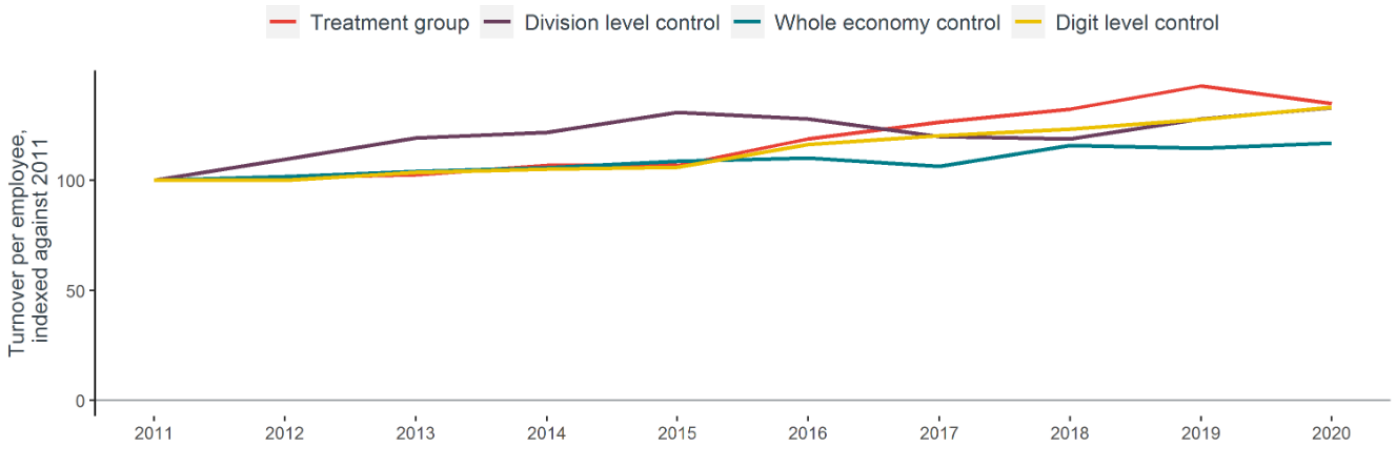
The table below presents the summary results from the ONS BSD sub-sector-level analysis on turnover per employee. It is followed by the individual analyses for each treatment group.

## TABLE 45 ONS BSD SUB-SECTOR ANALYSIS

| TREATMENT GROUP | CHANGE IN TURNOVER PER EMPLOYEE |
|---|---|
| Core construction | Following an increase from 2016–18 over and above the increases in the benchmark groups, from 2019-2020 there has been a slight decrease in turnover per employee for core construction that is not seen in the benchmark groups. |
| Construction product manufacturers | For the construction product manufacturers treatment group, turnover per employee has broadly followed the same trends as the sub-sector and sector benchmark groups. |
| Professional services for the construction industry | For the construction product manufacturers treatment group, turnover per employee has broadly followed the same trends as the benchmark groups. |

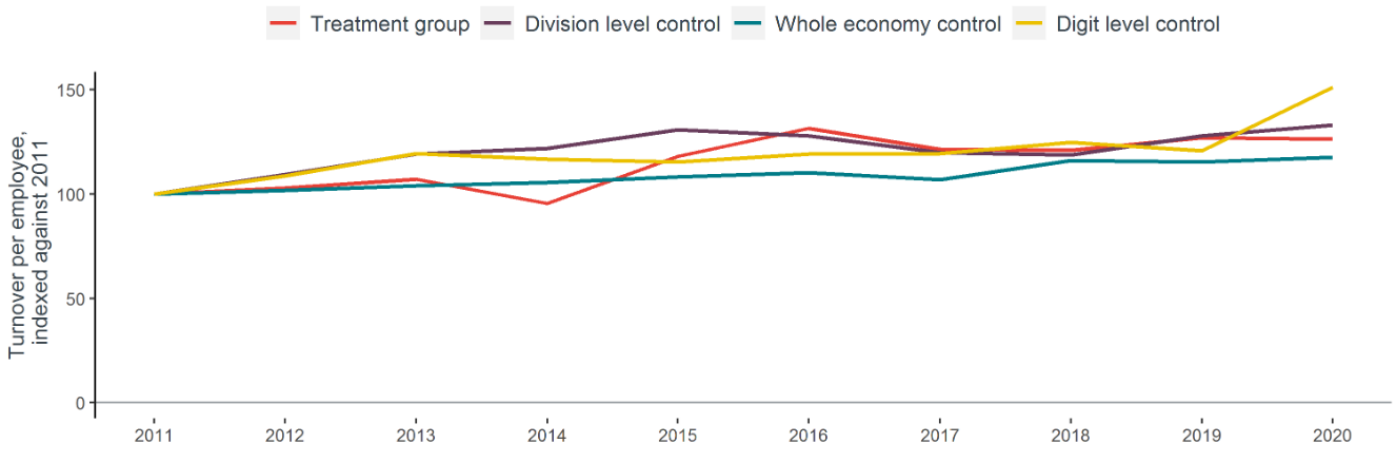
*Source: Frontier Economics based on ONS BSD data*

## FIGURE 109 TURNOVER PER EMPLOYEE (CORE CONSTRUCTION, INDEX=2011)



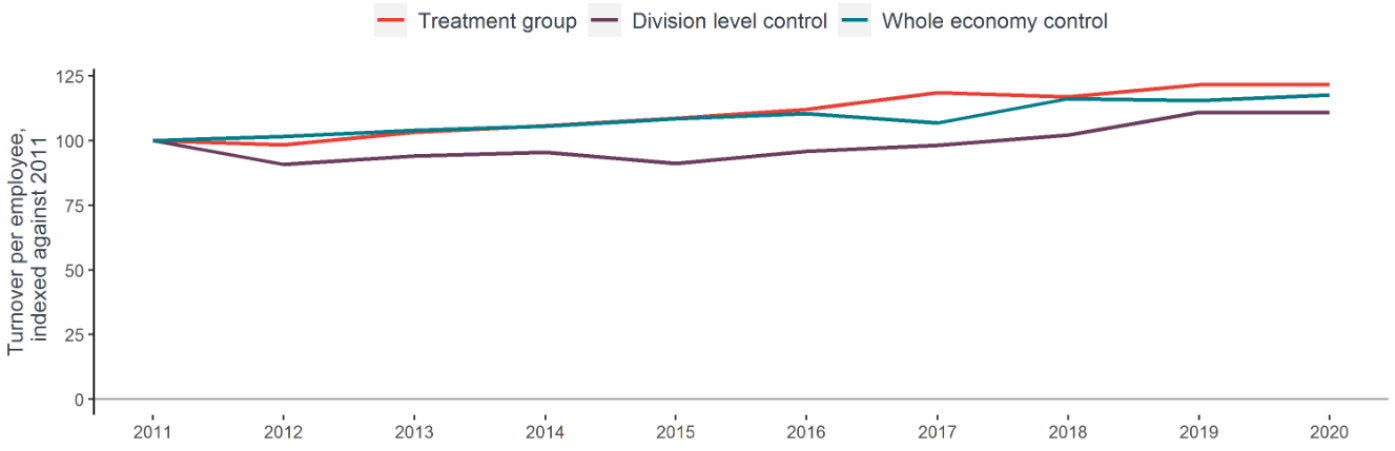

*Source: Frontier Economics based on ONS BSD data*

## FIGURE 110 TURNOVER PER EMPLOYEE (CONSTRUCTION PRODUCT MANUFACTURERS, INDEX=2011)




*Source: Frontier Economics based on ONS BSD data*

## FIGURE 111 TURNOVER PER EMPLOYEE (PROFESSIONAL SERVICES FOR THE CONSTRUCTION INDUSTRY, INDEX=2011)




*Source: Frontier Economics based on ONS BSD data*

# Annex H - VIEWS OF THE EXPERT PANEL

Interim findings based on initial analysis of the surveys, case studies and secondary data by evaluation theme were discussed and tested with external sector experts. The role of these experts was to:

- Provide critical challenge to our early interpretation of the evidence;
- Help contextualise evidence around wider trends affecting the construction sector;
- Help identify additional data sources that might inform the evaluation; and
- Provide their own reflections on the contribution of the TCC so far.

Working with the TCC, we identified a long list of experts who were invited to participate in the review process. These experts spanned industry bodies, Tier 1 construction companies, consultants and construction sector clients.

Experts were invited to attend a review meeting lasting an hour and a half and held virtually, which was facilitated by the Frontier team based on the themes identified in the interim report. Two separate expert review sessions were held, with a total of seven external sector experts in attendance.

Individuals from the TCC did not attend the meeting so that the experts would feel comfortable to offer their honest views. This annex presents a summary note of the views (without individual attribution) that was prepared and shared with attendees for review and sign-off.

## H.1 - THEME 1- ENGAGEMENT – FIRMS, PUBLIC BODIES AND ACADEMICS ARE ENGAGING IN PROJECTS RELATING TO TCC CONCEPTS

### H.1.1 - CONCLUSIONS PRESENTED TO THE EXPERT PANEL

- There has been an increase in collaboration and in the quality of collaboration for organisations that the TCC has engaged with. This collaboration can generally be attributed to the TCC.
- The TCC has enabled this collaboration through its high-profile nature, facilitator role and provision of funding.
- We are not able to draw conclusions on the effect of the TCC on collaboration in the wider industry and the wider industry trends in regards to collaboration.

### H.1.2 - VIEWS OF THE EXPERT PANEL

Overall, the expert panel agreed that the conclusions were in line with their expectations of the TCC and perceptions of the TCC's activities.

In particular, the experts agreed that there hads been an increase in interdisciplinary collaboration for those who are engaged with the TCC. A number of experts suggested that the TCC has acted as a critical focal point for organisations across the construction sector.

Experts agreed that organisations often do not have full visibility of the TCC. Experts suggested that organisations often have awareness of CIH and/or ABC but are not aware that they are part of the same programme and how they link to the TCC. This is the case for organisations which engage with CIH and ABC as well as the wider industry. There were mixed views across the experts about whether this visibility

matters. It was suggested that, in practice, it may not be necessary for organisations to be aware of other parts of the TCC programme. However, others suggested that the lack of across-programme visibility limits the extent of collaboration across the whole programme and creates problems in understanding the extent of the impacts that can be attributed to the TCC.

Experts did suggest that the communication between the TCC and wider industry could be improved to better foster collaboration. It was highlighted that the wider industry often does not have visibility of the outputs and products that are being produced by the TCC and their timelines. As a result, the engagement with the wider industry is not sufficiently structured.

The expert panel questioned the extent to which collaboration is happening in the 'right' way and amongst the 'right' people.

- **A number of experts believed that there has been more limited engagement with policy makers and academia.** It was recognised that engagement with policy makers is difficult and requires the right people in government to show a desire to be engaged. As a result, it was not expected that the TCC would be able to improve collaboration to the required levels in this area.
- **An expert highlighted that the links between the TCC and the wider government are not effective as they could be.** It was illustrated that the TCC often has similar objectives to government, e.g. promoting modernised construction but in a way that is affordable and compatible with budgets. This was particularly highlighted in terms of the links to BEIS and the IPA.
- **An expert suggested that there are limited examples of the pre-commercial collaboration in the wider industry.** An expert suggested that there have been limited changes in pre-commercial collaboration across the construction sector. They suggested that the TCC has not be able to influence this yet but that it is a critical area to influence. However, the expert highlighted that this is an area with broader behavioural and cultural issues.

The expert panel suggested the presence of a number of wider factors that have driven collaboration within the construction industry.

- **There has been an industry-wide movement to improve collaboration that pre-dates the TCC.** It was suggested that there was a movement towards greater collaboration in 2015 to 2016 driven by the Construction Leadership Council. This was matched by a distinct shift in academic research requirements around collaboration from research councils to collaborate with industry.
- **Covid-19 has increased collaboration.** A number of experts suggested that Covid-19 has helped foster collaboration across the industry and accelerated access to digital tools.

## H.2 - THEME 2 – PROCUREMENT – CONSTRUCTION SECTOR CLIENTS ENABLE TCC CONCEPTS TO BE USED IN THE PROCUREMENT PROCESS

### H.2.1 - CONCLUSIONS PRESENTED TO THE EXPERT PANEL

- There has been a change in the overall strategy within procurement to consider a wider range of impacts (e.g. on people and the environment) rather than just costs. The public sector is seen as leading on the changes to procurement strategy, ahead of the private sector.

- The change seen in terms of overall strategy cannot be directly attributed to the TCC as there are wider contextual factors such as environmental pressures and increased emphasis on digitisation that are seen as critical drivers which are enabling the change.
- However, overall the TCC is an accelerator of change through its engagement with the public sector, demonstrator programmes and role in promoting the standardisation of TCC concepts.
- There is limited evidence to date of TCC concepts being directly included in procurement processes and regulatory frameworks.

### H.2.2 - VIEW OF THE EXPERT PANEL

Overall, the TCC expert panel agreed with the conclusions presented. The experts highlighted that the TCC is an enabler of a movement towards TCC concepts in public sector procurement processes. However, they suggested that this cannot be attributed directly to the TCC due to the presence of wider factors, such as wider environmental pressure. The experts instead suggested that the TCC is an enabler of a movement towards TCC concepts being adopted in public sector procurement processes.

It was suggested by a number of experts that the TCC has picked up on concepts that were in conversation prior to the TCC within procurement and has acted as a 'broadcast mechanism' in order to promote their adoption further. Other bodies such as the Infrastructure Client Group are also influencing the adoption of TCC concepts in procurement. Therefore, the TCC adds to this voice, and thus impact cannot be directly attributed to it. This was expressed to be particularly the case for platform-based approaches.

The experts noted the importance of the Construction Playbook in changing public sector procurement, including via the incorporation of TCC concepts. However, experts showed mixed views and understanding of the extent to which the TCC had been engaged with the development of the Construction Playbook. One expert questioned the causal mechanism between the TCC and the outputs of the Construction Playbook. They highlighted that the TCC had been involved in the development of the Construction Playbook but the extent to which the TCC had driven the thinking behind the content included was not clear. Another expert expressed that we should be careful not to underestimate the role that the TCC, and in particular CIH, played in the outputs included in the Construction Playbook. Further, the TCC are expected to be similarly involved in the creation of a construction playbook for the private sector.

An expert suggested that there should have been a larger focus on procurement in practice and, further, that they were not aware of the extent to which the focus on procurement processes was a true focus of the TCC. The expert suggested that a focus on government procurement had the wider benefit of enabling and incentivising wider market adoption of TCC concepts. However, the expert expressed that changing mindsets within the public sector is challenging and is not an expected output of the TCC at this stage of the programme.

## H.3 - THEME 3 – INVESTMENT – CONSTRUCTION INDUSTRY AND VALUE CHAIN INCREASE INVESTMENT IN R&D RELATED TO TCC CONCEPTS

### H.3.1 - CONCLUSIONS PRESENTED TO THE EXPERT PANEL

- Sector-wide data suggests that there are increasing levels of investment within the construction sector, and this is reflected in increases in investment from TCC beneficiary firms.

- The survey suggests that increases in investment for beneficiary firms can be attributed to the TCC.
- The TCC has enabled increases in investment by providing a 'de-risking' role through matched funding, and allowing for investment to be facilitated in areas where, without the TCC, investment would not have occurred.

### H.3.2 - VIEW OF THE EXPERT PANEL

Broadly, the expert panel agreed with the conclusions presented. They suggested that this is a theme where they have high expectations for impact at this stage of the TCC. Consistent with expectations, the expert panel suggested that beneficiary organisations that the TCC has engaged with are focusing on R&D in TCC concepts but this is not the case for the wider industry.

An expert highlighted links between this theme's focus on investment and the focus in Theme 1 on collaboration. They suggested that the collaboration is a critical first step for investment and provides an important route for de-risking R&D.

The experts questioned whether the focus of R&D investment in the sector is appropriate:

- There is a perception that R&D is focused on near-term or 'fire-fighting' activities in order to provide immediate solutions compared to longer-term R&D. It was expressed that the TCC helps organisations focus on longer-term type R&D activities, and more so than would be possible in a purely commercial context.
- An expert suggested that ABC may have duplicated work that was already ongoing in academia prior to the implementation of the TCC.
- There was a suggestion that, while the TCC delivered benefits with respect to R&D in the commercial construction sector, there might have been a more optimum approach.

The experts illustrated that the TCC's impact on R&D investment has been focused on short-term R&D projects. Despite this the levels of investment in the industry are relatively low in comparison to where the experts believe they should be. Further, the experts questioned the extent to which the investment would continue in the longer term. An expert suggested that, without future TCC funding, it is unlikely that industry will be able to continue the increased level of R&D in TCC concepts seen, as organisations tend to be too focused on 'business as usual' activities.

An expert highlighted that there is potential for a future TCC project to build on the learnings from the current TCC programme, for example, the increasing focus on industry strategy developed in the latter stages of the TCC.

## H.4 - THEME 4 – ADOPTION – CONSTRUCTION SECTOR AND ITS SUPPLY CHAIN ADOPT

### H.4.1 - CONCLUSIONS PRESENTED TO THE EXPERT PANEL

- The organisations that the TCC has tended to engage with had good awareness levels of TCC concepts prior to TCC engagement.
- Relative to the baseline survey, we found an increase in awareness across all TCC concepts. The TCC has helped these organisations develop their understanding of TCC concepts, introduced

organisations to alternative concepts and helped develop standardisation/optimal use of TCC concepts.

- There is limited evidence on the extent to which the wider industry is adopting TCC concepts and the role of the TCC in wider adoption. This is consistent with the stage of the Challenge. Many of the projects are at a proof-of-concept/demonstrator stage. Therefore, we would not expect the TCC at this stage to have an impact on the wider industry adoption of the programme. This is consistent with case study evidence that suggests there is a long way to go before wider adoption is achieved.

### H.4.2 - VIEW OF THE EXPERT PANEL

The degree of adoption of TCC concepts was lower than the experts' initial expectations. However, given the landscape of the construction sector and the awareness of TCC concepts, the lower levels of adoption across the industry were not a surprise. The experts resonated with the conclusion that the adoption of TCC concepts is occurring in a small sub-sector of organisations, but with the majority of the sector reluctant to implement change in the absence of a clearly articulated business case.

There were mixed views across the experts on the uptake of TCC concepts, with uptake suggested to vary across concepts. An expert suggested that there are examples of disconnect between TCC frameworks and reality. Information management frameworks were highlighted as an example of this. However, other experts highlighted the successful adoption of other TCC concepts. For example, off-site manufacturing in housing, although it was highlighted that this was not always to pioneering and digitalised. Similarly, construction platforms were suggested to have moved forward and framed what the supply chain are doing and their role in platform-based in systems. For both of these cases, the TCC was credited with having raised awareness of the concepts and promoted their adoption in industry.

The experts highlighted the importance of the TCC building a legacy in order to encourage longer-term adoption of TCC concepts and change in the wider industry. The experts noted a need for a longer-term delivery vehicle for change in the construction sector in order to continue the progress made by the TCC. They suggested that it is critical that this is supported by government, given the barriers to investment and adoption of TCC concepts in the purely commercial setting. This is not to be unexpected, given that wide-scale adoption takes a significant period of time. An expert suggested this delivery vehicle should create change via 'disruption' rather than organic development.

The experts highlighted a number of barriers to wider sector adoption of TCC concepts:

- TCC concepts are expensive for organisations to adopt, with high upfront costs.
- The commercial sector is risk-averse, and so the time frames for change are slow.

## H.5 - THEME 5 – PERFORMANCE – INCREASED PERFORMANCE OF CONSTRUCTION SECTOR FIRMS AND THEIR SUPPLIERS

### H.5.1 - CONCLUSIONS PRESENTED TO THE EXPERT PANEL

- We expect that a longer time frame than the current implementation period is required to see the impact of the TCC on the performance of the construction sector firms and their suppliers.

- The activities that the TCC is involved with are generally at a proof-of-concept stage. Due to this, we find a limited change in the performance of construction sector firms and their suppliers that can be attributed to the TCC.
- However, there is clear optimism that TCC activities will result in a future change to the performance of construction sector firms and their suppliers.

### H.5.2 - VIEW OF THE EXPERT PANEL

Overall, the experts agreed that changes to the performance of the construction sector are a lagging metric, particularly when compared to collaboration and R&D investment. The experts suggested that the conclusions were consistent with their views of the programme.

The experts reflect the optimism in the case studies where they indicate that the TCC will be a critical driver of future change in the performance of the construction sector as a result of incorporating TCC concepts. The experts suggested that change is likely to be realised in the next 5 to 10 years due to the cycle of construction projects. That is, the projects that the TCC aims to impact tend to be larger-scale construction projects with long delivery lead times.

## H.6 - THEME 6 – DELIVERY – IMPROVED DELIVERY OF BUILT ASSETS (TIME, QUALITY AND WHOLE-LIFE COSTS)

### H.6.1 - CONCLUSIONS PRESENTED TO THE EXPERT PANEL

- There is early evidence of a potential future positive impact of the use of TCC concepts on the improved delivery of built assets in terms of annual revenue, profit and speed of delivery. This provides an indication of future impact through TCC's role of disseminating TCC concepts.
- There is evidence that the TCC has helped organisations with a good awareness of TCC concepts to improve performance through increased understanding and optimal use of TCC concepts.
- We do not find evidence for the TCC having an impact on the improved delivery of built assessments across the wider sector. This is expected given that activities are generally at a proof-of-concept/demonstration stage rather than being disseminated across the sector. However, there is overall optimism about the potential of TCC concepts to transform the delivery of built assets.

### H.6.2 - VIEW OF THE EXPERT PANEL

In the discussions on Theme 6, the experts echoed similar views as held for Theme 5. That is, changes to the delivery of built assets in terms of time, quality and whole-life costs are a lagging metric. However, there is optimism for change in the future as a result of the TCC, which is expected to be realised in approximately 5 to 10 years.

It should be noted that the time available to discuss Theme 6 in the expert review sessions was limited.

## H.7 - THEME 7 – ENVIRONMENT – IMPROVED ENVIRONMENTAL PERFORMANCE OF BUILT ASSETS

### H.7.1 - CONCLUSIONS PRESENTED TO THE EXPERT PANEL

- There is clear optimism for the role of TCC concepts in improving the environmental performance of built assets both through the activities that the TCC is conducting, and the potential impact of TCC concepts on performance.
- Qualitative evidence reaffirmed the critical role that TCC concepts will play in the sector meeting its net zero obligations.
- We do not find evidence for the TCC having a current impact on the environmental performance of built assets across the wider sector. This is expected given that activities are generally at a proof-of-concept/demonstration stage rather than being disseminated across the sector.
- It is expected that the integration of TCC concepts will result in improved environmental performance in the future. However, this change is driven by both the TCC and wider contextual factors (such as environmental pressures).

### H.7.2 - VIEW OF THE EXPERT PANEL

Overall, the experts agreed with the conclusions presented. A number of experts suggested that there is optimism that the TCC will have a positive impact on the environmental performance of built assets in the future, but this has not been realised yet.

There were mixed views across the experts on the extent to which change in the environmental performance of built assets should be attributed directly to the TCC. One expert commented that the environmental changes of built assets would be driven largely by the TCC. However, wider policy changes will be credited with the impact due to a lack of awareness of the activities of the TCC and its strands, particularly the link between the ABC and the TCC. Another expert suggested that it is important to see the TCC as one driver of change among many. They suggested that customer choices and behaviour as well as policy changes would have a more significant impact than the TCC in the long term.

It should be noted that the time available to discuss Theme 7 in the expert review sessions was limited.