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Civil Engineering



Engineering knowledge: the Institution of Civil Engineers and the UN Sustainable Development Goals

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Infrastructure systems have the potential to benefit all 17 of the United Nations Sustainable Development Goals (SDGs). In order to understand the role of civil engineers to contribute to the SDGs, the synergies and trade-offs between civil engineering projects, the 17 SDGs and their 169 targets were identified. Using a structured literature review of research published in key Institution of Civil Engineers journals, the priority targets for the SDGs that civil engineering is best placed to provide a contribution were identified. The highest synergies were noted in the sector of transport (Target 11.6), which highlights the need for a standalone transport goal for future SDGs beyond 2030. Across the transport, energy, water and waste management infrastructure, SDG 11 (Sustainable cities and communities) and SDG 12 (Responsible consumption and production) were found to have the highest synergies, but more work needs to be done to address the increasing uncertainty and threats of climate change (SDG 13). Finally, the civil engineering community needs to recognise the trade-offs between infrastructure projects with socio-economic SDG targets relating to health, education, gender equality and poverty reduction, which is best done by embedding the SDGs in projects from planning rather than at design or implementation stages.

Keywords: infrastructure planning; sustainability; United Nations Sustainable Development Goals

1. Introduction

The notion of sustainability was first coined in 1987 by the United Nations (UN) Brundtland Commission, and defined as meeting the needs of the present without compromising the needs of the future generations. The UN 17 sustainable development goals (SDGs) and their 169 targets, which were preceded by the UN Millennium Development Goals in 2015, provide comprehensive plans to achieve a better future for all. However, the world is set to miss the targets, especially key ones on improving access to basic infrastructure services. The SDGs provide a shared blueprint for eliminating extreme poverty, reducing inequalities, rehabilitating the natural environment, ensuring access to justice, improving well-being and building the

global partnerships needed for sustainable development. A key pillar in achieving the SDGs is promoting innovation in infrastructure and built environment, which lies in the mandate of the civil engineering industry (Thacker *et al.*, 2019). In fact, there is evidence to suggest that infrastructure such as energy systems (Nerini *et al.*, 2018) and sanitation that is well planned, designed and maintained can benefit all 17 SDGs (Parikh *et al.*, 2021). Indeed, civil engineering recognises the interconnectedness of the built environment and infrastructure across sectors such as health, education, poverty reduction and well-being. The challenge though is for the civil engineering community to prioritise key areas where efforts can yield multiple and wide-ranging benefits without inflicting harm. This is particularly the case for the socio-economic dimensions of delivering built

environment and infrastructure programmes, which is not always accounted for in a sector that is driven by economic growth.

Since the construction industry emits 37% of greenhouse gases (GHGs) (UNEP, 2023), those working in the sector, such as civil and infrastructure engineers, have a big responsibility to help address these significant global challenges and deliver the SDGs before the 2030 deadline. With over 200 years of history in shaping innovation in infrastructure and the built environment and 97 000 members worldwide, the Institution of Civil Engineers (ICE) is a key knowledge hub for civil engineers and their organisations to promote their work and learn from the civil engineering community. To this end, the ICE commissioned the research team at the Bartlett School of Sustainable Construction, University College London, to undertake a structured review of existing ICE publications. The team analysed SDG-related activities of the ICE global membership and built environment professionals by identifying synergies, trade-offs and gaps where built environment professionals have had, and can have, the greatest impact. In addition, potential changes to the current SDGs are suggested in order to inspire better action.

2. Methods

The ICE has been calling on civil engineers as part of its action plan to support the delivery of the UN SDGs (Baker, 2019). These 17 interconnected goals, which act as a blueprint to address the most urgent global challenges such as climate change and economic and social development, formed a key part of the call to action in the ICE's most recent *State of the Nation* report (ICE, 2024a). The authors conducted a structured literature review, working closely with ICE's Knowledge team, to identify key ICE journals and reports for the literature search and select inclusion/exclusion criteria in advance

of starting the review. This work was also supported by an independent steering group set up by the ICE to include industry experts.

2.1 Search strategy

Studies examining infrastructure projects, either in their planning, delivery or post-delivery stage, were identified across two main sources: nine ICE peer-reviewed journals and 18 grey literature ICE publications, such as the annual *State of the Nation* reports. (Grey literature refers to publications produced by various governmental, non-government, business, industry and educational bodies outside the control of commercial publishing (Schnopfel, 2010).) The peer-reviewed ICE journals enquiry was restricted to papers written in the English language and published between 2018 and 2023 in order to manage the number of reviewed publications since the authors opted to screen all the articles in the chosen journals instead of using search terms in order to capture the diversity of the ICE publications. For the grey literature, the review included all publications because these reports summarise ICE progress over the years on relevant topics such as sustainable civil engineering, energy and transport infrastructure development, in line with the UN SDGs.

The review was conducted in a three-stage screening process: title screening, abstract screening of included titles and full-text screening for final inclusion, as detailed in Figure 1. Paper relevance was determined through the application of the inclusion/exclusion criteria. This process was validated by the paper's co-authors to ensure inter-rater reliability.

The search, which was performed in March 2023, returned 1479 publications which underwent a multi-stage screening process:

- initial screening: 1479 documents identified
- title and abstract screening
- final screening: 340 documents included after applying inclusion and exclusion criteria in April 2023.

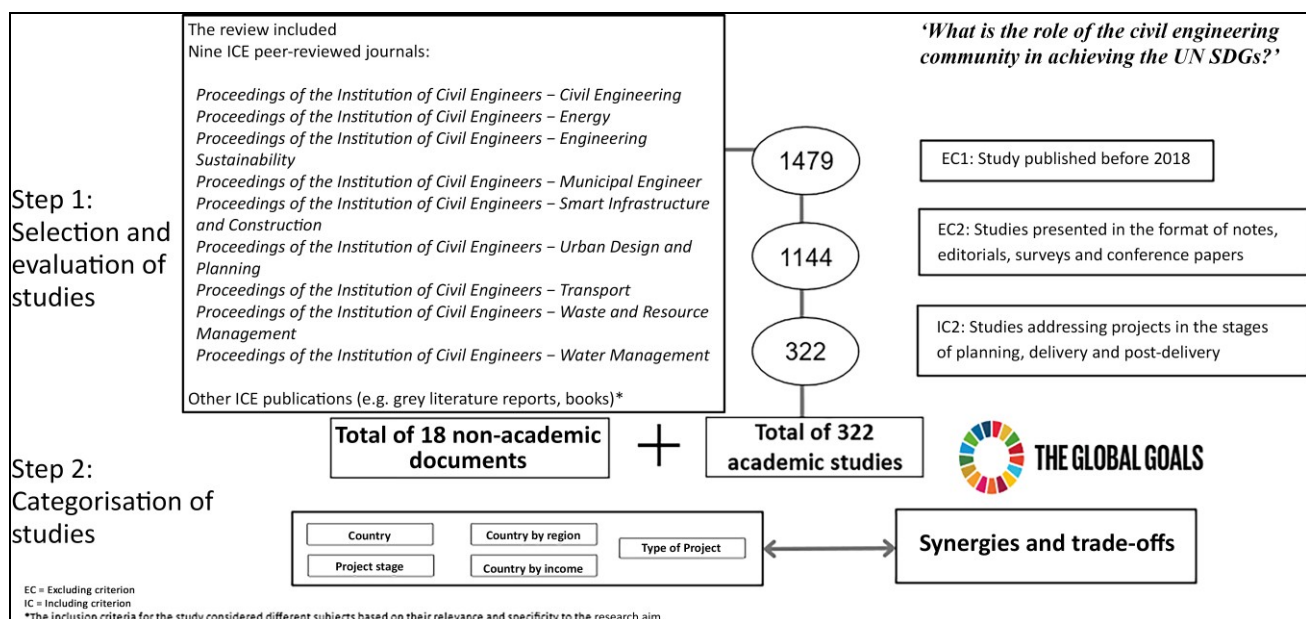


Figure 1. The search strategy for the ICE structured literature review

The exclusion criteria (EC) were

- EC1: exclude papers published before 2018
- EC2: exclude file types: notes, editorials, surveys, reviews and conference papers
- EC3: exclude theoretical studies, review papers and assessments that focus on the development of conceptual models.

The inclusion criteria (IC) were:

- IC1: include studies that address projects in stages of planning, delivery and post-delivery
- IC2: include studies that address case studies grounded in a geographical/organisational delimited dimension (i.e. community centre, UK railway etc.) and that bring practical and solid implications connected to the SDGs.

2.2 Data analysis

This study built on the global SDGs mapping framework (Martins *et al.*, 2024; Nerini *et al.*, 2018; Parikh *et al.*, 2021). The authors adapted and tailored the definitions of SDG synergies and trade-offs to fit the scope of this review. Synergies were noted when there was a positive relationship between different SDG targets and the mentioned case study or project, whereas trade-offs were noted when gains towards one SDG target would require sacrificing progress on another because they were contradictory in some way. The synergies and trade-offs were identified either directly or implicitly by the authors of the included publications. These were categorised as an evidenced synergy/trade-off or identified by the expert co-authors as potential or missed opportunities, as further explained in Section 4. The categorisation of the data

was validated by the experts who co-authored this paper and the sample was put through three stages of verification to ensure consistency of approach and what is known as inter-rater reliability. As shown in Figure 1, as part of the analysis, the studies were categorised based on: country, project stage, country by region, country by income level and type of project. The review then identified specific themes, topics or research within the journals that align with the SDGs targets, analysing both synergies and trade-offs. This analysis framework addressed the research question: What is the role of the civil engineering community in achieving the UN SDGs?

3. Characteristics of publications

Proceedings of the Institution of Civil Engineers – Engineering Sustainability and *Proceedings of the Institution of Civil Engineers – Transport* were the top journals in terms of publications in the chosen period (2018–2023), covering 12% and 6% respectively of the reviewed articles that explained the prominence of UN SDG 9 (Industry, innovation and infrastructure) and UN SDG 13 (Climate action). Most of the case study projects in the sample were implemented in the UK, which would be expected since approximately 74% of the ICE global membership is based in the UK (ICE, 2024b). The remaining publications were mostly from China, India, Türkiye and Iran, as shown in Figure 2 which offers a diverse set of countries across the globe. Such distribution is reflected on the distribution of the case studies presented in the review.

Most of the publications reported post-delivery performance, as shown in Figure 3. The post-delivery category was most prominent in the *Proceedings of the Institution of Civil Engineers*

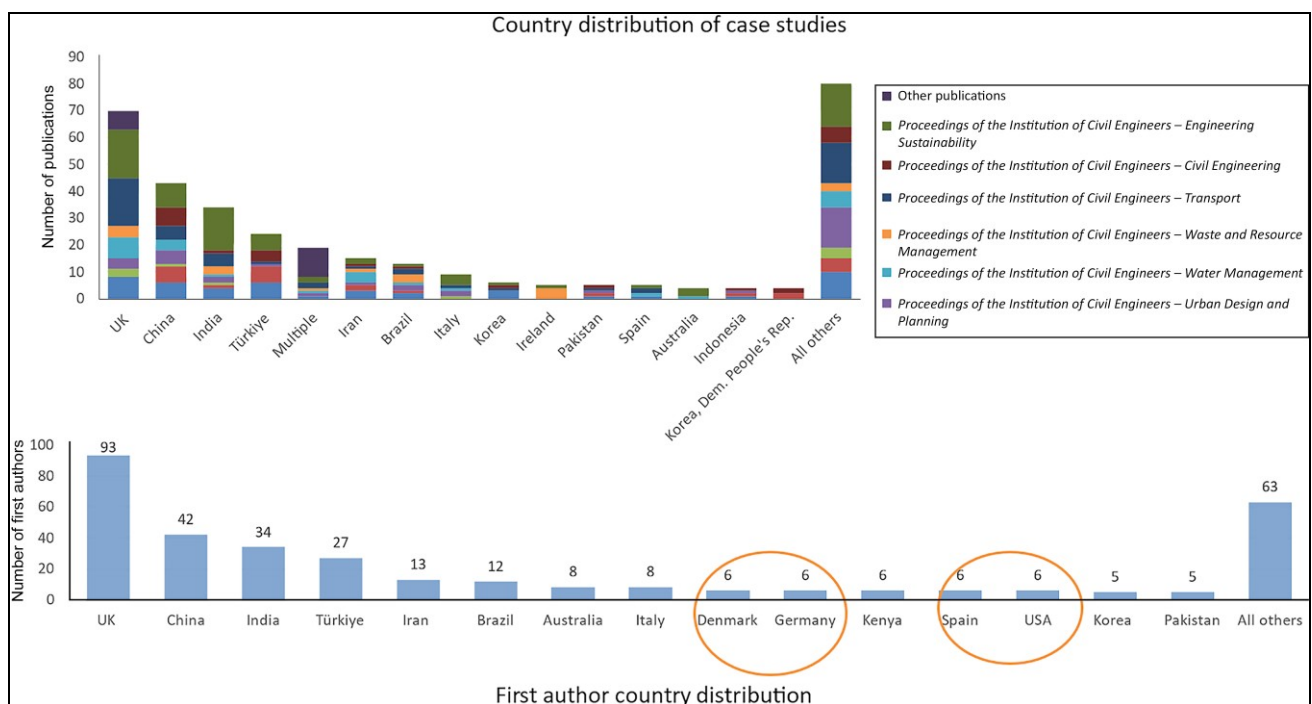


Figure 2. Country distribution of case studies and country distribution of first author in ICE publications

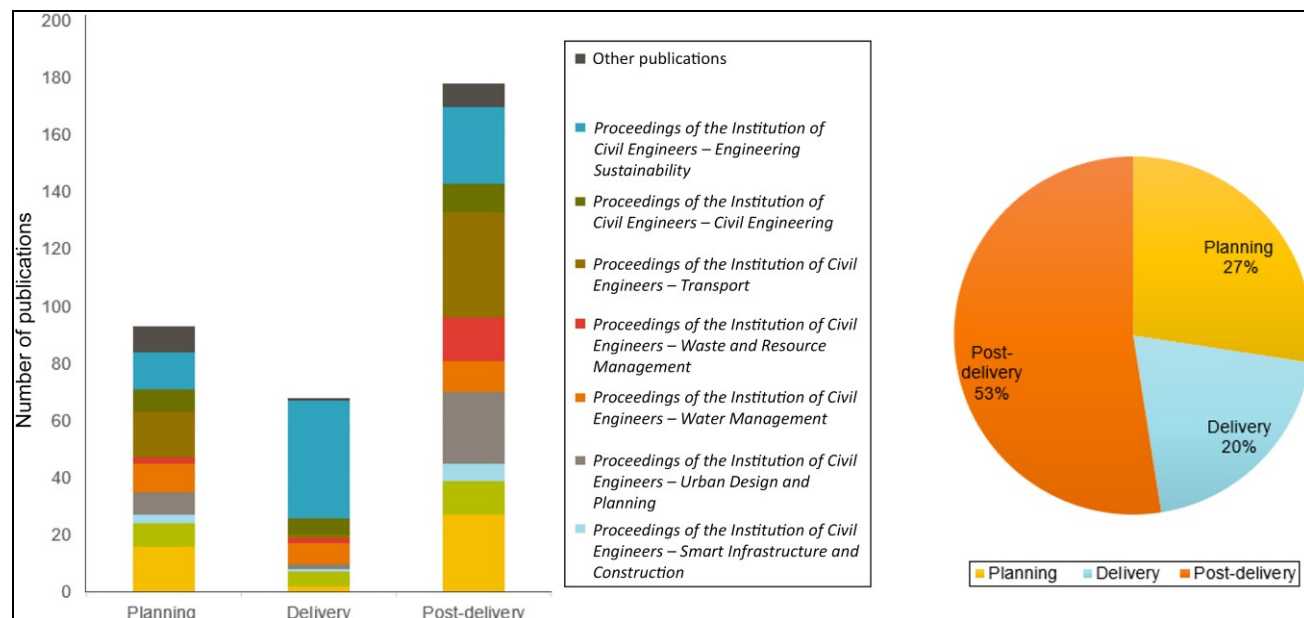


Figure 3. Distribution of publications based on project phase

Transport, Engineering Sustainability and Municipal Engineer. Interestingly, the delivery category, which reports on the performance of projects during implementation, was the least represented.

The included publications were first categorised into sectors focused on the key infrastructures systems identified by the SDGs energy, water, transport, sanitation, waste and housing, as illustrated in Figure 4. Later on, public service, ICT and materials were added as several publications were dedicated to those topics independent from the mentioned infrastructure. For instance, building materials

and how they were being prepared and transported for use featured heavily in several journals. Notably, 15% of the included publications focused on multiple infrastructure systems, which reflects the rise of cross-sector projects in the engineering industry. Some of the main links included the material category as prominent in *Proceedings of the Institution of Civil Engineers Engineering Sustainability* and the ICT category as prominent in *Proceedings of the Institution of Civil Engineers Smart Infrastructure and Construction*.

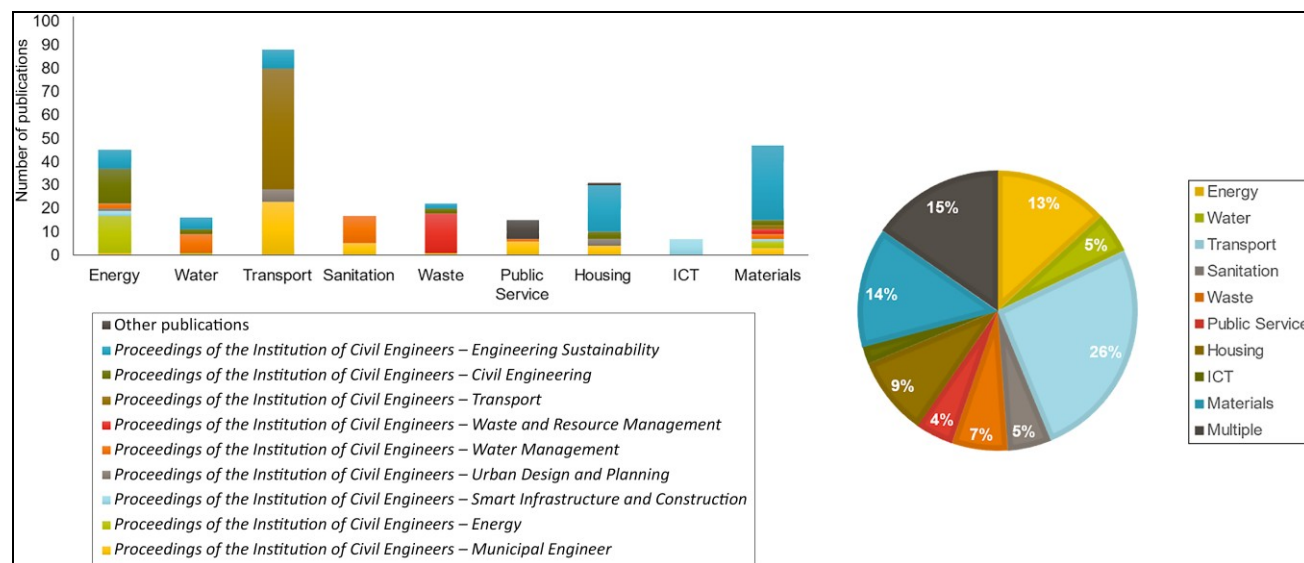


Figure 4. Sectorial distribution of the included publications across nine ICE journals

4. Results and discussion: synergies and trade-offs

This review found 1363 links across the included publications, of which 1057 were synergies and 306 were trade-offs. The numbers of synergies and trade-offs indicate the occurrences in publications where positive or negative links were identified with an SDG target. Although it is encouraging to see more synergies with the SDGs targets, the small number of trade-offs is potentially reflective of blind spots in identifying the shortcomings of the sector and the knowledge sharing culture that discourages sharing failure and lessons learned as opposed to success. As demonstrated in Figure 5, the top six synergy goals identified were:

- SDG 11: Sustainable cities and communities
- SDG 12: Responsible consumption and production
- SDG 9: Industry, innovation and infrastructure
- SDG 7: Affordable and clean energy
- SDG 17: Partnerships for the goals
- SDG 13: Climate action.

Interestingly, goals and targets with the lowest synergies were environmental and nature-related: SDG 6 (Clean water and sanitation) and SDG 8 (Decent work and economic growth) were neither in the top synergies or trade-offs. In addition, the socially oriented SDGs such as SDG 1 (No poverty), SDG 4 (Quality education), SDG 10 (Reduced inequalities) and SDG 16 (Peace, justice and strong institutions) barely had any coverage. These results highlight a gap in how engineers are delivering or identifying their

contribution and demonstrates the tension between civil engineering, the natural environment and societal well-being.

Most of the synergies focused on SDGs 9, 11, 12 and 13, with Target 11.2, which focuses on affordable and sustainable transport systems, being the most prominent. This means that these publications looked at how transport sustainability and affordability could be seen as compatible with other SDGs mentioned in the publications, and easily combined in terms of the greater good they generate.

As noted in Figure 6, the top synergy targets were found to be:

- Target 11.2 on affordable and sustainable transport systems
- Target 9.1 on developing sustainable, resilient and inclusive infrastructures
- Target 12.5 on sustainably reducing waste generation.

The top three goals where trade-offs were identified are:

- SDG 13: Climate action
- SDG 12: Responsible consumption and production
- SDG 9: Industry, innovation and infrastructure.

Trade-offs pose an opportunity and a challenge to the civil engineering community to take considered action in those sectors and reflect the much-needed transition of the civil engineering industry from building new carbon-intensive assets to putting existing assets, communities and nature at the forefront of development. As noted in Figure 7, most of the trade-offs focused on Target 13.2 (integrate climate change measures into policies and planning), Target 12.1 (implement the 10-year sustainable consumption and production framework), Target 9.2 (promote inclusive

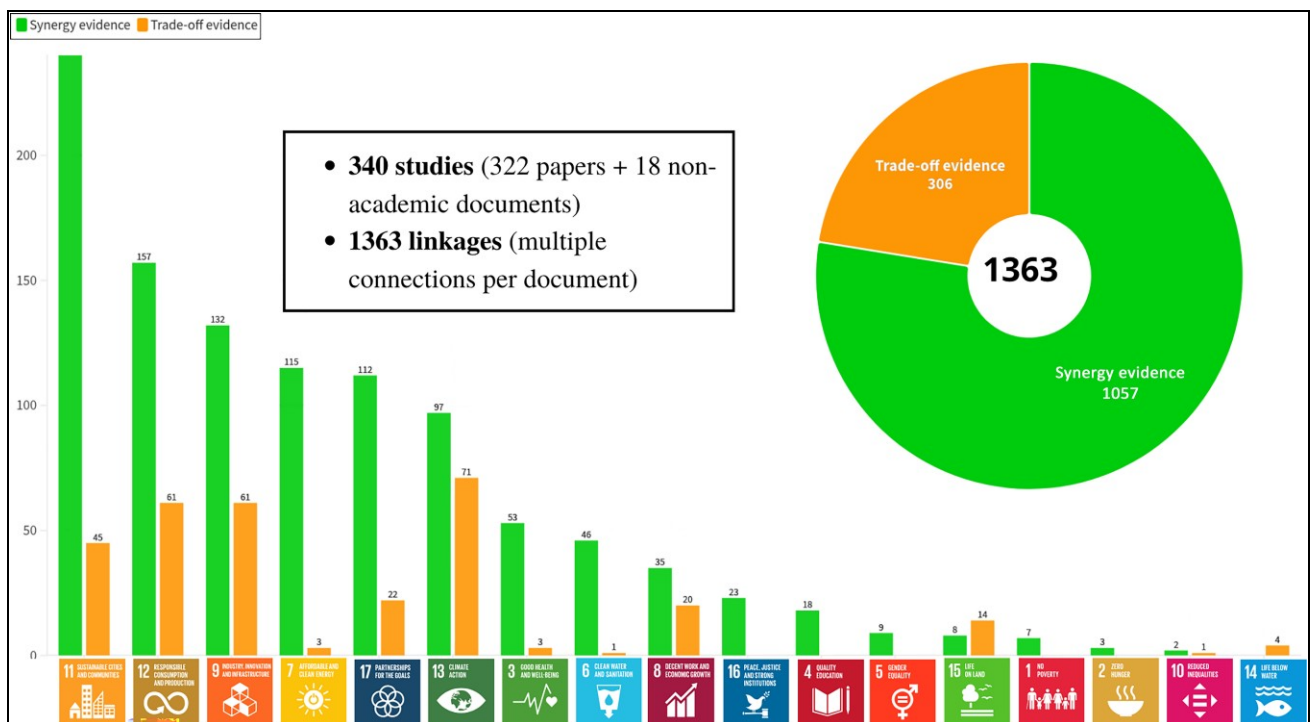


Figure 5. Distribution of synergies and trade-offs across the 17 sustainable development goals

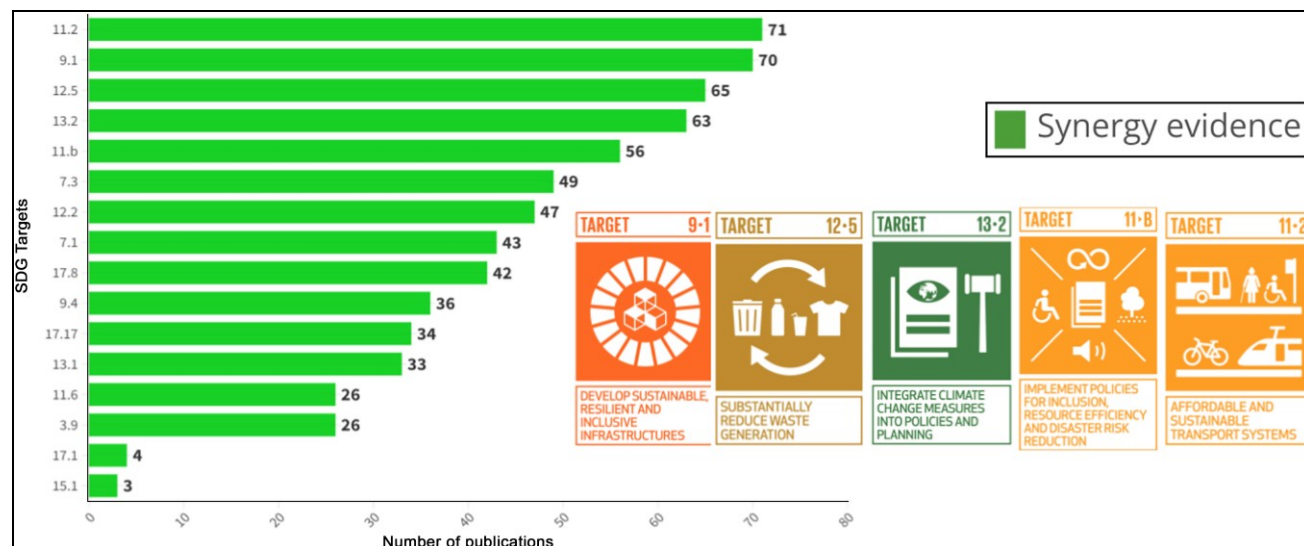


Figure 6. Top SDG target synergies across the included ICE publications

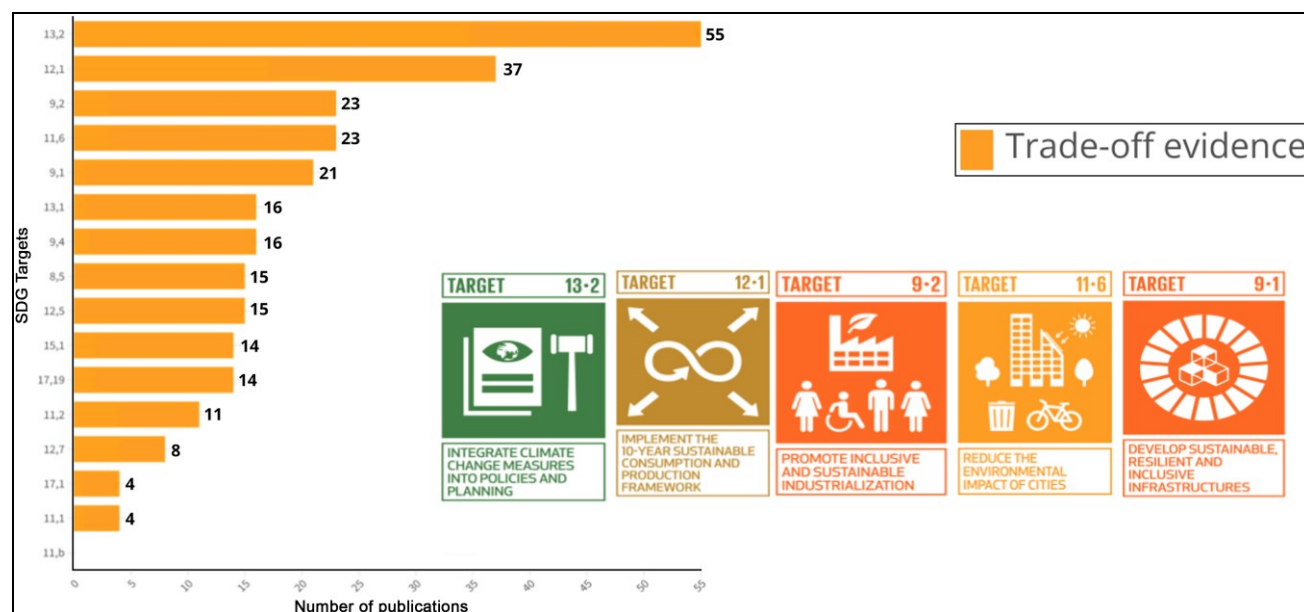


Figure 7. Top SDG targets trade-offs across the included ICE publications

and sustainable industrialisation), Target 11.6 (reduce the environmental impact of cities) and Target 9.1 (develop sustainable resilient and inclusive infrastructure).

These trade-offs reflect the moral dilemma that civil engineering needs to figure out in prioritising the increasing needs of the global economy and expanding urbanisation worldwide while promoting equitable, sustainable and climate resilient cities that put protecting our planet and all living creatures at the heart of its work. In addition, the civil engineering community needs to further identify trade-offs with SDGs targets focused on reducing

inequalities and poverty, which did not come up in this review. Building and retrofitting existing infrastructure needs to meet the changing needs of our world to address the need for equitable and inclusive access to basic infrastructure and economic opportunities and the increasing vulnerabilities of marginalised communities due to climate change.

The following sub-sections discuss the top SDG targets in both synergies and trade-offs: SDG 13 with a focus on Target 13.2, SDG 12 with a focus on Target 12.5, SDG 9 with a focus on Target 9.1 and SDG 11.

4.1 SDG 13: Climate action

As the world is realising the growing threats and uncertainties of climate change, realising the synergies between civil engineering practice and climate action (SDG 13) is crucial. Target 13.2 is particularly instrumental in driving progress towards this goal since high-level policy directs innovation for climate action. The review shows several synergies with this target from different sectors in civil engineering but, more importantly, this target scored the highest trade-offs, highlighting the challenges that the engineering community face in addressing climate action. Even projects that address ecosystem services and sustainable construction may often lead to unintended negative consequences. For instance, retrofitting buildings to reduce seismic risk or flood defence may require the use of materials and technologies that have negative environmental impacts, which may conflict with climate change policies (Cartwright *et al.*, 2019; Cload, 2023). While flood defences offer immediate protection, they use up substantial resources that could be used for long-term, climate-resilient solutions (Cartwright *et al.*, 2019). Similarly, GHG production from the transport and renewable energy industries, such as the Jubilee line extension in London, UK (Saxe and Guthrie, 2020) and the floating solar panels over lakes in Bengaluru, India, may still negatively impact the environment (Yashas *et al.*, 2021).

Furthermore, water resource allocation in regions like Sri Lanka's Mahaweli basin shows complex interactions between agricultural productivity, energy production and water conservation in the face of climate change (Chegwin and Kumara, 2018). This shows the conflict between urgent climate adaptation needs and sustainable infrastructure development. Similarly, green solutions, such as extensive green roofs, provide another example of these challenges. While effective for managing urban flooding and reducing heat islands, these solutions require significant upfront investment and ongoing maintenance. Decision makers need to weigh the long-term climate resilience benefits, and the pressing needs of marginalised communities are often the most vulnerable to climate change against immediate financial limitations. These examples highlight the complex decision making and advocacy needed when integrating climate measures into water management policies, where immediate needs and economic drivers often compete against long-term sustainability goals.

Civil engineering plays an important role in mitigating the production of GHG emissions through advancing the renewable energy sector and, in turn, alleviating fossil fuel consumption and GHG emissions (Ergul and Ozbek, 2022; Yashas *et al.*, 2021). Several transport studies have recognised the synergies with SDG 13 through promoting environmentally friendly transport policies and infrastructure, such as expanding pedestrian spaces and limiting car use, especially in compact and fast-growing cities (Loo, 2018; Pearson *et al.*, 2019). Addressing the impact of energy consumption on climate change also includes innovation in materials and construction. For instance, recycling (Cruz *et al.*, 2022) construction and demolition materials through geosynthetics (Ok *et al.*, 2023) and enhancing the performance of green concrete can reduce the carbon dioxide footprint of the construction sector (Suresh and Karthikeyan, 2018). Besides innovation, long-term maintenance of infrastructure assets for various sectors and services reduces the negative impact on the environment as it promotes climate resilience, longer life and better performance of such infrastructure (Blom and Guthrie, 2018).

4.2 SDG 12: Responsible consumption and production

SDG 12 prioritises the importance of responsible consumption of natural resources and production. Civil engineering can create several synergies with this goal, particularly to Target 12.5 (improve resource efficiency), through promoting sustainable and resilient solid waste management practices. Several studies have highlighted the various processes such as curbing waste generation (Nagalli and de Carvalho, 2019), waste sorting, recycling and biogas production from organic waste (Curry *et al.*, 2018; Saidan *et al.*, 2020) and their role in minimising land use (landfills) for waste disposal (Parihar *et al.*, 2019). Achieving Target 12.5 through solid waste management contributes to other SDGs (Targets 11.1, 11.6, 6.3 and 3.9) through reducing hazardous chemicals and air, water and soil pollution and contamination. In addition, prioritising sustainable waste management could stimulate green jobs creation (Targets 8.3 and 8.4), particularly for women (Target 5.5) (Pérez-Camacho and Curry, 2018; Teles *et al.*, 2019). However, such an agenda may require additional investments in waste management infrastructure, which could have environmental impacts and potentially lead to livelihood losses in the informal sector (Target 8.9), particularly in countries where waste picking is a common livelihood (Noufal *et al.*, 2020; Saidan *et al.*, 2020). In addition to promoting sustainable waste management, new practices and skills need to be incorporated in construction as well as behaviour change and school education to reduce waste generation at source (Target 4.7) (Tavri, 2021).

As waste generation is closely linked to human choices and living standards, housing, industrialisation and other activities could contribute to waste generation. Indeed, the Casa Minha Vida programme, which has made access to housing financing easier in Brazil, has led to an increase in waste generation due to the contractors working as small companies. By measuring waste generation and developing methods to reduce it, Teles *et al.* (2019) argue for creating synergies between construction planning and Target 12.5. Similarly, developing sustainable construction materials such as cold recycled asphalt for low-volume roads (Araneda *et al.*, 2022), using thermal insulation to increase building energy efficiency (Aslan, 2022), reusing construction and demolition materials (Ok *et al.*, 2023) and green concrete (Suresh and Karthikeyan, 2018) can curb waste generation. While civil engineering could promote synergies with SDG 12, it faces the moral hazard of inequitable distribution of resources and economic opportunities as advancing a circular economy often involves informal jobs (like waste pickers) and benefiting better-off communities.

The ICE *State of the Nation* report on infrastructure and the 2050 net-zero target (ICE, 2020) points to emerging circular economy trends that can increase the performance of new and existing assets throughout the life cycle and reduce waste in infrastructure sectors such as transport by focusing on product longevity, renewability, reuse and repair (Targets 12.5 and 12.7) such as the City of Toronto's Circular economy procurement implementation plan and framework, piloted in Canada in 2021. Similarly, the previous *State of the Nation* report (ICE, 2019) highlights Australia's three-tiered system of governance, with the state level responsible for waste management, in addition to the establishment of the Commonwealth National Housing Infrastructure Facility to finance housing-related waste management infrastructure (Target 12.5).

4.3 SDG 9: Industry, innovation and infrastructure

SDG 9 intersects with several industries and disciplines. This review showed that Target 9.1, concerned with sustainable, resilient and inclusive infrastructure development, is in particular a pillar for change to several societal, economic and environmental issues. Indeed, synergies with this target ranged from transport, water management, environmental conversation, urban planning and artificial intelligence. For instance, using artificial intelligence to predict transport demand, resilient transport alternatives contribute to increased safety and inclusive mobility to society (Ghadirzadeh *et al.*, 2022; Patel and Patel, 2022). Other studies showed the potential of introducing automated urban planning (e.g. automated parceling) to increase efficiency and productivity in urban development sectors and enhance resilience. Similarly, digitalisation of some sectors can increase efficiency and productivity in the urban development sector and enhance resilience (Koc *et al.*, 2022). However, this requires understanding the city hierarchy. Ensuring end-user participation and the dynamics of different cities helps in identifying areas where infrastructure improvements are needed to support the digitisation process (Bartle *et al.*, 2020). By bridging the digital divide and ensuring equitable access to digital tools and technologies (Korzer *et al.*, 2020), materials and construction-related studies have also highlighted synergies with this target. For instance, promoting affordable housing through heat recovery construction of buried infrastructure (Loveridge *et al.*, 2022).

Climate-sensitive infrastructure such as sustainable drainage systems improves living conditions, particularly during disruptive events like floods, and can even unlock renewable water and energy resources. More broadly, designing water and wastewater treatment infrastructure can be steered towards achieving economic development (e.g. circular economy and hydropower energy while increasing societies' resilience to climate change (Kafil and Albaji, 2018)). Similarly, innovative designs for green spaces and community centres such as linear parks can revitalise interstitial edge spaces in the post-industrial era as recreational assets, taking advantage of remnant areas alongside waterways, coastal edges, riparian zones and abandoned railroads (Faggi and Vidal, 2019). Achieving this target correlates with improving SDG targets related to well-being through increasing physical and mental health by creating outdoor recreational facilities (Panjaitan *et al.*, 2022). Doing so is best achieved through highlighting the role of the community in driving the creation of these spaces.

Although prioritising Target 9.1 in civil engineering could unlock progress in various sectors, challenges and trade-offs would arise, requiring civil engineers to actively negotiate and balance priorities to scale inclusive and resilient infrastructure. Njenga and Tanzarn (2020) emphasise the necessity of integrating gender mainstreaming in transport construction in South Africa, illustrating how infrastructure projects can inadvertently perpetuate inequalities if not designed with inclusivity in mind. Siamidoudaran *et al.* (2024) revealed correlations between environmentally friendly electric vehicles and road safety, indicating the need to consider public health outcomes (Target 3.6) alongside sustainable transport solutions. Liu *et al.* (2023) assessed optimal bus scheduling in China, balancing photovoltaic cell charging costs against carbon dioxide emissions (Target 13.2), exemplifying the intricate trade-offs in developing efficient public transport systems. The ICE (2018) report on infrastructure investment

underscores these complexities, highlighting initiatives like the UK government's Road to Zero Strategy, aimed at banning non-zero-emission cars by 2040. These studies collectively illustrate the necessity of aligning infrastructure development with environmental sustainability and social equity to achieve comprehensive progress across multiple SDGs.

4.4 SDG 11: Sustainable cities and communities

Similar to SDG 9, SDG 11 intersects with several industries and sectors, particularly in urban cities. This review suggests that Target 11.2, focused on affordable and sustainable transport systems, is a priority target for the civil engineering community. Among all the SDG targets, it had the highest synergies with the included publications. Transport-focused papers have highlighted the importance of sustainable transportation through promoting sustainable alternatives, including cycling and walking, and utilising technological advances such as artificial intelligence. Target 11.2 is a pillar for change in the energy sector, since transport is a major consumer of energy and particularly fossil fuel (7.3), so consequently contributing to SDG 13 (Climate action) (Harrow *et al.*, 2018). The ICE 2018 *State of the Nation* report on infrastructure investment highlights the Transport Research Laboratory case study as a prime example of the interconnections between transport and digital innovation as part of Target 9.5. This semi-automated 'lorry platooning' trial in Kent, UK, allowed lorries to travel more efficiently and with increased traffic flow and safety using communicative technology. Similarly, the ICE (2017) *State of the Nation* report on digital transformation points to the BaseStone redline drawing train review process used by Crossrail in the UK as an integrated system, which eliminated half of the steps compared with the traditional paper-based approach and achieved an average speed increase of 2.5 times. This is an example of a project that links together sustainable transport and printing waste savings, in line with Target 12.5.

Prioritising Target 11.2 could contribute to the well-being of society (Target 3.9), particularly through inclusive access to public transport (Target 11.7), which would improve access to education and employment for vulnerable groups (Campisi *et al.*, 2022; Chalumuri *et al.*, 2018; Llopis Serrano, 2022). Moreover, affordable transport reduces inequalities (Target 10.2) through inclusive access to public spaces (Target 11.7) and therefore access to employment and education, which ultimately creates peaceful societies (Target 16.7). Other infrastructure and services beyond transport contribute to resilient cities and transport infrastructure by reducing flood risk exacerbated by climate change (e.g. through sustainable drainage systems). Public spaces such as parks increase mobility, inclusivity, accessibility. Safety in public spaces including transport (Target 11.2), particularly for women and other marginalised groups, will ultimately contribute to social cohesion and peaceful living. Therefore, promoting community engagement (Target 11.6) is crucial in the planning stage of transport infrastructure to prevent impacting the well-being and livelihoods of the concerned communities and businesses (Chen *et al.*, 2020; Pearson *et al.*, 2019). This indicates the value of having a separate goal dedicated to the transport sector in the future.

4.5 Missed opportunities and ways forward

This section highlighted the top SDG targets found in the included case studies, namely Targets 13.2, 12.6, 9.1 and 11.2. However, several cases have failed to recognise synergies and trade-offs beyond its direct targets. Figure 8 contrasts the evidenced synergies and trade-offs against the missed opportunities in recognising synergies and trade-offs across the 169 SDG targets. The evidenced synergies and trade-offs are the instances where the authors of the included publications have explicitly drawn a connection between the project or the case study and the SDGs. The missed opportunities are the SDGs where the authors of this article used their judgement as experts to identify synergies and trade-offs that the included publications did not highlight. Reducing building energy consumption not only promotes efficient resource consumption (SDG 12) and sustainable cities (SDG 11) but also reduce GHG emissions and mitigates climate change (SDG 13) (Cruz *et al.*, 2022; Kon and Yüksel, 2019; Li *et al.*, 2022). Similarly, promoting cross-sectoral energy harvesting such as solid waste, water and sanitation not only address their respective SDG 12 and SDG 6 targets (Curry *et al.*, 2018; Duarte *et al.*, 2019; Nam-Chol *et al.*, 2023; Pérez-Camacho and Curry, 2018) but also contributes to SDG 7 and, in turn, creates synergies with SDG 13. In addition, energy-focused and waste management publications have often missed synergies with SDG 9: Developing quality, reliable, sustainable and resilient energy and waste management practices is a critical part of the infrastructure required to achieve the energy SDG targets (Nam-Chol *et al.*, 2021, 2023; Pezeshki *et al.*, 2020).

Although the review found increasing recognition from civil engineering to Target 11.2, several transport-related publications have missed the opportunity of creating synergies with this target, which highlights the need for a dedicated target that ties together the various relationships between transport and other sustainable development issues. For instance, structural monitoring of bridges could have contributed to sustainable urban development by assessing the effect of environmental factors on integral bridge abutment movement and providing data for designers to compare real and assumed effective bridge deck temperatures, earth pressures and abutment movements (Lai *et al.*, 2020; Skorpen *et al.*, 2020). Finally, although the review highlights increasing recognition of synergies across different sectors, there are 763 missed opportunities to recognise, leverage synergies and address unrecognised trade-offs. This is a call for the civil engineering community to consider wider socio-economic benefits of civil engineering projects.

5. Conclusion

This research shows that engineering has a significant impact on achieving the SDGs and is non-negotiable for achieving the targets, especially those relating to climate, if we can consider the risks at the outset. However, civil engineering has often come short when it comes to addressing or even acknowledging trade-offs with the natural environment and the socio-economic needs of the most vulnerable communities. This research provides a good reminder that the civil engineering community needs to get better at identifying links with socio-economic

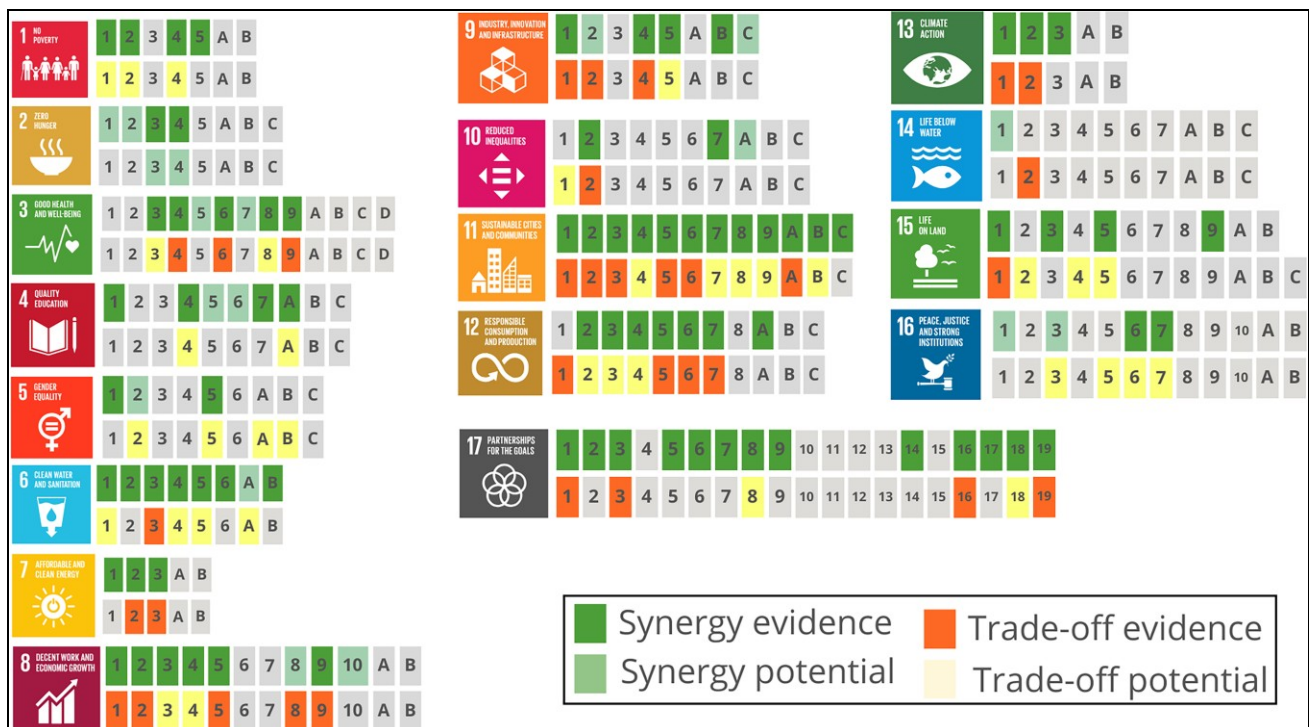


Figure 8. Mapping of evidenced and potential synergies and trade-offs across the 17 UN SDGs

benefits and articulating them clearly. For example, building a road that connects communities with schools, hospitals and opportunities for employment also needs to embed solutions beyond grey infrastructure to promote a sustainable future for society.

Currently, it is clear that the world is going to miss most of the SDG targets by 2030. The civil engineering community needs to take responsibility to accelerate and sustain progress through systemic change by embedding the SDGs from the planning stages and monitoring progress. Leveraging the impact of the engineering community can be achieved through:

- safeguarding the natural environment and embedding innovative solutions beyond grey infrastructure
- improving learning and embedding the SDGs to better identify synergies, links and trade-offs between the built environment and sustainable development
- embedding SDGs in the planning stage and continuing to monitor and guide progress through the life cycle of engineering projects.

- changing the status quo of technocratic engineering approaches to one that puts the environment and the society at the forefront of its mandate
- contributing to the next generation of SDGs based on their experience in tackling the current goals, particularly advocating for transport to be a separate goal in the future given the significance of the sector and the potential for wide-ranging long-term benefits.

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References

- Araneda ME, Pradena M, Silva R and Pardo M (2022) Sustainable paving alternative for low-volume roads using cold recycled asphalt. *Proceedings of the Institution of Civil Engineers – Engineering Sustainability* **175(6)**: 293–301, <https://doi.org/10.1680/jensu.21.00036>.
- Aslan A (2022) Effect of thermal insulation on building energy efficiency in Turkey. *Proceedings of the Institution of Civil Engineers – Energy* **175(3)**: 119–139, <https://doi.org/10.1680/jener.21.00053>.
- Baker N (2019) *GEC Action Plan for Sustainable Development Goals*. See <https://www.ice.org.uk/news-views-insights/inside-infrastructure/gec-action-plan-for-sustainable-development-goals> (accessed 14/05/2025).
- Bartle IR, Bouch CJ, Baker CJ and Rogers CDF (2020) End-user innovation of urban infrastructure: key factors in the direction of development. *Proceedings of the Institution of Civil Engineers – Municipal Engineer* **173(2)**: 69–77, <https://doi.org/10.1680/jmuen.18.00008>.
- Blom CM and Guthrie PM (2018) Infrastructure outcomes: what new project operational expenditure reveals as missing. *Proceedings of the Institution of Civil Engineers – Municipal Engineer* **171(4)**: 216–233, <https://doi.org/10.1680/jmuen.16.00025>.
- Campisi T, Moslem S, Al-Rashid MA and Tesoriere G (2022) Optimal urban planning through the best–worst method: bicycle lanes in Palermo, Sicily. *Proceedings of the Institution of Civil Engineers – Transport* **177(4)**: 213–213, <https://doi.org/10.1680/jtran.22.00013>.
- Cartwright A, Tsavdaris A, Burton R and Matthews D (2019) Delivering temporary flood defence deployment plans: lessons learned from case studies in the UK. *Proceedings of the Institution of Civil Engineers – Engineering Sustainability* **172(7)**: 345–353, <https://doi.org/10.1680/jensu.17.00016>.
- Chalumuri RS, Nath R and Errampalli M (2018) Development and evaluation of an integrated transportation system: a case study of Delhi. *Proceedings of the Institution of Civil Engineers – Transport* **171(2)**: 75–84, <https://doi.org/10.1680/jtran.16.00003>.
- Chegwin MR and Kumara S (2018) Energy, land and water nexus in Sri Lanka's Mahaweli basin. *Proceedings of the Institution of Civil Engineers – Energy* **171(3)**: 93–111, <https://doi.org/10.1680/jener.17.00026>.
- Chen C-Y, Yan S and Tseng H-T (2020) A model with a solution algorithm for the improvement of an existing bikeway network. *Proceedings of the Institution of Civil Engineers – Municipal Engineer* **173(1)**: 3–13, <https://doi.org/10.1680/jmuen.17.00015>.
- Cload L (2023) Net-zero carbon dioxide emissions in flood defence schemes. *Proceedings of the Institution of Civil Engineers – Engineering Sustainability* **176(4)**: 192–197, <https://doi.org/10.1680/jensu.21.00099>.
- Cruz VP, de Paula Campos ACS, Cardoso KR et al. (2022) Improving the efficiency of lighting energy in an office building in Brazil. *Proceedings of the Institution of Civil Engineers – Energy* **175(1)**: 2–10, <https://doi.org/10.1680/jener.20.00013>.
- Curry R, Pérez-Camacho MN, Brennan R et al. (2018) Quantification of anaerobic digestion feedstocks for a regional bioeconomy. *Proceedings of the Institution of Civil Engineers – Waste and Resource Management* **171(4)**: 94–103, <https://doi.org/10.1680/jwarm.17.00014>.
- Duarte F, Ferreira A and Champalimaud JP (2019) Waynergy vehicles: system prototype demonstration in an operational environment. *Proceedings of the Institution of Civil Engineers – Municipal Engineer* **172(2)**: 106–113, <https://doi.org/10.1680/jmuen.16.00071>.
- Ergul EU and Ozbek T (2022) Wave-energy plant site and converter type selection using multi-criteria decision making. *Proceedings of the Institution of Civil Engineers – Energy* **175(2)**: 49–63, <https://doi.org/10.1680/jener.21.00087>.
- Faggi A and Vidal CZ (2019) Uses and perceived benefits of two Latin-American linear parks. *Proceedings of the Institution of Civil Engineers – Municipal Engineer* **172(3)**: 137–144, <https://doi.org/10.1680/jmuen.15.00032>.
- Ghadirzadeh S, Mirbaha B and Rassafi AA (2022) Analysing pedestrian–vehicle conflict behaviours at urban pedestrian crossings. *Proceedings of the Institution of Civil Engineers – Municipal Engineer* **175(2)**: 107–118, <https://doi.org/10.1680/jmuen.21.00016>.
- Harrow D, Gheerawo R, Phillips D and Ramster G (2018) Understanding how attitudes towards autonomous vehicles can shape the design of cities. *Proceedings of the Institution of Civil Engineers – Municipal Engineer* **171(1)**: 31–40, <https://doi.org/10.1680/jmuen.16.00066>.
- ICE (Institution of Civil Engineers) (2017) *State Of The Nation 2017: Digital Transformation*. See <https://www.ice.org.uk/media/ahykvpau/ice-son-report-web-updated.pdf> (accessed 14/05/2025).
- ICE (Institution of Civil Engineers) (2019) *State of the Nation 2019: Connecting Infrastructure with Housing*. See <https://www.ice.org.uk/media/kupblejd/ice-state-of-the-nation-2019.pdf> (accessed 14/05/2025).
- ICE (2020) *State of the Nation 2020: Infrastructure and the Net-Zero Target*. See <https://www.ice.org.uk/media/u1elijy5/state-of-the-nation-2020-infrastructure-and-the-net-zero-target.pdf> (accessed 14/05/2025).
- ICE (2024a) *State of the Nation: Infrastructure in 2024*. See <https://www.ice.org.uk/media/ouldqt1j/state-of-the-nation-infrastructure-in-2024.pdf> (accessed 14/05/2025).

- ICE (2024b) *Institution of Civil Engineers Annual Report and Accounts 2023 Contents*. See <https://www.ice.org.uk/media/z4nmioor/annual-report-and-accounts-2023.pdf> (accessed 14/05/2025).
- Kafil M and Albaji M (2018) Selecting wastewater sites using analytical hierarchy and geographic information system. *Proceedings of the Institution of Civil Engineers – Municipal Engineer* **171(2)**: 86–92, <https://doi.org/10.1680/jmuen.16.00001>.
- Koc I, Cay T and Babaoglu I (2022) Approaches to automated land subdivision using binary search algorithm in zoning applications. *Proceedings of the Institution of Civil Engineers – Municipal Engineer* **175(1)**: 16–28, <https://doi.org/10.1680/jmuen.18.00066>.
- Kon O and Yüksel B (2019) Energy consumption based on insulation thickness of exterior walls in public buildings. *Proceedings of the Institution of Civil Engineers – Energy* **172(4)**: 135–147, <https://doi.org/10.1680/jener.19.00003>.
- Korzer T, Hübscher M, Schade K and Ringel J (2020) Rethinking retail digitisation in urban settings. The case of Leipzig, Germany. *Proceedings of the Institution of Civil Engineers – Urban Design and Planning* **173(5)**: 197–209, <https://doi.org/10.1680/jurdp.19.00019>.
- Lai H, Deng X, Chen H and Shi P (2020) Implementation of building information modelling standards for the Shanghai metro, China. *Proceedings of the Institution of Civil Engineers – Municipal Engineer* **173(3)**: 171–184, <https://doi.org/10.1680/jmuen.18.00040>.
- Li Y, Wang C, Yap JBH, Li H and Jiang H (2022) Energy-efficient design protocol for sustainable pitched roof modification from flat roof. *Proceedings of the Institution of Civil Engineers – Energy* **175(3)**: 103–118, <https://doi.org/10.1680/jener.21.00075>.
- Liu X, Ma X, Shi R and Liu Z (2023) Optimal electric bus scheduling by considering photovoltaic charging infrastructure. *Proceedings of the Institution of Civil Engineers – Engineering Sustainability* **176(5)**: 260–269, <https://doi.org/10.1680/jensu.22.00061>.
- Llopis Serrano G (2022) Traffic accidents in Spanish road tunnels. *Proceedings of the Institution of Civil Engineers – Transport* **175(1)**: 43–49, <https://doi.org/10.1680/jtran.18.00043>.
- Loo BPY (2018) Realising car-free developments within compact cities. *Proceedings of the Institution of Civil Engineers – Municipal Engineer* **171(1)**: 41–50, <https://doi.org/10.1680/jmuen.16.00060>.
- Loweridge F, Schellart A, Rees S et al. (2022) Heat recovery and thermal energy storage potential using buried infrastructure in the UK. *Proceedings of the Institution of Civil Engineers – Smart Infrastructure and Construction* **175(1)**: 10–26, <https://doi.org/10.1680/jsmic.21.00018>.
- Martins FP, De-León Almaraz S, Botelho Junior AB, Azzaro-Pantel C and Parikh P (2024) Hydrogen and the sustainable development goals: synergies and trade-offs. *Renewable and Sustainable Energy Reviews* **204**: 114796, <https://doi.org/10.1016/j.rser.2024.114796>.
- Nagalli A and de Carvalho KQ (2019) Model for estimating construction waste generation in masonry building. *Proceedings of the Institution of Civil Engineers – Waste and Resource Management* **172(1)**: 28–36, <https://doi.org/10.1680/jwarm.18.00016>.
- Nam-Chol O, Hwang C-J, Ri P-C and Kim C-H (2021) Investigating effective waste-to-energy options from refuse-derived fuel resources. *Proceedings of the Institution of Civil Engineers – Energy* **174(1)**: 35–44, <https://doi.org/10.1680/jener.19.00074>.
- Nam-Chol O, Choe T-H, Kim J-H and Choe C-M (2023) Characterising municipal solid waste to analyse life-cycle energy demand and emissions. *Proceedings of the Institution of Civil Engineers – Energy* **176(3)**: 154–166, <https://doi.org/10.1680/jener.21.00099>.
- Nerini FF, Tomei J, To LS et al. (2018) Mapping synergies and trade-offs between energy and the sustainable development goals. *Nature Energy* **3(1)**: 10–15, <https://doi.org/10.1038/s41560-017-0036-5>.
- Njenga P and Tanzam N (2020) Scaling up gender mainstreaming in transport: policies, practices and monitoring processes. *Proceedings of the Institution of Civil Engineers – Transport* **173(2)**: 64–75, <https://doi.org/10.1680/jtran.18.00152>.
- Noufal MJ, Maalla ZA and Adipah S (2020) Challenges and opportunities of municipal solid waste management system in Homs city, Syria. *Proceedings of the Institution of Civil Engineers – Waste and Resource Management* **173(2)**: 40–53, <https://doi.org/10.1680/jwarm.19.00020>.
- Ok B, Sarici T, Demir A, Talaslioglu T and Yildiz A (2023) Investigation of construction and demolition materials reinforced by geosynthetics. *Proceedings of the Institution of Civil Engineers – Engineering Sustainability* **176(5)**: 285–298, <https://doi.org/10.1680/jensu.22.00077>.
- Panjaitan TWS, Pojani D and Darchen S (2022) Alternative public space: experiences and lessons from Indonesian cities. *Proceedings of the Institution of Civil Engineers – Urban Design and Planning* **175(2)**: 56–66, <https://doi.org/10.1680/jurdp.21.00005>.
- Parihar RS, Ahmed S, Baredar P, Sharma A and Ravi Kiran T (2019) MSWM in Bhopal city: a critical analysis and a roadmap for its sustainable management. *Proceedings of the Institution of Civil Engineers – Municipal Engineer* **172(2)**: 83–95, <https://doi.org/10.1680/jmuen.17.00011>.
- Parikh P, Diep L, Hofmann P et al. (2021) Synergies and trade-offs between sanitation and the sustainable development goals. *UCL Open Environment* **3**: e016, <https://doi.org/10.14324/111.444/ucloe.000016>.
- Patel SJ and Patel CR (2022) Prioritising barriers for successful implementation of public bicycle-sharing system. *Proceedings of the Institution of Civil Engineers – Municipal Engineer* **175(2)**: 61–71, <https://doi.org/10.1680/jmuen.18.00068>.
- Pearson R, Philp S and Hoyle S (2019) Delivering shared-space schemes: two case studies from Bournemouth, UK. *Proceedings of the Institution of Civil Engineers – Municipal Engineer* **172(4)**: 197–208, <https://doi.org/10.1680/jmuen.18.00045>.
- Pérez-Camacho MN and Curry R (2018) Regional assessment of bioeconomy options using the anaerobic biorefinery concept. *Proceedings of the Institution of Civil Engineers – Waste and Resource Management* **171(4)**: 104–113, <https://doi.org/10.1680/jwarm.17.00015>.
- Pezeshki Z, Soleimani A and Darabi A (2020) Taguchi method to determine the best location for cooling and heating appliances. *Proceedings of the Institution of Civil Engineers – Energy* **173(1)**: 13–44, <https://doi.org/10.1680/jener.18.00024>.
- Saidan MN, Abu Drais A and Al-Manaseer E (2020) Opportunities of 'waste to (positive) energy' project in refugees-hosting communities. *Proceedings of the Institution of Civil Engineers – Waste and Resource Management* **173(3)**: 65–78, <https://doi.org/10.1680/jwarm.20.00002>.
- Saxe S and Guthrie P (2020) The net greenhouse gas impact of the Jubilee line extension in London, UK. *Proceedings of the Institution of Civil Engineers – Engineering Sustainability* **173(4)**: 184–195, <https://doi.org/10.1680/jensu.19.00006>.
- Schnopfel J (2010) Towards a Prague definition of grey literature. Presented at *Twelfth International Conference on Grey Literature: Transparency in Grey Literature*. Grey Tech Approaches to High Tech Issues, Prague, Czech Republic, pp. 11–26. See http://archivesic.ccsd.cnrs.fr/sic_00581570/document.
- Siamidoudaran M, Siamidoudaran M and Konuralp H (2024) Environmentally friendly electric vehicles: a silent menace to vulnerable road users? *Proceedings of the Institution of Civil Engineers – Transport* **177(2)**: 114–126.
- Skorpen SA, Kearsley EP, Clayton CRI and Kruger EJ (2020) Structural monitoring of an integral bridge in South Africa. *Proceedings of the Institution of Civil Engineers – Smart Infrastructure and Construction* **173(3)**: 63–72, <https://doi.org/10.1680/jsmic.20.00001>.
- Suresh GV and Karthikeyan J (2018) Performance enhancement of green concrete. *Proceedings of the Institution of Civil Engineers – Engineering Sustainability* **171(4)**: 191–203, <https://doi.org/10.1680/jensu.15.00066>.
- Tavri P (2021) Briefing: Resurgence of reuse at the organisational level: a reactive development in the UK. *Proceedings of the Institution of Civil Engineers – Waste and Resource Management* **174(3)**: 73–77, <https://doi.org/10.1680/jwarm.20.00007>.
- Teles RD, González MAS and Kern AP (2019) Waste measurement procedure for Brazilian social housing projects. *Proceedings of the Institution of Civil Engineers – Waste and Resource Management* **172(2)**: 42–48, <https://doi.org/10.1680/jwarm.18.00002>.

Thacker S, Adshead D, Fay M *et al.* (2019) Infrastructure for sustainable development. *Nature Sustainability* **2**(4): 324–331, <https://doi.org/10.1038/s41893-019-0256-8>.

UNEP (United Nations Environment Programme) (2023) *Building Materials and the Climate: Constructing a New Future*. United Nations, Nairobi, Kenya.

Yashas V, Aman B and Dhanush S (2021) Feasibility study of floating solar panels over lakes in Bengaluru city, India. *Proceedings of the Institution of Civil Engineers – Smart Infrastructure and Construction* **174**(1): 1–10, <https://doi.org/10.1680/jsmic.21.00002a>.

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