Global responsibility of engineering

The extent to which global responsibility is embedded into engineering practice: an exploratory study.

With thanks to...

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Executive summary

Engineers play an integral role in shaping humanity's interactions with the world around us. As a profession that has the power to transform the world for the better, engineers are uniquely placed to tackle global challenges, improve quality of life, protect the environment, and increase our resilience to risk.

At the same time, engineering has played a fundamental role in contributing to the unjust and unsustainable practices that dominate the world today. Evidence has shown that human development and the advancement of technologies are directly linked to increasing carbon emissions, biodiversity loss and human exclusion. As a result, we are now faced with the reality that our current way of life cannot be sustained for generations to come.

Recognising the significant influence that the profession has had in shaping our world to date, it is clear that engineers must also have a critical role to play in determining our future. Our ability to combat global challenges and create a safe and just future that balances human needs with the needs of the planet will, in many ways, rest on engineers' willingness to prioritise these issues and take necessary action to combat them through their work.

To achieve this, this report proposes that the sector embraces *global responsibility* as a core tenet of engineering. As a concept, globally responsible engineering proposes that engineers must critically reflect on the role of engineering in society and recognise the social, environmental and economic impacts engineering has, both locally where solutions are implemented and globally through supply chains and operational outputs.

Through a study of existing literature and interviews with engineers working in the built environment sector, in this report, we highlight the existing understanding and role of global responsibility as a concept within the sector. We explore the following: What is understood by global responsibility in engineering, and what are some of the preceding concepts that have led to this point? How well is the urgency for adopting a globally responsible approach in engineering grasped? To what extent do engineers feel it is their responsibility to take action and what is accelerating or dampening that?

Alongside this, to understand the practical barriers holding back progress in day-to-day practice, the report explores:

- Competing factors or values mean engineers deal with **uncertainty and complexity in decision making** across the design life of engineering decisions. Multi-criteria decisions mean identifying priorities and most likely making trade-offs. This can lead to compromises on certain aspects of engineering outcomes. What is compromised may not always be known or foreseen if holistic systems thinking is not applied throughout the process, and particularly if diverse viewpoints are not sought.
- The **relationship between the client and engineer** provides opportunities and challenges for globally responsible engineering. Advocating for better solutions with social and/or environmental benefits can be challenging unless client-oriented goals are met, such as cost and time-saving benefits, which are often seen as being at odds with other benefits.
- Skills, competence, confidence and supportive opportunities to propose new ideas are critical for empowering individuals and teams to challenge business-as-usual and to uphold ethical and inclusive decisions. **Engineering company culture** can nurture or hinder global responsibility in day-to-day decision making.

The exploratory design of the research study allowed for data to be collected on a topic where little prior research had been conducted; the method opens up the space for more targeted work in the future and provides an initial step towards a long-term objective of achieving globally responsible decision-making across engineering fields.

Our recommendations for practice and future work are to:

- **Promote a shared understanding** of global responsibility and the implications for engineering by critically reflecting on the role of engineering in society and understanding the impacts engineering has, locally and globally, for example through material use, supply chains and operational outputs. This would be aided by rigorous and frequent discussion of ethics across the profession.
- **Create consistent and shared approaches across the profession** for predicting and measuring actual outcomes of environmental and social sustainability, mechanisms for contributing new ideas, and procedures for implementation industry-wide. New globally responsible standards may then themselves become part of procurement processes.
- **Evolve governance to enable critical reflection** and foster a company culture that embraces the curiosity to challenge the status quo and find ways to support people voicing new and different perspectives, including those of early career engineers.
- **Evolve professional competencies and graduate attributes to require demonstration of deep commitment to acting responsibly** by broadening the competency frameworks for students, engineering educators and emerging engineers to embed global responsibility at the heart of engineering practice.

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There is no doubt that we have passed the point where we can afford to sit on the fence and wait for others. We have no planet B and we have to ensure that the engineering community is serving all people and our planet better than ever before. Global responsibility in engineering is not a choice if you believe in our collective long term future.

Katie Cresswell-Maynard, Executive Director, Engineers Without Borders International

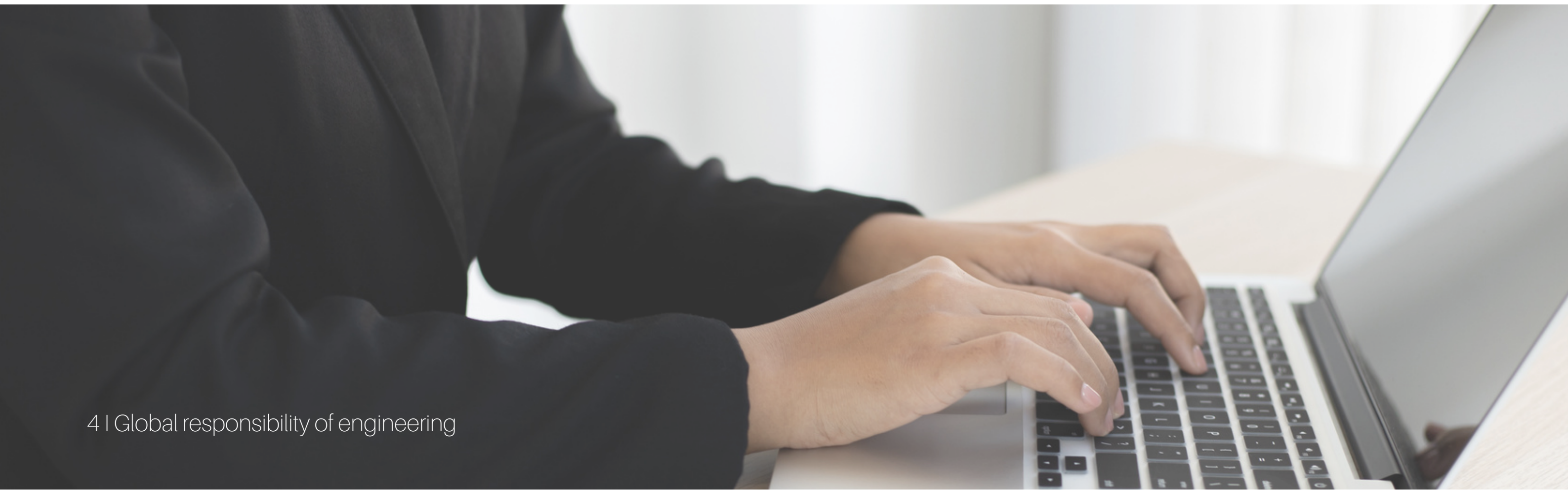
How to use this report

This report is structured so that chapters can be digested, disseminated and discussed collectively or individually. We have also provided open-ended case studies and practical challenges that we have explored with engineers in the built environment sector, to encourage readers to critically think about the urgent challenges society and the planet face and how to be globally responsible in their own role and day-day-decision making. As you read this report, what are the questions you are raising about the opportunities and barriers to practise global responsibility in your own work?

Notes on this exploratory study of global responsibility in engineering

This study leverages crossovers between a literature review and interviews to explore: (1) How are the three pillars (environmental, economic, and social sustainability) valued in engineering practice? (2) How are these values embedded in engineering practice? (3) What are the opportunities and barriers for global responsibility in engineering practice? Attention was primarily focused on built environment engineers in the UK.

1. **Literature Review:** Literature to assist in understanding global responsibility was provided by organisations including the American Society of Civil Engineers, Engineers Without Borders UK, the Institution of Civil Engineers and the Royal Academy of Engineering. Full literature review details have been published (Chance, et al., 2020, 2021a, 2021b).
2. **Semi-structured interviews:** Interviews were conducted with nine participants working in the built environment sector. Participants were asked about times they made decisions related to global responsibility and also to summarise their personal definition of the term. The research team used this data to identify opportunities and barriers these engineers had encountered while putting global responsibility into practice.



Thematic analysis (e.g. open and axial coding with constant comparison) was used to distil findings around global responsibility within the day-to-day experience of decision making among civil engineers. These qualitative research methods help researchers understand human perception and behaviour (Savin-Baden & Major, 2013). NVivo 12 was used for data management.

The findings of this initial study have provided an opportunity for further development. To date, we have analysed the data and reported findings regarding ethics (Chance, et al., 2021a) and from the perspective of early career engineers (Chance, et al., 2021b).

Limitations

The interviews were conducted in 2019. Since this time, there has been notable global recognition of the challenges confronting society and the planet. The SDGs have entered a crucial decade of action, governments globally have recognised and declared the world is facing a climate emergency, and many countries are still combatting the COVID-19 pandemic while others look ahead to recovery. Engineering is crucial to all of these global challenges. The participants' experience in industry are representative of 2018/19, and with these changes interviews conducted today may likely find greater awareness and understanding of global responsibility than three years ago, however, it is still felt that in general the findings and recommendations are as applicable today.

The sample size of nine interviewees used in this exploratory study (in-depth interviews with nine engineers) is consistent with established research practice and with exploratory research studies, which are intended to open new lines of enquiry and, often, to help guide future work. Limitations of this study include:

- The number of interviewees was relatively small.
- The interviewees all worked in or within the vicinity of central London.
- The interviewees were recruited via communications from Engineers Without Borders UK, indicating that those who volunteered for the study were already interested in the topic.
- All participants were Chartered Engineers or were pursuing chartership (or a PhD in one case), which reflects a higher level of professional engagement than required for practising engineering in the UK. These individuals would, for instance, report their activity in sustainability via annual CPD reports, making them more aware of their activity in this realm.
- All but one interviewee was comfortable discussing a topic that they saw as ambiguous and not-yet-clearly defined: ‘global responsibility’. This may indicate that the personality types of interviewees were fairly similar.

What is global responsibility in engineering?

Global responsibility in engineering means critically reflecting on the role of engineering in society and understanding the social, environmental and economic impacts engineering has, both locally to where it is implemented and globally through supply chains and operational outputs. It enables the engineering community to proactively consider how we can address the destruction of global ecosystems and the current failure to meet the basic human rights of everyone. Now more than ever, there is greater public and sectoral attention on sustainability and addressing the social and environmental inequalities that exist globally. Evidence of innovative, divergent and systems thinking are emerging throughout the sector, and goals, such as the UN's 2030 Agenda for Sustainable Development, are providing direction and deadlines for change. However, without radical changes to how engineering is taught and practised, progress to achieve the cultural shift required in engineering will remain slow.

Pillars of sustainability

The sustainability movement galvanised its activities around concepts set out by the World Commission on Environment and Development, in what is known as the Brundtland Report (1987, p. 43), defining sustainability as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs". This means considering more broadly the impact on individual lives, and producing infrastructure and products (Broers, 2005, p. 3).

Underpinning this movement have been the three pillars of sustainability: environmental, social and economic. It is felt that two pillars, environmental and social, have been neglected over time. As financial considerations have taken priority in capitalist economies and neo-liberal systems, the social aspect of sustainability is often the first to be overlooked. Furthermore, concern for environmental sustainability often dominates over social sustainability. 'Sustainability' is commonly equated with 'environmental sustainability', unconsciously omitting social and economic factors. The Sustainable Development Goals (SDGs) and the term 'global responsibility' represent efforts to rectify this mis-understanding.

Culture, which can be described as a fourth dimension in relation to sustainable development, also plays an important role in promoting and enabling sustainable development. Cultural diversity as a source of exchange, innovation and creativity is as necessary for humankind as biodiversity is for nature. In the workplace, culture can play an important role for diverse perspectives, widening understandings and challenging status quo assumptions, approaches and beliefs.

Engineering for the Sustainable Development Goals

The UNESCO Engineering Report 2021 highlights the crucial role engineering plays in achieving each of the 17 SDGs. It emphasises that addressing the global challenges facing the world today "requires adopting a more thoughtful approach that encompasses the social, human, economic and environmental impacts of engineering". The report further highlights that these values have yet to be incorporated into engineering curricula within most educational institutions. Achieving sustainable development in engineering requires action from three main parties, according to Dodds and Venables (2005, p.45):

- **Universities and training managers** "have a responsibility to deliver to the world graduates and qualified engineers who understand sustainable development and can deliver significantly more-sustainable solutions for society".
- **Practising engineers** "have a duty to become and remain competent to deliver sustainable development in their day-to-day work, and may need to actively seek out courses and other development support to achieve this objective".
- **Courses and teaching** "need to inspire every student and participant to make a difference to the world through sustainable development based upon wise practice of engineering".

In September 2019, the United Nations Secretary General called on all sectors of society for a Decade of Action (2020-2030) to advance efforts on the 2030 Agenda by accelerating sustainable solutions to all the world's biggest challenges, from poverty and gender to climate change, inequality and closing the finance gap. This is an ambitious and transformative change in how we approach social and environmental injustices, particularly for engineers looking to create solutions to deliver on the SDGs, to transform our world into one that is more resilient, inclusive and sustainable.

At the same time, COVID-19 has created an unprecedented health, economic and societal crisis which threatens lives and livelihoods. The Sustainable Development Goals Report 2020 revealed the impact COVID-19 has had on the stalled progress towards all 17 SDGs, highlighting that a global health crisis has quickly evolved into a human and socio-economic crisis (UNDESA, 2020).

> First, global responsibility means working for the betterment of humanity. Practically this means using one's talents and skills for constructive rather than destructive purposes. Second, it means speaking out, individually or collectively, against dangerous and destructive uses of science and technology. Third, it means putting the welfare of humanity as a whole ahead of the considerations of any one nation.
>
> *Kirieger (2007)*

Advocating for global responsibility in engineering

To enable the development of a sustainable, inclusive and regenerative society, it is in the best interest of people and the planet for global responsibility to be embedded in engineering. The Engineers Without Borders UK movement works to put "global responsibility at the heart of engineering" for a safe and just future for all, by inspiring, upskilling and driving change within engineering education and the profession (see: www.ewb-uk.org). The organisation's 2021-2030 strategy sets out four key principles for global responsibility that should be embedded into the culture of how engineering is taught and practised (Engineers Without Borders UK, 2021). These state that engineers, individually and collectively, must be:

- **Responsible** - to meet the needs of all people within the limits of our planet. This should be at the heart of engineering;
- **Purposeful** - to take an active approach in considering all the impacts of engineering on people and the planet, globally and locally, from a project or product's inception to the end of its life;
- **Inclusive** - to ensure that diverse viewpoints and knowledge are included and respected in the engineering process and outcomes;
- **Regenerative** - to maximise the ability of all living systems, to achieve and maintain a healthier state and naturally co-evolve.

Figure 1. Engineers Without Borders UK - Principles of global responsibility

While the use of the term 'global responsibility' itself is limited in practice and literature, some aspects of the principles of globally responsible engineering have individually received attention and are gaining ground (e.g. diversity, equity and inclusivity (towards inclusive), ethics (towards responsible) and sustainability (towards regenerative)). Aspects of global responsibility are also evident in projects aimed towards positive social and environmental outcomes (e.g. improving public transportation services, housing, water infrastructure, etc.).

Business as usual is no longer acceptable

The urgent global challenges facing people and the planet means critical reflection of how engineering is practised is needed now. Innovative solutions to accelerate decarbonisation and promote the sustainable use of resources will be crucial moving forward, however, in a Decade of Action we cannot wait for new technology to solve the issue. Engineers can create the opportunities to change, evolve and adapt current practices in response to the challenges today; they can deliver inclusive and equitable engineering outcomes, finding new ways to manage resources, use less material, regenerate habitats, support biodiversity, and achieve social justice.

Societal foundation and an ecological ceiling

Human activity is now at such a scale that it is a significant deciding factor in the future of the planet and our own future on it. It has been shown that the growth of human development is directly linked to the increase of carbon emissions, loss of biodiversity and exclusion of many people from quality life experiences, with the IPCC declaring unequivocally in 2021 that human influence has warmed the atmosphere, ocean and land (IPCC, 2021).

As a result, humanity and life on earth are facing significant challenges and threats:

- The highest concentration of carbon dioxide in our atmosphere for 3 million years is pushing the climate to the point of catastrophic change within the next decade. The global temperature has risen with the most optimistic scenarios estimating a global temperature increase of 1.5-2.4°C (IPPC, 2018, 2021).
- The planet is facing a mass extinction of species, only the sixth such event in around 540 million years (IPPC, 2018, 2021).
- The COVID-19 pandemic has had a devastating impact on society, the economy and mental wellbeing, irrespective of nationality, race, gender, or social and economic status. Recovery will take years.
- An estimated 698 million people, or 9% of the global population, are living in extreme poverty, that is, living on less than $1.90 a day (Development Initiatives, 2021).
- Approximately 2.2 billion people still lack access to safely managed drinking water services, 4.2 billion people lack access to safe sanitation services and 2.8 billion people lack access to clean cooking, putting their lives at risk everyday just to meet their basic needs (IEA, 2019; UN Water, n.d.).
- The climate emergency, persecution and conflicts globally such as in Afghanistan, Ethiopia, Ukraine and Yemen, are forcing millions to be displaced. From 42.7 million in 2011 to just over 89.3 million people worldwide by the end of 2021 (UNHCR, 2021).

- The global progress of the 2030 agenda, along with humanity's very own survival, is in danger due to cascading and interlinked crises (United Nations, 2022).

Engineering has played a major role in getting us to this point. In terms of global emissions alone, the building and construction sector is responsible for 38% of global emissions (UNEP, 2020), while 70% of all carbon dioxide emissions can be traced directly or indirectly to the creation and use of everyday infrastructure (ICE, 2021). Engineers will therefore be critical influencers in our pursuit of a safe and just future. Through the sustainable use and management of natural resources, engineers can ensure we mitigate the impacts of the climate emergency (JBM 2021; UNESCO, 2021) without compromising future generations' ability to meet their own needs (RAEng, 2020).

The climate emergency and the Conference of the Parties (COP)

In November 2021, the 26th Annual Summit of the Conference of Parties, COP26, was hosted in Glasgow. The outcome of COP26, the Glasgow Climate Pact, was agreed by nearly 200 countries: to keep the goal of limiting global temperatures from rising 1.5°C above pre-industrial levels and to finalise the outstanding elements of the landmark Paris Agreement set in 2016 at COP21.

Unfortunately, since COP26, the IPCC has predicted the current trajectory will hit 1.5°C above pre-industrial levels between 2030 and 2052. In addition to this, the Climate Action Tracker has warned that the world is heading towards a warming of 2.4°C or higher within this century, if only 2030 targets are met. In order to ensure the Glasgow Climate Pact can be delivered, it is therefore paramount that concerted and immediate global efforts are made.

In November 2022, COP27 sought to build on the outcomes of COP26, including focusing on mitigation, adaptation, finance and collaboration, as the growing energy crises, global emissions and extreme climate worsen. However, the final outcome of COP27 hasn't resulted in strengthening the commitment to the 1.5°C above pre-industrial levels goal as expected. Clear mitigation commitments to phase out all fossil fuels, phase down on coal, and ensure emissions peak before 2025 have all been omitted from the final agreement.

Despite the agreements on mitigation having been weakened, a new funding arrangement on loss and damage (a collective fund for the countries most affected by the climate emergency) has been agreed upon after more than 20 years of campaigning. Campaigners and representatives from vulnerable nations have stated that the agreement is a historic milestone for climate justice and recognising the inequalities of the climate crisis (UNFCC, 2022).

Doughnut Economics

Raworth (2017) illustrates that providing a safe space for humanity lies within two concentric rings (Figure 1). The inner ring represents a social foundation (to ensure no one is left falling short on life's essentials), and an outer ring represents an ecological ceiling (planetary boundaries that protect Earth's ecosystems). The 12 dimensions of the social foundation are derived from the internationally agreed standards, which are represented by the SDGs. The nine planetary boundaries of the environmental ceiling are set out by Rockström et al., 2009, who set out unacceptable environmental degradation and potential planetary system tipping points.

The Doughnut Economics Model provides a useful framework for conceptualising global responsibility in engineering. The social foundation and ecological ceiling provide engineering design parameters built from a basis of social and environmental justice. When analysing the categories within the Doughnut Economics Model, and investigating their interactions with each other, it becomes clear how engineering plays direct and indirect roles in the unjust and unsustainable use and facilitation of resources. For example, engineering is critical to delivering the social foundation of housing that provides safety and security to people. To provide housing we use the planet's resources such as land, which can negatively impact on biodiversity; water, which can impact on freshwater withdrawals; and construction materials such as concrete, which is one of the largest carbon emitters in the world.

Many existing multi-criteria assessment tools prompt engineers to think about these multiple factors, but how well do these tools illustrate the tensions between them? Could a framework such as the Doughnut Economics Model provide a useful starting point for engineers to think critically about the implications of engineering?

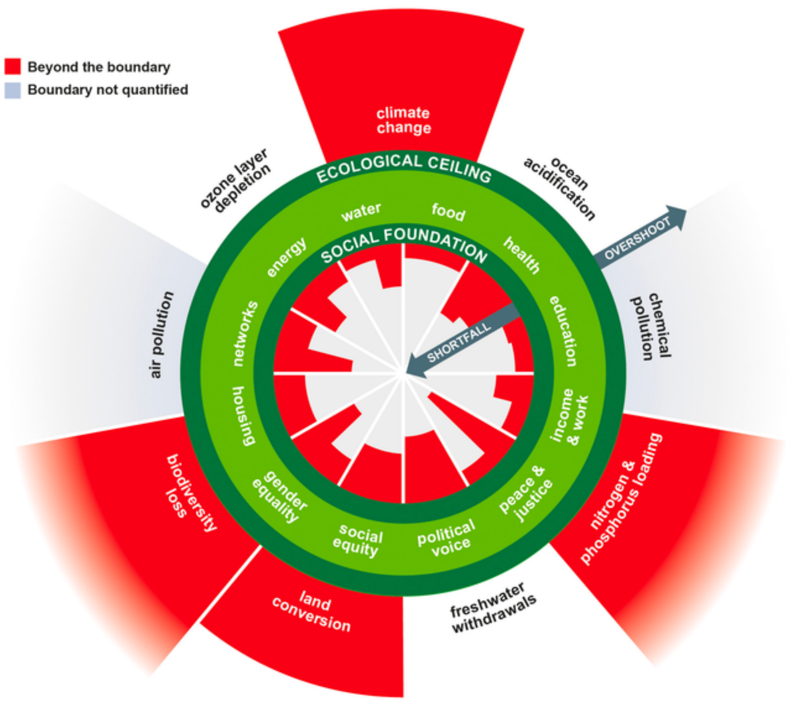


Figure 2: The Doughnut of social and planetary boundaries. Credit: Kate Raworth and Christian Guthier. CC-BY-SA 4.0. Source: Raworth (2017)

Box 1: Amsterdam puts the Doughnut Economics Model into action

In 2019, Amsterdam was one of the first cities to embed this model to shape a post pandemic society. They began by asking the question: *How can our city be a home to thriving people in a thriving place, while respecting the wellbeing of all people and the health of the whole planet?*

This question was broken down into four sub-questions combining the local and international priorities of the city, as well as considering the UN SDGs and greater mission of working within planetary boundaries. After compiling responses to address these questions, and pairing them with statistical analysis of the city's relevant contributing factors, the group produced portrait of the city that illustrated its priorities within the doughnut framework.

The resulting model encourages an interrogation of ongoing global relationships within a society, including imports and exports. Amsterdam's port is the single largest importer of cocoa in the world, arriving largely from west Africa where labour practices can be exploitative.

> *"Who would expect in a portrait of the city of Amsterdam that you would include labour rights in west Africa? And that is the value of the tool," Kate Raworth.*

Amsterdam's ambition is to bring all 872,000 residents inside the doughnut, ensuring everyone has access to a good quality of life, but without putting more pressure on the planet than is sustainable. They have begun by introducing new standards for sustainability and circular use of materials for contractors in all city-owned buildings. Anyone wanting to build will need to provide a "materials passport" for their buildings, so whenever a building is taken down, the city can reuse the parts.

The model also inspired the response during the pandemic, when the city realised that thousands of residents didn't have access to computers that would become increasingly necessary to socialise and take part in society. Rather than buy new devices, which would have been expensive and eventually contribute to the rising problem of e-waste, the city arranged collections of old and broken laptops from residents who could spare them, hired a firm to refurbish them and distributed 3,500 electronic devices to those in need.

You can find other examples of cities putting Doughnut Economics into Action at the Doughnut Economics Action Lab.

Findings from practising engineers: How well is the urgency understood?

Social and environmental sustainability

Among most participants interviewed for this study, day-to-day opportunities for engagement in social and environmental aspects of sustainable design and construction were low, aside from specifying materials with slightly improved carbon footprints. Participants described what they could affect in their work, and also described times they felt frustrated by not being able to pursue opportunities to do better. Several described having limited capacity to effect change as many fundamental decisions in any given project – such as the structural material to be used – are out of their control or outside their job remit.

Beyond material selection, other successes they described involved streamlining for enhanced efficiency. Such benefits inspired them to continue on with the hope of having greater ability to affect outcomes positively in the future. Specific examples where participants were able to practise and engage with sustainability and longevity included:

- Updating standards and company-wide documentation to improve performance and decrease environmental harm caused by concrete;
- Working toward making calculation sheets for tracking embodied carbon;
- Reducing tonnage of steel and concrete used on a project, or using recycled aggregate;
- Making allowances to retain trees on a construction site and minimise groundworks.

Whilst the suggestions they offered to clients to reduce carbon and contribute to social responsibility were encouraged, such ideas were typically only accepted by private clients when they were also found to be cheaper.

> *"When I think of 'global responsibility', it's easy to think 'sustainability'. I don't know if that's what other people have made it tangent to, but it's what decisions do I make today, which will have a positive impact on the Earth, basically, on the people living on the planet. And for future generations as well," James.*

Carbon and the climate emergency

Connections between carbon and climate were left implicit in almost all interviews. However, it is clear carbon was considered in the participants' work and that they associated carbon reduction with global responsibility. Consideration included trying to estimate and limit embodied energy and carbon emissions related to transporting materials as well as building with concrete and steel.

> *"...trying to implement sustainable solutions. That could be sourcing materials in the UK, for example, instead of picking and using steel sourced from China, which is coming over by ship, etc.," James.*

Although many participants made comments about carbon that indicated they are conscious of embodied carbon, most participants did not say exactly what consequences (e.g. climate change) they were trying to avoid. Notably, terms such as 'climate crisis' and 'climate emergency' were not mentioned. Participants were not, during the spring of 2019, using these terms frequently, nor were they referencing 'climate change' with a tone of urgency.

> *"One project that I'm working on at the moment is going to be a concrete frame residential building, and we did quite a lot of work internally on reducing the embodied carbon of the frame, so even though it will be built in the same time, and hopefully cost the same, we've managed to reduce that by looking at concrete grades, levels of reinforcement, aggregate mixes, and things like that. I think we saved 30 tonnes of embodied carbon. It's small, but it's something," Mia.*

The responsibility of engineers

The role of engineers is vital in driving change towards a sustainable society and inclusive economy. Engineering decisions can be controversial, from the materials being sourced or the land used for development, to fatal mistakes that can be made as a result of poor planning. Considering the nuances of these complexities is a crucial aspect of being globally responsible. Engineers don't just provide technological solutions, they deliver technological solutions that drive fundamental societal impact and, as such, it can be argued that their remit is wider than technology alone.

What should engineers be responsible for?

There is an often-posited argument that the remit of an engineer is mainly to produce technology and engineering artefacts – that any resulting societal or environmental impacts are the responsibility of others, primarily those who commissioned the work. Yet it is engineers who have the insight to understand and define what those impacts might be. There are grounds to suggest that this responsibility is, at the very least, shared.

If we propose the boundary of responsibility for engineers as being technology, then engineers are implementers and experts in modern technology and they work to apply and implement current practices to solve specific problems in a specific place, environment or industry. Yet, the relationship between technology and society is far from neutral. In practice, engineers consider competing factors and make compromises to bring ideas into reality at every stage of the engineering process (i.e inception, development and use of technology, use of materials, etc.). Judgements are made to balance risk and benefit and all these decisions are value laden. Engineers and clients consider how valuable the technological outputs will be relative to economic factors, social factors, and environmental factors, whether this is done knowingly or not.

With the greater awareness of the impact of engineering on people, the planet and our future comes a realisation that there is a responsibility of engineers beyond just the technological factors. The sector is being called to adopt the knowledge, skills and behaviours that reflect the broader impacts that their decisions have on society and the environment. This is the global responsibility of engineers.

Box 2: Inclusivity and diversity in artificial intelligence

Joy Buolamwini, a researcher in the MIT Media Lab's Civic Media group, ran an experiment that interrogated three commercially released facial-analysis programs from major technology companies. In her TED talk, Buolamwini explained the 'coded gaze' and highlighted the outcomes of the team's research. After analysing the facial-analysis results of 1,270 unique faces, severe gender and skin-type biases were uncovered in all three programs. The best performer showed almost no error in identifying lighter male faces, while the worst performer struggled to identify darker female faces, with a failure rate of over one in three and only a 50% chance of being correct.

Evaluating the performance and accuracy of Artificial Intellicence (AI) is essential to avoiding unintended bias and discrimination. Existing databases used to 'train' AI systems have an over representation of male faces and lighter skin tones. At best this risks developing ignorance in AI systems but at worst risks false identification and persecution of demographics that are under-represented in the databases used to train AI deployed to support policing and security services.

For example, consider if a university decided to install an enhanced security system built around facial recognition technology to enable access to buildings. What policies and safeguards could be put in place? Should the system's potential flaws be disclosed, and how? How could a just and inclusive outcome be achieved?

Prioritisation and tradeoffs between competing factors in the engineering process

Competing factors across the design life of engineered projects means engineers often find themselves prioritising and making tradeoffs in decisions. Making these decisions requires placing relative values on various factors to determine what gets prioritised. One of the original definitions of 'value engineering' was defined by Larry Miles as the ratio between functionality and cost. Functionality is the sum of functions a design can deliver, which may or may not be what it was designed for. Cost in this context is not about making things cheaper but, rather, can be interpreted to include the impacts of delivering a functionality. This would bring the impacts on people (for example, the decline in health as a result of air pollution brought about by burning fossil fuels) as an offsetting agent against the functionality obtained. In a world where it is increasingly easy to measure and track the impact of decisions along global supply chains, accountability for impact also becomes easier to assign. These are ethical dilemmas for engineers to grapple with.

Conversely, adding value in the design process can be interpreted as the benefit to people and the planet rather than today's interpretation of value engineering (i.e. the financial benefits). You could achieve a higher value for the same cost by adding functionality to the design. Focussing on the outcomes/functionality of the design process, such as adding social value, is a way of maximising the benefits of public procurement by encouraging employment opportunities, developing skills and improving environmental sustainability (HM Government, 2020). By adding more functions to the design there are more opportunities to invest into it.

A practical example of multi-functional design is the PEARL (the Person Environment Activity Research Laboratory) at the University of College London which opened in 2021. The university's first net-zero carbon in-use building is a purpose built research facility to test how people use infrastructure and cities. The design is built for the circular economy, uses recycled and recyclable materials and is powered by a photovoltaic array covering the entire roof, ensuring both regulated and (predicted) unregulated energy is entirely renewable. The building houses community-facilitating facilities, flexible workspaces and encourages the local community to engage with research. This has enabled a discovery of the effect that design has on people’s daily activities and behaviours (see https://nla.london/projects/ucl-pearl for more information).

As the person(s) best placed to understand the potential impacts of a technology, engineers have a role in bringing in the voices of all those who will or may be affected, and considering how the voiceless (e.g. future generations) are represented.

Findings from the practising engineers: What is the engineer's role?

When asked about global responsibility, participants in this study mentioned sustainability, environmental aspects of civil engineering work, social aspects of civil engineering work, and job-site health and safety.

Sustainability, and predominantly environmental sustainability, was the most widely discussed topic. They explained that environmental sustainability tied most directly to their work. They felt it was also the most readily understood aspect of sustainability, but indicated that they lacked the tools and authority to design for sustainability at the levels they felt capable of. Graduate engineers described being able to affect some aspects of design: the specification of material with lower carbon footprint, efficient use of material, decreased transportation demand, or decreased water usage.

Overall, participants aimed to use resources efficiently and responsibly, and not at the expense of current or future generations. Some stated the desire to obtain necessary resources in environmentally responsible ways. They described minimising resource depletion and extraction by, for example, specifying recycled products and locally sourced materials that require fewer resources in supply chains. A senior engineer explained:

> *"What I'm trying to say is global responsibility is about not asset stripping the planet on which we live simply because it's the cheapest thing to do today. It's actually considering the legacy you're putting in place for the increased population and increased demands on resources that are going to be in the future. I'd like to think that civil engineers [have] got a big part in that," George.*

Practical barriers in the workplace

Engineers are well placed to address global challenges by taking a globally responsible approach. Nevertheless, in the day-to-day of engineering, it may feel like there is limited scope or opportunity to practise global responsibility. Engineers face challenges in their decision making where social and environmental compromises are made in favour of other competing priorities – priorities that can be driven by a client or a company's culture. In this section we illustrate some of the practical barriers confronting engineers in the workplace.

The complexity and uncertainty involved

Grappling with socio-technical complexities presents a significant challenge, particularly considering the interface between technical and social systems within a given environmental context. The intricate societal and global challenges reflect complex systems; straightforward cause-and-effect relationships are rare. Uncertainty involves how people will interact with technology in the present and the future, including if and what the impact will be.

Tools to manage complexity

Creating strategies and visions requires complex thinking. In civil engineering, multi-criteria decision-making tools are commonly used to assist in managing design and construction. Simple calculations that can be achieved using SDG Impact Assessment Tools allow for reflection and assessment of how projected design responses might impact the various SDGs. Circular economy approaches in engineering are also often described as alternatives to the traditional linear approach most frequently assumed in the construction industry. Circular approaches can enable longer building lifetimes, greater reuse of building materials and fewer expended emissions. However, factors such as a lack of knowledge on how to apply them, ineffective supply chains, the overall complexity of building design and incentivising designing for a building's end-of-life can challenge the implementation of circular approaches.

Balancing making decisions now with future uncertainty: locked in design lives

Engineering decisions have the potential to maximise existing and future opportunities for people and the planet, however, they also have the potential to limit future options. Decisions can have 'fixed futures' with choices locked in for a design-life of 10, 50, 100 years or longer. Consider the long service life of dams, gas networks, and road design that frequently extend even beyond what their designers originally envisioned. Engineers "need to integrate consideration of whole-life environmental and social impacts, positive as well as negative, with the mainstream and commercial aspects of their work. Wise use of natural resources, minimum adverse impact and maximum positive impact on people and the environment are the targets" (Broers, 2005, p. 3).

Life Cycle Analysis (LCA) considers the overall costs associated with the design, construction, operation, maintenance, reuse and/or demolition of engineered components and systems. However, priorities can often be dominated by time and up-front cost considerations and/or capital expenditures. Prioritising the reduction of the initial capital costs of new infrastructure may result in greater operational and maintenance costs and requirements from future generations.

Box 3: Designing for future-proof systems

The challenge of engineering is that decisions are made in the face of much uncertainty, particularly when designing systems that will serve future generations. Engineers won't know what future generations will need or what challenges people will face in the future. Flexibility and adaptability are therefore needed across time.

London's sewage system was designed in the 1860s for a population of approximately 4 million people. Today the population has more than doubled, expanding to an estimated 9.4 million people in 2021, and expected to be 16 million by 2160. While the sewage system is still operating well in terms of durability, the system is struggling in terms of capacity. Overflow into the Thames River occurs every year particularly during times of moderate rainfall, causing significant environmental and health concerns. In response, the Thames Tideway Tunnel has been designed as part of a 3-stage project that aims to cut river pollution and clean up the Thames. The 25km tunnel aims to capture overflow from the old Victorian sewage system, particularly during storm events in London. It is designed to protect the river for at least 100 years and is scheduled to be completed in 2024/25.

How could the designers at the time have designed the underground sewage system to be future proof? What flexible approaches could be taken (such as adaptability and expansion) that don't restrict the option of future generations? What could one do to allow the flexibility to tackle the global challenges of the future (due to rapid urbanisation, population increases, weather extremes caused by climate change, etc.)?

Findings from the practising engineers: What opportunities are there for global responsibility in decision-making?

Building for future generations

The longevity of civil engineering outcomes can be an attractive aspect of the sector. Of the five interviewees who mentioned longevity in their interview, three participants specifically discussed efforts to not "hinder" or "compromise the needs of future generations", recognising that civil engineering places demands on natural resources and that new infrastructure can significantly change a place and how it works. However, multi-criteria decision-making means priorities and trade-offs can lead to compromises on certain aspects of engineering outcomes.

> *"You go into civil engineering because you're building for future generations. You're not going in there to mortgage it for the future but you eventually encounter lots of trade-offs about future maintenance costs versus high capital," George.*

Environmental decisions

Participants' main strategies for being responsible in their day-to-day involves efficient selection of materials with environmental preservation in mind. For them, this means selecting materials that have a less detrimental effect on the planet. Most consider embodied energy of the materials they select, which is closely linked to the amount of carbon dioxide produced, the production of concrete (and steel), extraction methods, chemical processing, and carbon footprint related to transporting the materials. One participant also described the well-being of people upstream (those involved in the production of these materials), and many (particularly those involved in the construction end of the civil engineering cycle) consider the ramifications of their decisions on those working up-stream on the construction site.

Economic decisions

How the project is funded directly impacts whether new thinking and innovative alternatives can be considered. Interviewees suggested that projects with a focus on capital expenditure were less likely to prioritise global responsibility.

> *"Often capital expenditure will be prioritised, I would say, over life cycle costs [...] there might be two or three different solutions to a problem. And you might pick one, because it has a bigger contribution towards how you feel about global responsibility. But ultimately, the client might well choose a different option because, as I said, capital expenditure might govern. Even if the whole life cycle cost could be greater," James.*

While the participants in the exploratory study hold these values of global responsibility, they usually have little sway in the development process overall. Factors that act against change include: aspects that aren't qualified or prioritised and are often overlooked, the design and construction sequence being fragmented, decisions that are made before the engineer is involved, false labelling and greenwashing, and habits (collectively and individually) that maintain the status quo.

Decisions impacting society

All nine participants discussed social justice topics in relation to global responsibility, although some did so in much more detail than others. Often, they feel limited influence to affect the social aspects of their work, although they clearly understand their civil engineering efforts as serving society. In general, social responsibility seemed to be understood as helping to raise the standard of living for others by, for instance, creating jobs or positively impacting local businesses to spark additional growth, or catalysing regeneration of ageing areas. Overall, however, social sustainability was more difficult for participants to visualise and describe than environmental sustainability.

Ethical decisions

By far, the greatest focus in the area of ethical behaviour across the construction industry, as reported by the participants, had to do with health and safety on site in the construction industry. Concerns for health and safety featured centrally in day-to-day decision-making for many of them. A primary goal is that all site workers return home at the end of each day without injury, and this extends to protecting the long-term health of site workers by specifying protective measures.

Competence in global responsibility

In 2019, the UK became the first major economy in the world to pass laws to reduce all greenhouse gas emissions to net zero by 2050. However, a report by EngineeringUK has highlighted the risk of an education and skills gap that could hinder decarbonisation across the UK economy and fall short of net-zero 2050 targets (EngineeringUK, 2022). Further, a survey by the Institution of Engineering and Technology (IET) found that only 7% of engineering companies with a sustainability strategy had the staff with the skills to fulfil it, while only 53% believed it was possible for them to meet net zero targets by 2050. (IET, 2021).

Critical thinking, necessary to determine and implement ethical decision-making, "can be promoted by providing space for dialogue and exchange within the learning environment (through seminars, multidisciplinary projects and active learning pedagogies, for example) to explore contentious and controversial aspects of engineering" (Bourn & Neal, 2008, p. 8). Although many graduate engineers have learned about ethics and are now under pressure to enact these values, they may not have the professional standing and/or mastery of techniques needed to actually implement change. Higher education and continued professional development courses are core to accruing the skills and capacities needed across the industry, in order to enact long-term worldview perspectives. Prior efforts are evident in the UK to build the needed skills and capacities in engineering. Bourn and Neal (2008) created a framework for conceptualising "the global dimension within the engineering profession" (p. 12). They characterised the skills needed to address the global dimension as:

1. Holistic thinking, critical enquiry, analysis and reflection;
2. Active learning and practical application;
3. Self awareness and empathy; and
4. Strong communication and listening skills.

The general dispositions or set of values they say that are necessary are:

1. Commitment to promoting social justice and responsibility;
2. Appropriate values and informed perceptions;
3. Integrity and trustworthiness; and
4. Seeing oneself or one's organisation as a continuous learner.

UNESCO (2021) recognises value-based engineering has yet to be embedded in engineering curricula in education institutions globally. Indeed, the engineer's responsibility is to do a competent job, act within the law, and ensure the health and safety of workers on the job site. Most decisions that could have environmental and social impacts may be outside the scope of an engineer's day-to-day, as priorities are often financial and time dependent.

Continued professional development

Engineering education is a small part of an engineer's learning. Continuing to develop professional competencies through lifelong learning is recognised through the requirements of Incorporated and Chartered Engineers. While those who pursue chartership are making a commitment to improve their capability and skill sets, limited continued professional development and monitoring, within the civil engineering profession for example, is a challenge for upskilling globally responsible engineers in the workplace (Chance, et al, 2021a).

Dealing with complexity in engineering systems means tackling a degree of uncertainty in the problems or solutions. The revised fourth edition of the Engineering Council's UK-SPEC (published on 31 August 2020) describes the responsibility of Chartered Engineers to "Develop solutions to engineering problems using new or existing technologies, through innovation, creativity and change. [Engineers] May be accountable for complex systems with significant levels of risk" (Engineering Council, 2020a). Levels of risk to wider society and the planet in engineering decision-making can mean project decisions are made in the face of many uncertainties.

UNESCO (2021) highlights the need for complexity within engineering education through the Cynefin framework (a decision-making framework categorising system behaviours into obvious, complicated, complex and chaotic), combining teaching and learning methods with the increasing need to understand complexities (Snowden and Bloom, 2007), particularly to aid critical thinking and reflection on engineering outcomes. Further, encouraging more diverse representation in engineering and the decision-making process enables diverse viewpoints and knowledge to be included and respected in the engineering process, to reduce unintended consequences or bias in engineering outcomes and challenge existing assumptions.

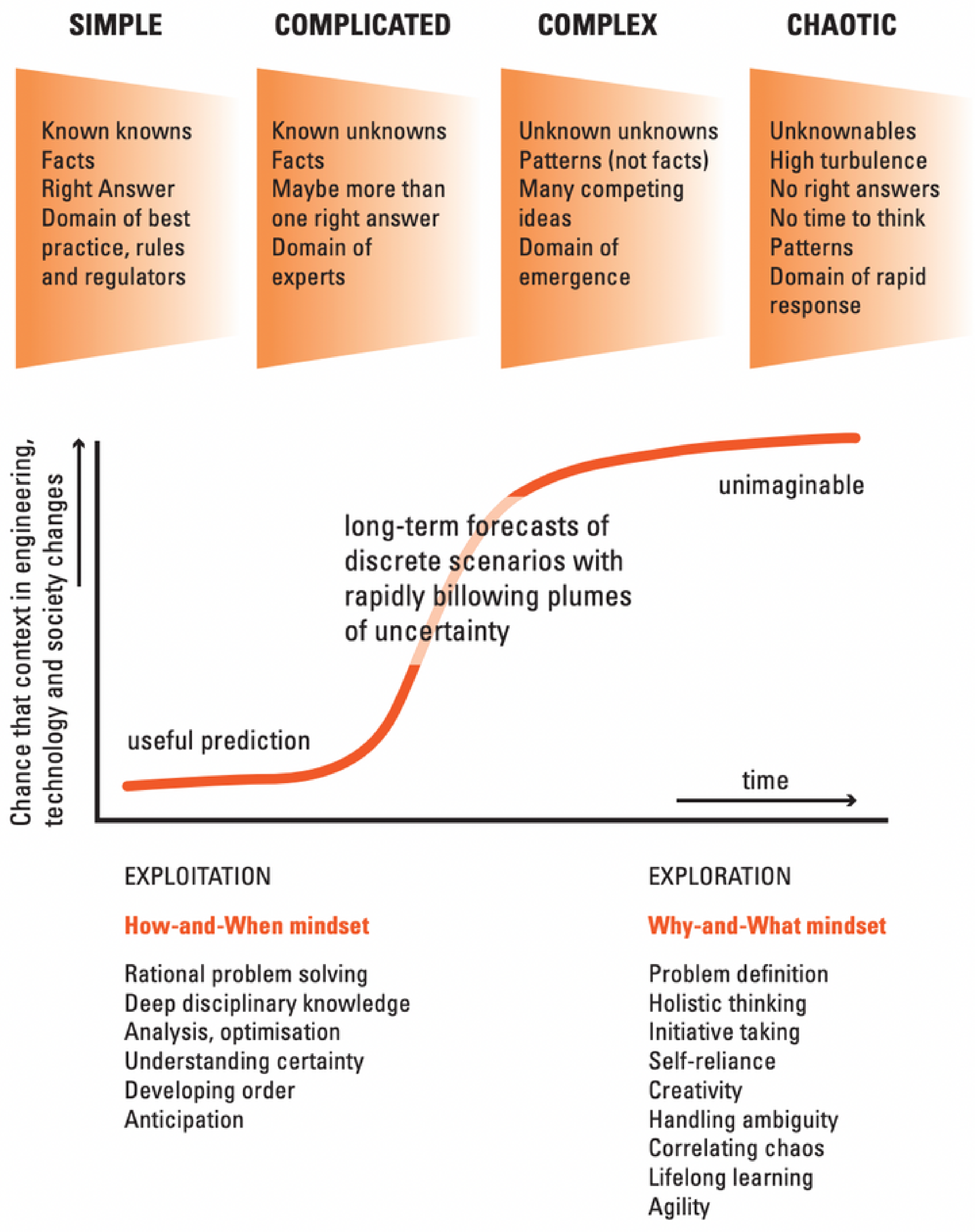


Figure 3: The shift from the "traditional and simple" situation of known knowns to the chaotic situation of unknown unknowns and the changing needs for engineering graduates. Source: Kamp (2020)

Findings from the practising engineers: Where is global responsibility competency learnt?

Formal education

The interviewees firmly asserted that it was, in their experience, entirely possible to graduate with a degree in engineering without ever studying environmental or social responsibility topics. Sustainability was felt to be an add-on consideration rather than a driving force behind their lectures and assignments in formal education. When specifically asked about ethics within formal curricula, participants indicated that this was only briefly mentioned, with primary associations being codes of conduct and health and safety. That said, anti-corruption codes were primarily learnt in the workplace rather than university.

> *"Not when I was at university. [...] When you start working, it's a big thing. [Because of] the commitment that British companies have to make, to acting ethically, and not accepting bribes and the like. And we have to do mandatory training around that kind of thing. And, companies [understand] that acting ethically is of a benefit to an organisation as well." Thom*

It is acknowledged that some degree programmes are changing, and students enrolled in education today may encounter more content in the curriculum regarding ethics. Yet it is worth considering how much content about global responsibility, and ethics in particular, practising engineers have been exposed to and how their knowledge can be extended.

People in workplace

Practising on the job and discussing environmental and social aspects of their work with colleagues were the primary ways participants learnt about global responsibility in the workplace. Opportunities to research and teach colleagues about specific environmental topics related to aspects of their work, through formats like internal "Lunch and Learn" sessions, was highlighted. In this way, individual engineers can generate new knowledge for the company and beyond.

In relation to global responsibility, the drive for new approaches is down to individual interest, project briefs and client requests, particularly when the client is a public entity.

> *"Any job that comes through would require a certain amount of research, in order to come up with the best solution. Whether or not that's reading papers, reading books, just talking with other people, just lots of different sorts of avenues to try and come up with our best solution." Jack*

> *"In my spare time, I read through that [sustainable concrete] document and I brought it around the rest of the office as well to make sure people were reading it, because it's a really nicely set out, set of information. [From that I developed] a company standard document that's used throughout all of our concrete projects." Mia*

Cultural sources

All interviewees highlighted that they learn about global responsibility in their own time through books, magazines, engineering-related documents, news and media, and by participating in research and civic organisations. There was a strong link between developing an understanding through cultural sources and how they learn in the workplace, as often these cultural sources are discussed with colleagues and, where appropriate, are used to build evidence for justifying alternative approaches and/or informing clients. Participants described seeking out new sources of information and artefacts to study in order to learn more about environmental and social topics to enhance their work. This quote illustrates one engineer's desire to learn on the job:

> *"[Concrete] is a material we all know [and] we work with a lot and so, I suppose it's easier. [...] Working with timber or prefabricated or even prefab concrete, it's not something we do an awful lot. There would be more time associated with it, so it's a cost on our part as well, but I think that there's much more interest from our side because we like to learn, as engineers. It's very boring just using the same thing all the time. It's much more interesting when a client does come to you and say, 'we want to use timber.' And you go, 'Great. Let's have a look at this.' Because you get to go back to school and learn how to do it again," Mia.*

Participants note it's often easier to implement global responsibility at a personal, rather than professional, level. News and social media have prompted them to consider a wider array of ideas at both levels.

> *"I probably think of it: I think I have a global responsibility as an engineer. I have a slightly different global responsibilities as a human [...] that is perhaps an easier way to affect the outcome. It's become probably ever more apparent, with the media coverage of things. Some people suggest we should stop eating meat, that's the best thing we could do. But then as an engineer, we just think about the built environment we live in," Charlie.*

Beyond the workplace

Attending lectures/events, registering for e-mail lists, attending full-day workshops, and teaching the wider community were common activities beyond the office. Most interviewees learned about professional standards of behaviour as part of their preparation for chartership or as part of their company's requirements to uphold ethics.

> *"We have to do mandatory training around that kind of thing. [...] You have a duty to act ethically and uphold the Code of Conduct [...] For chartership, you [have to read about these things]. You have to fulfil all these objectives. Most of them are work-based technical things or management type things, but they have aspects of understanding legal context and understanding aspects of sustainability." Thom*

The engineer and client relationship

The ability to propose new ideas and approaches, and to have them supported, is a critical factor in the extent to which global responsibility can be embedded into engineering. Engineers are required to be ethical in their decisions and behaviours and to challenge any unethical behaviour.

Clients advocating for global responsibility

The engineer-client relationship is a key avenue for engineers to provide leadership and advocate for global responsibility. Engineers can communicate the consequences and opportunities from engineering and technology on society and the environment (WFEO, 2021), including diverse and multi-disciplinary perspectives that might challenge any preconceived ideas and solutions to enable better outcomes. The challenge comes if a client advocates for priorities that have the potential to conflict with a globally responsible approach or less responsible approaches, for example, heating a building using fossil fuels over alternative energy supplies or energy-efficient designs. What ideas could engineers come up with as alternatives if given the option? Some clients build indicators into their weighting systems for assessing bids and granting contracts that can align with globally responsible principles (e.g. occupational health and safety, diversity and equity, sustainability) (Constructing Excellence, 2013). Without clients getting involved this way, particularly on smaller, developer-driven projects, engineers can feel limited in their options. They may not be empowered to maximise the benefits for society or help preserve the environment.

Engineers advocating for global responsibility

Practising global responsibility in engineering ultimately means “engineers must recognise and exercise their responsibility to society as a whole, which may sometimes conflict with their responsibility to the immediate client or customer” (Dodds & Venables, 2005, p. 8). Costs are often a barrier for advocating for global responsibility (e.g. environmental impacts, inclusivity, social benefits). However, where costs create barriers against ideas to be accepted, opportunities remain to cut waste and streamline designs (Chance, et al., 2021b). At any time and any stage during the project, it is the engineer’s responsibility to raise topics of concern within their company and to the client regardless of any stated interests. If engineers are not presenting their clients with alternative options, then how is a client meant to know what is possible? If engineers as a collective found ways to routinely express concerns and highlight opportunities, together they could change the status quo, and help clients realise that global responsibility is crucial. Together, the engineering profession could shift global responsibility from being seen as an optional add-on to being viewed as required, similar to the way the UK shifted its value system to make job-site safety a priority.

Box 4: Duty and responsibility to society as a whole in engineering decisions

There is a common assumption that engineers are at the mercy of the client and therefore their ability to embed this practice is limited. However, in recent years, examples such as Google employees protesting against a contract with the US government to improve the targeting of drone strikes through AI, has proved the potential impact of collective action in an engineering setting. After more than 4,000 employees signed a petition stating 'Google should not be in the business of war', Google pulled out of the deal.

Some argue it was a knee jerk reaction to protect brand reputation, others see it as a decision based on nuanced ethical considerations. Google followed the decision by publishing a set of ethical principles that set out their 'commitment to develop technology responsibly and establish specific application areas we will not pursue'.

Engineering professionals have a duty to abide by and promote high standards of leadership and communication. Even if an engineer isn't going to make the final decision, they still have a responsibility to highlight the potential consequences. How can engineers voice where engineering is disproportionately impactful? How can we express concern about aspects that aren't in the remit, such as duty to wider society, producing equitable solutions, the practicalities of maintaining the solution over its lifetime, or what happens at the end of its life?

When an individual engineer recognises a potentially problematic direction, what is the opportunity to demonstrate leadership and their professional commitment to global responsibility? Who could be consulted for support in persuading a client and/or company about adapting the requirements of a project?

Findings from the practising engineers: How is the client relationship viewed?

Clients can control the agenda

The main overriding message from participants was that the client controls the agenda. The client can request the engineers implement more responsible approaches, and the individual engineer or engineering team can highlight issues and opportunities to be more responsible. However, ultimately, if the more responsible option either costs more or takes longer, it is often a challenge to gain support from a private client. Conversely, public works and government-funded projects can and often do prioritise social benefit and sometimes environmental benefit as well.

> *"That's definitely the biggest barrier for us because you can try as much as you can and you can promote alternative materials, different construction methods, prefab brought in on the site, but if there is not a monetary positive, it'll get beat down. [...] if you take it way back when you're providing the client with a fee. If we know straight from the offer they're going to be going concrete, we know that we can provide them with a competitive fee, because we know that we can do that work quickly. Whereas if we're going to be looking at a different material, we might put in more contingencies there, and give ourselves more time to be able to do it, and so, we'll be slightly less competitive. So, I guess that's a reason not to from our point of view," Mia.*

Stages of a project

While specific project stages were not discussed (e.g., RIBA stages 1-7 for building construction), it was clear that the perceived ability to embed global responsibility into civil engineering is related both to the stage of the project at which the individual gets involved and to how the priorities of the client align with the principles of global responsibility. Highlighting opportunities to embed global responsibility into engineering from the outset, alongside asking challenging questions, were viewed as essential for achieving change.

Highlighting opportunities to the client

The main opportunities identified for embedding global responsibility were the material selection, carbon and energy calculations, and advocating for responsible choices to clients. Some participants described using tools or calculating and comparing options, but the project scope and funding levels do not always (or even typically) permit them to use these tools or apply this knowledge. Even when they calculate benefits, the information is easily and readily ignored by many clients. Frequent or repeated rejection from clients was recognised as detrimental or discouraging to practising or advocating for globally responsible approaches on future projects.

> *"Usually only if it's cheaper, or if it's quicker or more efficient, and if you can tick the box of either of those two, plus a reduction in carbon, something that has greater social responsibility, then that's, that's going to get the go ahead," Jack*

Public sector clients

In public infrastructure projects, there is a responsibility to spend public funds wisely, and so interviewees felt that projects for public sector clients can and often do prioritise social benefit and sometimes environmental benefit as well. It was recognised that there is more room to consider life cycle costs such as operations, maintenance, refurbishment, demolition, etc., rather than simply the capital cost. This support from public sector clients also enables the engineers to make the case when presented with challenges from other teams working on the same project but from different angles, highlighting the importance of a clear commitment from the outset that is supported at the highest level of any project.

Engineering company culture

Similar to the engineer-client relationship, the culture within an engineering company can nurture or hinder global responsibility in day-to-day decision making. Business as usual is highlighted as an inadequate response to the challenges faced that engineering should play a role in, so the ability to propose new ideas and approaches and have them supported is a critical factor in the extent to which global responsibility can be embedded into engineering.

Office culture

Office culture plays a big part in who gets exposed to messages and ideas underpinning global responsibility. Firms can encourage more critical engagement, active participation in sustainability decisions, and enable employees to voice social justice concerns. In doing so, employers can facilitate frequent opportunities to develop and apply richer, more informed understanding of globally responsible practice as employees work towards chartership. Ongoing professional development equips individual engineers to take leadership roles and lead change in increasingly holistic ways.

Challenging the status quo

The Engineering Council's Statement of Ethical Principles requires engineers to act with honesty, integrity and leadership (Engineering Council, 2020b). In doing so engineers are required to challenge behaviours or decisions that are a cause for professional concern. Questions of “how can we do this ethically?” should be active at every stage of the engineering process. It is not enough to solely reflect on whether decisions were ethically made.

Professional engineering institutions, such as the Institution of Civil Engineers, offer training and issue statements regarding ethics, codes of conduct, sustainability and the achievement of the SDGs. In practice, early-career graduate engineers must focus on their own small part of the decision-making process. However, graduate engineers can feel little ability to affect decisions beyond the specification of materials (at the design end of the project) or construction coordination and value engineering (nearer the construction end of projects). There is a risk that they then have to proceed with the status quo (i.e. the materials and methods that their team has the most experience and comfort using). While there may be enthusiasm to pursue opportunities to research alternatives and innovate their practices, such opportunities can be limited.

Box 5: The engineer's role in designing prisons

Working in prisons is just one of the many examples that can be interrogated when considering the reality of ethics in engineering. In 2004, the non-profit organisation Architects / Designers / Planners for Social Responsibility (ADPSR) issued a call for architects and design industry professionals to stop working in prisons because of ongoing concerns regarding social justice. In December 2020, the American Institute of Architects approved new ethics rules prohibiting members from knowingly designing spaces intended for execution or torture, including for prolonged periods of solitary confinement.

> *"We are committed to promoting the design of a more equitable and just built world that dismantles racial injustice and upholds human rights," Jane Frederick, president of the American Institute of Architects.*

Engineers are often asked to work on projects that are controversial. Does each individual have the opportunity to consider the arguments for and against working on such projects? And if they choose to work on such a project, what opportunities do they have to drive an outcome based on social justice?

What are possible arguments for working on the project?

- Prisons are often proposed as necessary for a well functioning society (law and order). Could engineers influence socially acceptable prison design?
- Will prisons be less safe and functional if built without expertise?
- Could accepting this work help ensure the sustainability of our company and keep our team members employed?
- If the prison is based on a progressive model of reform, could participation demonstrate progressive leadership as a company?

What are possible arguments against working on the project?

- By accepting the work, are engineers contributing to injustice if current prison systems are unjust and/or ineffective?
- If the prison is built solely for profit, could it be less humane than one built for wellbeing?
- By refusing to build prisons, could this invoke the need for reform in the system?
- If the prison is based on non-progressive reform models, could refusal demonstrate progressive leadership as a company?

Findings from the practising engineers: How does office culture reflect global responsibility?

Coordination and support

Holistic approaches and better integration across disciplines were highlighted as opportunities for improvement, particularly where multiple companies are involved in the design and construction of a single product. In general, lack of coordination was noted to cause issues for projects beyond the integration of global responsibility. New ideas were easier to suggest where projects and approaches were clearly stated and coordinated. Participants described being under pressure to meet demanding deadlines, always feeling a bit “frantic”, and often not having the time available to explore and test options. Without support structures in place or with unclear common objectives, there is a risk people will give up when they perceive change is not happening. Some participants found this de-motivating when pursuing global responsibility agendas, and looked forward to having more influence in the future. Others looked for how to influence the world outside their companies and sought ways to get involved in volunteer initiatives.

Priorities and Tools

Notably, participants see the tools they currently have as inadequate and not all projects use the tools that are available. Recurring errors and omissions in calculation tools, such as embodied carbon calculations, can lead to low motivation and even resistance to addressing the problem. Greenwashing (false claims of environmental benefit and/or awarding of environmental certifications based on questionable or incorrect information) and misleading political messages are seen as dangerous and counter-productive. Participants emphasised that creating systems to quantify and track indicators, for both environmental and social aspects of sustainability, is critical for empowering engineers to consider these issues in their work, particularly at the junior/graduate level. Without the remit to investigate these topics, they cannot justify the time it takes to run environmental calculations.

> *“I would suggest that if I had time or if there were a budget for whatever, all projects should have an embodied carbon tool, or should have some metric for social sustainability, or ‘how many people are we employing, how many jobs are we creating, what is the impact on the supply chain?’ A lot of them, BREEAM, for instance, try to do it but they're often not as effective, and don't capture information that you necessarily want,” Arthur.*

Professional values

Many of the areas discussed aligned with aspects of the Engineering Council's Statement of Ethics. Corruption control measures (e.g. employees have to declare received goods from clients) were in place and were conveyed during company orientations. Professional values have shifted in recent decades, and protecting occupational health and safety on site is now more of a priority than it was before. Risk assessments, and prioritising the health and safety of workers, were taken as the highest priority even in cases where these were financially costly to the company. Thus, the profession of civil engineering has an opportunity to expand its focus on health and safety, that is today intent on protecting life and safety of the construction community while at work. The profession can more visibly embrace 'wellbeing' as a core value, and it can endeavour to protect the health, safety, and wellbeing of everyone in and around the building during and after construction, and indeed the public more globally.

Professional qualification

A primary driver participants described for pursuing a deeper understanding globally responsible engineering topics was to accrue the professional competencies needed for chartership. In this system, participants seek learning opportunities themselves, as a means to develop their understanding and/or learn whilst on the job. Participants were often supported by their companies to conduct research or attend professional development events such as lectures and training courses offered by professional organisations (e.g. Institution of Civil Engineers). Participation helped them develop a broader understanding of contexts and the impacts of projects. Other opportunities to develop themselves and accrue CPD credits included mentoring others, encouraging youth involvement in engineering and other STEM fields, and conducting volunteer and pro-bono work. A particular concern was the absence of ethics teaching from degree courses and the limited understanding of how ethics applies beyond corruption, bribery and health and safety. Most interviewees learned about professional standards of behaviour as part of their preparation for chartership or as part of their company's requirements to uphold ethics.

Opt-out policies

In several instances, companies allowed participants to opt out of working on projects that they fundamentally disagree with. Whilst generally held to be a sign of a positive working culture (e.g. a policy that is supportive of people having diverse opinions), these policies can become problematic. Internal peace and harmony is ensured by allowing the engineer to avoid internal discord in the short term. Yet this practice also enables the profession to continue business as usual and face fewer challenges to the system. Individuals are much less likely to encounter and confront troubling aspects of a project that need to be addressed if they are not involved with the project in the first place. The company, the profession, and society at large miss out on opportunities to improve when conscientious engineers are given the option to simply ignore troubling issues. In most cases, interviewees described trying to do something to align with global responsibility rather than nothing at all, but they also accepted limits they perceived in their day-to-day work. Making significant change happen was seen as mostly beyond reach for the early-career engineers in our study. They hoped to develop the ability and professional status needed to achieve greater change and, indeed, the senior engineer in the study described having and using this ability.

Recommendations

In this report we highlight the urgency, role and some of the practical barriers related to embedding global responsibility in engineering practice. Through interviews with engineers working in the built environment sector, some of the practicalities around how an individual can embed a globally responsible approach in their day-to-day have been explored. The exploratory design of our study allowed data to be collected on a topic where little prior research exists, to inform and guide more targeted work in the future. The study represents an initial step towards a long-term objective of achieving globally responsible decision-making across engineering fields. As you read this report, what questions did you raise about the opportunities and barriers to practice global responsibility in your own work?

Promote a shared understanding

Global responsibility and its implications for engineering are not widely understood, being frequently mis-conceptualised as relating to environmental sustainability only. To ensure the concept's transition into the mainstream, we must therefore move towards a shared understanding of globally responsible engineering; to mean critically reflecting on the role of engineering in society and understanding the social, environmental and economic impacts that the profession has, both locally to where it is implemented and globally through resource allocation, supply chains and operational outputs.

At the same time, there is an opportunity for more rigorous and frequent discussion of ethics across the profession – to expand ongoing conversations within professional organisations and to encourage public deliberation. We need more careful consideration of what it means to be ethical, to construct a code of material ethics, to develop a stronger code of social ethics, and to acknowledge that ignoring these topics represents a form of unethical conduct. The profession has embraced job-site health and safety, showing that change is possible. The levers (policies, procedures, messaging systems, and communication practices) used to operationalise this change and realise success can provide a helpful roadmap for how to make this needed shift.

Create consistent and shared approaches across the profession

Lack of knowledge, conflicting priorities and a lack of accepted tools and frameworks to present more globally responsible options to clients were seen as barriers to improvement. Generally, more familiar materials, products and approaches tend to be used, making it difficult to challenge the status quo. Convincing arguments could be constructed if more universally accepted methods were available for predicting and measuring outcomes of environmental and social sustainability. Also needed are mechanisms for contributing new ideas, and challenging ineffective procedures, to encourage industry-wide change in engineering. These are urgently needed if we are to meet the UN’s SDGs and address pressing global challenges.

The SDG Impact Assessment Tools and Raworth's Doughnut Economics Model are good initial steps. New globally responsible standards can be constructed with the help of such tools, and may then themselves become part of procurement processes. Mechanisms for flagging concerns and reporting errors and omissions without fear of personal retribution are essential. This is particularly relevant for young professionals who were educated to uphold ideals but who are not currently provided tools for confronting unsustainable mainstream practices.

Evolve governance to enable critical reflection

Rather than offering those with the curiosity to challenge the status quo the opportunity to 'opt out', company culture should seek to embrace the challenge and find ways to support the integration of these new and different perspectives, which seem particularly strong in those at the earlier stages of their careers. This itself may challenge the traditional hierarchical structure of a company's expertise but the benefits to expediting changes to projects, ethics, health and safety, wellbeing, etc., may well outweigh any drawbacks. Exploring the ways in which this could be achieved and what types of support companies might need to put it into practice would be the recommended next step.

Evolve professional competencies and graduate attributes to require demonstration of deep commitment to acting responsibility

There is an urgent need to upskill current and future generations of engineers to tackle global challenges, meet the needs of industries, and deliver on sustainability strategies. This requires broadening competency frameworks to include the skills needed for embedding global responsibility in everyday practice for engineers seeking professional chartership. It is important to provide emerging engineers with opportunities to engage with people and the environment, to explore social and environmental sustainability topics, and to encounter ethical questions and effectively confront ethical dilemmas, through both formal and informal curricula (e.g., extracurricular and co-curricular activities, design competitions, service learning, and the like). Engineering students must have hands-on engagement with engineering to bring abstract concepts to life at a scale and with a feel and texture that they can relate to, internalise, and make part of their vocabulary. Engineering programs can and must seek to influence globally responsible values, skills and behaviours of students before they graduate into the profession.

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Appendix: Participant demographics

Table A1. Participant demographics

Participant Pseudonyms	Gender	Degrees held	Professional years	Type of work/ employment sector	Charter status
Ava	F	M.A. & M.Sc. (Sustainable Development)	3-5	Sustainable Development (Consulting & Research)	N/A (Ph.D. Underway)
George	M	M.A. & M.Sc. (Civil Engineering)	30-40	Rail (Design Management)	Chartered
Mia	F	M.Eng. (Civil Engineering)	3-5	Structural Engineering (Building Design)	Chartered (Underway at time of study)
Thom	M	M.Eng. (Civil & Structural Engineering)	5-10	Structural Engineering (Infrastructure Design)	Chartered
Jack	M	B.Sc. (Geoscience)	10-15	Ground Engineering (Construction Costing)	Chartered
Charlie	M	M.Eng. (Civil & Environmental Engineering)	5-10	Rail (Infrastructure Construction Planning)	Underway
Emma	F	M.Eng. (Civil & Environmental Engineering)	3-5	Structural Engineering (Infrastructure & Building Design)	Underway
Arthur	M	M.Eng. (Civil & Architectural Engineering)	3-5	Structural Engineering (Building Design)	Chartered
James	M	M.Eng. (Civil & Structural Engineering)	5-10	Rail (Design Management)	Chartered

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