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Engineering for the Far Future – Rethinking the Value Proposition

Anthony Hargreaves, Marianna Cavada and Chris Rogers (University of Birmingham)

In preparation for a call for proposals, a workshop was held with representatives from the Institution of Civil Engineers' (ICE) Research, Development and Innovation towards Engineering Excellence Panel, academia, Innovate UK, the Engineering and Physical Sciences Research Council, Highways England and the consulting industry. The overarching theme that emerged was that infrastructure does not adequately take into account the value that could be gained from its long-term service provision. This has therefore been selected as an appropriate cross-cutting theme for the 'Spring 2019 Call for Proposals for the ICE's Research and Development Enabling Fund'. The findings from this research and development initiative are required to be presented at a half-day event, as well as to form the subject of papers and/or briefings to be published in relevant parts of the ICE Proceedings and other forms of dissemination, thus ensuring that they are brought to the attention of ICE's members. This briefing is a summary of challenges that need to be embraced by the profession, as revealed by the workshop discussions and which therefore reflect the collective views of all those at the workshop (who are listed in the Acknowledgements).

There is a need for civil engineers to be more involved in the early-stage planning of projects. Although civil engineers do identify opportunities that could benefit their clients, these are usually solutions to current specific problems – such as how to relieve a congested part of the highway network or reduce local flood risk – rather than fundamentally rethink the systems that have led to the problems. Civil engineers are rarely involved in strategic longer-term planning, even though this is where the greatest value could be added. Hence, engineers all too rarely propose schemes that would have a broad and long-term transformational impact. In the same vein, while it is recognised that civil engineering schemes can deliver multiple forms of value (Rogers, 2018), 'value engineering' has become synonymous with reducing costs rather than adding long-term social and/or environmental value. Strategic planning is a multidisciplinary activity that includes social and economic development, environmental enhancement, land use, 'harder' infrastructure and 'softer' urban systems and their interdependencies and so on. It involves qualitative judgements about social justice and the ecological environment. Implementation often involves political considerations. This is a complex landscape in which there are many uncertainties, and one that can be uncomfortable for engineers who are trained to produce quantitative solutions.

In Victorian times, often regarded as a golden age for engineering, it was civil engineers who were at the forefront of proposing major projects that added long-term value and transformed society. In

more recent times, engineers have retreated from this contentious area of public engagement in favour of focusing on excellent technical solutions. It is currently politicians, the business community and media that are at the forefront of identifying and debating problems. This then goes through a policymaking and planning process until the overall concepts have been sufficiently defined for engineers to design and construct a (necessarily constrained) solution. At this point, a questioning of the premise, the very essence of the problem, is rarely welcomed. This raises questions about whether governance changes are needed so that engineering expertise is engaged at an earlier stage and whether engineers need greater awareness of these planning and political processes and a wider skill set. In particular, schemes that involve public expenditure need to be appraised on their social value compared to the alternative solutions. Social value in this context means having greater awareness of the social welfare or well-being arising from an engineering intervention (HM Treasury, 2018). Unless the necessary engineering expertise is engaged at a sufficiently early stage, it is questionable whether the solution with the greatest social value not only has been identified, but is able to be incorporated in the engineering outcome. However, in recent years the market conditions in the built environment sector have passed progressively more risk and responsibilities from clients to contractors through a selection process that has focused on price rather than judgement and quality. These market conditions will need to change so that client organisations are incentivised to deliver long-term value and acquire the skills to manage an improved procurement process. This will then create a demand for the engineering capabilities needed and for reliable data to provide a high-level 'proof of value'.

In the past, the city engineer had a degree of independence from elected council members and would propose and recommend schemes that were in the city's long-term interests. Now council officers primarily execute the policies of the council members, and the work requiring specialist knowledge and skills is contracted out to consulting and outsourcing companies. Hence, much of the strategic decision-making will have already taken place before engineers become involved. This may not be the case in cities, such as London, that have a well-established mayoral office supported by in-house expertise, such as Transport for London. However, most other UK towns and cities do not have this level of expertise and local planning authorities have recently suffered major cuts due to austerity. Some mayoral combined authorities have recently been established with greater devolution of decision-making, and this may now provide greater opportunities for engineers to become more involved in the planning and decision-making process. However, there needs to be a regeneration of capacity and capability, and a reawakening of the role of the 'municipal engineer' who can take a holistic view of the engineering of infrastructure and city systems (UKCRIC, 2018) for this to be effective.

It has been widely recognised that there is a need for a more integrated approach to the planning and design of projects, not just between different sectors of the construction industry and the statutory authorities, but also involving the future users of what is created by projects and those who will be impacted. Interdependencies between sectors have been increasing as infrastructure has become more complex and reliant on digital communications and 'smart' systems. This can reduce costs, energy use and the use of natural resources. However, as systems become more complex, they become more vulnerable to disruption. Such failures could occur due to a system fault, natural disaster or malicious intervention. Moreover, the failure of one system can impact on others – for example, the loss of power of a water-pumping system due to an electrical substation failure (Walsh et al., 2015) or a burst pipe flooding a nearby metro station – and this has led to a growing focus on infrastructure interdependencies (iBUILD, 2015, 2018; ICIF, 2018).

Modern cities are increasingly organised to simplify and regulate the user experience. Service provision has been aggregated to gain economies of scale. However, this can reduce resilience because system failure then has a much wider impact. In contrast, less developed cities in the world still have diverse ways of delivering services with greater local community cohesion, and this can enable greater adaptability. It could therefore be argued that modern cities should be reinvesting some of the wealth generated by their efficient infrastructure systems into ways of increasing their adaptability, resilience and reserve capacity. The increasingly rapid changes in technology, social behaviour, economy, climate, politics and suchlike are contextual factors that necessarily influence a civil engineer's creations and mean that the governance and urban systems need to be increasingly agile to adapt to these changes.

The UK has been in relative economic decline over recent decades compared to other parts of the world, and the cost of maintaining its urban areas and infrastructure services has become increasingly unaffordable. There is a need to find ways of delivering the services that people need and expect at a lower cost. More integrated and smarter systems and forms of governance may help achieve this aim. Elsewhere in the world, rapid economic growth and urbanisation have created problems of pollution and increasing social inequity. As affluence increases, there is more per-capita consumption with greater carbon dioxide emissions and degradation of natural resources.

Therefore, engineers need to be cognisant of the different contexts within which they work around the world and develop a comprehensive, multidimensional appreciation of how engineering affects society, the economy and the environment.

The day-to-day reality for most engineering practitioners is that they need to create value for their organisation and clients. Hence, their focus is usually on a specific project with little influence over what has happened, or will happen, in its surrounding area.

This is seen as the responsibility of the statutory authorities. Local planning authorities adopt a local plan with planning guidance, but the design of each individual scheme is usually the outcome of negotiations between the developer and planning authority. Developers increasingly have the upper hand, particularly in the more economically disadvantaged areas. Many engineers recognise the benefits of an area-wide and integrated approach to create synergies between schemes and thereby add long-term value. However, there will need to be governance mechanisms in place to create a level playing field so that any added costs to their clients of achieving this wider vision are proportionally and temporally allocated to those who benefit (Rogers, 2018). If done appropriately, the overall value added by this collective approach would exceed, and often far exceed, any additional costs to design and construction. Most examples of a collective approach have been for specific purposes and have been usually motivated by a shared commercial incentive – for example, transport corridor contributions from developers towards transport improvements or business improvement districts in which local businesses contribute towards the cost of improvements to their urban environment. However, the broadening of this approach to achieve wider objectives over a larger area would be a challenge, particularly in economically disadvantaged areas. This would require a method of estimating the in-service benefits to society to justify this more demanding integrated planning and engineering process.

The costs and impacts of the construction process and supply chains have been well researched and guidance is available – for example, PAS 2080:2016, which is on the carbon dioxide management of infrastructure (BSI, 2016). However, the in-service benefits far exceed the construction impacts. Examples of these in-service benefits include lower operational carbon dioxide emissions and improved productivity, health and quality of life. However, these are currently difficult to assess, and, although there has been some research, this is usually specific to a particular project or sector. There is a need for comprehensive and long-term monitoring and sharing of data on how well schemes meet the needs of users so that this can be taken into account in the design of future schemes. This would then allow a national database to be created which would provide the evidence needed to improve the planning, design and construction process. This needs further research on what would be the best way of collecting, searching and presenting these data and how this could make use of spatial mapping and search engines (UKCRIC, 2018).

One of the difficulties of implementing this more integrated approach is that it is currently unclear who pays for and takes ownership of this integration process. Greater integration to increase in-service benefits may increase the planning, design and capital costs. Therefore, governance changes will be needed so that the opportunities for integration are correctly assessed and valued. These added costs to the delivery of schemes will need to be recognised and proportionally remunerated.

There will need to be greater openness and sharing of methodologies to increase mutual understanding and integration. This more integrated approach requires greater co-operation and interaction between the different parties in the planning, design, construction and operation of schemes. This could make it more difficult to distinguish their responsibilities and liabilities, so changes may be needed to the design of contracts so that they are fit for this purpose.

Ultimately, the aim is for engineers to provide what society wants and needs, but this is a difficult thing to assess and understand (Rogers and Hunt, 2019). It is uncertain whether people can know what they will want in future, and many of the people who will inhabit the far future have not yet been born. Also, many of the infrastructure technologies that have transformed society, such as the mechanisation of factories, building of railways and introduction of the motorcar, were initially controversial and were often opposed. Therefore, the current public opinion is not necessarily the best guide for the future. A greater understanding is needed on how urban planning, buildings, transport and other infrastructure can be better integrated to add value. Governance systems need to be better able to engage with all aspects of society to inform decision-making about planning, investing and building for the far future, and engineers need to be actively involved in these ongoing and evolving consultations and debates.

Therefore, a more flexible approach may be needed so that engineering the near future is sufficiently nimble to change over time in response to new requirements and able to adapt to new opportunities and challenges. This would be similar to the 'plan, monitor and manage' approach to development, but with a wider and longer-term perspective to avoid lock-in to obsolete legacy schemes and with built-in resilience to unforeseen shocks (Lombardi et al., 2012; Rogers et al., 2012). The civil engineering profession needs to be open to new possibilities because radical solutions may be needed to address the challenges of urbanisation, climate change and diminishing natural resources. Ways of developing and testing scenarios for doing things differently will be needed, rather than progressing incrementally along the same trajectory. This is currently difficult because the rapid evolution of technology and social change means that often there are not enough historic data to calibrate models for testing these scenarios fully. One possibility for this scenario testing process would be to develop and assess visions of the future to select those with the greatest social value (GOFS, 2016) and then consider whether the necessary conditions either exist already or can be put in place to achieve this desired future (Rogers et al., 2012) and what would be needed for this desired transition to take place over time.

The following is a summary of questions that will help to address the aforementioned challenges. The research and development (R&D) proposals can address one or more aspects of these questions within the scope of the identified challenges.

- How could greater involvement of engineers in strategic planning increase the long-term value of projects to society? Specifically, to what extent does this need to be more of a two-way process between planning and the feasibility testing and assessment of solutions? How would current governance structures and processes need to change to achieve this? What changes to the skill sets and training of civil engineers are needed to prepare them for this broader role?
- What are the appropriate spatial and temporal scales for integration between different disciplines and sectors? How does this vary between sectors and disciplines? What are the barriers to such integration and how could they be overcome? How could a greater mutual understanding and sharing of methodologies, data, terminology and metrics be achieved, and what would be the added value to project outcomes? What changes would be needed to governance, funding and contracts to allocate responsibilities for this integration process and remunerate the extra resources needed?
- What would be the best way of collecting information about the in-service costs and benefits of projects? What impacts should be measured and how could qualitative impacts be included? What would be the best way of collecting, storing, securing, searching and mapping data so that they can be used to improve the planning and design of future projects? What would be the potential barriers to and challenges of creating a shared national database for all projects, and how could these be overcome? Are there low-cost ways of monitoring in-service performance over the lifetime of a project – not just the physical systems, but also productivity, health and quality of life? What would be needed to create accurate and comprehensive, and therefore reliable, data sets for high-level proof of value, and how could this improve the planning, design, construction and operation of future projects?
- What is the appropriate balance between making cities more efficient while ensuring that they are resilient? How can technologies such as smart systems, big data and machine learning make urban systems more resilient, rather than more vulnerable? How should the provision of reserve capacity and adaptability be valued? What governance needs to be in place for this to be recognised and funded? Could similar technologies be used to reduce the cost of delivering services, and can lower costs and resilience be mutually compatible? How could resilience be more explicitly included in engineering practice and standards?
- If investors, developers, local businesses and statutory authorities were to agree on a local plan to create long-term value through their collective action, could a 'level playing field' be created – for example, through design standards, planning guidance and a collective fund –

to compensate for any disproportionate costs incurred by individual parties? How would such standards and planning guidance be updated and the fund be replenished over time and fairly administered? How could broader social and environmental benefits be estimated and funded? What implications would this have for planning and design briefs of engineering practitioners? What are the lessons to be learnt from other similar types of scheme?

- If radical visions of the future were developed and assessed to identify those with the greatest social value, could the necessary conditions to achieve them be identified and put in place for a transition to this desired far future over time? How could civil engineers contribute to this process through the planning, design and construction of projects, and how could they be involved in the development and assessment of these visions and strategies? What other organisations and disciplines would need to be involved, and what methods, tools and data would be needed? Could the engineering of the near future be sufficiently adaptable to changing requirements, deal with uncertainties and new opportunities, avoid lock-in to obsolete legacy schemes and be resilient to future shocks and challenges? How could the needs, preferences and views of society be included in this process, and could digital media offer opportunities for greater engagement between engineers and society on the planning and design of schemes?
- Accepting that national and local governments have three roles to play in this (policymaking, regulation and owner operation for service delivery), what changes in governance (policymaking and regulation) would be needed so that market conditions in the built environment sector motivate and incentivise these improved long-term performance outcomes? How should the business models – the balance between benefits derived from a civil engineering intervention, whether public or private, and the costs and adverse consequences of its implementation – be formulated to best overall effect – that is, to realise the multiple social and environmental benefits as well as the intervention’s primary purpose? What changes would be needed to the skills of client organisations to manage better the procurement process?

These questions should set an agenda for civil engineers’ current thinking, and it will be useful if evidence could emerge alongside the findings of this R&D on good practice within the profession of research, development, innovation and case studies. This could then provide policymakers and practitioners with the evidence base for making the radical changes needed to move towards a more sustainable and resilient future.

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References

- BSI (2016) PAS 2080:2016: Carbon management in infrastructure. BSI, London, UK.
- GOFS (Government Office for Science) (2016) Future of Cities: Foresight for Cities. GOFS, London, UK.
See <https://www.gov.uk/government/publications/future-of-cities-foresight-for-cities> (accessed 04/04/2019).
- HM Treasury (Her Majesty's Treasury) (2018) Green Book: Central Government Guidance on Appraisal and Evaluation. Her Majesty's Stationery Office, London, UK.
- iBUILD (Infrastructure Business Models, Valuation and Innovation for Local Delivery) (2015) Are You Being Served? Alternative Infrastructure Business Models to Improve Economic Growth and Well-being. iBUILD Research Centre, Newcastle University, Newcastle upon Tyne, UK. See <https://research.ncl.ac.uk/media/sites/researchwebsites/ibuild/ibuildreport%20optimised.pdf> (accessed 04/04/2019).
- iBUILD (2018) Closing the Gap: Local Infrastructure Business Models to Support Inclusive Growth. iBUILD Research Centre, Newcastle University, Newcastle upon Tyne, UK. See <https://research.ncl.ac.uk/ibuild/2018finalreport/iBUILD-Report-web-compressed.pdf> (accessed 04/04/2019).
- ICIF (International Centre for Infrastructure Futures) (2018)
https://www.ucl.ac.uk/qaser/research/Projects_in_Progress/icif (accessed 04/04/2019).
- Lombardi DR, Leach JM and Rogers CDF (2012) Designing Resilient Cities: a Guide to Good Practice. IHS BRE Press, Bracknell, UK.

- Rogers CDF (2018) Engineering future liveable, resilient, sustainable cities using foresight. Proceedings of the Institution of Civil Engineers – Civil Engineering 171(6): 3–9, <https://doi.org/10.1680/jcien.17.00031>.
- Rogers CDF and Hunt DVL (2019) Realising visions for future cities: an aspirational futures methodology. Proceedings of the Institution of Civil Engineers – Urban Design and Planning, <https://doi.org/10.1680/jurdp.18.00010>.
- Rogers CDF, Lombardi DR, Leach JM and Cooper RFD (2012) The urban futures methodology applied to urban regeneration. Proceedings of the Institution of Civil Engineers – Engineering Sustainability 165(1): 5–20, <https://doi.org/10.1680/ensu.2012.165.1.5>.
- UKCRIC (UK Collaboratorium for Research on Infrastructure and Cities) (2018) UKCRIC's Mission Maps. UKCRIC, UK. See <https://www.ukcric.com> (accessed 04/04/2019).
- Walsh CL, Glendinning S, Castan-Broto V, Dewberry E and Powell M (2015) Are wildcard events on infrastructure systems opportunities for transformational change? Futures 67: 1–10, <https://doi.org/10.1016/j.futures.2015.01.005>.