The Liveable Cities Method

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The Liveable Cities Method: Establishing the Case for Transformative Change

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Abstract:

There is currently great interest in the creation of sustainable and liveable cities, both in the UK and globally. While it can be argued that good progress is being made in thinking about the needs of future cities, meeting these needs and aspirations in practice poses major challenges of understanding and measurement (what is meant by these terms and how can progress towards their achievement be measured?), complexity (cities are complex systems of systems with many interacting parts) and resilience (will interventions made today be relevant and effective in the future?). The Liveable Cities research programme created a systematic decision-making method for improving urban sustainability and liveability: the Liveable Cities Method (LCM). The LCM prioritises four criteria – individual and societal wellbeing, resource security, resource efficiency, and carbon emissions as a proxy for environmental harm (Leach, et al., 2016a) – in an interconnected framework and assesses the need for, and the resilience of, interventions designed to move cities towards improved sustainability and liveability. This paper illustrates the LCM through an example intervention made to the city of Birmingham, UK, and highlights how addressing sustainability and liveability in this way offers unique opportunities for the UK civil engineering profession to lead thinking amongst urban professionals.

Introduction: challenges to achieving urban sustainability and liveability

Civil engineers use ingenuity to address the problems and take advantage of the opportunities posed by society, and the dual influences that the environment and economy have on it. They use creative thinking to develop processes and strategies, and systems and artefacts, which in many cases are required to function for decades, and sometimes even centuries ((Balmforth, 2015) and for an example, see de Silva & Paris (2015)). This means that engineers are well placed to affect progress towards sustainability, resilience and liveability (Pearce, et al., 2012), and are encouraged to do so – not least through this Journal: see Fenner, et al., (2006) for an early perspective and

Fenner, et al., (2014) and Byrne & Mullally (2014) for implications for civil engineering education. Sustainability has been much defined, being enriched from Brundtland's (1987) oft-quoted concept of intergenerational equity and opportunity by a multitude of insights published in this journal. Likewise resilience – ensuring engineering interventions continue to function, and deliver their benefits, in the face of contextual change no matter how rapid (Rogers, et al., 2012; Arup, 2015; Lloyd's Register Foundation, 2015) – is well understood and embraces adaptability as one effective response. However, the longevity of engineered systems and artefacts also means that there is a danger that engineers create path dependencies for problems that are by their nature dynamic and, therefore, deliver outcomes that cease to be efficient and/or effective in the medium-to-long term. In contrast, liveability is less clearly-established (Leach, et al., 2017b), a weakness that this paper seeks to address hereafter. Moreover, the outcomes of the civil engineering profession are inevitably context-dependent (Pearce, et al., 2012; Shareef & Altan, 2017), and it is this dynamic, changing context that adds to the complexity of the civil engineer's role in serving society (see Roohnavaz (2017) for the implications for construction projects in developing countries).

Given that the changing contexts in which civil engineers currently operate include a markedly growing population, increasing urbanisation, climate change and a changing demography (United Nations, Department of Economic and Social Affairs, Population Division, 2014; Balmforth, 2015; Hunt, et al., 2018), improving the performance of cities provides one of the primary points of focus for the civil engineer. In turn, it is a vision of cities of the far future that must inform today's activities if future outcomes are to deliver the efficiency and efficacy that the often considerable investment demands within the context of sustainability and liveability (Rogers, 2018). This leads to fundamental questions of: what is the nature of cities of the future and, more specifically, what is the nature of citizens and societies of the future? Also, what is "the nature of any compromises or trade-offs that need to be made in balancing such requirements in order for us [engineers] to be explicit about the impacts associated with our choices"? (Gaterell, 2016, p. 223) – the focus of a recent issue of this journal. Answers are required to develop policies and strategies, and associated briefs and designs, for future sustainable and liveable city systems and the infrastructures and organisations that support them (see Whitehead (2015) for a case study of Balfour Beatty's sustainability journey).

While there is great interest in the creation of sustainable and liveable cities, both in the UK and globally, there is no convergence as to the best processes for achieving the desired outcomes (Leach, et al., 2016a). The need for tools and techniques to enable engineers to engage in the many and varied decision-making processes involved in improving sustainability was recognised by this journal in 2013 (Gaterell, 2013). At about the same time, the Liveable Cities research programme (*liveablecities.org*) set out to transform the engineering of cities by ensuring that radical engineering solutions to the problem of engineering future sustainable and liveable cities take into account the human dimensions of living and working in a city including quality of life, wellbeing and citizen aspirations. One outcome is a systematic decision-making method for improving urban sustainability and liveability: the Liveable Cities Method (LCM).

This paper introduces the nine-step LCM, a decision-making process that identifies potential barriers to achieving urban sustainability and liveability by making explicit how strategic ambitions (i.e., for the desired future performance of a city and its citizens) link to operational activities (i.e., interventions) and how vulnerable operational activities are to future change. The LCM enables users to explore possibilities and aspirations for a city as opposed to being a deterministic procedure towards quantifiable results. Importantly, it is applicable across scales, which is crucial within a multi-scalar discipline such as engineering (Gaterell, 2016; see also Keaton, 2017 for a brief discussion about the scales at which the concepts of sustainability and resilience operate and their relevance for geotechnical engineering). This paper illustrates the LCM through the example of an intervention made to the city of Birmingham. It highlights how addressing sustainability and liveability in this way offers unique opportunities for the UK civil engineering profession to lead thinking amongst urban professionals.

This section has briefly described some of the challenges for engineers in achieving sustainability and liveability in cities. The following section describes and illustrates via a case study how the Liveable Cities Method can be used to address them. This is followed by reflection upon the implications for UK civil engineering. Crucially, the LCM, and its extensive evidence base (*www.liveablecities.org.uk*), has the potential to transform the engineering of cities to deliver a more profound set of benefits when meeting the basic needs of cities and their infrastructure systems.

The Liveable Cities Method: a method for improving urban sustainability and liveability and its application to the city of Birmingham, UK

The Liveable Cities Method was developed from a comprehensive review of the sustainability, resilience, liveability and city performance, measurement and assessment literature; primary research to address the evident research gap; a series of consultations with local authorities, urban designers and planners and other urban experts from the private, public and third sectors (including academics); and, testing in three UK cities: Birmingham, Lancaster and Southampton (Leach, et al., 2017b). It builds upon the Designing Resilient Cities Method (Lombardi, et al., 2012; Rogers, et al., 2012), which is incorporated into the LCM and is shown in blue in Figure 1.

The LCM assesses the need for and the vulnerability of interventions designed to move cities towards improved sustainability and liveability. Figure 1 illustrates the LCM's nine steps, acknowledging that the illustration presents only the very essence of the process (its critical path) and strips away the inevitable messiness and iterative nature of decision-making (Mintzberg & Westley, 2001). However, iteration is an essential part of engineering decision-making processes – it is the mature engineering response to systems thinking – and will occur throughout Steps 1 to 5 and once Step 9 has been reached, a return to any of Steps 1 to 5 might happen to refine the thinking. Only once the intervention has been finalised can its likely resilience be determined using the Designing Resilient Cities Method by following Steps 5 to 9.

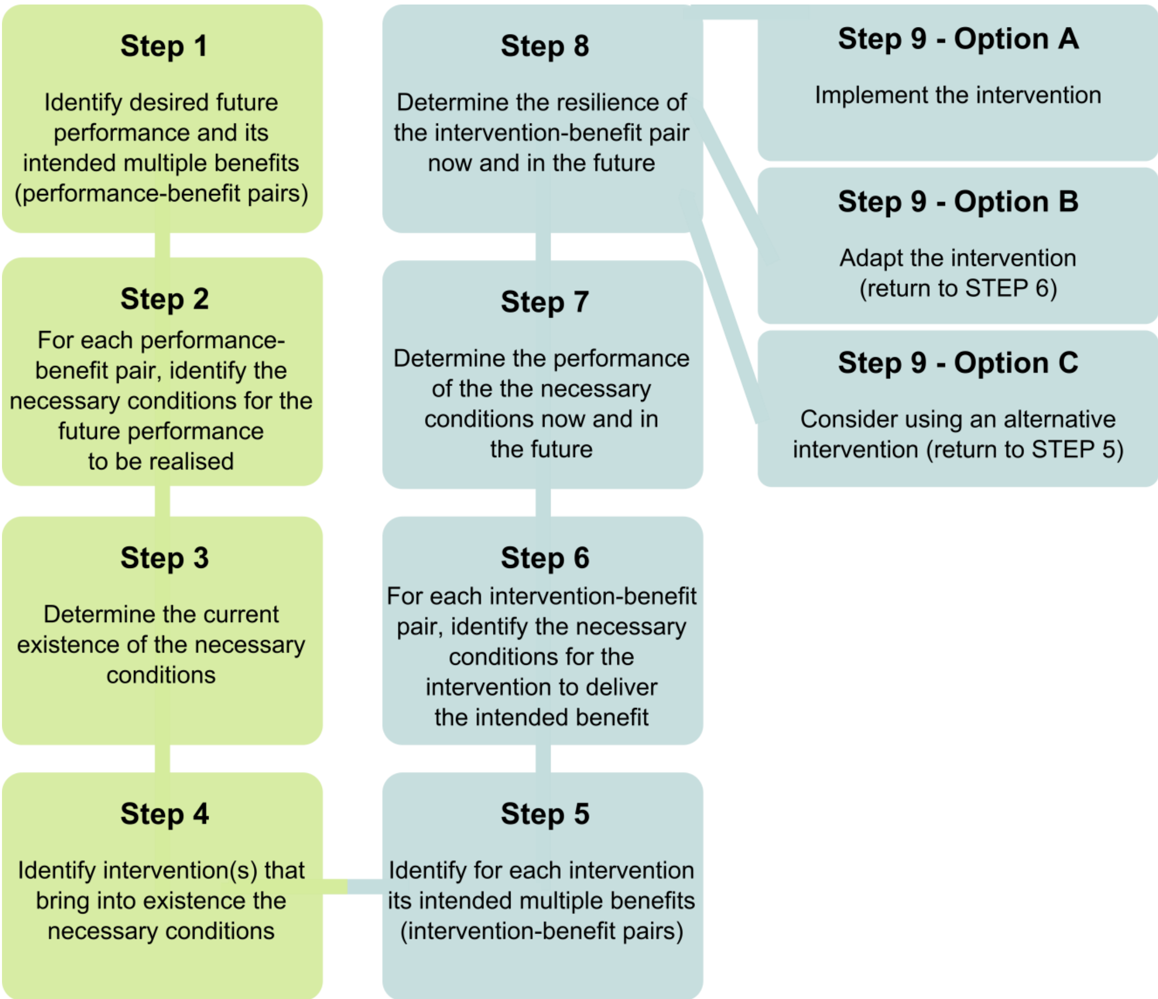

Figure 1: The Liveable Cities Method

Step 1: identify desired future performance and its intended multiple benefits (performance-benefit pairs)

The first step in the LCM is for a city to identify what it wants to be like in the future (i.e., its desired future performance). For each element of performance, concomitant ‘intended benefits’ (i.e. the benefits that have been designed to arise from implementing performance improvement measures, which will take the form of ‘interventions’ in the city and its infrastructure systems) should be identified, where possible taking advantage of multiple intended benefits (Rogers, 2018). If more than one intended benefit is identified then the LCM should be followed for each intended benefit.

Describing future performance (desired or predicted) is a subject of great interest and there exist several approaches (Rogers, 2018; Hunt & Rogers, 2015a; Government Office for Science, 2016a). However, none of the approaches are specific to Liveable Cities’ four criteria (individual and societal wellbeing, resource security, resource efficiency and carbon emissions). In order to effectively identify performance-benefit pairs relevant to these criteria, Liveable Cities created a vision for a future sustainable and liveable city – the Ideal City Model (Ortegon-Sanchez & Tyler, 2015), see Figure 2 – and this model will be used herein to illustrate the LCM. The Ideal City Model incorporates five future city visions (desired performances) and their underlying principles (which will inform the intended benefits of city interventions), see Table 1.

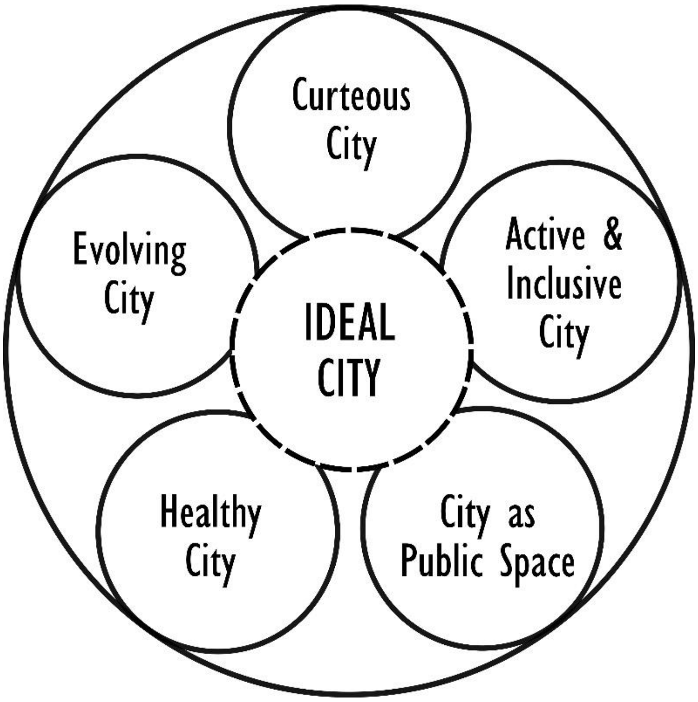

Figure 2: The Liveable Cities Ideal City Model. Adapted from Ortegon-Sanchez & Tyler (2015)

Table 1: The Liveable Cities' Ideal City Model: future performance and intended benefits. Adapted from Ortegon-Sanchez & Tyler (2015)

FUTURE PERFORMANCE	INTENDED BENEFITS
Courteous City	Stimulates positive social interactions and promotes behaviours that facilitate the functionality of the city
Active and Inclusive City	Ensures people's fair access to opportunities to meet their needs and aspirations
City as a Public Space	All public spaces are designed as open and accessible to provide protection, safety and security and create a sense of belonging and ownership
Healthy City	Ensures the good health of people and the environment today and for future generations
Evolving City	Designed to be adaptable, flexible, innovative and responsive especially for its soft infrastructures (i.e. governance, policies, financing and economy, amongst others), and which learns and adapts dynamically accordingly to people's behaviours

From the Ideal City Model, one desirable future performance is to create an 'active and inclusive city'. This is chosen as the case study for this paper because it complements the city of Birmingham's objectives "to develop Birmingham as a city of sustainable neighbourhoods that are safe, diverse and inclusive with locally distinctive character" and "to provide high quality connections throughout the City and with other places including encouraging the increased use of public transport, walking and cycling" (Birmingham City Council, 2017, p. 18). Moreover, and importantly, it aligns well with the aspirations of Birmingham's stakeholders (Hunt & Rogers, 2015b).

Creating an 'active and inclusive city' has an intended benefit of 'ensuring people's fair access to opportunities to meet their needs and aspirations'. Achieving this intended benefit means, amongst other things, enabling affordable, safe, sustainable and accessible mobility, including active mobility; and, that there need to be public transport options that promote walking and cycling as part of the overall journey (see Deegan (2016) for a useful analysis of the London Cycle Network plus project). There are, of course, other aspects to creating an active and inclusive city, such as ensuring opportunities (employment) and other activities (leisure, culture, education, health) which are accessible physically and spatially, but also accessible financially (affordable) to promote inclusiveness. There are also additional benefits to be generated by creating not just an active and inclusive city, but also a healthy city and an evolving city, and so on. This paper will focus upon 'enabling affordable, safe, sustainable and accessible mobility, including active mobility' and the additionalities described above won't be pursued, but it is to be noted that it is in the bringing together of multiple desirable future performances and their benefits that the strength of the LCM lies.

- Performance: to create an active and inclusive city
- Benefit: to ensure people's fair access to opportunities to meet their needs and aspirations by enabling affordable, safe, sustainable and accessible mobility, including active mobility

Step 2: identify the necessary conditions for the future performance to be realised

The next step in the LCM is to identify the conditions that are necessary to enable delivery of the intended benefit. It is helpful here to consider 'what if?' questions for changes in society, technology, economy, environment and policy (a STEEP analysis) (Lombardi, et al., 2012). Quantitative modelling can also be employed (Hall, et al., 2017). It is also helpful to consider the current barriers to achieving the desired future performance. One way of doing this is to back cast from the desired future performance to today's performance, which was undertaken for this study. UK City Liveability Indicators Framework Edition 1 (UK City $LIFE_1$) (Leach, et al., 2017b) was used to describe the current performance of Birmingham, UK, although numerous other city measurement and assessment frameworks exist and can be used (Kitchin, et al., 2015; Leach, et al., 2015; Astleithner & Hamedinger, 2003; Mayer, 2008; Ness, et al., 2007; Pires, et al., 2014; Colantonio, 2010). For our identified performance-benefit pair, the following necessary conditions were identified (noting that this list is kept purposefully simple).

Necessary conditions required to enable affordable, safe, sustainable and accessible mobility, including active mobility for the purpose of creating an active and inclusive city:

- That affordable, safe, sustainable and accessible transport alternatives exist where they are needed.
- That affordable, safe, sustainable and accessible transport options will exist into the future.
- That affordable, safe, sustainable and accessible transport options are environmentally, socially and economically sustainable.
- That low-carbon options exist where affordable, safe, sustainable and accessible transport is not feasible (e.g., during inclement weather, under time and distance constraints).
- That the urban form facilitates affordable, safe, sustainable and accessible mobilities (i.e., an equitable land use mix within the city).

- That transport options (especially public transport) provide the required linkages (e.g., suburbs to centre) and are affordable, safe, sustainable and accessible for all.

Step 3: determine the current existence of the necessary conditions

Step 3 asks if each necessary condition currently exists. This requires judgement and synthesis, drawing on expertise, experience and knowledge of the local context. This also requires knowledge of the city's current performance and UK City $LIFE_1$ has been used here to assess the current performance of Birmingham, UK (Leach, et al., 2017a) alongside an in-depth review of Birmingham's transport ecosystem (Leach, et al., 2016b). The results of this analysis can be found in Table 2, noting that they have been vastly simplified in order to retain clarity (UK City $LIFE_1$ contains a total of 346 potentially-relevant indicators of city performance, from which the most-relevant have been chosen to illustrate the method).

Table 2: Existence of the necessary conditions in Birmingham, UK

NECESSARY CONDITION	EXISTENCE IN BIRMINGHAM (base year 2016)
That affordable, safe, sustainable and accessible transport alternatives exist where they are needed.	At risk, as buses and taxis were (and still are) the primary public transport alternatives in Birmingham and these are privately operated. Walking and cycling in the city centre requires improvement in terms of wayfinding, quality of the environment and connectivity of public transport systems.
That affordable, safe, sustainable and accessible transport options will exist into the future.	At risk, as bus and taxi operators need to make a profit and so operate accordingly. The cycling network in Birmingham is being expanded, but in the least-cost, least disruptive way (e.g., via existing canal towpaths) and while some will be 'protected' those associated with road layouts could easily be reversed.
That affordable, safe, sustainable and accessible transport options are environmentally, socially and economically sustainable.	At risk, as they were (and still are) primarily buses and taxis – which currently respond primarily to commercial (i.e., economic) pressures – and more limited walking and cycling – and these modes of transport require improvement and protection in Birmingham (see other necessary conditions for commentary on some of these).
That low-carbon options exist where affordable, safe, sustainable and accessible transport is not	No, as in Birmingham taxis and buses were the main public-transport alternatives (although there are now air quality targets for these modes of transport).

feasible (e.g., during inclement weather, under time and distance constraints).	
That the urban form facilitates affordable, safe, sustainable and accessible mobilities (i.e., an equitable land use mix within the city).	No, as there were (and still are) local concentrations of employment, retail and housing of different types throughout the city.
That transport options (especially public transport) provide the required linkages (e.g., suburbs to centre) and are affordable, safe, sustainable and accessible for all.	No, as buses and trains were (and still are) ineffective in connecting the suburbs to the city centre in many cases: for many these are not a reliable mode of travel, and few alternatives exist for 'hop on, hop off' travel.

Step 4: identify interventions(s) that bring into existence the necessary conditions

Once the existence or absence of the necessary conditions is known, it becomes possible to design interventions (i.e., potential solutions to problems) that can overcome the barriers to and exploit the opportunities for bringing the necessary conditions into being, and thus achieve the desired future performance. Interventions can be anything from physical interventions (and for engineers this often means infrastructure, which is highly interdependent with and interconnected to policies promoting behaviour change (Montgomery, et al., 2012)). In some cases large-scale interventions are demanded; in others a portfolio of smaller interventions is preferable. How these play out for desirable long-term agendas may vary: "[s]ustainable options can be mundane, as well as magnificent." (Keaton, 2017, p. 1).

For the purpose of this example, an intervention that was in the process of being implemented in 2016 has been chosen. This intervention addresses the existence of the necessary condition 'that low-carbon options exist where affordable, safe, sustainable and accessible transport is not feasible (e.g., during inclement weather, under time and distance constraints)'. In Birmingham, the electric light rail (Metro) is undergoing a phased expansion that in 2016 saw it extended into the city centre as a low-carbon alternative to traversing the wider city centre area and in particular connecting to Birmingham New Street railway station, a major station on the UK passenger rail system (Bourke, 2015) – see Figure 3.

- Intervention: extending Birmingham's light rail (Metro) into the city centre

- To satisfy the necessary condition: that low-carbon options exist where affordable, safe, sustainable and accessible transport is not feasible (e.g., during inclement weather, under time and distance constraints)

Figure 3: The Birmingham City Centre Metro Extension outside New Street Railway Station

It is beyond the scope of this paper to explore the possible additionalities afforded by interventions that address more than one necessary condition, but it should be noted that doing so is important when engaging in a full analysis. For example, the Metro extension could have been designed to additionally satisfy the following necessary condition: ‘that transport options (especially public transport) provide the required linkages (e.g., suburbs to centre) and are affordable, safe, sustainable and accessible to all’. If this were the case, then the Metro would not only be designed to provide a service in the city centre and its immediate surroundings, but also to connect in a systematic manner the city’s suburbs to its city centre (not currently part of the phased extension plans, although the authors acknowledge that such plans may be part of a long-term strategy not in the public domain). In other words, the Metro extension plan does not appear to deliver a strategic suite of necessary conditions.

Step 5: identify for each intervention its intended multiple benefits (intervention-benefit pairs)

Once designed, an intervention must be tested for potential future vulnerabilities, as well as its potential in maximising the range of additional benefits it might realise, and redesigned and retested as necessary. Although there exist a number of tools and methodologies for achieving this – and particularly so within engineering (Pearce, et al., 2012) – the Designing Resilient Cities Method is relevant as it uses UK-based future urban scenarios to pressure test the resilience of interventions to future change. A full description of this method alongside examples and case studies is available from Lombardi, et al., (2012) and Rogers, et al., (2012). As such, the Designing Resilient Cities Method has been revised and incorporated into the LCM and comprises Steps 5 to 9. Step 5 requires that for each intervention, intended benefits are identified (intervention–benefit pairs). Where more than one intended benefit is identified (multiple benefits) then Steps 5 to 9 should be carried out for each intended benefit (Lombardi, et al., 2012). It is also possible to use UK City $LIFE_1$ to identify multiple benefits. A description of how this works for the Metro extension is available in Leach, et al., (2016a). Identifying multiple benefits is desirable, but beyond the scope of this paper. The intervention-benefit pair identified from this paper's example is:

- Intervention: Birmingham's light rail (Metro) city centre extension
- Intended benefit: to create a low-carbon, public transport option in the city centre that is affordable, safe, sustainable and accessible

Step 6: for each intervention-benefit pair, identify the necessary conditions for the intervention to deliver the intended benefit

Next, taking each intervention-benefit pair in turn, the conditions that enable the intervention to keep functioning and delivering its intended benefit into the future are identified. In other words: what are the conditions that enable people to use the intervention so that it delivers its intended benefit (Lombardi, et al., 2012)? Necessary conditions can be identified using the previously-identified methods as well as by using quantitative modelling and assessment. For this example, the authors have identified the following necessary conditions (the list has been kept purposefully short and simple in order to retain clarity).

- That the Metro connects the city centre in useful ways
- That the Metro is reliable
- That the Metro is affordable to all
- That the Metro is safe to use
- That the Metro is sustainable (economically, socially and environmentally)
- That the Metro is accessible to all

Step 7: determine the performance of the necessary conditions now and in the future

Step 7 guides the user in determining whether each necessary condition is present now and if it is likely to be present in the future. Regarding the 'now', the user should make their determination in the most appropriate way, such as by reviewing documentation, observation, and deduction. Regarding the 'future', there exist a number of ways of determining the presence of necessary conditions (Rogers, 2018). For consistency, the authors have used the Designing Resilient Cities Method for this purpose. Table 3 shows the outcome of this analysis. The Designing Resilient Cities Method uses future scenarios to pressure test the existence of each necessary condition in each of four extreme yet plausible futures in different directions of travel from today's world. The reasoning is that if a necessary condition exists today and in the four scenarios then it is likely to exist no matter how the future actually develops since the scenarios cover the essential range of societal structures (Lombardi, et al., 2012). The four scenarios are Fortress World, Market Forces, Policy Reform and New Sustainability Paradigm (see Figure 4). Fortress World is characterised by a bifurcated society: the 'haves' (i.e., the rich and empowered) and the 'have nots' (i.e., the poor and disenfranchised). Market Forces lets the free market dominate unrestricted by social and environmental concerns. Policy Reform steers us towards sustainability through policy interventions and strong governance, whether citizens and businesses like it or not. New Sustainability Paradigm is characterised by citizens who want to live as sustainably as possible (Lombardi, et al., 2012).

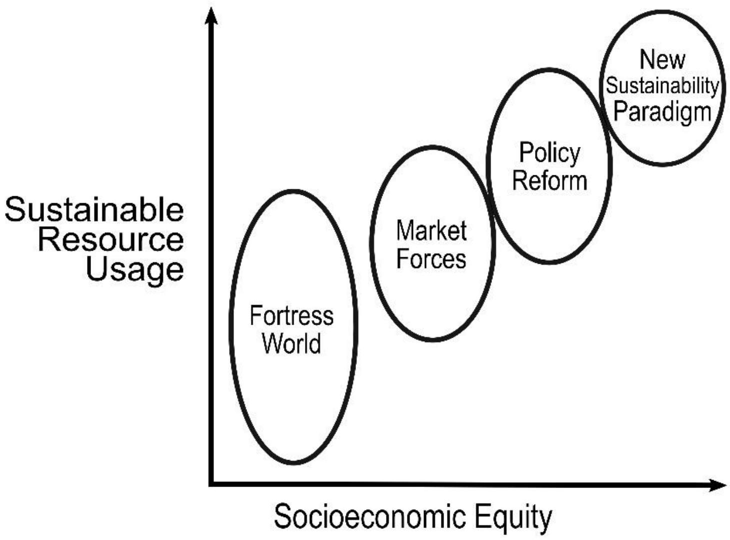

Figure 4: Designing Resilient Cities' Four Future City Scenarios. Adapted from Rogers, et al., (2012)

Table 3: Future performance of necessary conditions determined using the Designing Resilient Cities Method

Necessary Conditions	Now (2016)	Fortress World	Market Forces	Policy Reform	New Sustainability Paradigm
Connects the city centre in useful ways	At risk as the expansion of the Metro is	Haves: yes, as the money is available and	At risk as the route and stops will be	Yes, as this will have been required as part	Yes, as this will be desired by the City, the

	currently incomplete and relies, at least in part, upon the completion of the national high-speed rail link between London and Birmingham (HS2).	other resources are scarce so maximum functionality must be achieved. Have nots: at risk, as money and other resources to achieve connectivity to poorer areas are scarce.	determined by their potential for making a profit.	of the permission granted by the City to extend the Metro, and it will be retained as part of strong governance of such city assets.	citizens and the Metro's operators (all of whom will value the social and environmental, as well as economic, benefits it delivers).
Is reliable	Yes, as the Metro system runs mostly to schedule. In addition, in the city centre the trams run close together, enabling a 'hop on, hop off' user experience.	Haves: yes, as there is money and a safety imperative for this. Have nots: at risk, as services to the disenfranchised poor will be a low priority in financially-constrained times.	Yes, as reliability is linked to greater usage and thus greater profits.	At risk, as although reliability can be legislated, in practice those maintaining the Metro may not be as rigorous or respond to breakdowns as quickly as necessary.	Yes, as this will be desired by the City, the citizens and the Metro's operators (all of whom will value the social and environmental benefits it delivers).
Is affordable to all	At risk. Although the Metro is competitively priced, it is not free and so inevitably excludes some members of society.	Haves: yes, as the 'haves' are (relatively) wealthy. Have nots: at risk, as the 'have nots' are poor and their accessibility needs will not be prioritised.	No, as this would probably reduce the profit margin – market forces will determine the most profitable charging structure.	At risk, as although prices for travel can be legislated, there will be many demands on budgets and priorities will determine this aspect of service provision.	Yes, as this will be desired by the City, the citizens and the Metro's operators (all of whom will value the social benefits affordability delivers).
Is safe to use	At risk. The Metro is built to a high standard with safety as a priority, but economic factors (cost) will have impacted this.	Haves: yes, as safety is a priority. Have nots: no, as there is little resource for ensuring safety on routes servicing solely the have nots.	At risk, as in order to achieve this safety measures must align with economic priorities.	Yes, as safety is legislated.	Yes, as this will be desired by the City, the citizens and the Metro's operators (all of whom will value safety).
Is sustainable (economically, socially and environmentally)	At risk. The Metro has been designed to be economically sustainable first, followed by environmentally and socially sustainable.	Haves: at risk, as the haves prioritise safety and utility over other factors. Have nots: at risk, as in order to achieve these priorities they must align with	At risk, as in order to achieve social and environmental priorities they must align with economic priorities.	Yes, as sustainability is legislated.	Yes, as this will be a top priority for the City, the citizens and the Metro's operators (all of whom will value sustainability).

		maximising use of limited resources.			
Is accessible to all	At risk as excluding some potential customers may serve to maximise profit.	Haves: yes, as the money is available and other resources are scarce so maximum functionality must be achieved. Have nots: at risk, as the money and other resources are not available to service the disenfranchised.	At risk, as excluding some potential customers may serve to maximise profit.	At risk, as although accessibility can be legislated, those operating the Metro may opt to exclude potential customers in order to maintain service delivery (which is also legislated for).	Yes, as this will be desired by the City, the Metro's designers and the citizens.

Step 8: determine the resilience of the intervention-benefit pair now and in the future

At this point it becomes possible to determine the current and future resilience of the intervention. This requires judgement and synthesis, prioritising the importance of the necessary conditions and balancing these against the potential vulnerabilities identified (Lombardi, et al., 2012). From the simplified example presented here, it is evident that Birmingham's Metro extension only delivers a 'low-carbon, public transport option in the city centre that is affordable, safe, sustainable and accessible' if the world-view embraced by the City develops towards New Sustainability Paradigm – thus it is at risk – unless strong governance safeguards are put in place to legislate for its continued service functionality (affordability, accessibility, etc.). It is also evident that the market cannot deliver the intended benefit on its own, reliance on policy might result in delivery compromises and there is a clear polarisation of service delivery between the rich and the poor.

Step 9: (a) implement the intervention, (b) adapt the intervention (and return to Step 6) or consider using an alternative intervention (and return to Step 5).

It is now up to the user to decide whether (and how) to implement the intervention, adapt it to make it more resilient to future change or to deliver additional benefits, or replace it altogether.

The LCM informs this decision by elucidating the implications of implementing the intervention without adjustments and identifying how the intervention can be improved. For example, for Birmingham's Metro line extension accessibility and affordability are highlighted as particular vulnerabilities. Birmingham may therefore wish to explicitly address these aspects of the intervention. For example, it could follow Manchester's lead by augmenting its Metro with a free city-centre bus service, whilst at the same time ensuring the buses are low-carbon and recognising that financing such an intervention may be difficult in the current climate of austerity. Providing strategic linkages with walking and cycling routes to facilitate a 'hop on, hop off' mode of travel in uncertain weather (helping to improve citizen health), and ideally aligning the walking/cycling routes with green corridors (bringing people into routine close contact with nature and improving their wellbeing) would enhance the benefits that could be achieved (Hunt & Rogers, 2015b).

Implications for civil engineering

This paper uses the Liveable Cities Method (LCM) in combination with UK City $LIFE_1$ and the Ideal City Model to identify where a city should be in terms of future performance, analyse where it is currently, identify the conditions that need to be in place to support the desired future performance, and make specific recommendations that are optimal for ensuring those conditions exist today and into the far future. The LCM provides a process for constructing an evidence base and a plausible narrative describing how to get from a city's current performance to a desired future performance. In essence, it establishes the 'business case' for the intervention, from which alternative business models can be constructed directly using the intended benefits to point to the value that is realised (Rogers, 2018), enhanced by systems mapping to enrich the opportunities for value creations and realisation (Bouch & Rogers, 2017; Bouch, et al., In Press) and set against alternative forms of investment (Bryson, et al., 2018). Through determining how the intervention can deliver multiple benefits to substantially advance the city in its journey towards a more sustainable, resilient and liveable future, it makes the case for transformational change. Such a narrative forms the basis for the engineering strategies that are needed now and in the future.

Civil engineers engineer for the betterment of society, their ultimate client, and their creations are often required to function, and deliver their benefits for very many years; usually decades. Equally, what they create is inevitably context-dependent – it must function in the context in which it is created and it must continue to function as the context changes if it is not to become inefficient or redundant. When this context is cities, the context is a highly complex system-of-systems all of which are interdependent to different degrees (Government Office for Science, 2016b): intervene in one system and substantial impacts can be felt in many others. Civil engineers therefore need to develop both a deep understanding of the current context and a broad appreciation of how this context might change into the far future.

Aided by the Liveable Cites Method, civil engineers and civil engineering as a profession can take a more prominent role in addressing the wicked problems of today's cities – such as the energy/water/food nexus, soil nutrient levels, high-density living and wellbeing; all can be tested using the LCM. Moreover, because of the inherently multi-disciplinary spectrum embraced by the civil engineering discipline (Byrne & Mullally, 2014), engineers are well-equipped to take a lead in these debates amongst urban professionals, reaching back to the profession's roots when civil engineering covered the totality of societal support before specialisms initiated by the industrial revolution (mechanical, electrical and electronic, aerospace, etc.) were required.

The Liveable Cities Method is at the heart of a set of processes that have been established as good practice in the engineering of cities by a major, and largely coherent, portfolio of research into sustainable urban environments, the resilience of cities and their infrastructure systems and urban liveability. These processes are summarised in Table 4, along with references to some of the sources of evidence generated by the Liveable Cities team members; though this is far from (and was never intended to be) complete and many of the papers published in this journal, for example, will support and enrich the processes, as will the findings from the many UK and international research teams who have been working on these topics. A logical structure to the research findings has been created for the purpose of this discussion. The specific programmes referred to are as follows.

- Birmingham Eastside Research (BER) *esr.bham.ac.uk*
- VivaCity2020 (V2020) *vivacity2020.co.uk* (Cooper, et al., 2009)
- Designing Resilient Cities (DRC) *designingresilientcities.co.uk* (Lombardi, et al., 2012)
- The many Sustainable Urban Environment programmes (SUE), including a three-phased programme of research funded by the Engineering and Physical Sciences Research Council (EPSRC) *epsrc.ukri.org/newsevents/pubs/suearccreview*
- Liveable Cities (LC), especially the tools, case studies, Little Books and papers *liveablecities.org.uk*
- The two consortia researching infrastructure interdependencies and novel business models:
    - iBUILD *ncl.ac.uk/iBUILD*
    - ICIF *ucl.ac.uk/steapp/research/projects/icif*
- Urban Living Birmingham (ULB) *tinyurl.com/UrbanLivingBirmingham*
- The Foresight Future of Cities project (FFoC) *gov.uk/government/collections/future-of-cities* (Government Office for Science, 2016b)
- The University of Birmingham Policy Commission on Future Urban Living (PCFUL) *birmingham.ac.uk/research/impact/policy-commissions/future-urban-living* (Rogers, et al., 2014)

Table 4: Lessons from the UK Cities Research Portfolio of Liveable Cities Team Members

Lessons from Cities Research Portfolio	Evidence Base
To address a specific problem in a city, assemble an appropriately-broad, multi-disciplinary, multi-sectoral group of potentially interested parties who are able to represent the views of all stakeholders affected by the problem and its potential solutions.	BER, V2020, DRC, LC, FULPC, many SUE projects and the sustainability literature.
Understand deeply the aspirations of the city and its citizens, and the context in which the city exists (including both its history as well as its current context).	FFoC, LC, FULPC, BER, V2020, DRC, Rogers (2018), and the sustainability literature.
Diagnose fully the problem, noting the DRC experience that engineers focus upon solutions to problems while social scientists focus upon problem exploration, and other disciplines lie within this spectrum – a balance is required.	ULB, DRC, LC, Leach, et al., (2018)
Establish the baseline performance of the city in terms of its sustainability, resilience and liveability. It is helpful to make explicit the components of the city and infrastructure systems related to the problem and those that will be impacted by potential interventions by mapping them and establishing the dependencies and interdependencies between these systems.	DRC, Boyko, et al., (2012), LC, Leach, et al., (2017b; 2017a), iBUILD, Bouch & Rogers, (2017; In Press), ULB. *Covered explicitly in the LCM.*
Apply ingenuity to the solution of the problem, yielding a number of alternatives from which to choose the most appropriate.	Arguably what engineers (should) do.
Assess the impact of the interventions on the city's urban and infrastructure systems using one of the many sustainability assessment frameworks, resilience frameworks and the LC Liveability Framework (the City Assessment Methodology embodied in UKCityLIFE; see Leach, et al., (2017b; 2017a). Iteration will be needed between the design of alternative solutions and impact assessment.	BER, V2020, DRC, SUE and the literature. LC tools, case studies and papers. *Covered explicitly in the LCM.*
Conduct a futures analysis to explore whether the interventions are vulnerable to future contextual change (resilient), i.e., they will continue to deliver their benefits and therefore the investment proves good into the long-term.	DRC, Lombardi, et al., (2012), Rogers, et al., (2012) LC. *Covered explicitly in the LCM.*
Make the case for change – establish a compelling 'business case' for the proposed intervention. The LCM was created specifically for this purpose and provides perhaps the most comprehensive evidence base.	While much research supports the action, this is LC's specific target. *Covered explicitly in the LCM.*
Develop a suite of alternative 'business models' that capture the different forms of value that might be generated by the intervention, set against the investment required to implement it (perhaps in different ways).	Much research supports the identification of economic, social and environmental value. iBUILD & ICIF, Bouch & Rogers (2017; In Press), Bryson, et al., (2018), Rogers (2018)
Understand all of the dimensions of governance (formal and informal) relevant to the intervention and the context in which it is to be implemented, and engineer changes to all of these systems in order that the intervention can be implemented without impediment.	DRC, LC, Honeybone, et al., (2018). *Covered explicitly in the LCM.*
Influence policy by drawing on research findings to help shape local and national government policy and make the case for the intervention to policy-makers.	FFoC, FULPC, LC, Honeybone, et al., (2018)
Influence practice via tools and case studies that enable the research findings to be translated to practice.	V2020, DRC, LC tools and case studies
Inform the public of the issues and how they might be addressed.	LC videos and Little Books, ULB, outreach activities

This research portfolio is now being taken forwards in part under the umbrella of a new multi-university initiative: the UK Collaboratorium for Research on Infrastructure and Cities (UKCRIC, see *ukcric.com*). UKCRIC has seen an investment of £138m, matched by institutional and industrial funding, in a suite of new laboratory, urban observatory and modelling and simulation facilities across the UK between 2016 and 2021. It is exploring new ways of working and delivering on collaborative research, exploring, for example, how learning frameworks can support the generation of new knowledge across multi-disciplinary teams engaging on engineering challenges (Taylor, et al., 2017)

Conclusions

This paper introduces the Liveable Cities Method (LCM), a decision-making process that identifies the conditions that need to be in place to support a sustainable and liveable city of the future and provides an important contribution to building the transitional narrative and engineering strategies needed to get us there. In so doing, it provides the essential component when making the case for transformational change towards a more sustainable, resilient and liveable future and, crucially, the transformative step to make it happen.

The LCM is demonstrated through the example of Birmingham's ambition to create a more active and inclusive city achieved, in part, by extending its light rail (Metro) system into the city centre. The example follows the nine-step LCM in a linear fashion, starting at Step 1 and finishing at Step 9, in order to demonstrate the value offered by the method. In doing so, this paper has ignored the necessarily messy and iterative nature of decision-making and the fact that it is not always possible, or even desirable, to start at Step 1 and work forward, while acknowledging that pervasive iteration is a vital component of the systems thinking that lies at the heart of the LCM. In addition, by focusing narrowly upon the given example the richness of simultaneously considering multiple ambitions and multiple interventions, their sequencing and scales, and their arising benefits has been lost. And yet, it is argued by the authors that these have the potential to offer very considerable additional value and insights; for example, by aligning interventions so that they not only simultaneously deliver multiple benefits but also simultaneously address multiple strategic ambitions.

The example has demonstrated that the LCM provides the necessary decision-making process to engender bold and assured policymaking and, crucially, make explicit how cities can advance towards their common goals of sustainability, resilience and liveability. As one member of Birmingham's City Council explained: we must change ***how we think*** about making decisions so that we do so in an evidence-based way – this is different to how things are currently done. This has particular implications for engineers, who often consider these common goals as simply 'good engineering' (Keaton, 2017). The Liveable Cities Method facilitates such a transformation by making explicit the thinking behind decisions and by aligning goals, designs and interventions. In doing so, engineers can use the LCM to actively move from 'good engineering' to 'better engineering': "[w]hat we call 'sustainable engineering' today is more than just good engineering, but it is less than what good engineering will become in future decades" (Keaton, 2017, p. 1). By embedding transformation within an evidence-based and repeatable process that encourages innovative approaches for positive additionalities, the LCM overcomes some of the reasons engineering innovation is 'hard and slow' (Ainger, 2015) and contributes to the 'systemic approach to engineering sustainability' called for by this Journal in 2014 (Mayfield, 2014), a call which continues to be relevant today.

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