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Decision making under uncertainty in climate change mitigation: introducing multiple actor motivations, agency and influence

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ABSTRACT

Climate change mitigation has two main characteristics that interact to make it an extremely demanding challenge of governance: the complexity of the socio-technical systems that must be transformed to avoid climate change and the presence of profound uncertainties. A number of tools and approaches exist, which aim to help manage these challenges and support long-term decision making. However, most tools and approaches assume that there is one decision maker with clearly defined objectives. The interaction between decision makers with differing perspectives and agency is an additional uncertainty that is rarely addressed, despite the wide recognition that action is required at multiple scales and by multiple actors. This article draws inspiration from dynamic adaptive policy pathways to build on current decision support methods, extending analysis to include the perspectives and agency of multiple actors through a case study of the UK construction sector. The findings demonstrate the importance of considering alignment between perspectives, agency and potential actions when developing plans; the need for mobilizing and advocacy actions to build momentum for radical change; and the crucial influence of interaction between actors. The decision support approach presented could improve decision making by reflecting the diversity and interaction of actors; identifying short-term actions that connect to long-term goals and keeping future options open.

Key policy insights

- Multiple actors, with differing motivations, agency and influence, must engage with climate change mitigation, but may not do so, if proposed actions do not align with their motivations or if they do not have agency to undertake specific actions.
- Current roadmaps, which assume there is one decision maker with control over a whole system, might overstate how effective proposed actions could be.
- Decision making under deep uncertainty needs to account for the motivations and agency of diverse decision makers and the interaction between these decision makers.
- This could increase the implementation and effectiveness of mitigation activities.

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Introduction

It is widely accepted that avoiding the worst effects of climate change requires radical reductions in GHG emissions (IPCC, 2014). This scientific consensus is increasingly being translated into political aspirations, but delivering on these aspirations presents three main challenges.

Firstly, GHG emissions arise from a complex, interconnected system of technology embedded in society and the environment, interacting with public and private institutions (Foxon, 2011). Interactions within this complex[1]

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system mean that it is unstable and unpredictable, making it hard to identify actions to deliver the necessary emissions reductions, particularly because such actions will include many that are not directly related to climate change (Costanza et al., 1993; Grubb, Hourcade, & Neuhoff, 2014a; Liu et al., 2007).

Secondly, decision making in climate change mitigation is fraught with uncertainty. This includes endemic uncertainty arising from '*insufficiency* of models, *necessities* to set boundaries […], *inaccuracy* of measurements, and other issues that systemically generate *ignorance* as a function of constructing knowledge' (Butler, Demski, Parkhill, Pidgeon, & Spence, 2015 p. 666, emphasis from original). It also includes irreducible uncertainties, where it is not possible to generate probabilistic estimates of outcomes of particular actions or where it is difficult to reach agreement on the desirability of outcomes (Funtowicz & Ravetz, 1993; Stirling, 2010). Irreducible uncertainty severely limits the ability to generate and describe futures on which decisions can be based (Butler et al., 2015).

Finally, the fragmented delivery environment means that action is required from many actors in different sectors and at multiple levels (Marsden, Ferreira, Bache, Flinders, & Bartle, 2014; Ostrom, 2010). However, these actors have different motivations and decision-making processes, as well as differing levels of agency over aspects of the complex system. There is no optimal solution over which one organization has control (Grubb, Hourcade, & Neuhoff, 2014b; Leach, Scoones, & Stirling, 2010). The coordination of decisions at multiple levels in this fragmented environment presents significant challenges to action (Niemeier et al., 2012).

A number of approaches exist, which aim to help decision makers to understand and manage the uncertainties associated with long-term decisions in complex systems. These uncertainties include the effect of social and environmental change (e.g. Dessai & Hulme, 2007; Haasnoot, Kwakkel, Walker, & ter Maat, 2013; Hallegatte, Shah, Lempert, Brown, & Gill, 2012; Hall et al., 2012; Walker, Haasnoot, & Kwakkel, 2013) and of interaction between systems (e.g. Young & Hall, 2015). However, most approaches assume that there is one decision maker with clearly defined objectives (Madani, Darch, Parra, & Workman, 2015). The variety of actors and the differences in their decision making is rarely recognized, as evidenced by the lack of specific discussion of actors or responsibility in current methods. Therefore, decision support approaches are needed that address different drivers of decisions (including behavioural, investment and strategic) and account for different approaches to risk and uncertainty (Grubb et al., 2014b). These approaches must recognize the following:

- Actors involved in mitigation activities have differing motivations and agency. An actor's ability to carry out desirable actions is dependent on whether actions contribute to individual or institutional objectives and perspectives (Leach et al., 2010); whether they have the capabilities or resources to implement these actions; and, whether they are constrained by factors such as existing infrastructure or decisions by other actors (Grubb et al., 2014a).
- Mitigation requires a series of connected decisions over long time periods. Change will not result from an isolated decision, but rather from a series of activities in different sectors and over decades. The response to particular actions cannot reasonably be predicted and so decision support approaches should be reflexive and allow for flexibility to adjust future actions based on the outcomes of previous actions. (Leach et al., 2010; Lindblom, 1959). However, the future implications of short-term decisions must be considered in order to keep desirable future options open (Haasnoot et al., 2013; Stirling, 2010).
- Mitigation activities must be directed towards a particular goal. The scale of emissions reductions required implies a radical transition towards an urgent goal. Activities cannot be purely incremental (without the need for clarity over guiding objectives) and some level of acceptance of the necessary long-term outcome is required. Furthermore, actions must be cumulative; action by different actors and over time need to build on, not neutralize, other actions (Cashore & Howlett, 2007). Therefore, decision support approaches must be able to balance the recognition of complexity with the need to be anticipatory and to steer transitions (Grubb et al., 2014a).

Adaptable approaches to support long-term decision making under deep uncertainty are gaining prominence and have been described in detail by Walker et al. (2013). The relevance of some of the principal existing approaches to the challenges outlined above is described in supplementary information S1. In summary, these approaches attempt to improve the adaptability and robustness of decision making. They do this by examining the assumptions and uncertainties that underpin long-term decisions and putting in place corrective actions in the event those assumptions change or are broken. Monitoring is an essential part of these approaches, to detect change in assumptions or uncertainties, and signal when corrective or contingency actions are required. Many approaches use scenarios to depict multiple views of the future. Potential actions are tested in these scenarios to identify actions that perform well in a range of plausible futures.

Existing approaches offer many benefits in support of decision making under uncertainty, including exploring a wide range of uncertainties, connecting short-term targets with long-term goals and encouraging commitment to short-term action while keeping options open for the future (Walker et al., 2013). However, none of them explicitly address the multiple, and often conflicting, decision-making processes involved in long-term strategies. Some researchers have started to explore the implications of pathways for different stakeholder perspectives (Offermans, Haasnoot, & Valkering, 2011) but none recognize the specific motivations and agency of different actors and how these drive or constrain their engagement. Nor do they attempt to understand the interactions, influence and coordination of actors that is crucial to the delivery of change in a complex system where no actor is able to influence all parts of the system (Grubb et al., 2014a).

This article presents a modified approach to decision making that contributes to managing deep uncertainty associated with social and environmental change and, crucially, incorporates different stakeholder perspectives, as well as different levels and types of agency of multiple actors. This approach is tested on the case of the UK construction sector, where we discuss its benefits and possible extensions. Whilst we do present results and insights specific to the context of the construction sector, our principal aim is to consider the role of decision support tools and methods in the policy process in general.

The construction industry is crucial to climate change mitigation, with buildings and their construction together accounting for 39% of annual global energy-related CO_2 emissions (UN Environment and International Energy Agency (IEA), 2017). The global floor area of buildings is expected to double by 2060, and current policy commitments are insufficient; therefore, additional action is needed in the construction industry (Kuramochi et al., 2018; UN Environment and IEA, 2017). The industry is composed of a complex network of actors with differing influence and motivations. These actors face multiple sources of uncertainty around the required future performance of assets, the viability of mitigation options, and the skills needed to deliver them (Giesekam, Densley, Tingley, & Cotton, 2018). The sector therefore presents an ideal setting in which to evaluate and develop approaches to decision making under deep uncertainty.

Case study description

The construction industry in the UK does not generate significant emissions itself, however, it directly influences emissions through its supply chain and the operation of the assets it creates. Emissions from the built environment amounted to 202 $MtCO_2e$ in 2012, with 78% attributable to *operational emissions* from existing assets, and 22% attributable to *embodied emissions* from the construction of new assets (Steele, Hurst, & Giesekam, 2015). Embodied emissions are those created during the abstraction, processing and manufacture of the materials used in construction as well as their transportation and assembly on site. The majority of these embodied emissions are associated with the manufacture of materials such as steel and cement (Giesekam et al., 2014).

The UK's principal construction strategy aims to halve emissions from the built environment by 2025 (HM Government, 2013). Reductions of 80% are expected by 2050, consistent with targets in the UK Climate Change Act 2008. The 2013 Green Construction Board Low Carbon Routemap for the Built Environment sets out a possible trajectory for achieving these reductions (Green Construction Board, 2013). However, a recent update demonstrated that the industry has fallen behind the target trajectory and additional interventions will be required, particularly in relation to embodied emissions, which have increased since 2013 (Steele et al., 2015). It is highly unlikely that the industry carbon reduction targets for 2025 or 2050 can be achieved without significant reductions in embodied emissions (Giesekam et al., 2018). Policy interventions have supported reductions in operational emissions; however, there is no equivalent policy targeting embodied emissions. In the absence of strong commercial or policy drivers, a minority of construction firms are assessing or targeting reductions in embodied emissions (De Wolf, Pomponi, & Moncaster, 2017; Giesekam et al., 2016) but there is no clear plan to ensure that this practice becomes mainstream. As a result of the current lack of action on embodied emissions, and their important contribution to achieving emissions reductions targets, the case study will focus specifically on embodied emissions.

Modified dynamic adaptive policy pathways approach

The Dynamic Adaptive Policy Pathways (DAPP) approach developed by Haasnoot et al. (2013) most comprehensively addresses the three main challenges outlined in the introduction. The DAPP approach combines Adaptive Policy Making (APM) (Walker, Rahman, & Cave, 2001) and Adaptation Planning (AP) approaches (Haasnoot, Middelkoop, Offermans, van Beek, & van Deursen, 2012). It builds adaptability into a plan while directing action to a particular goal. The approach places emphasis on system analysis to identify objectives, constraints and uncertainties affecting decision making. Actions are identified that overcome challenges to achieving an objective or exploit opportunities arising from change or uncertainty. These actions are classified in the same way as APM as shaping, mitigating, hedging and seizing actions. Sequencing of these actions is important in DAPP to form the basis for adaptation pathways as described in the AP approach. Tipping points are identified as the point after which a sequence of activities is insufficient to achieve specified objectives. At these points, alternative (contingency) actions are identified to respond to change or open up a new series of actions.

The result of this analysis is a series of pathways of activities through which alternative routes may be defined to meet specified objectives. The results are presented in a graphical format which identifies pathways, tipping points, and any alternative routes after a tipping point (which includes transfers onto different pathways). This allows planners to identify no regrets actions (e.g. pathways that have several options once a tipping point is reached), lock-ins (pathways that have no options once a tipping point is reached) and the timing of important actions. This ability to assess the importance of timing and sequencing of actions, and to identify points at which it is possible to transfer to other pathways and how options can be kept open, is crucial to balancing adaptability with confidence that a plan's objectives can be met in the long-term. Furthermore, the graphical presentation of results is a real benefit for engagement of stakeholders in plan development.

The DAPP approach includes monitoring to continually assess the implementation of the plan and to apply contingency actions where necessary. Furthermore, it includes monitoring of the situation, objectives and uncertainties to assess whether more fundamental changes to the plan are required, making it a more dynamic process.

Nevertheless, DAPP suffers from a number of limitations relating to the realities of decision making. There seems to be little recognition that more than one actor is responsible for actions in the dynamic adaptive plan, nor are there mechanisms through which this distributed responsibility might be co-ordinated. Furthermore, there is no analysis of the alignment of actions with the motivations or agency of actors expected to engage.

In this section we describe a modified approach which attempts to address these limitations. Only those steps involving significant modifications to DAPP (described in Haasnoot et al. (2013)) are discussed. Proposed modifications are presented in Table 1.

Data collection

The system understanding and problem analysis were initially developed through analysis of publicly available documents setting out the challenge of reducing emissions in the construction sector and proposing potential strategies or roadmaps (e.g. Battle, 2014; Green Construction Board, 2013; HM Government, 2013; Steele et al., 2015). The content of documents was analysed to identify common themes relating to the generation and management of embodied emissions. Initial actions were also taken from these publications and from an industry workshop addressing the reduction of embodied emissions in the construction sector, held in March 2015. The results of this initial analysis were discussed in detail at a 4-hour practitioner workshop held in July 2015 to confirm objectives, uncertainties, gaps and actor characteristics. Practitioners were asked to review and revise the provisional list of actions. They were then asked to consider the compatibility of actions with the responsible actors, along with their motivations and agency.[2] Participants were also asked to assess their likely effectiveness, flexibility and longevity, using the template presented in supplementary information S3. Finally, participants

Table 1. Proposed modifications to DAPP.

DAPP step	Current approach	Proposed modification
System understanding	Describes current system in terms of a physical system. Sets objectives of pathways. Identifies uncertainties relating to data and modelling.	Describe actors involved with system, including motivations, influence and agency. Align objectives with range of actors. Identify uncertainties that relate to specific actors, e.g. public perception.
Problem analysis	Compares current situation and possible futures (which may be detailed modelling outputs or descriptive narratives) to pathway objectives to identify gaps between futures and objectives. A gap indicates that action is needed to exploit an opportunity or address a vulnerability that would affect achievement of objectives.	Ensure representation from actors expected to engage in the plan when undertaking gap analysis to broaden perspectives.
Possible actions	Identifies mitigating actions (to reduce likely adverse effects of a plan); hedging actions (to spread or reduce the uncertain adverse effects of a plan); seizing actions (to seize likely available opportunities) and shaping actions (to reduce failure or enhance success).to move system towards achievement of objectives.	Include 'advocacy' actions to encourage engagement of actors who are not currently active. These are different to 'shaping' actions in that they are specifically focussed on changing actor behaviour. Associate actions with a particular actor to recognise distributed responsibility and support development of coordination mechanisms. Ensure representation from actors expected to engage in the plan to identify a wider range of actions.
Evaluate actions	Evaluates effectiveness of actions in a range of scenarios to identify promising actions to take forward. Presents evaluation in the form of a scorecard to enable comparison. Evaluation should identify the 'sell by date' of actions – when they no longer contribute to achieving objectives.	Evaluation should also address alignment of action with actor motivations, agency and influence.
Pathway assembly	Sequences actions to identify potential pathways. Considers actions that must be completed before others can be implemented; those that might extend the reach or effectiveness of a particular action; those to which it is possible to transfer if a particular action is not successful.	Consider actions that would only be feasible if an actor not currently engaged became active and those that are required to advocate for change before a particular action becomes compatible with the framing of a particular agent.

were asked to organize individual actions into sequences that might deliver embodied emissions reductions. Organizations who contributed to this workshop are listed in the supplementary information S2 and included clients, designers, contractors, policy makers and advocacy organizations (two cross-sector and one specifically materials and products). Following the workshop, the authors assembled sequences identified by workshop participants into pathways. The system understanding and problem analysis were revised as a result of workshop outputs and using literature published after the workshop.

Results

In this section we report the results of applying the modified DAPP approach to our case study of embodied emissions in the UK construction sector. The analysis focuses on the areas where significant modifications were made, and is intended to illustrate the benefits of these modifications, rather than represent a detailed alternative pathway.

System understanding and problem analysis

Actors, motivations and agency

Responsibility for embodied emissions in UK construction falls between numerous government departments. Although the Department for Business, Energy and Industrial Strategy (BEIS) bears responsibility for the achievement of national emissions reduction targets, the Department for Communities and Local Government (DCLG) determines building regulations, and several other government departments – e.g. Department for Transport (DfT) – determine demand for construction through their investment decisions.

Development priorities vary widely between these departments and can conflict. Least-cost emissions reduction, including measuring and mitigating embodied emissions, has been promoted as a key objective within the latest Government Construction Strategy 2016–2020 (IPA, 2016). However, it offers few drivers to support this objective, with most policy levers residing in other departments. By contrast, BEIS prioritises improving productivity, promoting growth and exploiting the industry's export potential. Other departments commissioning construction have further priorities, such as the reduction of traffic congestion or meeting housebuilding targets. This highlights the fact that an 'actor', such as 'government' can have widely divergent perspectives and priorities.

In parallel, the devolved administrations,[3] cities and city regions are developing a more significant role in commissioning construction and managing emissions. This has increased further the number of actors with responsibility for emissions reduction and resulted in greater policy variation geographically. For example, a 'zero carbon' housing target for developers of homes forming part of major development applications has recently been introduced by the Greater London Authority (GLA, 2016). Demonstrable reductions in embodied emissions can be used to help meet this target.

In the absence of clear leadership from a single government department, climate policy relating to the construction industry has been inconsistent, with policy changing suddenly and with little stakeholder consultation. It could be argued that the construction sector is particularly susceptible to this change because of the lack of leadership and 'ownership' in this sector. A prominent example is the abandonment of the national Zero Carbon Homes policy[4] which would have significantly reduced operational emissions (Greenwood, Congreve, & King, 2017).

Within this fractured policy context, influence over embodied emissions is distributed along a complex supply chain of actors who specify, design and construct buildings and structures as well as the many organizations that produce and supply construction products and materials. These actors are supported by a plethora of organizations that disseminate best practice, develop industry consensus and advocate change in policy. Figure 1 presents a summary of the principal industry actors and their perspectives. For clarity, the figure omits a number of actors that are less prominent in decision-making processes, including: project financiers; trade unions; research technology organizations; standards organizations; end users; and civil society organizations.

This mapping of actors and perspectives highlights some important issues and reinforces the need for more detailed actor analysis. Workshop participants identified that none of the actors involved in construction frame emissions reduction as an issue that should be prioritized over issues such as cost efficiency, risk management and capturing market share. Furthermore, issues such as risk management and market share are related to organizational behaviour, which implies that actions need to target not only investment (which is the focus of many long-term strategies), but also changes to business processes and organizational structures.

No actor controls the entire chain of decisions relating to materials selection and construction methods; one workshop participant highlighted the role of construction contracts in breaking the 'flow' of control. Therefore, there is no natural 'owner' of a plan to reduce embodied emissions in the absence of clear government policy. Even if there was a clear policy, it would require action by a number of different agents.

Actors have varying agency over materials selection and construction methods, for example, a contractor subject to a build-only construction contract may have limited control over the materials they use. These constraints on agency must be taken into account when identifying actions and allocating responsibility.

The influence of actors over others and the interaction between them varies significantly. This can be affected by project specific factors such as procurement route, time constraints and project culture. However, certain actors have more connections to others (such as clients, and material and product producers) and have more influence over the whole supply chain. One of the workshop participants described these actors as 'fulcrums of influence', which should be exploited when designing actions.

Key uncertainties

The magnitude of embodied emissions reduction required (which are the focus of this case study) to meet sector targets is dependent upon multiple uncertain factors. These include the rate of energy system decarbonization; the viability of carbon capture and storage for material and product suppliers; and the demographic trends that drive demand for buildings and infrastructure. Scenario analysis by Giesekam et al. (2016b) suggests

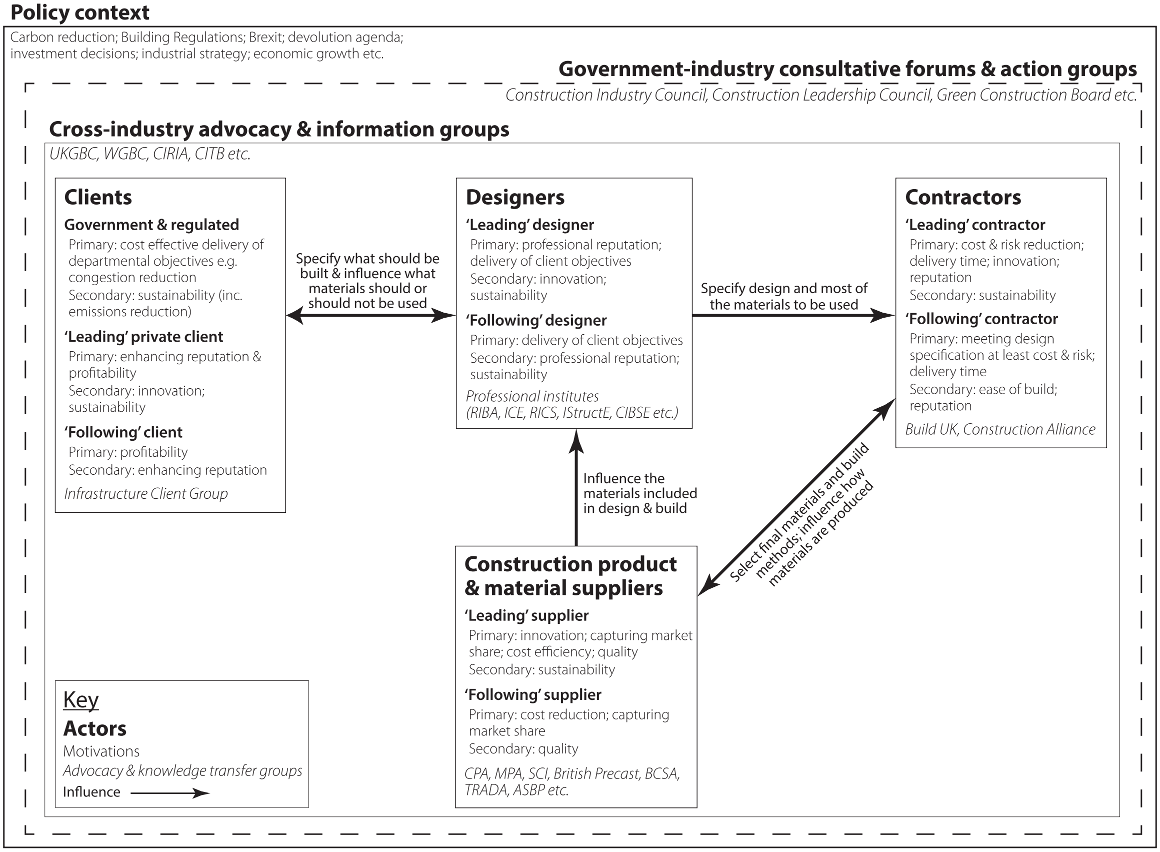


Figure 1. Simplified actor and influence map of the UK construction sector showing types of actors, their motivations and how they interact to influence material and product use and construction methods (which in turn influences embodied emissions). These interactions occur within a policy context, which is influenced by numerous actor-specific and cross-industry advocacy and information organizations.

that only modest reductions in embodied emissions, of approximately 7% in the next decade, may be required if all factors progress favourably. However, if external factors are highly unfavourable, then reductions averaging 67% across all projects will be required as early as 2027.

The absence of carbon intensity data for materials, products and projects is a widely cited barrier to the uptake of alternative materials and construction methods (Giesekam et al., 2016b). It also makes it difficult to establish appropriate benchmarks for inclusion in procurement documentation (Giesekam et al., 2016). The drivers for development of such data are weak, and many construction product manufacturers are unlikely to invest in the development of Environmental Product Declarations (EPDs)[5] without additional controls.

The uptake of alternative materials and construction methods also requires the acceptance of the building or structure's end users. While research has explored industry attitudes to alternative materials and products (Giesekam et al., 2016b; Jones, Stegemann, Sykes, & Winslow, 2016; Windapo & Ogunsanmi, 2014), there is little comparable work exploring end user perceptions. In the absence of evidence, assumptions about the conservative preferences of end users may restrict innovation or result in solutions that are unacceptable to them (Hamilton-MacLaren, Loveday, & Mourshed, 2013; NHBC Foundation, 2012).

Delivering a transition in data, materials, processes and attitudes needs prolonged support through policy intervention. Our workshop participants cited the current lack of policy ownership for this issue as a key uncertainty, a view supported by the UK's Committee on Climate Change (2018). Workshop participants found it difficult to envisage any substantial interventions in the near-term. In the longer term it may prove difficult to maintain consistent support through repeated changes in government and personnel.

Identify actions

The list of potential actions, developed from documentary analysis and the initial workshop, was grouped by the supply chain area affected (Table 2). This was presented to participants in the second workshop and was revised through a process of discussion of the system and action sequencing. The revised list of actions is included in Figure 2. Actions are more concentrated in areas of the supply chain where actors were deemed by participants to be fulcrums of influence.

Evaluate actions

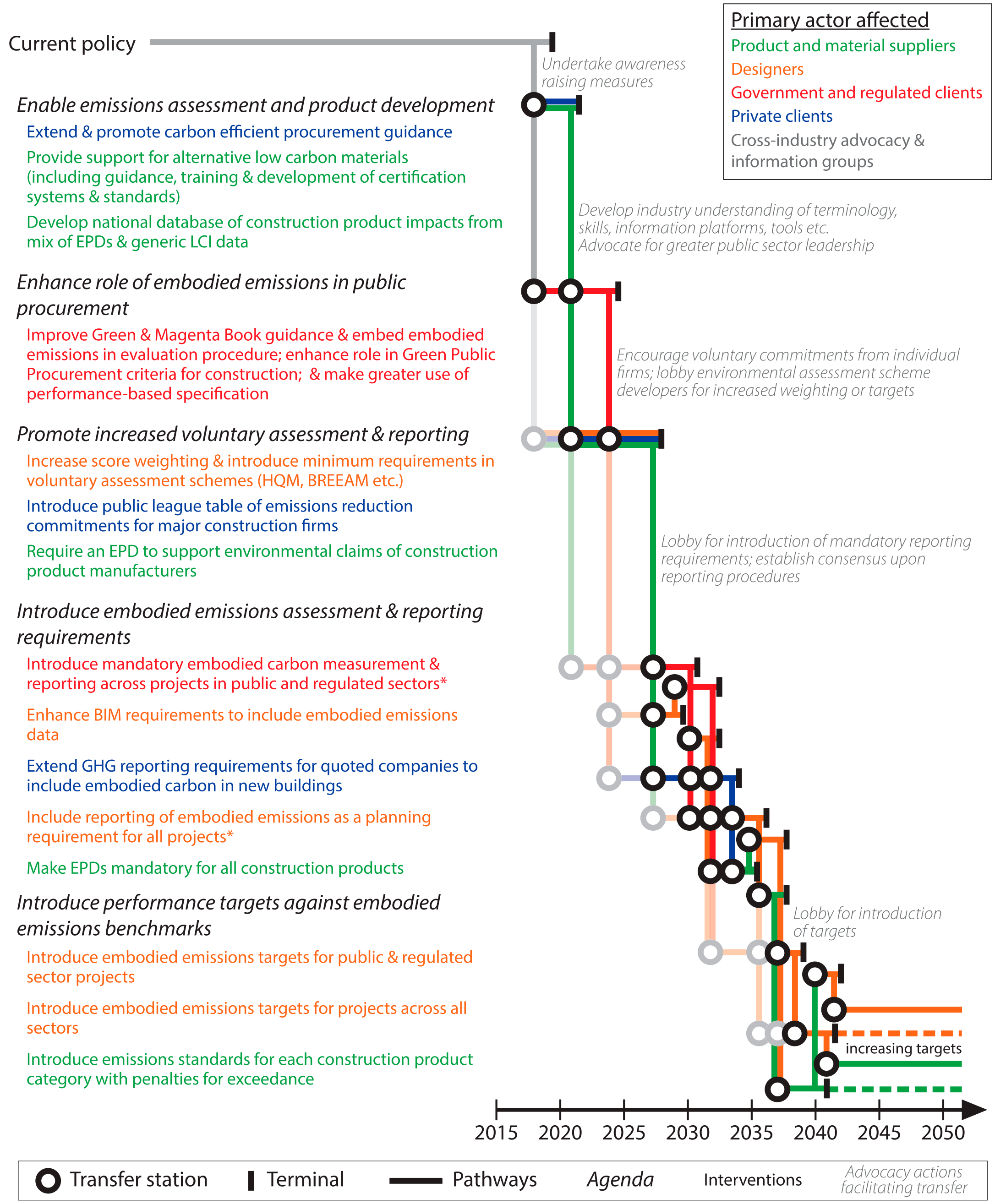
The evaluation of potential actions revealed several key issues relating to actors, motivations and responsibility that influenced subsequent pathway development.

Workshop participants noted that there is poor alignment of many of the actions with current actor motivations (including policy actors). For example, the mandatory production of EPDs identified in Table 2 would conflict with the motivation of cost efficiency identified in Figure 1, because EPDs are time and resource intensive to produce. More evidence is needed to demonstrate how actions do (or do not) contribute to actors' primary concerns, for example how an EPD would help to reduce costs or capture market share.

Many actions require organizational change (such as measuring and reporting embodied emissions for product material suppliers and clients), not just a physical change in the system (such as building/changing a structure), which affect behavioural drivers, not just investment drivers. Actions that exploit the influence of clients, through procurement, and material and product suppliers, through EPDs, will be a crucial part of any pathway. Construction clients from government and heavily regulated sectors in particular have the potential to pilot new mechanisms, such as monitoring and reporting, and to gather evidence to justify more stringent actions, stimulating wider change.

Table 2. Potential action list informing stakeholder workshop.

Actor affected	Policy/action
Construction product and material suppliers	Develop UK National Embodied Carbon Database from mix of Environmental Product Declarations (EPDs) and generic Life Cycle Analysis data that allows product comparison
	Support update of UK National Embodied Carbon Database
	Legislate to make production of EPDs mandatory
	Legislate to achieve minimum EPD standards with penalty for exceedance
	Develop certification systems for alternative materials
	Provide guidance and training in use of alternative materials
	Promote and advocate for alternative materials
Clients – government and regulated sectors	Develop approach for performance-based specification across all sectors and construction types
	Extend public sector green procurement framework to be more rigorous and relevant to construction
	Require mandatory measurement and reporting of Embodied Carbon on public and regulated sector construction
	Include more detailed guidance on Embodied Carbon in Green Book (UK government guidance on how to appraise and evaluate policies, projects and programmes) and increase from optional to mandatory
	Include explicit calculation and reporting of capital carbon in National Infrastructure Plan
Clients – private sector	Extend Waste and Resources Action Programme's (WRAP) work on Carbon Efficient Procurement to make reporting on embodied emissions mandatory and to strengthen methods
	Promote strengthened work on Carbon Efficient Procurement
	Companies listed on the stock exchange must report GHGs embodied in new buildings
Designers	Voluntary requirement for large contractors to add embodied emissions data to WRAP Embodied Carbon Database
	Mandatory requirement for public sector projects to add embodied emissions data to WRAP Embodied Carbon Database
	Planning requirement to report capital carbon
	Benchmark capital carbon for projects (by type)
	Legislate to achieve minimum capital carbon standards with penalty for exceedance
	Planning requirement to report measures to design for deconstruction
Contractors	Minimum efficiency standard for site accommodation
	Emissions standards for construction plant
End of life	Mandatory labelling of products that have potential for re-use
	Develop database of materials in use that are suitable for re-use



* All data to be uploaded to common repository to facilitate benchmarking (likely facilitated by organisation such as RICS)

Note: numerous other measures were considered such as the development of a material re-use database & platform; the introduction of material passports; requirements to design for deconstruction; requirements to design for adaptability; and the mandatory labelling of re-usable construction products but these options have been omitted from this figure. Although such measures may deliver emissions savings over multiple product uses, these savings will be delivered over a timeframe that extends beyond this analysis.

Figure 2. Initial pathways map for embodied emissions reduction in the UK construction sector.

In the absence of a clear policy narrative, intermediary organizations, such as the Green Construction Board and the UK Green Building Council, have a crucial role in advocating change and coordinating the actions of disparate actors.

Develop pathways

Drawing upon the views expressed by workshop participants and their attempts at action sequencing, the authors developed an initial pathways map (see Figure 2). This map is a starting point for further debate and has not been subject to detailed quantitative assessment. The terminals represent moments at which prior actions are projected to prove inadequate at meeting carbon reduction targets. These terminals have been approximated based upon the analysis described in Giesekam et al. (2016a).

Actions have been categorized by the primary actor affected, which allows analysis of alignment with actor motivations and supports identification of additional actions to improve alignment. Advocacy actions, those that are specifically designed to encourage engagement of crucial actors, are shown in grey on the right-hand side of the figure.

Figure 2 highlights some important insights. Many action sequences start with voluntary systems to build evidence to generate sector benchmarks and articulate how actions align with other motivations. This is followed by regulation of measurement and reporting, which will further expand the evidence base and support behavioural and organizational change. Then, more stringent regulation is required to enforce minimum standards, which tighten further as familiarity with low emissions design and construction increases. This regulation can only occur when policy support is stronger and it is possible to demonstrate that emissions reduction aligns with other government priorities, such as sector growth.

This sequencing of activities and the need for long lead-in times to align motivations results in a less logical progression between actions than in many plans based on more physical actions and investment decisions (e.g. Haasnoot et al., 2013). The timing of actions is crucial and any delay to initial actions to collect data could slow the regulation that drives substantive emissions reductions in the longer term.

Government clients are essential to build momentum and the evidence base to demonstrate how actions contribute to other actors' motivations and perspectives. However, they cannot act alone: expenditure in the public and regulated sectors only accounts for a third of total sector embodied emissions in a typical year (Giesekam et al., 2016b). Consequently, deep reductions in later years will require action across all types of construction.

Measures targeting product and material manufacturers and measures focussed on procurement and design must be developed in tandem to ensure that change in one area is not stifled by inertia in another. This highlights the importance of understanding the interaction between actors and where influence is most strongly felt.

Discussion

Climate change mitigation requires that we engage systematically with complexity and specifically that we incorporate the perspectives of different actors within and between sectors, at different levels, and with different agency. In this section we evaluate the effectiveness of the modifications we suggest in achieving this outcome and the substantive policy insights arising from this work.

Effectiveness of modifications and application to other cases

The systematic analysis of actors related to the case study exposed the divergence in perspectives and priorities between different types of actors. Similar results have been found in other sectors (Leach et al., 2010; Roelich, Bale, Turner, & Neall, 2018) so the advantages described below are considered to be relevant to other sectors. The actor-centric analysis also highlighted divergence within some types of actors that are often considered as homogeneous groups (e.g. 'policy makers') that would need to be explored in more detail in future research.

The proposed modifications emphasized interactions between actors, and revealed that these interactions have significant potential to affect the success of long-term plans. The case study identified, but did not analyse in detail, the potential for decisions taken by particular actors, including government strategy and policies, to constrain the actions of other actors. Future analysis should pay more attention to interactions with actors in other sectors, such as finance, or at different scales, such as local and regional government.

Existing modelling approaches used in support of long-term planning rely on physical system models (Walker et al., 2013), which are unable to represent the influence of actor perspectives and agency on the effectiveness of actions and therefore on wider system change. Additional modelling approaches may be required that are better able to represent actors and how they affect change in the system of interest.

Associating actions with particular actors further revealed the limited agency of some actors and the significant influence of others. As a result, actions were directed to those most able to act or build capacity in those with limited agency. The focus on allocating actions to actors exposed the lack of government ownership and the resulting plan relied heavily on those (e.g. advocacy organizations) who could lead in the absence of policy.

Evaluating the alignment of proposed actions with actor motivations had a significant influence on action sequencing. Partly because of the dissonance in perspectives, time is required to allow actors to become familiar with new systems, such as monitoring and reporting, and adapt business models before implementing tighter restrictions. This also highlighted a crucial gap between who was engaged and who needed to be engaged and therefore highlighted the need for new types of actions. Advocacy actions were required to build capacity and raise awareness and have a crucial role in enabling transfer between one set of often voluntary actions and another set of often mandatory ones. Therefore, advocacy and information groups, particularly those with a cross-sector remit, play a vital role in coordinating action and by implication, in distributing responsibility among multiple actors.

Conclusions

The purpose of making these additions to the DAPP method was to improve the relevance of decision support tools in the policy process, particularly in complex and fragmented policy areas such as climate change mitigation. Therefore, we do not make recommendations for the mitigation of embodied emissions in the construction sector, but rather for the content and role of decision support tools and associated methods of analysis.

Our findings suggest that current decision support approaches overlook the important influence of actor motivations and agency on the acceptability and efficiency of individual actions. As a result, current roadmaps might overstate how effective proposed actions could be. A more actor-centric approach to decision making offers significant advantages.

In order to secure engagement of a multitude of actors within and between sectors we cannot assume that one issue (e.g. cost or carbon) is universally motivating. Both the decision tools used to support the policy process and the policy process itself should take this into account. The involvement of multiple actors requires that a plan simultaneously appeals to (and monitors) multiple co-benefits and actor motivations. This increases the likelihood of implementation and the overall effectiveness of any plan or policy.

Representing the perspectives of broader range of actors does increase the burden both on those seeking to develop a plan or policy, and those who are engaged with it. However, closer engagement of those affected can open up space to identify a more comprehensive range of activities (Leach et al., 2010; Stirling, 2010) and this should be encouraged in both decision support tools and in the policy process.

Even if well aligned with actor motivations, some actions may be ineffective because of limits to actor agency. The agency of actors, and any constraints to action, should be better understood so that additional actions can be identified to either reduce constraints, build capacity or identify alternative routes.

Linking actions to actors highlights the challenge of coordination across scales, e.g. national, regional and local government, and between sectors. The potential for decisions at one scale or sector to constrain the decision of those at another scale or sector should be addressed explicitly in policies and plans. Furthermore, mechanisms should be put in place to manage these interactions and reduce constraints.

A focus on actors highlights the need for changes in practices or business models, which represent significant changes in routines and organizational behaviour and not just individual, investment-related decisions. It is important that policies or long-term plans influence organizational practices, and not just rely on cost optimization and markets to drive change (Grubb et al., 2014a).

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Notes

1. By complex we mean the presence of a number of factors which are related to each other and from which the properties of the wider system are derived. The behaviour of the system cannot be predicted by an understanding of the elements within it (Bale, Varga, & Foxon, 2015).
2. By agency, we mean the capacity of individuals to act independently and to make their own free choices.
3. In the UK, some aspects of administrative, executive, or legislative authority have been devolved to new institutions operating only within a defined part of the United Kingdom, including Scotland, Wales and Northern Ireland.
4. Plans for Zero Carbon homes were set out in a consultation document 'Building a Greener Future' in 2006. The proposal was amended in 2013 to strike a balance between zero carbon goals and stimulation of growth in house building. In 2015, however, the newly elected Conservative government announced it would not proceed with the scheme (House of Commons Library, 2016).
5. An Environmental Product Declaration is a document that communicates verified, transparent and comparable information about the life-cycle environmental impact of products. It is currently a voluntary declaration but has an international standard for the calculation of impact: ISO 14025.

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References

Bale, C. S. E., Varga, L., & Foxon, T. J. (2015). Energy and complexity: New ways forward. *Applied Energy*, *138*, 150–159.

Battle, G. (2014). *Embodied carbon industry task force recommendations. Proposals for standardised measurement method and recommendations for zero carbon building regulations and allowable solutions*. Retrieved from http://asbp.org.uk/wp-content/uploads/2016/01/Embodied-Carbon-Industry-Task-Force-Proposals_June-2014_Final.pdf

Butler, C., Demski, C., Parkhill, K., Pidgeon, N., & Spence, A. (2015). Public values for energy futures: Framing, indeterminacy and policy making. *Energy Policy*, *87*, 665–672.

Cashore, B., & Howlett, M. (2007). Punctuating which equilibrium? Understanding thermostatic policy forestry dynamics in pacific northwest. *American Journal of Political Science*, *51*, 532–551.

Committee on Climate Change. (2018). *An independent assessment of the UK's clean growth strategy: From ambition to action*. Retrieved from https://www.theccc.org.uk/2018/01/17/uks-ambitious-clean-growth-strategy-must-translated-urgently-action/

Costanza, R., Wainger, L., Folke, C., Mäler, K., Costanza, R., Wainger, L., & Folke, C. (1993). Modeling complex ecological economic systems. Toward an evolutionary, dynamic understanding of people and nature. *Bioscience*, *43*, 545–555.

De Wolf, C., Pomponi, F., & Moncaster, A. (2017). Measuring embodied carbon dioxide equivalent of buildings: A review and critique of current industry practice. *Energy and Buildings*, *140*, 68–80.

Dessai, S., & Hulme, M. (2007). Assessing the robustness of adaptation decisions to climate change uncertainties: A case study on water resources management in the East of England. *Global Environmental Change*, *17*, 59–72.

Foxon, T. J. (2011). A coevolutionary framework for analysing a transition to a sustainable low carbon economy. *Ecological Economics*, *70*, 2258–2267.

Funtowicz, S., & Ravetz, R. (1993). Science for the post-normal age. *Futures*, *25*(7), 739–755.

Giesekam, J., Barrett, J., Taylor, P., & Owen, A. (2014). The greenhouse gas emissions and mitigation options for materials used in UK construction. *Energy and Buildings*, 78, 202–214.

Giesekam, J., Barrett, J. R., & Taylor, P. (2016a). Construction sector views on low carbon building materials. *Building Research & Information*, *44*, 423–444.

Giesekam, J., Barrett, J., & Taylor, P. (2016b). Scenario analysis of embodied greenhouse gas emissions in UK construction. *Proceedings of the Institution of Civil Engineers – Engineering Sustainability*, *171*(4), 178–190.

Giesekam, J., Densley-Tingley, D., & Barrett, J. (2016). Building on the Paris agreement: Making the case for embodied carbon intensity targets in construction. In L. Jankovic (Ed.), *Zero carbon buildings today and in the future* (pp. 161–169). Birmingham: Birmingham City University.

Giesekam, J., Densley Tingley, D., & Cotton, I. (2018). Aligning carbon targets for construction with (inter)national climate change mitigation commitments. *Energy and Buildings*, *165*, 106–117.

GLA. (2016). *Housing supplementary planning guidance*. Retrieved from https://www.london.gov.uk/sites/default/files/housing_spg_revised.pdf

Green Construction Board. (2013). *Low carbon routemap for the UK built environment*. Retrieved from http://greenconstructionboard.org/otherdocs/Routemap%20final%20report%2005032013.pdf

Greenwood, D., Congreve, A., & King, M. (2017). Streamlining or watering down? Assessing the “smartness” of policy and standards for the promotion of low and zero carbon homes in England 2010–15. *Energy Policy*, *110*, 490–499. doi:10.1016/j.enpol.2017.08.033

Grubb, M., Hourcade, J.-C., & Neuhoff, K. (2014a). Conclusion: Changing course. In *Planetary economics: Energy, climate change and the three domains of sustainable development* (pp. 447–493). London: Routledge.

Grubb, M., Hourcade, J.-C., & Neuhoff, K. (2014b). *Planetary economics: Energy, climate change and the three domains of sustainable development*. London: Routledge.

Haasnoot, M., Kwakkel, J. H., Walker, W. E., & ter Maat, J. (2013). Dynamic adaptive policy pathways: A method for crafting robust decisions for a deeply uncertain world. *Global Environmental Change*, *23*, 485–498.

Haasnoot, M., Middelkoop, H., Offermans, A., van Beek, E., & van Deursen, W. P. A. (2012). Exploring pathways for sustainable water management in river deltas in a changing environment. *Climatic Change*, *115*, 795–819.

Hall, J. W., Lempert, R. J., Keller, K., Hackbarth, A., Mijere, C., & Mcinerney, D. J. (2012). Robust climate policies under uncertainty: A comparison of robust decision making and info-gap methods. *Risk Analysis*, *32*, 1657–1672.

Hallegatte, S., Shah, A., Lempert, R., Brown, C., & Gill, S. (2012). *Investment decision making under deep uncertainty application to climate change* (No. 6193), Worked bank policy research working paper. Retrieved from https://openknowledge.worldbank.org/handle/10986/12028

Hamilton-MacLaren, F., Loveday, D. L., & Mourshed, M. (2013). Public opinions on alternative lower carbon wall construction techniques for UK housing. *Habitat International*, *37*, 163–169.

HM Government. (2013). *Construction 2025*. Retrieved from https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/210099/bis-13-955-construction-2025-industrial-strategy.pdf

House of Commons Library. (2016). Briefing paper number 6678 – Zero carbon homes.

IPA. (2016). *Government construction strategy 2016–20*. Retrieved from. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/510354/Government_Construction_Strategy_2016-20.pdf

IPCC. (2014). *Working group III – mitigation of climate change*. Technical Summary.

Jones, K., Stegemann, J., Sykes, J., & Winslow, P. (2016). Adoption of unconventional approaches in construction: The case of cross-laminated timber. *Construction and Building Materials*, *125*, 690–702.

Kuramochi, T., Höhne, N., Schaeffer, M., Cantzler, J., Hare, B., Deng, Y., & Blok, K. (2018). Ten key short-term sectoral benchmarks to limit warming to 1.5°C. *Climate Policy*, *18*, 287–305. doi:10.1080/14693062.2017.1397495

Leach, M., Scoones, I., & Stirling, A. (2010). Governing epidemics in an age of complexity: Narratives, politics and pathways to sustainability. *Global Environmental Change*, *20*, 369–377.

Lindblom, C. E. (1959). The science of ‘muddling through’. *Public Administration Review*, *19*, 79–88.

Liu, J., Dietz, T., Carpenter, S. R., Folke, C., Alberti, M., Redman, C. L., & Provencher, W. (2007). Coupled human and natural systems. *AMBIO: A Journal of the Human Environment*, *36*, 639–649.

Madani, K., Darch, G., Parra, F., & Workman, M. (2015). *Using game theory to address modern resource management problems*. Grantham Institute Briefing note No 2. Retrieved from https://www.imperial.ac.uk/media/imperial-college/grantham-institute/public/publications/briefing-papers/Using-game-theory-to-address-modern-resource-management-problems-Grantham-Briefing-Note-2_web_2.pdf.

Marsden, G., Ferreira, A., Bache, I., Flinders, M., & Bartle, I. (2014). Muddling through with climate change targets: A multi-level governance perspective on the transport sector. *Climate Policy*, *14*, 617–636.

NHBC Foundation. (2012). *NF40 today’s attitudes to low and zero carbon homes: Views of occupiers, house builders and housing associations*. Retrieved from https://www.nhbcfoundation.org/research/

Niemeier, D., Beamish, T., Kendall, A., Grattet, R., London, J., de la Pena, C., & Sze, J. (2012). Characterising the impacts of uncertainty in the policy process: Climate science, policy construction and local governance decisions. In H. Geerlings, Y. Shiftan, & D. Stead (Eds.), *Transitions towards sustainable mobility: The role of instruments, individuals and institutions* (pp. 119–136). Farnham: Ashgate.

Offermans, A., Haasnoot, M., & Valkering, P. (2011). A method to explore social response for sustainable water management strategies under changing conditions. *Sustainable Development*, *19*, 312–324.

Ostrom, E. (2010). Polycentric systems for coping with collective action and global environmental change. *Global Environmental Change*, *20*, 550–557.

Roelich, K., Bale, C. S. E., Turner, B., & Neall, R. (2018). Institutional pathways to municipal energy companies in the UK: Realising co-benefits to mitigate climate change in cities. *Journal of Cleaner Production*, 182, 727–736.

Steele, K., Hurst, T., & Giesekam, J. (2015). *Green construction board low carbon routemap for the built environment – 2015 routemap progress technical report*. Retrieved from http://www.greenconstructionboard.org/otherdocs/2015%20Built%20environment%20low%20carbon%20routemap%20progress%20report%202015-12-15.pdf

Stirling, A. (2010). Keep it complex. *Nature*, *468*, 1029–1031.

UN Environment and International Energy Agency. (2017). *Towards a zero-emission, efficient, and resilient buildings and construction sector*. Global status report 2017. Retrieved from https://globalabc.org/

Walker, W. E., Haasnoot, M., & Kwakkel, J. H. (2013). Adapt or perish: A review of planning approaches for adaptation under deep uncertainty. *Sustainability*, *5*, 955–979.

Walker, W. E., Rahman, S. A., & Cave, J. (2001). Adaptive policies, policy analysis, and policy-making. *European Journal of Operational Research*, *128*, 282–289.

Windapo, A., & Ogunsanmi, O. (2014). Construction sector views of sustainable building materials. *Proceedings of the Institution of Civil Engineers – Engineering Sustainability*, *167*, 64–75.

Young, K., & Hall, J. W. (2015). Introducing system interdependency into infrastructure appraisal: From projects to portfolios to pathways. *Infrastructure Complexity*, *2*, 2.