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RESEARCH

Preparing 'middle actors' to deliver zero-carbon building transitions

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Abstract

The urgent transition to a zero-carbon economy requires building professionals to be supportive of, and prepared for, delivering zero-carbon buildings. Building professionals are important 'middle actors' who can either enable or inhibit such societal transitions. This paper explores building professionals' perspectives on delivering zero-carbon buildings, leading to a practical synthesis of knowledge and skill requirements and training pathways. It draws on the middle-out perspective (MOP) and secondary analysis of three UK case studies. The MOP suggests that middle actors in a system are not perfectly responsive to policy push or market pull. Instead, they exert their own agency and capacity downstream to customers and clients, sideways to other middle actors and, occasionally, upstream to policy-makers. The data comprise: interviews and a small survey with building professionals on energy efficiency and refurbishment; the observation of a specific commercial office building design and development and a workshop to identify zero-carbon knowledge and skill needs of middle actors. Building professionals addressed in this paper include vocational trades, engineers, designers, project managers and 'clerks of works' (site-based quality technicians). Although formal training pathways for these roles differ, each can develop expertise 'sideways' interacting between professions.

Practice relevance

- Collaboration between academia, vocational training and industry could support *sideways* initiatives to better enable delivery of zero-carbon buildings.
- Policy-makers and regulators need to create routes to capture, listen to and use the perspectives of building professionals. At present, these actors have very little upstream influence.
- Middle-actor groups in construction undertake different activities, but share training routes, knowledge support systems and professional networks.
- These routes, systems and networks would allow actors to facilitate change from the 'middle-out' in a way complementary to top-down change driven by policy and bottom-up changes led by citizens.
- Training routes can include formal, on-the-job (informal) or e-learning. Prioritising on-the-job knowledge-sharing could promote upskilling.
- Roles such as a clerk of works could assist in overseeing construction processes.
- Vocational professionals are the priority group of middle actors to build capacity, knowledge and influence.

Keywords: construction industry; delivery; influence; innovation; middle-out; vocational education and training; zero carbon; UK

1. Introduction

The urgent rapid transition to a zero-carbon economy requires building professionals to be supportive of, and prepared for, delivering zero-carbon buildings. Upskilling needs to happen across the entire value chain of the construction sector (EU 2019). All professions need to be aware of new and upcoming challenges relating to zero-carbon buildings. This is in terms of new materials and products, integration of renewable energy, and new systems and processes such as certification schemes and digital tools (EU 2019).

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A middle-out perspective (MOP) focuses on 'middle actors', such as building professionals, who are located between 'top' actors making change through public policies and 'bottom' actors demanding change via grassroots action (Janda & Parag 2012; Parag & Janda 2014). Janda & Parag (2012) argue that building professionals are middle actors because they exert influence through enabling (or disabling), mediating and aggregating (or disaggregating) *upstream* to policy-makers, *downstream* to clients and *sideways* to other building professionals.

Building professionals can initiate and be part of the system change needed to create new zero-carbon homes and buildings, as well as refurbishing existing homes and buildings to reduce carbon emissions (Janda & Parag 2012; Parag & Janda 2014). These professionals have habits, practices, and ways of thinking and working that affect their ability to provide zero-carbon buildings (Killip 2008; Janda & Killip 2013; Maby & Owen 2015; Wade *et al.* 2016a). Yet, the role of these middle actors has been largely neglected in policy development debates (Owen *et al.* 2014).

The construction industry is complex and interconnected with uncertain processes, through which new knowledge of zero-carbon buildings needs to be diffused downstream, sideways and upstream through a highly fragmented supply chain (Peterman *et al.* 2012). Downstream knowledge flow from building professionals to clients has been observed, for example, informing householders (Janda & Parag 2012; Wade *et al.* 2016b; Wade *et al.* 2017a; Wade *et al.* 2017b; Simpson 2017). Professionals may turn sideways to builders' merchants for information and advice (Killip *et al.* 2020), to fellow team members during meetings (Reindl & Palm 2020) or through discussion of new regulations during informal interactions between professionals (Wade *et al.* 2016a).

Building professionals have been found to learn on the job, where time is available for them to do so, for example, within projects setting progressive carbon goals, enabling situated creativity to achieve the standards required (Lowe & Chiu 2020). The insights gained from such projects are then communicated to policy-makers upstream. To achieve zero carbon, an iterative approach is necessary in which researchers and decision-makers learn from building professionals and completed new-build and retrofit programmes to feed into future decision-making (Killip *et al.* 2020), and potentially find a way for other actors, such as academics and local authorities, to support the necessary upskilling.

Within the larger set of building professionals, this paper focuses on a variety of middle actors in construction including: vocational trades, clerk of works (a British term for a site-based quality checking professional), technical consultants (for mechanical and electrical (M&E) services), designers (architects) and project managers. While the industry and formal training provision differs for trade professionals and other professionals such as architects and engineers, all these groups have the potential to foster (or disrupt) change from the middle out. Therefore, both trade and design professionals are considered as middle actors for the purposes of this paper.[1] It looks at the relationship between building professionals, middle-out change and training routes, arguing that training, or on-the-job skills and knowledge development, can actively develop the agency and capacity of building professionals to deliver environmental innovations (Janda & Killip 2013). Transforming training offers an opportunity for the construction industry to rebrand as a modern industry which can address climate change and fuel poverty (Clarke *et al.* 2019) through mainstreaming zero-carbon practice across all construction vocations and professions.

This paper is structured as follows. Section 2 maps the current position with regard to construction and refurbishment activity, training and research related to the role of construction middle actors in delivering zero-carbon buildings. Section 3 introduces the research approach and case studies, explaining how secondary analysis was undertaken. Section 4 presents the insights from this analysis. Section 5 discusses the findings in terms of training opportunities and routes for each actor. Section 6 concludes.

2. Scope

2.1 Supporting the delivery of zero-carbon buildings

2.1.1 Repair and maintenance to retrofit

The repair, maintenance and improvement (RMI) sector includes general maintenance as well as deep retrofit aiming to achieve zero carbon. Building professionals in repair and maintenance often work across trade skill boundaries as 'general builders' using learning from working on-site within projects and transferred to other projects, informally. While training for specific trades, such as bricklaying, plastering and carpentry, does exist, standardised training to become a general builder does not exist in the UK. This impacts the ability of those individuals to take a 'whole-house' approach to energy performance and related issues such as moisture movement and indoor air quality (Maby & Owen 2015). Recent progress has been made in the retrofit sector in the UK, for example, publishing new technical standards for retrofit of existing UK homes (Trustmark 2020).

Wade *et al.* (2016a) found that teams may choose to recommend and install particular products which are trusted to protect their reputation (Wade *et al.* 2016b; Killip 2013) and allow for the storage and transportation of products they regularly install and repair (Banks 2001). To progress beyond regular practices, additional support may be needed to allow professionals, and others, to gain knowledge and skills of desirable zero-energy technologies, while allowing them to protect their hard-earned expert identity (Wade *et al.* 2016a).

2.1.2 New build

New-build projects include residential and commercial buildings. The RIBA *Plan of Work* (2020), which is the industry-accepted model for building design, construction and post-occupancy processes, was reviewed in terms of sustainability

by a collaboration between RIBA and the Chartered Institution of Building Services Engineers (CIBSE) (CIBSE 2018). It now includes conservation, sustainability and fire safety strategies, amongst other additions. As technology advances, the building regulations in the UK governing the design and construction processes are updated. Part L (Conservation of fuel and power) may be updated by the Future Homes Standard for new dwellings, along with Part F (Ventilation) (MHCLG 2019). However, such changes do not usually lead to direct changes in practices following information added to training schemes, but multiple interpretations leading to diverse results (Wade *et al.* 2016a). As information will be shared informally, approaches to work with the grain of this could be of use.

A recent industry-backed initiative, developed in Australia, for zero-carbon-progressive office builds is the Design for Performance (DfP) approach (Cohen *et al.* 2016; NABERS 2019). The Better Building Partnership (BBP) in the UK chose to adopt the DfP voluntarily for a more accurate assessment method of office buildings, recognising that without good measurement, legislating energy use is difficult to enforce and monitor (BBP 2017). The focus on measured data, rather than modelled estimates, aims to overcome the design–performance gap (Young 2018). It includes a 'Commitment Agreement Protocol' to design, construct and manage new office buildings to agreed levels of actual in-use energy performance, forming a contract between the tenant and the building owner (Cohen *et al.* 2016). This requires a new way of working for middle building professionals, focused on energy performance. Information shared between professionals working on this could assist in improving the quality of learning opportunity on zero-carbon metrics.

2.2 Training types

This section provides a brief overview of training types. The drivers for training were cited by the CITB (2018) to be new legislative or regulatory requirements (52%) and the introduction of new technologies and equipment (40%); with new ecological or energy-saving design and build methods for 34% of the self-employed, higher for larger businesses. Highlighting the opportunity to train following legislative changes.[2]

Formal vocational training routes have been required to adapt and innovate, following technological and social change in countries and economies across the world (Clayton & Harris 2018), such as the development of renewable technologies (Cedefop 2018). Cedefop (2018) suggests that as part of this, it is important to create systems in which innovation can occur. This can include developing links between research institutions, small businesses and wider industry (UCEM 2017). Formal routes include college and university courses or apprenticeships, and ongoing continuous professional development (CPD). Apprenticeships allow direct engagement and input from employers. For CPD, accreditation organisations offer training. However, not every profession requires membership with a professional body. The UK Construction Industry Training Board has launched a suite of environment and sustainability courses including 'low carbon retrofit', 'cut the carbon in construction', 'solar panel installation' *etc.* (CITB 2020). This could apply to multiple professions from trades to designers.

On-the-job training is the method most frequently adopted in construction, usually via learning from a more experienced team member (CITB 2018: 62). Projects such as the Retrofit for the Future (RftF), which offered funding for 100 deep-dwelling retrofits by Innovate UK (2013), allowed building professionals to learn through doing.[3]

Learning via digital platforms is on the increase. For example, the BUILD UP Skills Advisor app, released in 2015, aims to provide on-the-job building professionals job-specific advice and short upskilling opportunities (BUILD UP 2020). The Green Register (2016) offers courses for building professionals, including CPD sessions (since 2000) in organisations across the UK and e-learning modules, such as Futureproof.uk (2020).[4]

2.3 The middle-out perspective (MOP)

The MOP is a framework developed by Janda & Parag (2012) to complement conceptualisations of societal change from the top down and bottom up in sociotechnical transitions. It recognises the agency and capacity of middle actors such as building professionals and commercial real estate companies, enabling the exploration of additional ways in which ideas, practices and behaviours might be reshaped or even transformed (Janda & Parag 2012; Parag & Janda 2014). Top actors (*e.g.* policy-makers) can have influence downwards, and bottom actors (*e.g.* building users) can have influence upwards. Middle actors can have influence up, down and also sideways within and across their networks. This perspective acknowledges that building professionals have agency and capacity beyond simply serving government policy and client needs (Janda & Parag 2012; Parag & Janda 2014), to deliver zero carbon.

Parag & Janda (2014) did not invent the term 'middle-out'. It has appeared across multiple disciplines since the late 1970s. Janda & Parag (2012) and Parag & Janda (2014) developed a framework around this term that serves to rethink the identity, agency and capacity of 'middle' actors in a system relative to 'top' and 'bottom' actors.[5]

3. Research approach

Insights from Janda & Parag's (2012) and Parag & Janda's (2014) MOP are used here to undertake a secondary analysis of data from two case studies focused on building professionals' perspectives on the knowledge and skills to deliver sustainable buildings. A third case study engaged wider stakeholders, including 'top-down' perspectives from policy decision-makers and training leaders in addition to middle actors. The third study is not analysed using MOP due to the presence of those top-down perspectives in workshop discussions, but the insight provided by the third case study is still a valuable contribution to the discussion of the ideas developed from the MOP analysis.

Secondary analysis allows data from multiple projects to be combined and considered through a new lens. This has been a successful approach adopted by other researchers examining facets of sustainable construction, combining insight from projects through the lens of a new theory, or to strengthen insight where similar findings are evident.[6] The studies providing the framework and data sets for this paper were part of previous research led by the authors on energy performance, skills and retrofit processes (Janda & Parag 2012; Owen *et al.* 2014; Simpson 2017). The case studies were originally intended to inform policy, training or local action, based on middle-actor perspectives. Undertaking secondary data analysis using the MOP allows a theoretical reflection and generates a synthesis of understanding from the two studies together which cannot be developed from either study taken alone.

3.1 Case studies

This section presents the case studies adopted. Starting with A and B adopted for secondary analysis using the MOP, then C, adopted to highlight training needs and pathways. **Figure 1** summarises the case studies. All studies were approached to better understand middle-actor knowledge, skill and training needs, to achieve zero carbon. Studies A and B specifically from the middle-actor perspective; study C includes wider perspectives.

3.1.1 Study A (SA)

SA included surveys and interviews with vocational and other building professionals carried out from north Lincolnshire. The knowledge was co-produced with a student intern in a college-based setting (Trigwell & Shale 2004). The survey sample was selected through use of personal, local and professional online networks. The sample selection criterion was that they had previously worked on domestic refurbishment projects. Emails and phone calls received a fairly low response rate, so the researchers also gathered survey responses from outside the main entrance of a local builders' merchant (with permission), which proved effective and led to a diverse random sample, for example, builders, gas engineers and building consultants. The semi-structured interviews lasted up to 30 minutes, or longer where the participant wished to share further insights. The interviews were audio-recorded and transcribed verbatim. Participants for interview were selected from survey respondents who had indicated a willingness to be interviewed, to give a variety of perspectives. For a summary of SA participants' job roles, see Table S1 in the supplemental data online.

3.1.2 Study B (SB)

SB engaged building professionals involved in a development including an office build with planned residential and commercial new-build and retrofit projects in Leeds, as summarised in Table S2 in the supplemental data online. The relationship with the local developer began in planning the workshop of study C. The development was selected for further research due to the multiple construction projects planned for one site, involving a variety of actors in addition to on-the-job training provision by the local construction college. At the time of data collection, the teams were focused on the design of an office build, having recently completed another office build, allowing data to be collected drawing on both projects. The professionals were asked *What skills are needed to enable sustainable construction?* and *What*

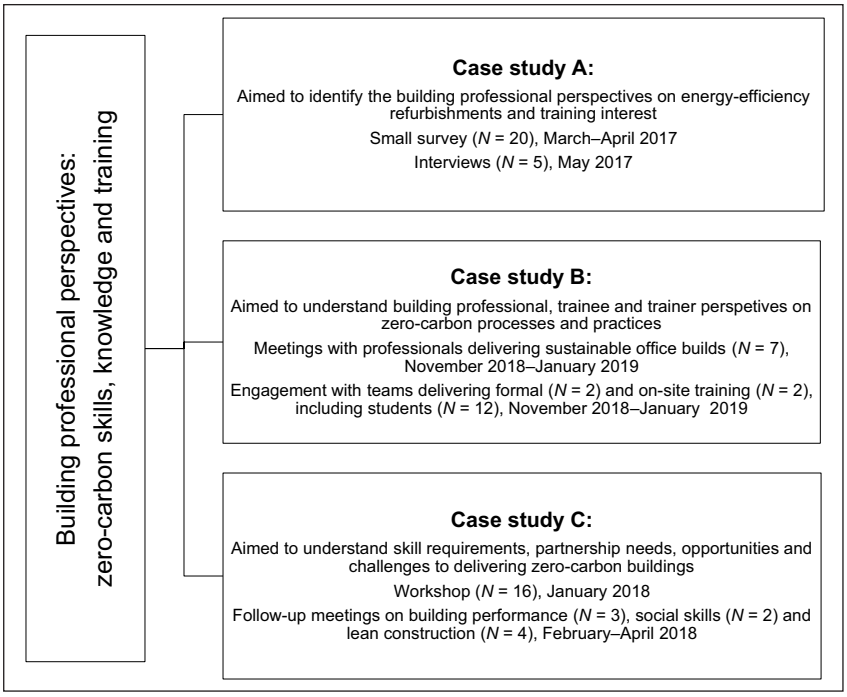

Figure 1: Summary of studies and their aims.

training pathways are suitable to enable this? An unstructured approach to follow-up questions enabled the teams to discuss tender and contract procedures.

3.1.3 Study C (SC)

SC included a workshop held in Leeds in January 2018, with three follow-up meetings. The workshop gathered participants including middle actors, local policy-makers and training providers, as shown in Table S3 in the supplemental data online. This enabled discussion between middle and top-down actors. Each brought expertise in either sustainable building, city-wide planning and development, or training and skills, from research, public and private sector organisations. Local professional networks were used to contact potentially interested attendees. Participants were initially emailed, then called for an informal discussion on the aims of the project before being formally invited. During the one-day workshop participants were asked *What skills are needed in enable zero carbon building? What are the challenges? What are the benefits?* and *What are the opportunities?* through a combination of discussion and written activities. Based on skill requirements recorded using post-its, pro-formas and the workshop transcript, three meeting themes were derived: *building performance*, *lean construction* and *social value*. These meetings focused on further developing training and assessment requirements. The insights and networks gained during SC led to SB, chronologically. However, the studies are presented in this order to reflect the application of secondary analysis using MOP to cases A and B. The presentation of insights into skills and knowledge requirements is then according to the insights gathered during the workshop.

3.2 Secondary data analysis

Three categories of actions or directions of influence are identified by the MOP: 'enabling or disabling', 'mediating' and 'aggregating', each of which can be 'upstream', 'downstream' or 'sideways' (Janda & Parag 2012; Parag & Janda 2014). The modes of influence building professionals have on the construction industry is bidirectional, so while they can enable the adoption of technologies, they can also reject them. The analysis framework for the secondary coding applied here is shown in **Table 1**.

4. Results: MOP analysis

4.1 Enabling or disabling

In this context, enabling refers to actions that allow or promote the deployment and adoption of technologies and techniques which reduce energy consumption in buildings, but can also include the opposing actions. The occasions where this was observed influencing upstream, downstream and sideways are described below.

4.1.1 Upstream

Upstream influences show how middle actors are able to support or inhibit the efficiency and carbon opportunities enabled by government policy or by utility company action. Government policy could in theory generate business opportunities for building professionals, if those groups are aware of the opportunity and have the skills required to create influence. But the gap between policy-maker and construction middle actors is profound. Some actors expressed

Table 1: Middle-out perspective (MOP): analysis framework.

	Directions of influence		
	Upstream	**Downstream**	**Sideways**
Enabling/disabling	Middle agents can support (or inhibit) efficiency opportunities required by governments and utilities	Professionals can variably encourage or discourage low-carbon technologies in specific projects and designs	Innovations and practices are transferred to professional communities through social learning and professional norms
CODES	EU	ED	ES
Mediating	Professionals can influence the trajectory of their professional requirements; they may also shape government policy through reports and consultations	Mediating between landlord and tenant to promote cooperation; collaborative design with clients	Innovations and practices may propagate between middle agents as competitive business opportunities; groups may change with new opportunities
CODES	MU	MD	MS
Aggregating	Aggregating across portfolios to maximise and mainstream savings opportunities for utilities or government	Aggregating across portfolios to maximise understanding for clients, which is particularly important in small businesses without dedicated capacity	Aggregating between businesses and professional firms to improve learning and knowledge-sharing
CODES	AU	AD	AS

a lack of information easily accessible to vocational professionals. This included core information within the building regulations, considered to be 'horrendously worded' (SA P1), in addition to information on suitable technologies, with vocational professionals asking builders' merchants or looking online:

> I think if there was more stuff out there, more information out there first of all, cause there's not, you have to go looking for information. (SA, P1)

Where information was accessed, policies could be found to be inconsistent (SA, P18). The way in which training is delivered 'infuriated' SA P3, who felt the approach was 'top down' and benefitted larger companies, instead of the existing home renovation installers, in small and medium-sized enterprises. A similar view was shared by SA P2 and SA P5 who had lost work to bigger companies:

> I've lost out on potentially 20 jobs over the last year because of my customers going to the likes of British Gas because they can offer the things like the scrappage scheme. (SA, P5)

While this quotation does not directly relate to training, it emphasises a middle-actors' perspective on policy focus towards bigger companies, that perhaps have a more direct upstream influence than smaller companies. The overarching message from our analysis is that some middle actors in the construction industry believe they have little, or no, upstream influence. Neither do they have a clear view of what capacities they need in order to create such influence.

4.1.2 Downstream

Downstream, middle actors can influence clients, but to do so, trust in the policy-delivery mechanisms, such as grants, and the related technologies is required. During the multiple-choice survey in SA ($N = 20$), in which participants could respond on a five-point scale from strongly disagree to strongly agree, 19 out of 20 either strongly agreed ($N = 11$) or agreed ($N = 8$) to *You are motivated to suggest energy efficiency technologies to customers*, with 18 out of 20 either strongly agreeing ($N = 8$) or agreeing ($N = 10$) that *Issues such as climate change and CO_2 emissions are important to you*. There is perhaps a disconnect between industry pressure, householder demand and motivation of trade professionals.

Vocational professionals were aware of their influence on customers, but a lack of customer awareness and demand for zero carbon were seen as a disabling factor to adoption:

> they [clients] don't know about things unless we tell them. So there could be more on maybe tv or adverts or stuff like that. Even [...] how to use the boiler efficiently and stuff like that, with radiator thermostats and room thermostats. (SA P4)

In addition to the considered lack of customer awareness, the vocational professionals expressed caution in recommending technologies which were not cost effective to clients:

> there's [...] risk there with ramming it down people's throats [...] and them forking out [...] money they haven't got. (SA P4)

Or if they do not feel confident in what they are offering, but were keen to gain this confidence:

> we don't know enough about it [...] we're not 100% sure how much they would save, and different products like, err boilers that take heat from air and just stuff like that [...] getting more information really. So we can give the right information and be confident. (SA, P4)

However, where grants were available, they reported increased client interest, but acknowledged the grants are usually temporary:

> When they did the grants there was a lot of people interested. (SA, P2)

The vocational professionals appeared to be risk averse and keen to be confident in what they offer.

4.1.3 Sideways

Innovation and practice can be transferred through social learning, professional norms and requirements. The engagement with both trade professionals and actors working on a new-build office development highlighted this as a valuable method of skills development. Trade professionals would gain information from colleagues, architects, builders' merchants and building control in addition to online searches and wider professional networks. However, it was recognised this was not as progressive as it could be:

> Erm, just through emails from work really [...] but there's a lot of new products we're not really getting on board with to be honest. (SA, P4)

Where trade professionals had not received specific training, information was gained from different sources. Two were using manufacturers' information (P1, P5); P1 followed guidance from an architect; Google and specific elements of Building Regulations were used by P2; and colleagues were also a source (P4, P5). The role of the builders' merchant, where construction products are purchased, came up repeatedly in terms of both information and product provision. There is also influence from the builder to the merchant where new technologies are requested:

> if I can't purchase it direct from the internet I'll go to one of the local merchants to say 'I need some of this, can I get you a price please?' (SA, P1)

Where merchants cannot supply requested products, this could quickly disable uptake:

> I went into the builders' merchants today for instance to buy a certain type of insulation, and the builders' merchants hadn't even heard of it. (SA, P1)

However, some trade professionals could exert influence on the merchants to supply products which could lead to future ordering of similar technologies as demand from trade professionals and interest in learning about such technologies increases. There was an appetite amongst survey participants for additional training, when responding to the multiple choice statement *There is adequate training provided for the installation of energy efficiency technologies*, three were neutral, nine disagreed and two strongly disagreed, in total 15 out of 20 who did not agree adequate training is provided. Some participants expressed interest in training being provided free of charge through the local builders' merchant or technical college. When responding to the statement *There is industry pressure to promote and install energy efficiency technologies*, 12 respondents were either neutral ($N = 5$), disagreed ($N = 4$) or strongly disagreed ($N = 3$), highlighting a gap in sideways knowledge exchange and encouragement.

For the actors working on a new-build office, shared learning appeared to be highly valued where aiming for progressive low-carbon developments. This was carried out both internally and between teams. For example, internally, the technical consultants (SB) held weekly lunchtime knowledge-sharing on key industry and research developments, to share information via an online platform between colleagues, and provide informal advice to external project partner teams during meetings, enabling sideways knowledge-sharing.

4.2 Mediating

This is about participation and change. Examples of mediation include knowledge-sharing and collaboration in terms of both project delivery and training.

4.2.1 Upstream

Trade professionals made suggestions for local further education or community college providers to showcase technological innovation on their own building stock, which could be another route to inspiring ongoing innovation and adoption of technologies used:

> [the local further education] College, that beautiful big building there [...] not one solar panel on it [...] grants over £40m last 2 years for buildings [...] not one solar panel. [...] They should be leading the way, a technical college. Government buildings like colleges and schools, they should be banging the **** things on everywhere. (SA, P1)

Where trade professionals do not see those delivering technical education, including engineering and construction colleges adopting technologies, they may be less willing to appreciate the value of such technologies. Collaboration between higher education, further education and schools could lead to projects that showcase zero-carbon technologies to local communities.

4.2.2 Downstream

This form of influence includes mediating by cooperation, for example, collaborative design with clients. The approach to tendering and contracting was suggested as one way to enable this in SB by the technical contractor, clerk of works and post-occupancy evaluator. They suggested that a traditional contract does not formally allow engagement between the construction team and the user or operation manager of the building. A two-stage approach allows the contractor to begin work for a limited appointment in the first stage and then agree a fixed price for the contract in the second stage. This can allow engagement and knowledge-transfer opportunities, enabling two-way discussion and knowledge-sharing to overcome design challenges and ensure both parties understand the building and project aims. However,

this was suggested by the team engaged as not always easy to do in practice because a two-stage tender process requires additional time (cost), as opposed to a traditional contract in which the contractor is appointed once the design decisions are made. A two-stage process can incur additional risks for the contracted team due to added liability of being involved in design decision-making processes. However, the team suggested it should lead to fewer misunderstandings than a traditional contract approach and reduce the risk of missing designed targets for all parties, especially in aiming for new zero-carbon buildings.

4.2.3 Sideways

Innovations and practices may propagate between different types of middle actors as competitive business opportunities and groups may reconfigure in order to take on new opportunities. Building professionals across both SA and SB valued training offered via their organisation, which led to a wider awareness of the impact of their construction work:

> I was working for a company, heating [...] systems [...] they trained me up [...] at first it was completely foreign to me but then I started getting on these courses and understanding things from not just a company or sales point of view, but really the genuine interest in the environment. Then [...] they went bust and I went too. (SA, P5)

The collapse of a company adopting zero-carbon technologies is likely to lead to risk-aversion from those involved in future. Being open-minded about integrating new ideas and technology was highlighted as a need for team members at all levels by the project manager, the technical consultant and the post-occupancy evaluator within SB. In order to progress in terms of sustainability, new methods and technologies must be trialled, but investing and installing relatively new technologies carries risk for businesses due to inconsistent demand and policies.

Employing a clerk of works to ensure designs were constructed accurately and with care on-site was highlighted by the technical consultant, the architect, the project manager and the design manager in SB. In addition, a clerk of works was considered to assist in minimising on-the-job energy demand through overseeing practices, for example, by ensuring generators were switched off at night.

Ensuring positive communication between contract teams was highlighted by the technical consultant, design manager and architect. This was achieved through ensuring defects are dealt with in a professional and considerate manner, for example, speaking directly with the contractor on a one-to-one basis, and generally communicating openly and regularly. The architect highlighted the benefit of keeping contractors on a 'retainer agreement', which is between a one-off contract and a permanent contract, to ensure they have a vested interest in doing a good job and an ongoing professional—and commercial—relationships.

There was an appetite from building professionals across both studies for increased training, especially where the training was offered free of charge. In addition, better information on available products was required: 'education isn't funded and that it the problem' (SA, P3). This was seen as a route to gaining confidence to let clients know what was available:

> education is important [...] product information [...] just getting things out there and letting people know about them. (SA, P1)

Alongside training, building professionals were keen to see incentives, particularly in recognition of their role as an informal advisor to clients:

> some sort of commission, or something like a reward to, not enforce it, but get it over to the consumer. (SA, P2)

During the meetings during SC, incentives discussed included the gold standard Construction Skills Certification Scheme, so that the professionals who had trained were rewarded and recognised for their expertise. Other suggestions included setting requirements within contract agreements for building performance standards and local authority enforcement of skills certification.

4.3 Aggregating and disaggregating

This category of influence concerns whether and how actors develop an understanding across multiple building projects and think laterally to apply their knowledge and insight gained from experience to other cases.

4.3.1 Upstream

Knowledge of technologies may be applied to multiple buildings and aggregated across a building stock. Examples of where this process leads to maximising savings or opportunities for local or national government or upstream teams are discussed below. The technical consultants employed within the office build for SB enabled upstream aggregation by transferring knowledge of the DfP (Cohen *et al.* 2016) agenda and requirements to the project funder, who then adopted the agenda and included requirements to meet the standard within contract agreements. This highlights the influence from a contractor directly up to the funder. As a result of this influence, more capital was invested into the

build phase to achieve design outcomes that would be measured post-occupancy. Working towards the DfP agenda required energy-performance targets to be set early in the design process and collaborations between design teams to commence earlier than they would under a traditional contract.

4.3.2 Downstream

Trade professionals can enable aggregation downstream by applying knowledge and skills learned during prior installations to new individual building projects, such as domestic retrofit. Building professionals across SA and SB discussed experiences from previous projects, exhibiting how common it is for them to aggregate skills and knowledge across projects and over time. However, this aggregation could be limited if opportunities to work on progressive projects were not available, or where post-occupancy evaluation (POE) does not allow monitoring and feedback cycles. Where they were pioneering innovation or had worked with particularly progressive designers, trade professionals were found to take inspiration beyond a focus on profit by large companies:

> looking to the likes of Scandinavia and Germany and Denmark, they've had their heads on with this **** for generations now, but they obviously have different motives compared to what we've got. We're completely swallowed by, very distracted by what's going to line the corporate pocket more than it is the educational side. (SA P5)

Inspiration from other places, such as Sweden, has been gained by trade professionals training there, particularly in the thinking behind it 'it's just ingrained in their psyche' (SA, P5), but later disappointment arose where UK funding was not available for that work:

> I was doing heat pumps, air source, ground source, erm energy collectors and stuff like that. I really did try getting down that avenue but it was during the time we were in the recession and that, people were getting laid off left right and centre so, I just don't think there was enough invested into employment then. There was more going in to promoting it and products than there was actually putting it into the minds of the new generation. (SA, P5)

One participant was interested to find out about more available products in the UK: 'we all need educating, and we need to know what products are out there' (SA, P1).

4.3.3 Sideways

Knowledge can be aggregated between businesses and firms to advance expertise through shared learning. This was found to happen both formally via contracted routes and informally via meetings, phone calls and virtual communication tools.

In relation to construction technology and on-the-job processes, the clerk of works (SB) reported spotting 'thousands' of small installation issues that could have led to problems with building performance. The technical consultant suggested a clerk of works responsible for M&E services would be beneficial in future. To deal with this gap, the main clerk of works would photograph M&E queries and send them to the technical consultant for advice, then ensure the problems were rectified on-site. Achieving sustainable outcomes here was clearly dependent on close collaboration between these actors. The M&E contractor led to the implementation of the DfP agenda on the project, and engagement between them and the developer led to sustainability and carbon being prioritised over cost. Furthermore, within SB, the funder stipulated all contract teams must take on an apprentice learner, leading to further knowledge-sharing within teams and across teams where apprentices rotated around four companies within two years. This ran through a collaboration with the local construction college and led to students gaining a Level 3 Construction and the Built Environment course, plus a Construction Contracting Operations apprenticeship.

4.4 What does this mean for training of middle actors?

The presented insights highlight the ways in which building professionals serve as middle actors in the construction industry. This has shown how they can enable, mediate or aggregate zero-carbon technologies, in addition to how they can disable and disaggregate. It also shows how knowledge and skills can be transferred to enable positive change from the middle out. To summarise, building professionals can enable through recommending technologies where they feel trained and equipped to do so, especially where funding is available for clients. This is especially valuable for trade professionals who have direct contact and influence over clients, often householders making retrofit choices.

Mediation can occur between organisations, especially where training is funded by employers, or contract agreements enable knowledge-sharing between parties at the right stage in a project cycle, with benefits for large commercial projects. A clerk of works can oversee work on-site and enable physical errors to be quickly addressed through direct communication with the relevant professional. However, a lack of time and contract enforcement can prevent clerks of works being employed, or the right contract approach enabling ongoing dialogue. Aggregation can occur where knowledge from previous builds can be transferred to future builds, especially where pioneering projects have inspired

teams or agendas such as DfP in office builds require POE to ensure design goals are met, or where the installation of particular low-carbon technologies from one property can be repeated on a similar property in future. However, where teams do not work together again or work on very different projects, the potential for this is limited. The appetite for funded training was found, particularly among trade professionals.

4.5 Overview of training needs: SC

The workshop for SC led to the identification of knowledge and skills needs (Simpson *et al.* 2018). The insights relevant here are summarised in **Table 2**.

The pathways to deliver these topics and potential incentives were discussed. For the physical detailing, toolbox talks on-site with multiple building professionals were undertaken at the start of the project. For contextual and theoretical factors, short intense courses were suggested. These could be held in a formal classroom environment or online. There was discussion around encouraging continuous learning from the start via formal education routes early on in building professionals' career. Training was suggested to be integrated into existing formal training pathways where possible, but on the job during live projects for existing building professionals. POE of similar projects could inform this. The suggestion for a clerk of works to be included on all construction work was made by a few attendees, as this is not always the case in the UK, but reportedly was in the past. This would enable quality checking and the identification of defects on-site. Good communication between teams enables knowledge-sharing.

Stemming from SC, with insight from SA and SB, **Table 3** provides a synthesis of the training needs for a variety of construction industry groups and potential learning routes.

At present, formal training for many groups in the UK construction industry takes place only before they commence their profession, although some professions requiring continuous learning and development or training as part of re-registration for accreditation. Training on the job is favoured by employers (CITB 2018). However, this route could potentially lead to bad habits being transferred. In an industry which is competitive and values speed, ensuring quality installations can be a challenge.

The construction industry needs to upskill at pace using a mix of formal routes, on-the-job knowledge and skill transfer, and e-learning. Insight from middle actors looking online for information suggested digital platforms (e-learning) may assist in finding quality information, particularly as resources online advance (BUILD UP 2020; Green Register 2016; Futureproof.uk 2020). This could better support existing informal information-sharing. Such methods have previously been found to lead to a variety of interpretations (Wade *et al.* 2016a), so it could be paired with in-person discussion to clarify detail.

5. Discussion

The insights indicate that some construction workers have the appetite to train and become confident in zero-carbon technologies and installation processes. In short, there is potential for these groups to further develop their agency and capacity, enabling change from the middle out. Their opportunity for influence appears to be greater sideways and downstream than upstream. There is a particular need for trade professionals to upskill since they have a direct influence on the likely success of bottom-up change, such as that instigated by householders (Janda & Killip 2013; Janda *et al.* 2014; Wilson *et al.* 2013; Wade *et al.* 2016a, 2017a; Simpson 2017; Killip *et al.* 2020). Middle actors naturally

Table 2: Building performance and social value training needs and incentives.

Theme	Contextual training	Physical training	Process training	Incentives
Topics	· Climate change, CO_2 emissions from the building stock, comfort and health factors · What building performance targets are trying to achieve: healthy buildings, affordable to run · Whole lifecycle of buildings	· Practical issues/challenges: consequences of missing key 'principles' · Continuity of insulation and avoiding thermal bridging · Air-tightness and air movement within the space controlling the internal atmosphere and within the fabric · Building fabric: thermal, moisture *etc.* · Minimise waste	· Awareness of all trades and the whole process of building · Vertical integration of the supply chain and feedback loops · Materials and how they affect construction practice · Digital technologies · Offsite manufacturing processes · Work efficiently through 'lean thinking' · Communication skills · Respect of standards required	· Collaborative procurement · Limiting opportunities to professional who carry appropriate certificates · Requirement for 'Gold' Construction Skills Certification Scheme (CSCS) cards required · League tables based on building performance · Stringent building regulations and control

Source: Adapted from Simpson & Owen (2018).

Table 3: Middle-actor training opportunities and routes leading to and stemming from enabling, mediating and aggregating within construction teams and networks to accelerate zero-carbon developments.

	Training opportunities	Trade professionals	Clerk of works	Technical consultants	Project managers	Designers	Training routes
Enabling	Government schemes	·	·	·	·	·	E-learning
	Installation detail: On the job or design	·	·	·		·	Formal, on the job
	Cross-trade insight on building performance	·	·	·	·	·	Formal, on the job
Mediating	Awareness of products	·	·	·		·	E-learning, formal
	Awareness of skilled individuals	·	·		·	·	E-learning, on the job
	Accreditation	·	·	·	·	·	Formal
Aggregating	Experience of relevant building projects	·	·	·	·	·	On the job, e-learning
	Confidence: Technology application	·	·	·	·	·	Formal, on the job
	Ability to participate in collaborative contracts	·	·	·	·	·	On the job, formal, e-learning

Note: · = Suitable; blank = not directly relevant.

aggregate knowledge from one project to the next and learn from experience. This can take place via self-learning from on-site practice, knowledge gained during the design, construction and handover phases, or knowledge-sharing during meetings. Where there is an absence of POE, there is a missed opportunity to further develop knowledge and skills in achieving good-quality sustainable buildings.

Building professionals look online or learn from their network when they needed to know something. This mirrors the dominance of 'sideways' routes to influence reported by the participants represented in this data set. The provision of accessible and robust information online, via e-learning methods, or information portals, could assist in the transmission of knowledge. Information about previous projects teams have worked on, especially successful zero-carbon buildings, could be shared more widely, allowing further aggregation of expertise and experience gained.

In practice, training often happens informally through knowledge-sharing between teams relevant to specific projects. This approach has been adopted within Futureproof.uk (2020), using peer-to-peer learning, via a builder who has completed training. Formality attached to a contract route, perhaps requiring this standard, could assist ensure repeated quality. The content for training can be co-developed within a consortium including middle-actor teams with experience of zero-carbon builds, plus related teams from higher education, further education and industry, with expertise including building modelling and measurement, building technology (both applied and theoretical), building services, building physics, legal frameworks, sequencing, supply chains, and social value.

There are differing knowledge and skill needs for new-build commercial, new-build homes, on the job/off-site, retrofit approaches for specific building archetypes including construction methods and ages, low- and high-rise. Considering appropriate opportunities to actors working on differing project types could enable quicker mainstreaming of zero-carbon approaches within each group. For example, the risk for trade professionals deploying technologies they have less experience with needs to be managed, so confidence can be gained in new options (Wade *et al.* 2016a), with available support. As practices innovate in line with new technologies, new forms of training will be required to support building professionals (Topouzi *et al.* 2019). This will require continuous evaluation and development.

The skills building professionals gain will only be valued if they are coupled with demand from the top down or bottom up. This could be incentivised through effective contractual arrangements that require accreditation on specific projects, and potentially through policy incentives led by top-down approaches, to enable grassroots and bottom-up efforts to stimulate middle-out change. This broader economic stimulus could assist in mainstreaming the skills to avoid them remaining a specialist domain. Within contractual agreements, a clerk of works was considered a valuable team member to oversee the physical construction processes and communicate where defects occur, in relation to building performance, but also on wider construction processes. This role could assist the work and quality checking of external building control officers who cannot check that every process on-site complies with regulations.

New collaborations and mutual learning between academia, training and multiple middle-actor parties in the industry could build capacity and enhance knowledge development for creating and maintaining a zero-carbon built

environment. The progression to zero carbon requires that technologies and strategies be deployed at pace and with POE to evaluate physical performance continually (Killip *et al.* 2020) and to ensure occupant satisfaction with the deployed products and design strategies.

6. Conclusions

The middle-out perspective (MOP) was used to explore building professionals' perspectives on knowledge and skill requirements, and pathways to deliver zero-carbon buildings. This endeavour included multiple middle-actor groups of building professionals from trades to designers and project managers.

It reveals that middle actors in the construction industry need to be equipped to deliver zero-carbon buildings and require support—through training and knowledge acquisition, amongst other areas—to gain agency that enables them to deliver zero-carbon buildings. The insights gained indicate that building professionals have an interest to develop their technical skills and a desire to better understand routes to zero carbon, but are keen to minimise risk to their reputation and to clients by ensuring technologies are suitable and that they can install them correctly.

There is less apparent appetite for skill development in non-technical areas, although it is in the practice of such non-technical skills that middle-out influence is strengthened, for example, by developing communication skills between trades, or with up- and downstream actors. Middle actors seek a range of training routes, including formal, on-the-job (informal) and emerging e-learning options. Learning pathways for different groups of middle actors need to consider the specific needs of each professional group to gain the required skills and knowledge. Middle actors can share knowledge, for example, a clerk of works can oversee construction work on-site and guide processes to minimise building defects or shortfalls towards zero-carbon performance detailing. Post-occupancy evaluation (POE) data from similar projects could strengthen such knowledge-sharing. In addition, recognising the differing learning needs (and styles) of different middle-actor groups, the skill and training requirements and opportunities should reflect different types of project, such as repair and maintenance or commercial new-build, so that specific relevant knowledge is deployed on top of broad general principles.

At present, middle actors in construction appear to have very little upstream influence and it is perhaps therefore unsurprising that their views are not routinely used in policy design. Researchers could assist in filling this gap. If policy-makers, regulators and training/advisory bodies create routes to listen to and use middle-actor perspectives, then it is more likely that policy action will lead to the desired impact. Upskilling the construction sector to meet the zero-carbon challenge will require significant investment, particularly in evaluating projects and communicating success. It is vital that policy and training support are designed to be effective, then continually evaluated and improved. Continuous evaluation is necessary to keep pace with evolving and new technology options and installation processes.

Middle actors appear to naturally mediate sideways to share knowledge between teams. This could be a route to progressing knowledge, perhaps by enforcing through contract routes or with the provision of digital information they can easily access and share. Enabling more informed sideways mediation can then equip teams to influence both up- and downstream. One route for achieving this is through the aggregation of knowledge from experience in previous building projects, ensuring that insights gained from one project goes beyond word of mouth and appear within e-learning or information portals. A further powerful set of influences lies between professionals and clients. Client awareness (bottom up) is required to allow trained middle actors to deploy skills, in addition to effective contractual arrangements (sideways) providing the clear opportunity to do so.

Three areas of further research would be helpful to support middle-actor training and development in achieving the low-carbon building stock. First, a more granular method of applying the MOP would help by reflecting the specifics of different roles of middle-actor groups in construction. Second, further research and engagement is needed to increase the confidence and depth of understanding of building professionals as agents of middle-out change. Third, research that evaluates the actual impact of intended zero-carbon builds and retrofits is important to keep improving the connections between skills and knowledge, professional practice, and building performance.

Notes

[1] This approach complements previous work that has often focused on particular professions and their specific tasks (*e.g.* architects and engineers: Janda 1999; heating engineers: Wade *et al.* 2016a; or property agents: Schiellerup & Gwilliam 2009).

[2] Of employers in construction surveyed by the national body guiding construction training, 67% funded or arranged any training, either formal, informal, on or off the job during the 12 months between 2017 and 2018 (CITB 2018). While only 38% of surveyed self-employed firms ($N = 122$) funded and arranged training, 66% identified a need to acquire new skills or knowledge.

[3] For example, teams had the opportunity to develop skills such as replacing windows while aligning with external wall insulation to avoid thermal bridging, in collaboration with design teams. This took time, but teams reported that if they were able to do more, they could develop an understanding and a perfect a way to do it (Lowe & Chiu 2020: 6).

[4] Topics include moisture and breathability, renewable energy, air-tightness, ventilation and retrofit, site visits to Passivehouses, WELL-certified buildings and shorter sessions on the building regulations Part L, and heat and moisture simulation (WUFI) training (Green Register 2016).

[5] A full discussion of the MOP is beyond the scope of this paper, but in recent years these and other authors have further developed the MOP to address providers of housing refurbishment (Janda *et al.* 2014), heating engineers (Wade *et al.* 2016a), community-based organisations (Hamilton *et al.* 2014), facilities managers (Goulden & Spence 2015), social housing providers (Cauvain & Karvonen 2018), and public health officials (Kranzler *et al.* 2019). The term 'actor' has been previously adopted by Giddens (1984). As in the MOP, Giddens recognised that actors operate in social systems and some forms of dependence within those can lead to influence, such as by so called 'subordinates' to 'superiors' (p. 16). Recent adoption of the MOP has included combining the approach with practice theory to explore further how actors influence change in terms of technology, explicit rules, engagement and habits (Reindl & Palm 2020).

[6] For example, Killip *et al.* (2018) applied secondary analysis to four studies focused on low-carbon renovation with application of the co-evolution framework; Wade *et al.* (2017b) applied secondary analysis to two previous studies exploring professional identifies of professional actors engaged in domestic energy work using concepts from Abbott's 'system of professions' framework; and Bull & Janda (2017) studied two previous projects to explore opportunities for widening participation for energy management within organisations.

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Supplemental data

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Authors contributions

K.S., A.O., & K.J. conceptualised the paper. K.S. completed the secondary analysis and led the authorship. A.O., & K.J. provided draft feedback, edits and steered the direction of the paper.

Ethical approval

All three studies were subject to ethical review and approval at the higher education institutes where the researchers worked. Informed consent was obtained from all participants before data collection. While secondary analysis was applied, the overarching research topic of training, skills and knowledge for 'sustainable' construction and refurbishment remains the same and the participants consented in the primary studies that their insights gathered in the primary studies could be used, anonymously, in future journal publications.

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