MAPPING EMERGING SUBCONTRACTING NETWORKS FOR THE ENERGY EFFICIENCY RETROFIT OF HARD-TO-TREAT BUILDINGS

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The Energy Efficient Scotland Programme is the Scottish Government's flagship programme for improving the energy efficiency of every building in Scotland. This Programme represents an unprecedented effort to retrofit the entire Scottish building stock, but mixed-use urban buildings offer a particular challenge. Energy Efficient Scotland will run over the next 15-20 years and its delivery is critical for achieving ambitious targets to reduce emissions by 23% and 59% from domestic and non-domestic buildings, respectively, by 2032. Actors from across private, public, and civic sectors are critical for retrofit delivery. However, the contractual relationships, communication, and trust networks in place for energy retrofitting are currently unknown. Understanding of these supply chains is essential for identifying where responsibility lies for different activities, particularly in buildings of mixed-ownership. Consequently, this paper combines Social Network Analysis and qualitative interview data to explore communication and trust amongst an emerging supply chain for a retrofit project in a hard-to-treat mixed-use building. The results show that contractual, communication, and trust networks do not always overlap, with actors in influential roles carrying less risk, for example This provides critical understandings for policy makers seeking to develop clear guidance for roles and responsibilities of different actors involved in the delivery of national-scale energy retrofit.

Keywords: retrofit, social network analysis, local government, social capital

INTRODUCTION

Energy Efficient Scotland (EES) is the Scottish Government's flagship programme for increasing the energy efficiency of all buildings in Scotland (Scottish Government, 2018). This is critical for meeting the combined goals of reducing fuel poverty and meeting the ambitious target to reduce greenhouse gas emissions by 90% of 1990 levels, by 2050, set out by the 2018 Scottish Climate Change Bill. The success of Energy Efficient Scotland is reliant on the coordination of supply chain actors that will manage and deliver Energy Efficient Retrofit Services (EERS) on an unprecedented scale.

Following limited action on retrofitting to date, and the failure of the UK Government's Green Deal retrofitting programme (Rosenow and Eyre, 2016), there are serious questions concerning the factors that constrain or facilitate EERS diffusion at scale. Prior research has highlighted the need for greater innovation and integration

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throughout construction supply chains. However, little is known about how supply chain actors are actually creating project teams to deliver EERS.

This paper presents exploratory research which identifies the supply chain actors emerging for the delivery of EERS and the conditions that influence the success or failure of retrofit projects. It employs the concept of social capital alongside Social Network Analysis (SNA) to interrogate how supply chain actors negotiate network integration and innovation. Through this, we pilot a research model that explores the different types of tie in place for complex energy retrofitting. These include contractual, communication, and trust ties, and interrogation of how these ties overlap.

LITERATURE REVIEW

Reluctance for Building Retrofitting in the UK Construction Sector

The UK construction sector has long been characterised as fractured, adversarial, and innovation-averse, posing serious challenges for complex and innovative energy retrofitting projects (Pryke, 2012; Larsen, 2011; Latham, 1994). The Farmer Review (2016) identifies structural fragmentation, ambiguity in project planning, and lack of collaboration as some of the critical symptoms of poor performance in the UK construction industry. However, these challenges continue to be overlooked in the development of policy for energy retrofitting. In particular, the UK Government's Green Deal, which aimed to encourage adoption of energy efficiency measures by domestic householders, was cancelled in 2015 after achieving only .03% of the projected adoption rate over 2.5 years (Rosenow and Eyre, 2016). Failure of the Green Deal was attributed to an over-reliance on financing models while neglecting social factors, especially supply chains (Fuller, 2010; Rosenow and Eyre, 2016; BEIS, 2018).

Energy Efficient Scotland exists within an emerging and ambiguous market; it's success will rely on high levels of supply chain innovation and integration. EES faces several challenges owing to organisational, resource, and task complexities, coupled with uncertainties and the necessity for innovation in EERS projects (Moore *et al.,* 2018; Papadonikolaki *et al.,* 2017). Critically, whole-building approaches to EERS are recommended over isolated installations due to the interdependent nature of effects from EERS interventions (for example an upgraded heating system may not deliver potential energy savings if followed at a later date by additional insulation). However, a report on retrofit supply chain coordination by the department for Business Energy and Industrial Strategy highlights that "[whole house retrofit] requires coordination across trades … that the workforce is not equipped to deliver," (BEIS, 2018: 11). Thus, understanding how supply chain actors negotiate project relationships to facilitate (or fail to facilitate) integration and innovation needs to be a priority for further policy aiming to deliver energy efficient retrofitting.

Networks for Innovation in Construction

Supply chain complexity can be defined as the "number of transacting actors, extent of inter-relationship among actors, degree of differentiation among them in terms of practices and also their frequency of interaction" (Chakraborty, 2015: 4). Complexity is problematic in emerging markets, such as EERS, because accompanying uncertainty and risk may lead to increased transaction costs (the costs related to operational procedures and organisational processes which can rise proportionally to project complexity) (Moore *et al.,* 2018). Transaction costs can account for as much as 30% of EERS costs. This can inhibit delivering EERS at scale due to reduced

profit margins and increased investment risk associated with ambiguous markets and newer technologies (Moore *et al.,* 2018; Gooding and Gul, 2016). Several strategies have been implemented to mitigate this through the integration of construction supply chains. These include Supply Chain Management (SCM) and the New Engineering Contract (NEC3), which seek to facilitate greater cooperation and risk sharing amongst supply chain actors through formal contractual arrangements. Despite these, the generation of trust in construction supply chains can prove difficult due to their temporary nature (Meyerson *et al.,* 1996). In temporary networks characterised by high interdependence, actors must engage in "swift trust" (Meyerson *et al.,* 1996) to reduce uncertainty and risk. Actors who are positioned at critical junctures of communication and interaction may influence whether or not swift trust is generated in projects (ibid; Boddy *et al.,* 2010; Iturrioz *et al.,* 2014). Literature has increasingly recognised the critical role of informal relationships and social capital in facilitating supply chain integration while mitigating negative aspects of complexity in nascent and ambiguous project settings (Wichmann and Kaufmann, 2015).

Bonding and Bridging Social Capital in Supply Chain Networks

Social capital refers to the capacity and assets inhering in social networks by virtue of intersubjective relationships; these assets can be called upon by actors for both individual and collective benefits. Social capital can be categorised as bonding or bridging capital. Bonding capital (also referred to as strong ties) refers to social capital produced in dense groups where homogenous actors share many of the same mutual connections. Bridging capital (also known as weak ties or brokerage) refers to social ties that connect otherwise disconnected, distinct groups (Granovetter, 1973).

Bonding capital is generally understood to increase performance of supply chains due to its positive impact on interorganisational communication, trust, and alignment of goals and interests (Chinowsky *et al.,* 2008; Koh *et al.,* 2016). Densely bonded supply chain networks are also thought to be better equipped to mitigate risk and agilely coordinate adaptive responses to unforeseen circumstances in complex projects (Moore *et al.,* 2018). However, the role that bridging capital has on supply chains is more uncertain. Bridging capital is considered to be critical for innovation as it is thought to introduce new ideas and resources into groups and help coordinate otherwise siloed workgroups in organisational settings (Granovetter, 1973). However, empirical studies on construction supply chains find that the presence of network brokers (or bridges) fails to increase supply chain coordination, performance, and innovation (Carnovale and Yeniyurt, 2015; Larsen, 2011). Brokers can also present challenges including the bottlenecking of flows of relevant information (Borgatti and Li, 2009), and having the capacity to influence networks in opportunistic ways (ibid). Consequently, this research critically examines the role of network brokers in the delivery of EERS in a hard-to-treat mixed-use building. To do this, it applies qualitative interviews and Social Network Analysis; these are detailed in the following section.

METHOD

The Case Study Project

This research uses a case study of EERS on a hard-to-treat listed building of mixed-occupancy, including both domestic and non-domestic properties. This project is taking place under the Energy Efficient Scotland programme, through which Scottish Government provide funding for local authorities to coordinate retrofitting projects.

Local authorities contribute to the selection of properties for the pilots, and the design and procurement of the works taking place. The case study building has 12 residential properties in the block: six of these are holiday lets, three are long-term rentals, two are owner-occupied, and one is vacant. There are also two commercial properties. This is a listed building, wherein the council lacks authority to intervene on behalf of property owners. This project represents the complexity of both stakeholder interests and diverse skills in the supply chain; understanding these issues at this site has wider implications for the development of EERS supply chains. The case selection was also influenced by the willingness of stakeholders and supply chain actors to participate in the study. The researchers are aware of the Hawthorne effect, particularly that participants associated with the project may perceive the research as an opportunity to narrate and advocate for their position amidst various and sometimes competing interests. Evidence has been triangulated across documentary and verbal sources, and this has been considered in the selection and presentation of data. This is an active project; all actors and organisations have been anonymised in the presentation of data.

This paper focuses on the relationships between three central actors: the association of property owners for the building (the Project Client); the administrator of grant funds (the Administrator); and the lead architect (the Project Lead). The project proposal was submitted jointly by the local authority and the Administrator. The Administrator then held responsibility for managing the grant funds and monitoring project activities. They also instituted an owner's association as the Project Client, a legal entity with authority to make decisions on behalf of the building's property owners. The property owners are themselves heterogeneous, with differing interests and goals. As the Project Lead, the architect manages the contractual relationships for all other contracted work and provides the majority of project management duties.

Social Network Analysis Incorporating Quantitative and Qualitative Approaches

Social Network Analysis (SNA) is an approach for measuring and analysing social networks and social capital that is quickly gaining prominence in construction and supply chain management literature (Wichmann and Kaufmann, 2015). SNA utilises graph theory to plot relationships (ties) amongst actors (nodes) in a network (Scott, 2017). Mathematical formulae then allow for the quantitative analysis of social capital inhering in these networks. SNA has been used throughout construction sector research, most prominently to examine formal contractual ties between organisations in project-based supply chains, and levels of influence or stakeholder salience derived from those (Wichmann and Kaufmann, 2015; Pryke 2012; Mok and Shen, 2016; Aaltonen and Sivonen, 2009). However, SNA is increasingly used to examine informal ties to explore how structural, cognitive, and relational forms of social capital intersect with formal contractual ties. This is particularly useful for understanding how formal and informal ties influence construction networks and identifying the conditions for project success (Papadonikolaki *et al.,* 2017). However, while SNA provides a perspective of ways in which the structure of social relations impacts actor behaviours, constraints, and opportunities, it provides relatively little insight into the content of these relationships (Crossley, 2010). Consequently, we employ a mixed-methods qualitative SNA approach (Crossley, 2010), incorporating participant insights through qualitative interviews.

Data Collection and Analysis

We examine two types of network ties amongst project stakeholders (communication and trust ties). Data collection followed a snowball sampling approach, beginning

with the local authority and the Administrator, through whom we identified the Project Lead and the Project Client, along with remaining members of the design team and subcontractors. Semi-structured interviews included directed questions to elicit network data on contractual and communication ties, and issues of trust, which have been identified as salient to bonding and bridging capital (e.g. Pryke, 2012). The interviews also included open queries that allowed for probing of respondent-identified issues. The interviews lasted approximately one hour, they were transcribed and then coded using Atlas.ti. This process identified approximately 75 salient codes; of these, issues of communication, interest alignment, trust, transparency, and risk were selected as significant for the development of this network.

Adhering to guidance for deriving network data from qualitative data sources (Crossley, 2010), we interpreted interfirm communication on a four-point scale:

0 = no communication;
1 = communication channel present but infrequently used;
2 = semi-regular communication, e.g. progress meetings;
3 = regular or intense communication.

Trust was interpreted on a binary scale (0 = actor dyads fail to express a trusting relationship; 1 = actor dyads express a mutual level of trust). Contractual ties did not require qualitative interpretation and were assigned binary values. All communication ties were symmetrical and trust ties only show mutual responses based on the understanding that the benefits of trust are only engendered when mutually shared. Network measures of density and betweenness centrality were used to describe structural qualities of network cohesion and actor influence respectively for each type of tie. We used three SNA measures to examine structural features of the project network (density, degree centrality, and betweenness centrality).

Density is a global measure of how cohesive a network is, expressed as the proportion of actual ties to possible ties amongst all actors in a network. Possible density measures range between 0 (no ties existing amongst network actors) to 1 (all actors are tied to all other actors); measures over 0.5 are generally considered dense and under 0.1 are considered not dense. Density in communication and trust networks has been widely shown to have positive effects on construction supply chain performance (Larsen, 2011; Moore *et al.,* 2018). In this study, density of communication and trust networks is compared to examine whether communication leads to trust on a network level (Chinowsky *et al.,* 2008). Degree centrality is a node-level measure indicating the influence of an organisation on a network as expressed through its prominence. It is measured through the number of ties connecting to a node. This study measures the degree centrality of trust networks to identify organisations perceived by others as trustworthy or untrustworthy. Betweenness centrality is a node-level measure of network brokerage, expressed as a node's presence on the shortest path between other nodes. Like bridging social capital, the role of betweenness on construction supply chains is still ambiguous (Borgatti and Li, 2009; Carnovale and Yeniyurt, 2015). In this study, betweenness is measured for communication ties in order to examine which actors are influential in shaping information flows in the networks. Communication betweenness centrality is compared to trust degree centrality to examine the relationship between communication brokerage and trustworthiness. Qualitative analysis is applied to interrogate the content of ties and identify ways that brokering roles may promote or constrain network trust.

RESULTS

Describing the EERs Project Network

Figure 1: Map illustrating communication ties. Larger node size illustrates larger betweenness centrality. Thicker lines illustrate stronger communication.

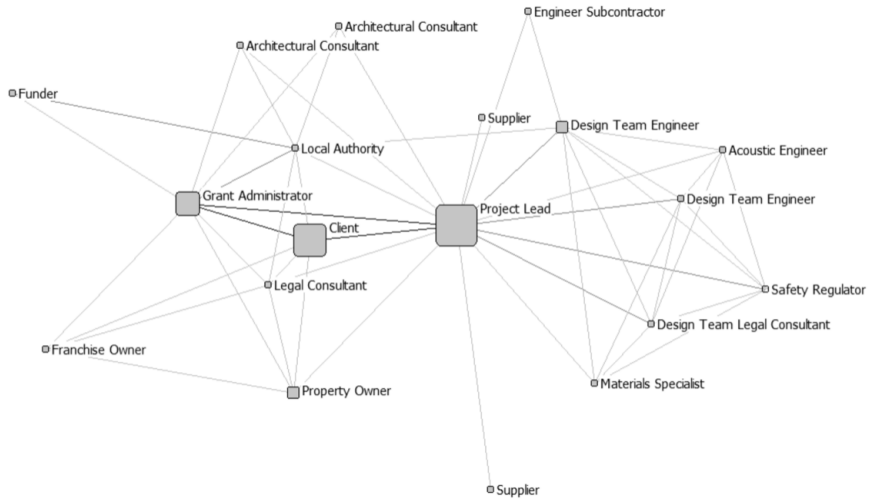
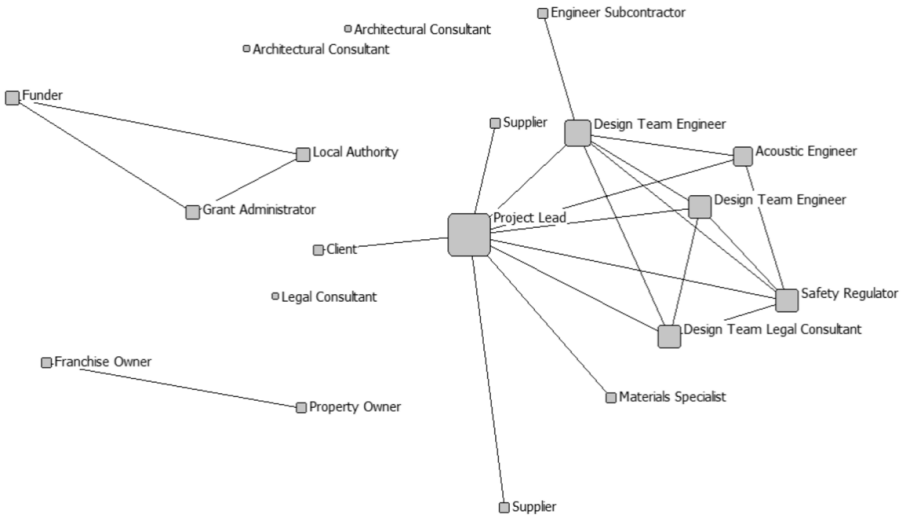


Figure 2: Map illustrating trust ties. Larger node size illustrates larger normalised degree centrality.



Measurement of communication channels and trust ties in the case study project reveals a moderate density in communication networks (0.334 - Figure 1), but a weak density in trust ties (0.123 - Figure 2). Discrepancy between densities suggests that communication has not uniformly matured into trust amongst project actors. Lack of trust amongst key stakeholders, namely the Client and the Administrator, may indicate a potential problem for coordination of ongoing project activities. The Project Client, Administrator, and Project Lead are clearly identifiable as the most prominent nodes in the network illustrated in Figures 1 and 2. Of these three, we observe the highest betweenness and degree centrality for the Project Lead on both communication and trust networks respectively. They thus act as a nexus of influence and control, acting as both a hub for project coordination and a broker for information between various stakeholders. Meanwhile the Administrator and Client have high communication betweenness but low degrees of trust, notably between each other. The following data

investigates the differences between these relationships and their possible impact on the project.

Betweenness Centrality and Brokering Relationships

Shared interests and transparency for developing trust

Central actors that share a large burden of risk, or have "skin in the game," are more likely to generate trust amongst others, especially those with whom they share risk. The Project Lead occupies the greatest communication brokerage role (normalised betweenness = 72.876). They also have the highest normalised degree centrality for trust (0.5), with trust between the Client and the Project Lead being especially noteworthy. This trust was particularly apparent during an interview with the Client representative:

> [The] Architects I'm entirely comfortable with… [they] have got such a huge stake in this in terms of future business and potential bad reputation if it doesn't go well so I could relax and I'm confident… [The Architect] stand[s] to make a fortune from this project, they're getting experience here in areas that no one else has got experience on (Client representative).

This echoes Chinowsky et al.'s (2008) assertion that communication exchange that focuses on building mutual understanding of the interests, constraints, and processes of different stakeholders helps facilitate trust. This also supports the overall capacity of actors to act cooperatively and with agility in uncertain and high-risk environments, like the hard-to-treat building studied here. In this case, the recognition of mutually aligned interests relates to perception of fair distribution of contractual risk. At another point in our interview, the Client Representative noted that: "you look at the risks, you look at the liability of the parties involved and […] if you recognise that the supplier has a vested interest then you don't need to make the contracts a problem".

Divergent interests and obscurity for diminishing trust

Actors with a high degree of centrality (and hence, influence) but who are risk averse appear less trustworthy. It is less problematic if actors with low centrality share little risk, as seen in the case of a subcontracted member of the design team who acts as a mechanical engineering consultant. Complexities and problems arising from the project have very little impact on the costs or reputation of the mechanical engineer, relative to those of the client and the project lead. However, because the mechanical engineer has only a peripheral centrality (contractual and communication betweenness centrality = 0), their lack of investment has a low influence on the overall trust and integration of the network. In contrast to this, the Administrator has high normalised betweenness (34.641), but a low normalised degree of trust (0.111), most remarkably in their relationship with the Client and with the Project Lead. At interview the Client explained some of the challenges of working with the Administrator:

> [The Administrator] is a different kind of beast and so I'm a bit less comfortable with them and there's a bit of antagonism's maybe too strong a word but concern...a number of the owners and the wording of this constitutive deed - they find the terms very onerous (Client representative)

While the client highlighted the lack of interest alignment and risk sharing by the Administrator, the Project Lead reported that the Administrator's lack of transparency hampers their capacity to coordinate the rest of the network:

> And at that point we didn't think there was scope to shift the programme because […] we've never seen or we've never been involved in any discussions with Scottish Government or the Council or the Administrator […] and we haven't seen their original funding application […] I really felt that the Administrator as the kind of the well not

> technically the grantee but the, as the project officers on this one […] they had someone who could say right well we could do this and that could kind of mitigate the impact on the project (Project Architect)

However, the Administrator, whose role it is to oversee that contracted works coincide with the dictates of the grant, expressed concern that owners often lack an understanding of the structure of the grant process: "for the [Client] you know, it's a different world and it's difficult to challenge […] what you are being told if you are not in the sector […]." These challenges to the Client's interests, while necessary for the management of the grant, are not always understood by the Client or the Project Lead, because neither of these have ever seen the original terms of the grant. As such, while stakeholders appreciated the role that the Administrator played in initially setting up the Client as a legal entity so that it could represent itself in contracts management, it appears that stakeholders are unclear on the role that the Administrator continues to play. They report that it feels like they introduce unnecessary complexity which in turn ends up increasing the transaction costs of the project and the costs incurred by the other stakeholders. Both the Project Lead and the Client expressed a desire to have more direct contact with the funders in order to understand more clearly the terms, and subsequently move forward with the coordination of works. There was also a view that the Administrator bottlenecks capacity to flexibly manoeuvre in response to complex and dynamic issues in the property itself, the Client's demands, and the rest of the supply chain.

DISCUSSION

While network brokerage is known to have some impact on supply chain cohesion (Iturrioz *et al.,* 2014; Boddy *et al.,* 2010), little is known about why some forms of brokerage facilitate cohesion, while others diminish it. This research seeks to address that gap. It builds on previous recognition that strong communication networks are critical to the formation and performance of teams for the delivery of innovative construction projects such as EERS (Chinowsky *et al.,* 2008; Larson, 2011). Focusing on the delivery of retrofit in a hard-to-treat mixed-use listed building, this study has interrogated the specific ways that actors occupying a brokering position facilitate supply chain integration and innovation. In agreement with Chinowsky *et al.,* (2008), we found that communication channels may or may not give rise to specific types of knowledge sharing that facilitate trust and goal alignment. These are necessary informal social capital resources that allow for network integration.

In this case, the Administrator held a high degree of betweenness centrality in both contractual and communication networks, but a low degree of trust. Meanwhile the Project Lead held the highest degree of betweeness centrality in contractual and communication networks, and highest degree centrality for trust. Trust amongst these central actors varies based on the intensity and frequency of communication, the transparency of communication, and the perception of mutually shared interests and shared risk. This is critical for the delivery of a programme like Energy Efficient Scotland, the success of which is reliant on retrofitting action taking place in all property types, including mixed-use, mixed-ownership buildings like that discussed herein.

The EES Programme is built on a model of local authority oversight of retrofitting projects. However, local authorities do not have the power to intervene in the management of privately-owned properties. In this case, the funding structure incorporated the choice to outsource grant management duties to an Administrator and

included the legal incorporation of property owners into a representative body responsible for decision making. This structure may infuse administrative organisations with a high degree of influence over the project, but unequal distributions of risk. This may hamper the capacity of the network to form cohesion and flexibly manoeuvre in the face of ambiguous and complex work environments.

CONCLUSION

This research has direct implications for policy approaches to the rollout of energy efficiency retrofitting programmes. The differing structures of communication and trust networks revealed here demonstrates the need for policy makers to develop clear guidance for the identification of roles and responsibilities for the different actors recruited into the delivery of complex retrofitting projects. The research presented herein is a preliminary look at the supply chain networks emerging for the delivery of building retrofitting. Further work is required to identify the variety of contractual networks emerging for different types of projects, for example, whether there are distinctions when project management is retained in-house by local authorities.

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