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A material lens on socio-technical transitions: The case of steel in Australian buildings

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ABSTRACT

Steel is a critical material for modern-day societies, and more than half of the world's steel is used in buildings. As the extraction of iron ore and the production and transport of manufactured steel have significant environmental costs, the fate of steel is important for socio-technical transitions towards more sustainable materials use. Using steel in buildings as a case study socio-technical transition, this paper develops a novel application of the multi-level perspective (MLP) that adopts an explicitly material lens. We focus on the circulation of steel between three key life stages for buildings which are treated as socio-technical regimes as described in the MLP. Drawing on concepts from assemblage theory, we consider the role played by the material and expressive qualities of steel within each of these regimes. Our material focus also requires attention to the spatial dimensions of these three regimes and their implications for socio-technical transitions. We describe the nexus of material affordances and inter-scalar relations that influences the use of steel in buildings and consider the potential for change. The main contribution of this paper is to extend the MLP to incorporate a focus on materiality and, in a related way, spatiality. Based on the analysis presented we consider how steel use in Australian buildings may be rendered more sustainable.

1. Introduction

Steel is a critical material in construction, infrastructure and manufacturing. Ever-increasing global population and urbanisation rates mean that the production and consumption of steel will continue to rise. However, steel production contributes almost 25% of the world's industrial carbon emissions (Allwood et al., 2010; Pauliuk et al., 2013) and accessing ore grades of declining quality has increasing impacts on ground water and on ecological systems more generally (Mudd, 2010, p.114). Buildings consume a significant proportion of steel; it has been estimated that 56% of end-use steel worldwide is used in construction, with buildings accounting for 42% (Allwood and Cullen, 2012, p.31). It is therefore critically important to understand how steel is currently used in buildings in order to promote a long-term transition towards more sustainable use.

Steel in Australian buildings is particularly unsustainable in terms of the global commodity chains involved in its production and use. Embedded in a global market, Australia is a significant *exporter* of iron ore, which accounts for over 20% of all its export revenue (DFAT, 2016). However, extraction for export comes with significant environmental and greenhouse gas emissions costs (Mudd, 2010). Additionally, as of up until 2013, fabricated steel *imports* have been steadily increasing at the expense of locally manufactured products (Australian Industry Group, 2014, p.24), and of all steel used in Australia approximately 35% is used in the construction industry (IBISWorld, 2016, p.14). Significant volumes of iron ore leave Australia, and at the same time increasing amounts of steel are imported for use in Australian buildings; the transportation of such heavy commodities entails significant environmental impacts. This indicates that finding more materially efficient pathways for steel in Australia is important, and these investigations must grapple with unsustainable global circulations of steel and their predominant use in buildings.

As a global commodity, steel flows are primarily driven by the political economy of global markets and supply and demand. Important decisions about the use of steel in buildings are made at three stages of its life cycle – demolition, scrap recycling and construction. Each is affected by various prices and costs, but due to the relatively long lifespans of buildings, decisions at each stage are generally made independently of the others. First, decisions about when a building reaches end-of-life and will be demolished are generally made by owners based on when it becomes more profitable to remove or replace a building rather than retain it. After demolition, scrap steel is processed into shredder feedstock which can then be used to manufacture recycled products. The price of scrap steel and transport costs

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affect the profits of scrap recycling businesses and influences the effort invested in procuring materials. Finally, decisions about which steel components to use in new buildings are made by construction companies who need to comply with standards set out in relevant building codes while minimising costs for their clients.

So what would more sustainable steel use in Australian buildings look like? Julian Allwood, along with other industrial ecologists, focusses on the idea of material efficiency, interpreted as "providing material services with less material production and processing" (2011, p.362). This could involve reducing material consumption, reuse and recycling (Kibert, 2008, p.246–8). While we acknowledge that material efficiency is just one element in the broader concept of sustainability, this principle will underpin our case study. We focus in particular on industrial (e.g. factories, processing plants), commercial (e.g. offices, shopping centres) and high-rise residential buildings because they consume significant volumes of steel (Allwood and Cullen, 2012, p.37). More sustainable steel use in these building types would require improved materials efficiency at the demolition, scrap recycling and construction stages, and more explicit alignment of decisions made between them, to facilitate this.

One of the more prominent frameworks for understanding such socio-technical transitions is the multi-level perspective (MLP), which has its foundations in innovation studies and science and technology studies. The MLP is constituted by interactions between three levels – niches, regimes and landscapes – which serve as "analytical and heuristic concepts to understand the complex dynamics of sociotechnical change" (Geels, 2002, p.1259).

Regimes refer to the currently stable and dominant set of technologies, actors and practices which constrain possible innovation to step-wise, incremental pathways (Geels, 2002, p.1260). Geels (2002) emphasises seven components of regimes: "technology, user practices and application domains (markets), symbolic meaning[s] of technology, infrastructure, industry structure, policy and techno-scientific knowledge" (p.1262). However, regimes are by no means indefinitely stable. Innovations can be developed in *niches*, often sheltered away from the selection pressures of regimes, such as markets (Geels, 2002, p.1261). These insulated spaces can also enable the development of "new codes of conduct, routines, visions, standards … and norms" (Raven et al., 2012, p.66) which can be nurtured through support networks and funding. These may eventually 'bubble up', compete with and usurp the dominant regime (Smith et al., 2010, p.440). *Landscapes* provide broad-level backdrops to regimes and niches, and are not directly or easily affected by activities happening at these other levels. Nevertheless, they may induce shocks at the regime level, and provide a more conducive environment for technologies cultivated within niches to emerge as viable alternatives. Under favourable circumstances and timing – some combination of tensions within regimes, the development of viable niche alternatives and landscape influences which undermine existing regime dominance – socio-technical transitions can be brought about (Geels, 2002, p.1262).

The MLP offers a useful framework to understand socio-technical transitions for steel in Australian buildings for several reasons. Each of the three stages outlined earlier – demolition, scrap recycling, construction – can be understood as industrial-regime complexes comprised of actors, organisations, government agencies, regulations, practices and technologies. Long building lifespans in Australia have led to the long-term stability of these industrial regime-complexes; Raven et al. (2012, p.67) argue that regimes generally remain stable for decades. There are also clear landscape-level features such as global commodity markets, which influence these industrial-regime complexes in varying ways, and emerging niches, such as alternatives to procuring building materials and approaches to building construction, which are beginning to be considered as viable options. The MLP therefore offers a useful framework through which to organise and conceptualise a more sustainable transition for steel in Australian buildings.

However, the MLP framework has mainly been applied to case studies on energy and transport and not on buildings (Coenen et al., 2012, p.968). The few empirical case studies applying the MLP to buildings have focussed on either individual buildings or on industry sectors and have not taken an explicitly material focus. Brooks and Rich (2016) employ the MLP as a guiding framework to explore how mega-projects in London can be viewed as 'niches' where more sustainable material use can be promoted, although they also recognise that the uptake of more sustainable materials in the construction sector more generally is likely to be incremental and beset by numerous barriers (e.g. limits to the appeal of sustainability). Their work focussed on a particular building type as opposed to buildings in general, and did not focus on a specific material. In a different application of the MLP, Gibbs and O'Neill (2015) do focus on the construction sector more broadly, but limit their ideas of a greener economy to energy and only consider materials in terms of embodied energy. Like Brooks and Rich they conclude that smaller, step-wise changes, which are relatively easy to implement, will be favoured in changes made to the construction sector.

We believe that an explicit focus on an important material (steel) offers valuable new insights for understanding building transitions and transitions more generally. Materials are not included amongst the seven components of regimes mentioned earlier. In explaining the logic underpinning the MLP, Geels argues that "technology, of itself, has no power, does nothing. Only in association with human agency, social structures and organisations does technology fulfil functions" (2002, p.1257). Therefore, the MLP focusses more on *technologies* and their *functions* as opposed to *materials* and their *properties*. Additionally, in outlining how socio-technical change may unfold, Geels (2005) tends to focus on how novelties and niches develop and become competitive. His explanation for both how regimes may actively suppress competition from niches, and how 'tension' may arise internally, are vague or downplayed and materials are invisible. In describing the latter, he suggests that "there may be internal technical problems in the regime, which cannot be met with the available technology. There may also be negative externalities in the regime, changing user preferences or stricter regulations, which create problems for the existing technology" (Geels, 2005, p.685). By focussing on discrete, functional entities such as technologies, the MLP overlooks how materials and their properties may influence and constrain how transitions may, and can, take place.

The MLP has already been critiqued for not adequately considering how space and context affect how transitions unfold. Transitions always take place in particular places, but this spatial aspect has only recently been emphasised as a critical analytical consideration requiring further attention (Raven et al., 2012). Research thus far has focussed mainly on national-level transitions, and as such the MLP could be more attentive to issues of geographical scale (regional, national, global), especially in conceptualizing how inter-scalar dynamics influence socio-technical transitions (Lawhon and Murphy, 2012 p.362). Given that steel is a global commodity, and that the industrial regime-complexes through which it circulates in Australia are embedded in contexts that span multiple geographical scales, this spatial focus is particularly important for understanding possible sustainable transition pathways.

To address these limitations, we argue that the MLP needs to be supplemented by approaches that explicitly recognise how the *materiality* and *spatiality* of socio-technical transitions impacts how they may unfold. Markard et al. (2012, p.956) have recognised the dominance of the MLP and sought to expand transitions thinking by incorporating ideas and frameworks from other disciplines. Geels (2010) argues that the MLP is ontologically compatible with a range of other frameworks, and considers potential connections with actor-network theory (for example, in describing regimes as 'stable networks' and niches as 'emerging networks (p.507)). We agree but, for our case study on steel in buildings, find that concepts drawn from *assemblage thinking* offer the most fruitful conceptual tools to supplement the MLP. Firstly, assemblage thinking enables direct consideration of how the material affordances of steel affect the stability of each of the three industrial-