Diagramming Commuting Practices: The connections within and between practices and their relevance for the shifting of energy demand in time

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Abstract

This paper takes as its context the need to better understand how flexible energy demand might be in the context of the need to balance intermittent renewable generation. The notion that energy is used as part of everyday practices has opened up new directions for research seeking to intervene in energy demand. We think understanding the structures and patterns of practices will provide insight into the ways in which they change and stabilise and may eventually, therefore, help with the design of more sustainable practices.

With this in mind, the paper explores the generally neglected connections within and between practices, both theoretically and empirically, to better understand the structure of practices. It considers both the detailed connections within and between elements of a single performance of practice (the *geometries* of practice), and the connections between whole practices and systems of practice (the *ecologies* of practice). It does this using the emerging methodology of practice network mapping which uses a quantitative form of network theory to generate empirically driven maps of social practices.

The paper reports on new empirical survey data in which participants sought to 'map' their commuting practices and their connections with other practices (both through shared elements and across time). This data is used to generate practice network maps of commuting. It uses commuting as an example of a deeply complex and embedded sociotechnical system of particular relevance for two reasons: the expected future increase in vehicle electrification and its tendency to happen during times of peak energy demand.

Novel contributions in this paper include the development of practice network mapping as a methodological approach which allows social practices to be represented graphically in a way that may eventually make them more amenable to quantitative modelling but also enables new insights into practices themselves. In particular, various forms of connectedness are explored. This results in the second major contribution of this paper – the theoretical consideration of the connections within and between practices in social practice theory (SPT).

Introduction

This paper arises out of an interest in balancing intermittent renewable energy generation by means of managing demand. The ability to time shift electrical demand in accordance with available low-carbon generation has mostly been treated as a technical endeavour – the remit of engineers and modellers – and good progress has been made. Richardson et al.'s (2008) high-resolution domestic building occupancy model has been widely cited and provides a basis for quantifying the availability and impact of demand response in the domestic sector. However, although this provides realistic occupancy data for UK households and thereby allows the identification and quantification of theoretically flexible electricity loads, the model offers little insight into the real potential for flexibility because it does not account for how practices use energy.

The notion that energy is used as part of everyday practices has opened up new directions for research seeking to intervene in demand. This approach rests on the idea that energy is consumed by practices and that these are defined by the material/ physical world of which they are a part, as well as by the specific contexts in which they exist (cultural, legal, historical, etc.) and the knowledge and skills of those enacting them – i.e. (Shove et al.'s 2012) so-called "three element model" comprising stuff, image and skill, respectively, which is adopted henceforth. This paper therefore builds on a series of papers exploring how to integrate insights from Social Practice Theory (SPT) into quantitative models of energy demand (Higginson et al, 2011, Higginson et al. 2014, Higginson et al. 2015). This is important because these models occupy a central place in policy-decision making around energy investments such as grid capacity (Pudjianto 2013), demand management (Barton et al. 2013) and the balancing of intermittent renewable generation (Gruünewald et al 2014, McKenna et al. 2015).

This paper is based on new empirical survey data on commuting practices. Commuting was selected as an example of a deeply complex and embedded sociotechnical system of particular relevance for two reasons: the expected future increase in vehicle electrification and its tendency to happen during times of peak energy demand. The timing and flexibility of this demand is of interest because the ability to shift demand will allow peak shaving in the short term and the inclusion of a higher percentage of intermittent renewables on the grid in the longer term, both of which will help to lower carbon emissions. It should be noted, however, that this paper does not seek to provide empirical insights into commuting and its variants (Pullinger et al. 2013) but rather uses commuting as a useful way to help focus on the connections within and between practices.

The overall aim here, therefore, is methodological and theoretical: to further develop our 'diagramming practices' method (Higginson et al. 2015) such that we might increase our ultimate understanding of the structure of practices. As it does in the physical sciences, we think understanding the structures and pattern of practices will provide insight into the ways in which they change and stabilise and may eventually, therefore, help with the design of more sustainable practices. Within this, our particular aim in this paper is to better understand the *connections* both within and between practices.

Review

Social practice theory (SPT) is an increasingly recognised approach to understanding energy use and has played an important role in broadening the analysis of how energy is consumed in the performance of everyday practices. Various theorists have defined practice theory but a commonly cited definition is that from Reckwitz, who describes a practice as:

> "A routinized type of behaviour which consists of several elements, interconnected to one another: forms of bodily activities, forms of mental activities, 'things' and their use, a background knowledge in the form of understanding, know how, states of emotion and motivational knowledge. A practice – a way of cooking, of consuming, of working, of investigating, of taking care of oneself or of others, etc. – forms so to speak a 'block' whose existence necessarily depends on the existence and specific interconnectedness of these elements, and which cannot be reduced to any one of these single elements." (Reckwitz 2002)

The idea that practices are comprised of elements has been widely adopted. Different writers have highlighted different key elements in practices as usefully summarised by Gram-Hansen (2010) and outlined in Table 1. The most frequently cited of these is the so-called three elements model Shove et al. (2012), which attributes practices with the elements 'stuff', 'image' and 'skill' and will be used in this paper. Kuijer (2014) takes a significant step forward by proposing that element categories are not single and homogenous but can be divided up and thought of as more or less central to the practice of which they are a part and this concept is drawn on extensively in this paper as well.

Table 1: Key elements in the understanding of practices

<table>
<tr><th>Schatzki (2002)</th><th>Reckwitz (2002b)</th><th>Warde (2005)</th><th>Gram-Hanssen (2010)</th><th>Shove, Pantzar, Watson (2005)</th></tr>
<tr><td rowspan="4">Practical understanding</td><td>Body</td><td rowspan="4">Understandings</td><td rowspan="4">Know-how and embodied habits</td><td rowspan="5">Competences (skill)</td></tr>
<tr><td>Mind</td></tr>
<tr><td>The agent</td></tr>
<tr><td>Structure/ process</td></tr>
<tr><td>Rules</td><td>Knowledge
Discourse/ language</td><td>Procedures</td><td>Institutional knowledge</td></tr>
<tr><td>Teloaffective structures</td><td></td><td>Engagement</td><td>Engagements</td><td>Meanings/ conventions (image)</td></tr>
<tr><td></td><td>Things</td><td>Items of consumption</td><td>Technologies</td><td>Products/ material artefacts (stuff)</td></tr>
</table>

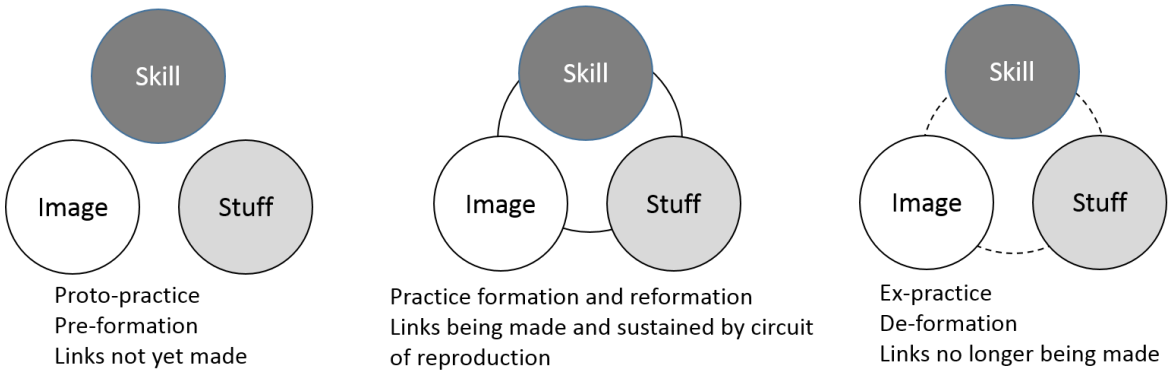
Source: Adapted from (Gram-Hanssen 2010) to include Gram-Hanssen's classification of elements

Given the attention it has received, however, we shall put aside further discussion of the elements of practice to note that the definition above describes practices as recognisable and routinized behaviours which consist of *interconnected and interacting* elements. When a practice (such as commuting) is enacted (or performed), its elements combine in different ways and are said to be connected. This "nexus" (Schatzki 1996) or "specific interconnectedness" (Reckwitz 2002) between the elements is continually stressed in the

literature and so, in addition to the already established role of elements within SPT, it could be said that the connections between elements are part of the fundamental building blocks of practices.

This is illustrated in Figure 1, which shows how diffuse elements may exist but may or may not be linked to each other and, therefore, may or may not form part of a practice. On the left of the figure are shown so-called 'proto-practices', a phase before a practice becomes recognisable as an entity. Here the elements exist but have not yet become connected. As elements are drawn together and links form between them (in the centre of Figure 1), so they become recognisable as being part of a practice – the links are made and remade by repeated performances (or the 'circuit of reproduction'). Later, however, links between elements may be destabilised or even broken as carriers defect from the practice and it "fossilises" (Shove et al. 2006) or 'deforms' and becomes an 'ex-practice', as is shown on the right hand side of Figure 1.

Figure 1: Proto-practices, practices and ex-practices



Source: Reproduced from Shove, et al. 2012

Relatively stable practices and complexes of practice are those that are consistently and faithfully reproduced and, because practices are inherently social in nature, standards or norms emerge and can be learned (Scott 2012). Within stabilised practices, how their elements are connected is essential to the meaning of the practice (the rhythm, sequence and timing as well as the place and spacing of practices is key both to the competent performance of a practice and to its being defined as one type of practice rather than another).

However, their iterative performance over time means that practices and the connections between them are dynamic and changing. As different practices are enacted, or performed, so those performances intersect with, influence and challenge one another, which means that practices are sustained, changed or destroyed as the links between them are created, maintained or broken. When existing links in practices break or elements become unstable, innovations may occur and practices or elements may be reinvented. Thus, practices may stabilise or change because of their elements but *also* because of the connections between them.

Understanding connections is therefore central to understanding how practices change and, by extension, to understanding how flexible a practice might be, an important issue in the management of energy demand. Given their importance, however, very little has been written about the connections within and between practices and the mechanisms by which they operate.

Most work has been done on the connections *between practices*. Shove et al. (2012) discuss how practices might group together through loose *bundles* due to being co-located in space or time or through "stickier" (p87) *complexes*, by means of which practices become co-dependent (whether through sequence, synchronisation, proximity or necessary co-existence) and are unable to be reduced to the individual practices of which they are composed. The relationship between practices may thereby become one of competition, as linkages break, or collaboration, as they become progressively denser and paths more dependent. Such is the means through which practices jostle each other for space and time in the coordination of daily life. The authors also describe how practices might be joined through shared elements, such as the shared (and unshared) images, skills and stuff visible in the relationship between horse-drawn carriages and cars as the latter form of transport overtook the former. However, exactly what constitutes a bundle or a complex and the characteristics of the links between and within them, is not explained.

In a recent paper, Shove et al. (2015) acknowledge that SPT needs to "develop a better understanding of how complexes of social practices and infrastructures develop together, and of the multiple connections involved" (p275), in their exploration of car dependence as a feature of practices. They propose some characteristics of the infrastructures that connect many practices, namely that they are generally connective, extensive, collective and obdurate. This suggests ways in which to think about connections between practices by means of elements (in this case 'stuff') and insofar as this hints at the 'nature' of those connections, it is useful for our purposes. However, the paper then goes on to say more about how energy demand, infrastructures and practices are connected to each other than about the connections between practices themselves, which is what is of particular interest here.

Watson's (2012) paper on decarbonising the transport system, suggests other forms of connection between practices. He demonstrates how the car is linked into *systems of practice* which both brings it into relationship with other practices and locates it within a system of elements – such as infrastructures, technologies, rules, norms and meanings – that sustain its dominance. Like Shove et al. (2012) he points out that the competitive or interdependent relations between practices lead to stabilisation or change but he adds that this is "rarely entirely endogenous to the practice concerned" but is rather a function of the "shifting relative location of a practice within broader *systems of practice*" (p491, Watson's emphasis). These systems persist through "the routinized actions of actors throughout the system, as they perform the practices which reproduce the institutions and relations comprising the system" (p493). However, although he talks about "links, flows and processes comprising a system", his analysis does not focus specifically on these connection mechanisms.

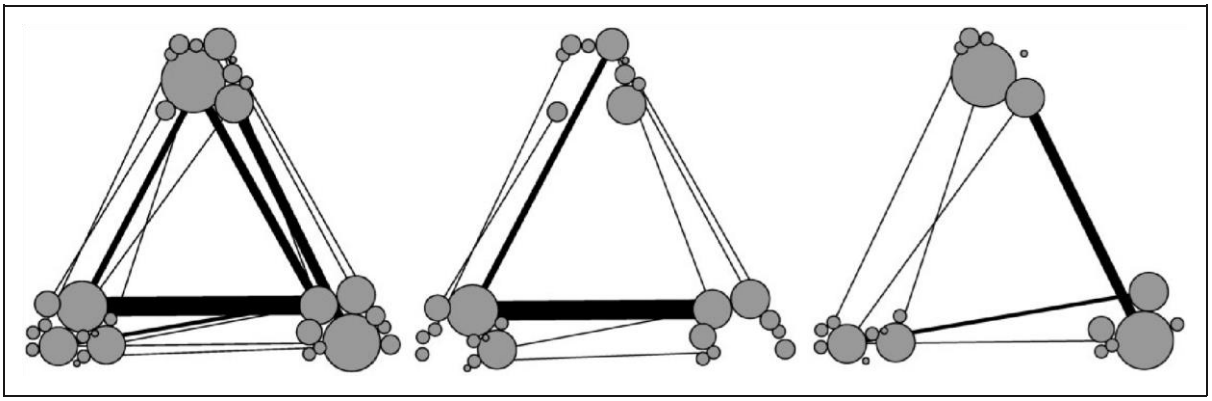
Cass and Faulconbridge (2016) continue to explore connections between practices in terms of time-space contingencies. Time and space are particularly interesting in SPT because both are simultaneously the cause and result of practices and this idea springs to life in their discussion of car travel. The realisation that cars enable the spatial distribution of practices that in turn are able to become more spatially dispersed by the use of cars demonstrates this point. Add to this the fact that these spatially dispersed practices are often still "tightly-knit together in time" (Shove et al. 2015, p281), such that only a car facilitates the successful performance of all the necessary practices, and it can be seen how the car also both accelerates the pace of life (so, effectively, creating our sense of time) and is simultaneously a product of the "harried" (Southerton et al 2001) nature of the modern world. They suggest creating "enabling timespace matrices" (p 9) to overcome the seemingly intransigent difficulties posed by this catch-22 situation, whereby it is not just the physical distance between sites of practice but "the topologies produced by the timespaces of sequenced

practices (that) matter" (p 9). This, combined with his contention that travel practices only become truly integrative when considered in combination with the particular activity they are linked to (such as work), results in a range of more or less radical options for promoting velomobility over automobility.

In the quest to understand the connections between practices, it makes sense to also investigate the connections between elements, though much less has been written about this. Schatzki (2011) conceptualises 'the social' as existing on a "single plenum of practices and arrangements that exhibits variations in the thinness and thickness and directness and circuitousness of relations. As traced by these variations and gradations, practices and arrangements form bundles and constellations of smaller or larger spatial-temporal spread" (p17). In other words, practices may exist within "systems of practice" (Watson 2012) or "timespace matrices" (Cass et al 2016) but these all exist on a single plane. On this plane, it is the "thinness or thickness" (or strength) and "directness or circuitousness" (or distance and direction) of their "relations" (or connections) that it is important to understand (Schatzki 2011).

In this context, Kuijer's (2014) work becomes very interesting. She proposes that each element category is comprised of a "constellation of groupings of elements" (p52), much like Schatzki's. Having established this, she conceives of each performance of a practice as a partial 'manifestation' of the practice entity (Figure 2), using different combinations of interconnected elements that can be conceptualised as having different "geometries" (Shove 2012, p51). Over multiple performances, certain elements will acquire more weight (Kuijer describes them as being more or less 'essential' to the practice) because they appear more frequently. By implication, and importantly for this paper, this also means that the connections *between* these elements (and their associated practices) will be different too and so, over repeated performances, they too will acquire more or less significance.

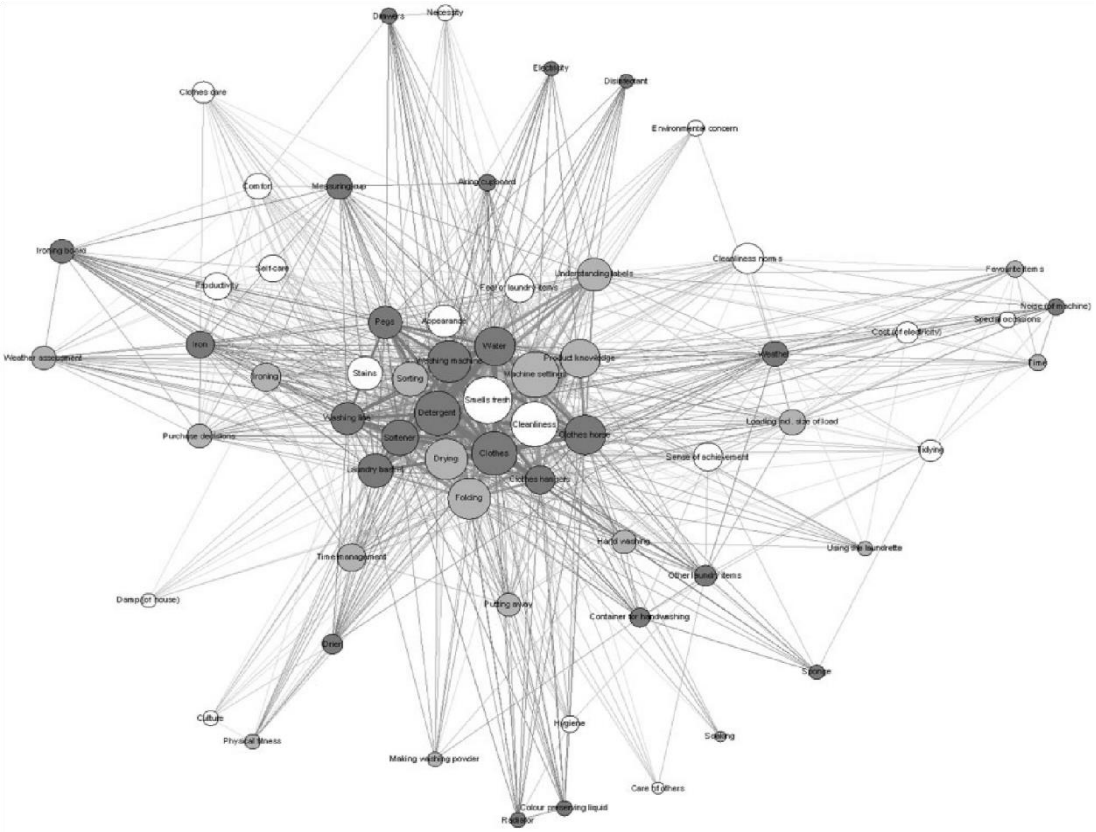
Figure 2: Practice as an entity (left), and two performances (centre and right). Based on Kuijer



Source: Higginson et al 2015, based on Kuijer, 2014

This is all very theoretical, however, and lacks empirical substance. Higginson et al. (2015) tried to rectify this in a number of ways by using network theory to produce practice network maps (see Figure 3), a way of diagramming practices based on empirical evidence that is also able to reveal the characteristics of elements and variants of practices, such as which elements could be considered core or peripheral, or how elements between variants could be shared. In other words, we were able to start exploring the geometry of practices, based on actual data.

Figure 3: A practice network map of laundry



Source: Higginson et al 2015.

However, based on the theoretical literature and the structure of our empirical data, all we were reasonably able to surmise about connections was that every element within a particular performance was equally connected with every other, a phenomenon we called the 'universal connection' convention. This meant that elements in our network graphs showed a reduced tendency to cluster into groups and their geometry was less obvious than it might have been, something we wish to correct in the current paper.

Taking stock, therefore, this review suggests different questions we may wish to pursue when thinking about connections. On the one hand, we could zoom out (Nicolini 2012) and think about the connections between practices – the *ecologies* of practice. Inspired by Shove's various efforts, we may wish to think about the nature of connections – what they are actually made of and what characteristics they have. We may want to consider what constitutes a bundle or a complex – what they look like and how they relate to each other. Watson's work on systems of practice may lead us to ask what systems are implicated in everyday practices – how systems and practices interact and which are core and peripheral. Cass et al.'s investigation of timespace matrices entices us to explore the topologies of practices and their connections – how they are structured and could change but also what different types and levels of connections might exist.

On the other hand, we might zoom into practices themselves, where much less work has been done, to better understand their structures – the *geometries* of practice. Schatzki and Kuijer provide a theoretical starting point by means of which to do this but it requires empirical exploration and validation.

This is an ambitious agenda and we will inevitably only cover part of it. To underpin our theoretical reflections, we have collected new empirical survey data in which participants sought to 'map' the elements

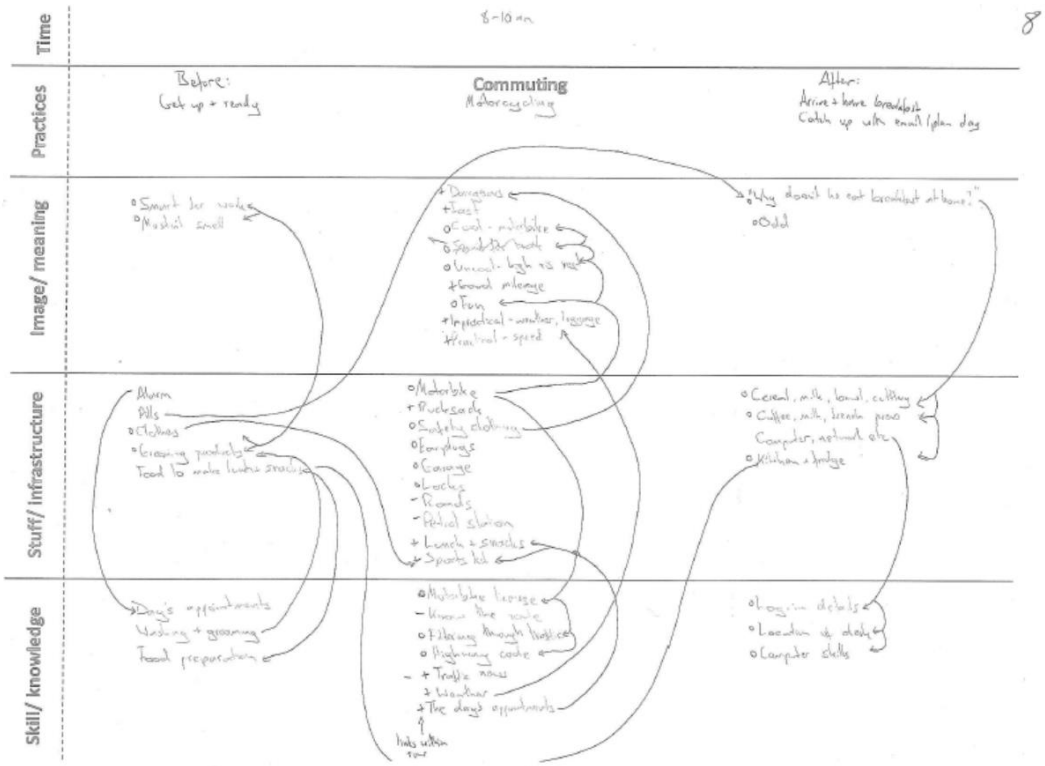
in their commuting practices and their connections with other practices (both through shared elements and, across space and time, between practices). This data will be used to generate practice network maps of commuting in which both the elements *and the connections* are generated by empirical data. Before doing that, however, we shall briefly explain our methodology.

Method

The methodology adopted to produce our network graphs in this paper follows very closely that which was previously (Higginson et al. 2015) and so will not be described in detail again here. However, our data collection was different and so will be outlined briefly. We collected data from 44 students familiar with SPT and 19 volunteer members of university staff who were not familiar with the theory. This resulted in maps showing several variants of commuting practice, namely walking, taking the bus, cycling, motorcycling and driving (both regular cars and electric vehicles). Our sample is small and skewed and some obvious variants are missing, such as train travel but, as we have noted before, our objective in this paper is not to reveal insights into commuting per se but to explore this methodology.

As has been stressed throughout, our main objective was that we capture data about the links within and between practices and we sought to do this by getting participants to draw a 'map' of their commuting practice. We therefore started by asking participants to name the variant of commuting practice most common to them in the centre of the page. We then asked them to list the elements of their daily commute, followed by drawing the links between these elements. Next, we asked them to write down the practices performed before and after commuting and the links within these. Finally, we asked them to draw the links between their 'before' and 'after' practices and their commuting practice. The result was the sort of map shown in Figure 4.

Figure 4: Example of the hand-drawn 'maps' of participants' commuting practice



These maps were then encoded into an ‘incident matrix’ in Excel, allowing a row for each participant, each of which equated to a performance of commuting. The number of elements were rationalised to a limited degree by grouping similar answers together and were then listed in columns. A note was also kept of the survey number from which each element derived, the type of element (stuff, image or skill) and whether the practice of which the element was a part was performed ‘before’, ‘during’ or ‘after’ the commute.

Next it was necessary to encode all the connections. The connections table consisted of a row for each connection in the network. This identifies, for each connection, the source element, target element, type of connection (all are undirected) and weighting. A note was made of whether the connections were between elements within a practice, or between elements of different practices.

Finally, a more ‘high level’ analysis of the elements was done, whereby elements were grouped according to the practice of which they were a part (e.g. ‘cleanliness’ became part of ‘hygiene practices’, ‘kid’s rucksack’ became part of ‘childcare’ and so on) and the connections between these was encoded. This time, for each connection, there was a source practice and target practice but otherwise the same process was followed.

To construct the network graphs, a Matlab script was written to convert the survey incident matrix into two tables: a nodes table and a connections table. The nodes table populated the network with a node for each element and the connections table populated the network with the lines between each node for each connection that had been drawn.

The tables were imported into Gephi – an opensource network visualisation and analysis tool – to produce the final network graphs. ‘Force atlas’ layouts were chosen to arrange elements and filters were used to highlight elements based on the node attributes specified in the nodes table, for example to differentiate between element types or to highlight when the elements appeared in the sequence of practices listed by the participant.

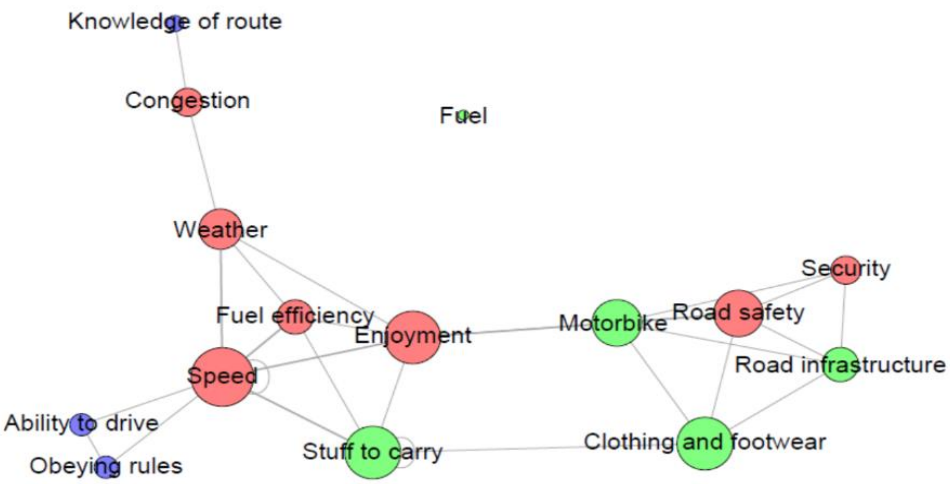
Results and Discussion

This section describes a series of element and practice network maps, as well as multi-element and multi-practice network maps (all formally known as graphs), based on the results of the participant data gathering exercise described above. The distinguishing characteristics of the graphs are considered, starting by zooming in to focus on the geometry of a single performance of a practice and considering that from different angles and then zooming out to look at the ecologies of groups of practices. Some of the implications of the method are as discussed as the graphs are presented.

The idea is to show what is possible using this method, assuming that one had access to a large dataset (one of the advantages of this method is its ability to be scaled up), rather than to provide insights into commuting as such. The data in the graphs below therefore represents only five performances of commuting practice, including one example of motorcycle commuting and four examples of car commuting, one of which was an in electric vehicle.

To start, Figure 5 is an element network map of just one performance motorcycle commuting, and is, in fact, a graph of the hand-drawn map shown in Figure 4. This is an element network map, so called because it represents a network of elements linked together by connections. The nodes of the graph are elements and the lines are the connections, as they are in all the graphs in this paper. The size of the nodes denotes the number of times they were mentioned and the thickness of the lines the number of connections. In this map and in Figure 6 the colours signify the three elements – blue for 'skills', red for 'image' and green for 'stuff'.

Figure 5: Commuting motorbike - showing elements



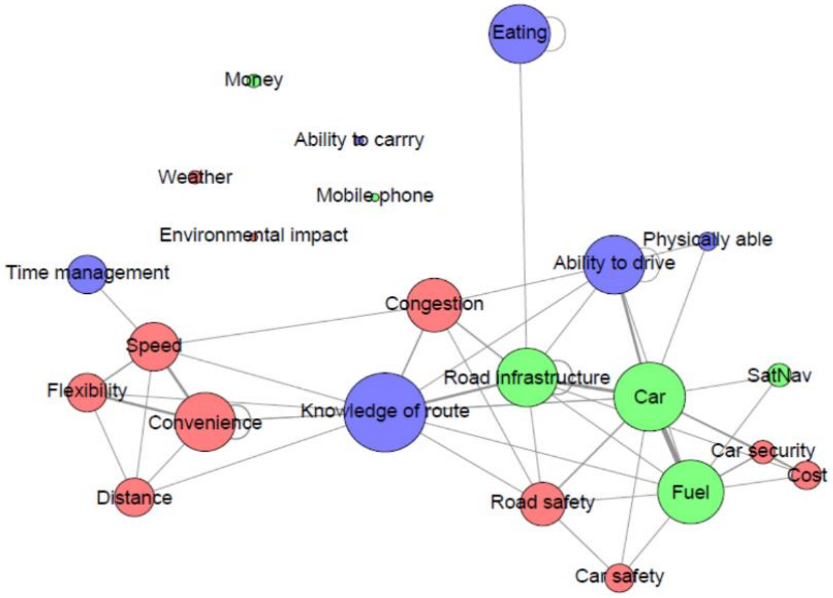
Although this element network map is very simple and actually only shows a particular practice-as-performance of a rather than a whole practice-as-entity, there are some features worth commenting on. First, it is clear how the three types of elements overlap/ intermingle with each other, suggesting that it does not make sense to deal with these separately. Second, there is a distinct geometry visible in this map resulting from the connections between the elements, with two distinctive clusters; one, perhaps, mainly about the experience of riding a motorbike ('enjoyment', 'speed', 'weather', 'stuff to carry') and the other about the practicalities involved ('road safety', 'infrastructure', 'clothing and footwear', 'security'). Third, notwithstanding the caveats about our sample already noted, it is evidently possible to analyse the elements

– how central or peripheral they are, what is shown or missing – and the connections – how long or short they are, how thick, what elements they connect and what geometries emerge as a result. This graph also shows an 'orphan' element – one that did appear in the performance but is not connected to the other elements – in this case 'fuel'. This is because we have only coded connections drawn by participants.

Figure 6 builds on the last figure and shows car commuting, a different variant to the previous figure. This is a practice network map, so called because it shows multiple performances. The colours are the same as Figure 5 but this graph is more complex, showing greater variation in both the size and diversity of elements and the thickness, length and number of connections. A distinct geometry is again evident, with unmistakeable clusters, and the image of driving as involving 'speed', 'convenience', 'flexibility' and 'distance' is interestingly juxtaposed against the other dominant cluster involving 'road infrastructure', 'road safety', 'congestion' and 'knowledge of route'.

As well as comparing clusters, we could compare variants. The small clique of meanings around 'speed' in both graphs (Figures 5 and 6) is interesting as it shows that multiple meanings are interconnected and perhaps 'hybridised' in the course of performing any single practice or, to put it another way, what gives 'speed' its particular meaning in this case is the way in which it emerges in relation to driving. The different relative positions of the elements in different variants might also be of interest. For example 'weather' is central for motorcycling but peripheral for the car whereas the opposite is true for 'knowledge of route'.

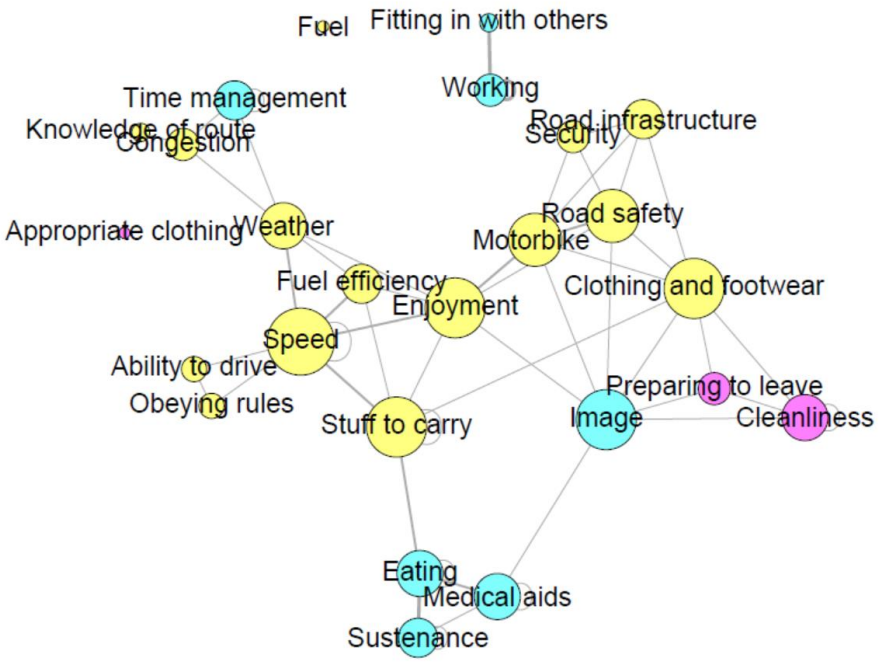
Figure 6: Commuting car - showing elements



There are two additional features of note in Figure 6. First, there are links within the element, which show as little loops next to some of the nodes. This is both the result of the coding rationalisation we did and signifies that there are connections inside the element node itself. Second, it is clear from both graphs that practices involve elements that are the products/outputs of other practices performed by other people e.g. 'road infrastructure' and 'car' appear as elements in these performances, but are themselves the products of extensive chains of practice. Both these points speak to the 'fuzziness' of the boundaries between elements and practices, itself the topic of much potential theoretical development.

Moving onto Figure 7 then, we go back to the relatively simple, single performance of motorcycle commuting but this time we have shown how this is located within a sequence of practices. This is a multi-element network map because it shows elements from multiple practices but only one performance of each. Here the colours have a different significance and indicate different time periods: the nodes in yellow are part of the performance of motorcycle commuting, the nodes in pink are part of the practice 'preparing to leave', which took place prior to the commute, and those in cyan are part of the practices of 'eating' and 'working', which took place after the commute.

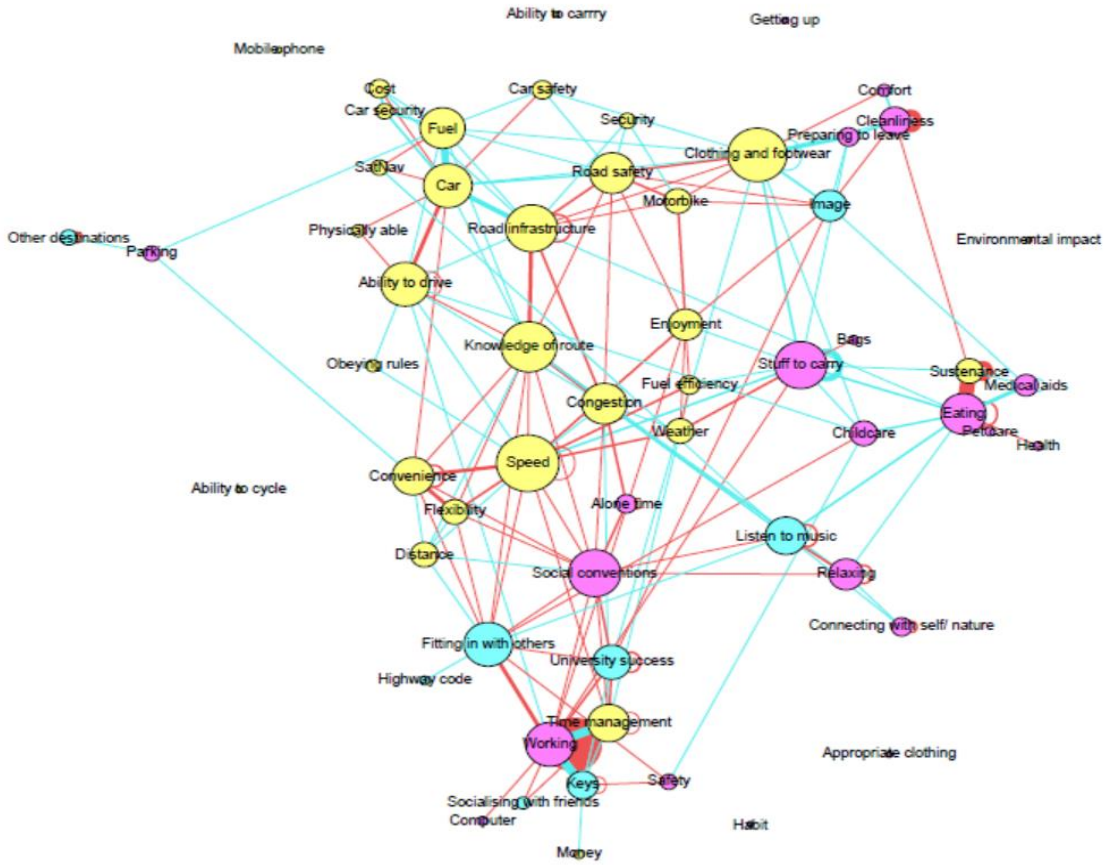
Figure 7: Commuting motorbike showing elements of practices before, during and after commute



A couple of points are worthy of attention. First, this could perhaps be interpreted as a diagram of one of Cass et al.'s (2016) timespace matrices: this practice was originally reported sequentially and spatially, as in Figure 3, as the practitioner moved from home, via the road infrastructure, to work between 8-10am, in pursuit of his daily routine. However, in this representation, it is striking that, aside from the colour code and labels on the nodes, the temporal and spatial aspects of this performance are no longer particularly evident and are certainly no longer represented in a linear progression as they were when drawn by hand. Instead, this new perspective reveals other potential clusters and connections that could conceivably suggest alternative intervention points. Second, the geometry of the original motorcycle commuting variant is recognisable (if Figures 5 and 6 are compared) but has been slightly distorted by the timespace matrix in which it now has its context and this distortion would become more pronounced were more practices to be included in the graph. We might therefore submit that Shove's bundles and complexes are starting to be visible in this more topological depiction of a practice, a feature which becomes even clearer in the next graph.

The graph in Figure 8 is a multi-element network map, like the previous figure and shows connections between all the elements and all the practices gathered across our sample of data, so includes both variants of commuting. The colours again represent movement through time (pink=before, yellow=during, cyan=after) and here the connections are also colour coded, so that the connections in red are links within a practice and those in blue are connections between different practices.

Figure 8: Commuting all with links between elements and practices



Features of interest here include the fact that it is possible to identify different practices solely from their elements and the fact that they cluster together: 'car commuting', 'preparing to leave', 'working' and 'eating' are all recognisable practices in this graph. This suggests that practices are more closely interconnected internally (at the level of elements) than they are to one another. It might seem redundant to restate that practices exist through the connections between elements but it does, perhaps, help to validate this method. It is also interesting to note which elements connect the different practices in this graph and to consider the implications. For example, 'social convention' connects working to commuting, 'stuff to carry' connects commuting to eating and 'clothing and footwear' connects commuting to preparing to leave.

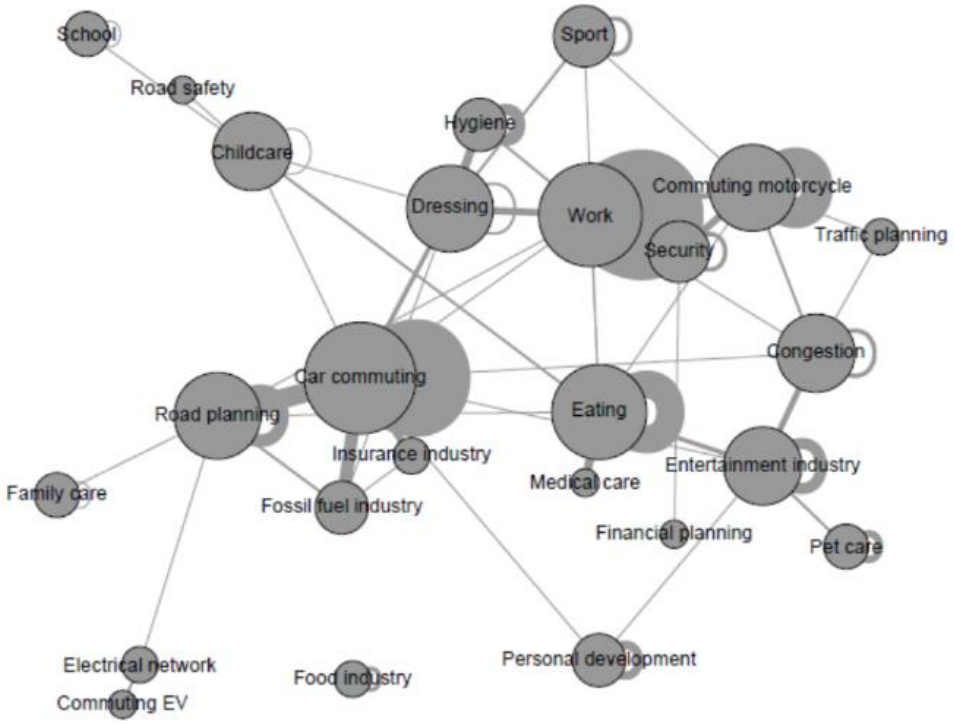
This graph also shows that practices are interconnected with one another in a very large number of ways. Although they are not colour coded according to the type of element involved, it is possible to see links within different types of stuff, image and skills, as well as between these element categories. It is also possible to see the passing of time in the colour of the nodes and, by looking at the content of the nodes, to work out connections through space (work, childcare, home, other destinations and so on). This is suggestive of how practices are both connected through 'life paths' (Pred 1981) as one practice carrier performs their daily tasks and longer term 'projects' (Ibid.) and also how life paths are connected with one another ('congestion', for example, is the product of lots of life paths intersecting in a particular timespace matrix).

A new feature in this graph is the distinction between links at the element and practice levels (red and blue connections respectively). This enhances the analytic capacity of the method because (although it may be

confusing in this particular figure) it enables the software to zoom in and out between the detailed geometry of the particular practices dealt with so far and the more abstract ecology of practices that come up next.

The final figure the, Figure 9, uses this analytic capacity to zoom right out and is the result of the 'high level' analysis of our data described in the methodology, whereby elements were coded according to the practices of which they were a part and then put into a graph. In the resulting multi-practice network map, the car and motorcycle commuting variants are still visible but as part of a wide array of associated practices, or an *ecology* of practices. Despite this more generalised view of our data, it can be seen that some of these practices are highly connected internally, as demonstrated by the significant loops next to some of the nodes (which indicate internal connections). Effectively, within each of these nodes, all of the sorts of connections discussed above are still captured and could be seen by drilling down into the data to see what is going on at a detailed level if required. Here, however, we are zooming out to look at the connections at a different resolution and the connections between practices become visible. A more 'normal' looking timespace matrix is revealed here, though we would remind the reader that within each node the temporal/ spatial folds may be much less obvious (see Figure 7) as the elements within each practice interact with each other. However, it is an encouraging validation of this method that zooming out of the chaotic details reveals familiar looking ecologies of practice.

Figure 9: Multi practice network map - commuting variants located within a topology of practices



What is also easier to appreciate from this perspective on the data, is an emerging view of Watson's (2012) 'systems of practice' as nodes like 'fossil fuel industry', 'insurance industry' and 'road planning' form a complex around 'car commuting' and thereby start to uncover the different systems of practice interacting with commuting. We are still coming to terms with this methodology but it would be possible to collect more data or, indeed, to analyse this data, in such a way as to expose these systems even more strongly, so as to potentially identify particular core systems that influence most practices or are tightly connected with particular practices of interest. This leads to fascinating speculations. We might anticipate, for instance, that

emerging ‘niches’ (Geels 2005) or ‘proto-systems’ (equivalent to proto-practices, Figure 1) might be more loosely bundled whereas dominant or established systems within the ‘regime’ (2005), would be more tightly connected complexes. The level of connectivity, in other words, might be an indicator of the status of the practice and we might speculate on whether more complex practices are harder to shift by virtue of their interconnectedness.

Final reflections and future work

The difficulty of collecting and capturing data for these graphs is a significant barrier to fully exploring this method at the moment and needs further work but we are developing ideas to overcome this. Nevertheless, we are encouraged by the steps we have taken in this paper towards understanding connections using graphs because perhaps the most exciting aspect of this method so far, is the fact that it does start to reveal what Schatzki was after in that we can start to appreciate the “thinness or thickness” (or strength) and “directness or circuitousness” (or distance and direction) of the “relations” (or connections) within and between practices and we can zoom in and out relatively easily as appropriate. There is no doubt that this method is at least helpful in starting to reveal the “variations and gradations (by means of which) practices and arrangements form bundles and constellations of smaller or larger spatial-temporal spread” (Schatzki 2011, p17).

Nevertheless, questions remain because, like elements, connections are complicated and the difficulty of understanding the nature of the actual links persists. Whereas, for instance, in most network graphs the ‘flow’ in the graph can be identified (a flow of information for example), it is not yet possible to identify what is flowing through these connections. However, it is now possible to think about this more precisely as this method helps sift through the complexity. Just as there are multiple types of elements, so too there are multiple types of connections. We have, for instance, managed to graphically represent connections, based on empirical data, through time, space and elements (i.e. ‘stuff’, such as infrastructures and resources; ‘images’, such as emotions and cultural mores, or ‘skills’ such as fitting in with others and time management).

We have also identified connections at different levels: within a practice, between practices and even between clusters of practices. In future work it may yet be desirable to introduce different terms for these different types of connections; perhaps links, connections and interconnections, respectively? There awaits also the task of identifying the characteristics/ nature of the connections with a view to later naming them. So far, for instance, we can already recognise frequency, strength, direction and length – there may be more.

We shall end then, with these two quotes by Schatzki (2011) to spur on our endeavours:

> “Social existence transpires as part of bundles of practices and arrangements, whose material dimension is considerably malleable. Indeed, arrangements continually evolve along with, and as a facet of, changes in bundles.” (p17)
>
> “Social change is messy. Small changes always occur, large changes embrace and arise from myriad smaller ones, and the difference that any change makes to the world is open until the world responds. There is no easy template for studying or fostering sociotechnical change. Studying it requires examining actual cases through investigations of the interrelated bundles and constellations involved that are informed, not by theories or models, but by concepts and typologies with which aspects of this mass can be analyzed.” (p25)

We would therefore invite the academic community to join us in thinking about these issues. This is a work in progress but we believe that it starts to open up interesting questions and prompts us to look in sensible places for the answers. Perhaps one of the most important traits of the method is that it helps us to distinguish order and patterns rather than being overwhelmed by the huge complexity of practices. Given the need to draw quickly alongside our colleagues in various disciplines and fields to address the urgent work of energy demand, we are hopeful that this method will increasingly provide a platform that will enable these sorts of conversations.

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References

Barton J, Huang S, Infield D, Leach M, Ogunkunle D, Torriti J and Thomson M. (2013) The evolution of electricity demand and the role for demand side participation, in buildings and transport. Energy Policy; 52: 85–102

Cass, N and Faulconbridge, J (2016) Commuting practices – New insights into modal shift from theories of social practice, Transport Policy, Vol 45, pp 1-14

Geels, F (2005) Processes and patterns in transitions and system innovations: refining the co-evolutionary multi-level perspective. Technological forecasting and social change, 72(6), 681-696

Gram-Hanssen, K (2010) Standby consumption in households analysed with a practice theory approach, Journal of Industrial Ecology, vol. 14, no. 1, pp. 150-165

Gruünewald P, McKenna E and Thomson M (2014) Keep it simple: time-of-use tariffs in high-wind scenarios. Renew Power Generation, IET; 9: 176–183.

Higginson, S, McKenna, E, Hargreaves, T, Chilvers, J, Thomson, M (2015) Diagramming social practice theory: An interdisciplinary experiment exploring practices as networks. Indoor and Built Environment, 24, 950-969

Higginson, S, McKenna, E, Thomson, M (2014) Can practice make perfect (models)? Incorporating social practice theory into quantitative energy demand models, In: Proceedings of the 3rd Behave Energy Conference, Oxford

Higginson, S, Richardson, I, Thomson, M (2011) Energy use in the context of behaviour and practice: The interdisciplinary challenge in modelling flexible electricity demand, Loughborough Institutional Repository, University of Loughborough

Kuijer L (2014) Implications of social practice theory for sustainable design. PhD Thesis. Delft: Delft University of Technology, http://studiolab.ide.tudelft.nl/studiolab/kuijer/thesis/ (accessed 28 July 15)

McKenna, E, Gruünewald, P and Thomson, M (2015) Going with the wind: temporal characteristics of potential wind curtailment in Ireland in 2020 and opportunities for demand response. Renew Power Generation, IET; 9: 66–77

Nicolini, D (2012) Practice theory, work, and organization: An introduction. 1st ed. Oxford: Oxford University Press.

Pudjianto, D, Castro, M, Strbac, G and Gaxiola, E (2013) Transmission infrastructure investment requirements in the future European low-carbon electricity system. In: 10th International Conference on the European Energy Market (EEM), IEEE, Stockholm, Sweden

Pullinger M, Browne A, Anderson B, Medd W. (2013) Patterns of water: The water related practices of households in southern England, and their influence on water consumption and demand management. Lancaster, UK: Lancaster Universit. Available at: http://www.sprg.ac.uk/projects-fellowships/patterns-of-water/patterns-of-water-final-report (accessed 7 May 2015)

Pred, A (1981) Social reproduction and the time-geography of everdyay life, Geografiska Annaler Series B - Human Geography, vol. 63, no. 1, pp. 5-22.

Reckwitz, A (2002) Toward a theory of social practices: a development in culturalist theorizing. European Journal of Social Theory, 5(2), pp. 243

Richardson, I, Thomson, M, Infield, D (2008) A high-resolution domestic building occupancy model for energy demand simulations, Energy and Buildings. 40(8), pp. 1560–1566

Schatzki, T (1996) Social Practices. A Wittgensteinian Approach to Human Activity and the Social. Cambridge University Press, Cambridge

Schatzki (2011) Where the Action Is: On Large Social Phenomena Such as Sociotechnical Regimes, Working paper 1, Sustainable Practices Research Group

Scott, K (2012) Designing change by living change, Design Studies, vol. 33, no. 3, pp. 279-297

Shove E (2012) Energy transitions in practice: the case of global indoor climate change. In: Verbong G and Loorbach D (eds) Governing the energy transition: reality, illusion or necessity? Routledge, Abingdon, UK.

Shove, E, Watson, M, Spurling, N (2015) Conceptualizing connections: Energy demand, infrastructures and social practices, Europena Journal of Social Theory, Vol 18(3) 274-287

Shove, E, Pantzar, M (2006) Fossilisation. Ethnologia Europaea, 35, pp. 59-62

Shove E, Pantzar M and Watson M. (2012) The dynamics of social practice: everyday life and how it changes. 1st ed. Thousand Oaks: Sage, CA

Southerton, D, Shove, E, & Warde, A (2001) 'Harried and Hurried': Time shortage and the coordination of everyday life, CRIC, University of Manchester.

Watson, M (2012) How theories of practice can inform transition to a decarbonised transport system, Journal of Transport Geography, Vol 24, pp 488-496